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END USES OF ENERGY IN THE U.S. ECONOMY, 1967

Ronald L. Knecht
Clark W. Bullard III

January 1975

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by

Ronald L. Knecht and Clark W. Bullard III

Center for Advanced Computation
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

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This work was supported by the Energy Research and Development Administration in cooperation with the National Science Foundation.

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BIBLIOGRAPHIC DATA SHEET	1. Report No. UIUC-CAC-DN-75-145	2.	3. Recipient's Accession No.
4. Title and Subtitle: END USES OF ENERGY IN THE U. S. ECONOMY, 1967			5. Report Date: January 1975
			6.
7. Author(s): Ronald L. Knecht, Clark W. Bullard III			8. Performing Organization Rept. No. CAC 145
9. Performing Organization Name and Address: Center for Advanced Computation, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801			10. Project/Task/Work Unit No.
			11. Contract/Grant No. NSF-EN-44177
12. Sponsoring Organization Name and Address: National Science Foundation, 1800 G. Street, Washington, D. C. 20301			13. Type of Report & Period Covered: Research
			14.

15. Supplementary Notes

16. Abstracts

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The data are intended for use with the Center for Advanced Computation energy and employment policy model, described in other Energy Research Group reports. With this end use data incorporated into the model, effects of fuel substitution can be analyzed explicitly via interfacing with an existing model of the energy supply system. The combined model that results is a predictive energy and employment policy model, not merely an assessment model.

17. Key Words and Document Analysis. 17a. Descriptors

Economy
Economic modelling
Energy
I/O structure

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement: No restriction on distribution. Available from National Technical Information Service, Springfield, Virginia 22151	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 148
	20. Security Class (This Page) UNCLASSIFIED	22. Price

ABSTRACT

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PREFACE

The work described in this report represents the first attempt to obtain data on end-uses of energy in 111 sectors of the U. S. economic system. It was done here for 1967, the latest year for which a compatible input-output model was available.

We intend for this to be viewed as a preliminary draft, and actively solicit constructive criticisms and suggestions for improving the methods. Readers are encouraged to use the errata sheet provided on the next page to transmit corrections and suggestions to us. We will keep all who do so informed of the availability of updated editions of this report.

ERRATA

Please fill out this sheet and send to the authors at

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ERRORS (Indicate page numbers)

SUGGESTED METHODOLOGICAL IMPROVEMENTS (Indicate section numbers)

ADDITIONAL SOURCES OF DATA THAT SHOULD BE EMPLOYED

Please use additional sheets if necessary.

ACKNOWLEDGEMENT

Major contributions were made by Mr. Mark Swift, an employee of Brookhaven National Laboratory, who spent considerable time at CAC and coordinated the interface with the Brookhaven energy systems optimization model.

We wish to thank several Graduate Research Assistants, Lawrence Bertschi, Alan Stockner, and James Toscas, who contributed to earlier drafts of certain sections. We also thank Killion Noh and Nadine Abbott for computer programming assistance, and David Simpson and Anthony Sebald for helpful guidance to energy data sources. Finally we are indebted to Marcie Howell and Veronica Soltys for retyping more drafts than we care to admit.

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1.0 INTRODUCTION

This report documents new data recently incorporated into the CAC energy-employment policy model [1], an input-output (I-O) model of the U. S. economy, similar to the Bureau of Economic Analysis (BEA) model [11]. The changes add a predictive capability to the model, make it possible to analyze impacts of technological changes and fuel substitutions in the U. S. energy system, and make it possible to use the CAC model in tandem with the Brookhaven Energy Systems Optimization Model [27], a linear programming (LP) model of the U. S. energy system.

We begin with a discussion of the motivation and method (adding several new sectors corresponding to energy end-uses to the model) and then describe the interface with the LP model of reference [2]. Acquisition and development of the new data are described in sections 2-11. The last section describes the assembly of the modified I-O matrices.

A more general exposition of the enhancements to the CAC energy-employment model is contained in reference [3].

1.1 MOTIVATION FOR MODEL IMPROVEMENTS

A basic problem in applying I-O models to time series studies or future scenarios lies in defining and establishing the technological coefficients for a model. Each technological coefficient is a measure of the amount of input from a given sector necessary to produce a unit output from another given sector. These coefficients are the elements, $A_{i,j}$, of the A matrix in the equation:

$$X = A \cdot X + Y , \qquad (1.1)$$

where X and Y are the total outputs and aggregated final demand vectors, respectively. The usual approach to I-O modeling defines the technological coefficients to be constant over the times and situations to be studied and establishes their values for a base year in the past for which hard data are available. There is no theoretical reason why these coefficients must be held constant; one could define a new A matrix for each point in time or each scenario and some work has been done along this line by the U. S. Department of Labor in their employment forecasting model. The problem is a practical one: one first needs justification for changing any coefficient or set of coefficients, and changing a coefficient in a column means that other coefficients in the column must be changed in order to keep the model consistent. Since a sophisticated I-O model has a large number of sectors and since the number of entries in the A matrix is the square of the number of sectors, the task becomes unmanageable unless an elegant, systematic and defensible method can be devised to make the changes.

Whatever the reason for constant coefficients, there are two economic interpretations of the fact. The most important interpretation is that constancy of input coefficients rules out substitution of one input for another, for example, aluminum for steel in some auto parts. Another interpretation is that constancy of input coefficients excludes the possibility of technological advancement, for example, the more efficient burning of diesel fuel for transportation motive power in a better-engineered vehicle. In either case, constancy of input coefficients is an especially weak assumption for fuel or other energy supply inputs since, for example, steam can be produced by burning coal or natural gas or refined petroleum products or by using electrically-powered heat sources. This assumption is weakest when employed in a model which is being used to study the energy needs of an economy. A model with such a limitation can only be used for the assessing of the contours of energy use in the present or past and not for predicting future demands with any reliability. The use of such a model in policy studies in which fuel substitution and improved technologies are the basis of many policy options is very limited.

1.2 ALLOWING FOR FUEL SUBSTITUTION AND TECHNOLOGICAL CHANGE

This document develops a modified I-O model which can be linked to an existing LP model of the energy system [2] to produce a new A matrix in a simple, systematic and defensible way. This LP model takes a vector of inputs from the I-O model, and, considering such factors as fuel prices and supply constraints, returns as outputs a new set of coefficients for the energy sectors of the A matrix, a set of coefficients which changes the structure of the energy system to simulate likely future fuel substitution possibilities and new technologies. This method for simulating energy supply substitutions and technological improvements by changing coefficients in the modified A matrix is defensible because the LP model was designed to account for most factors which would cause the input coefficients from any energy supply sector to other sectors to change and it quantifies these changes. It is systematic in that it does not change the input coefficients from just one or two energy supply sectors to other sectors, but examines and redefines the contours of the whole energy system and all the relevant coefficients. It is simple and usable because it is restricted to modifying a small number of coefficients in the modified A matrix, the input coefficients from the energy supply sectors to other sectors. Coupling these two models and developing a sequential and iterative solution algorithm has provided us with a more powerful policy study tool and modeling procedure preserving the valuable features of both models, but without many of their limitations when employed individually. With the development of this predictive model, we can now study the energy and dollar costs and employment impacts of future development schemes and policy alternatives. Subsequent enhancements could allow evaluation of capital formation and construction needs and environmental impacts of such alternatives.

1.3 STRUCTURE OF THE MODEL AND SECTOR REDEFINITION

The structure of this modified I-O model and the mechanics of linking it to the LP model to form the new combined model are of course, closely linked. The structure of the modified I-O model is based on a fiction which developed from an observation. The observation is simply this: while fuel and energy supply inputs to any given product or sector may often be freely substitutable, what we shall call the "energy products" produced from these fuels and supplies are very nearly always constant inputs into a product or sector. As an example, a restaurant needs a constant amount of cooking heat for its medium-rare twelve-ounce filet mignon, but that cooking heat could be supplied by electricity, by burning natural gas or by burning wood. The conversion of fuels or energy supplies to energy products is a matter usually handled by the user (final demand or intermediate user) to whom the fuel is sold.

Our fiction, however, proceeds by establishing and adding to the model a set of fictitious sectors, one for each of eight basic energy products. The addition of these sectors to the model is shown schematically in Figure 1. We assume that every non-energy sector gets all its energy in the form of energy products from these new energy product sectors and none of the non-energy sectors gets fuel or other inputs directly from the energy supply sectors. Energy supply sectors also receive inputs of energy products (since, for example, offices of natural gas utilities do require space heat) but energy product sectors get no energy product inputs (since, for example, making water heat from fuels does not directly require air-conditioning). The energy product sectors need only fuel and energy supply inputs and so they are allocated all of the net output of the energy supply sectors (which in the old model was allocated directly to all sectors) and they are allocated no other inputs currently. The energy product sectors are allocated the net output of the energy

	8 Energy Supply Sectors	8 Energy Product Sectors	85 Non-Energy Sectors
8 Energy Supply Sectors	Real	Imaginary	0
8 Energy Product Sectors	Imaginary	0	Imaginary
85 Non-Energy Sectors	Real	0	Real

Figure 1.

EPTT or EPA Schematically

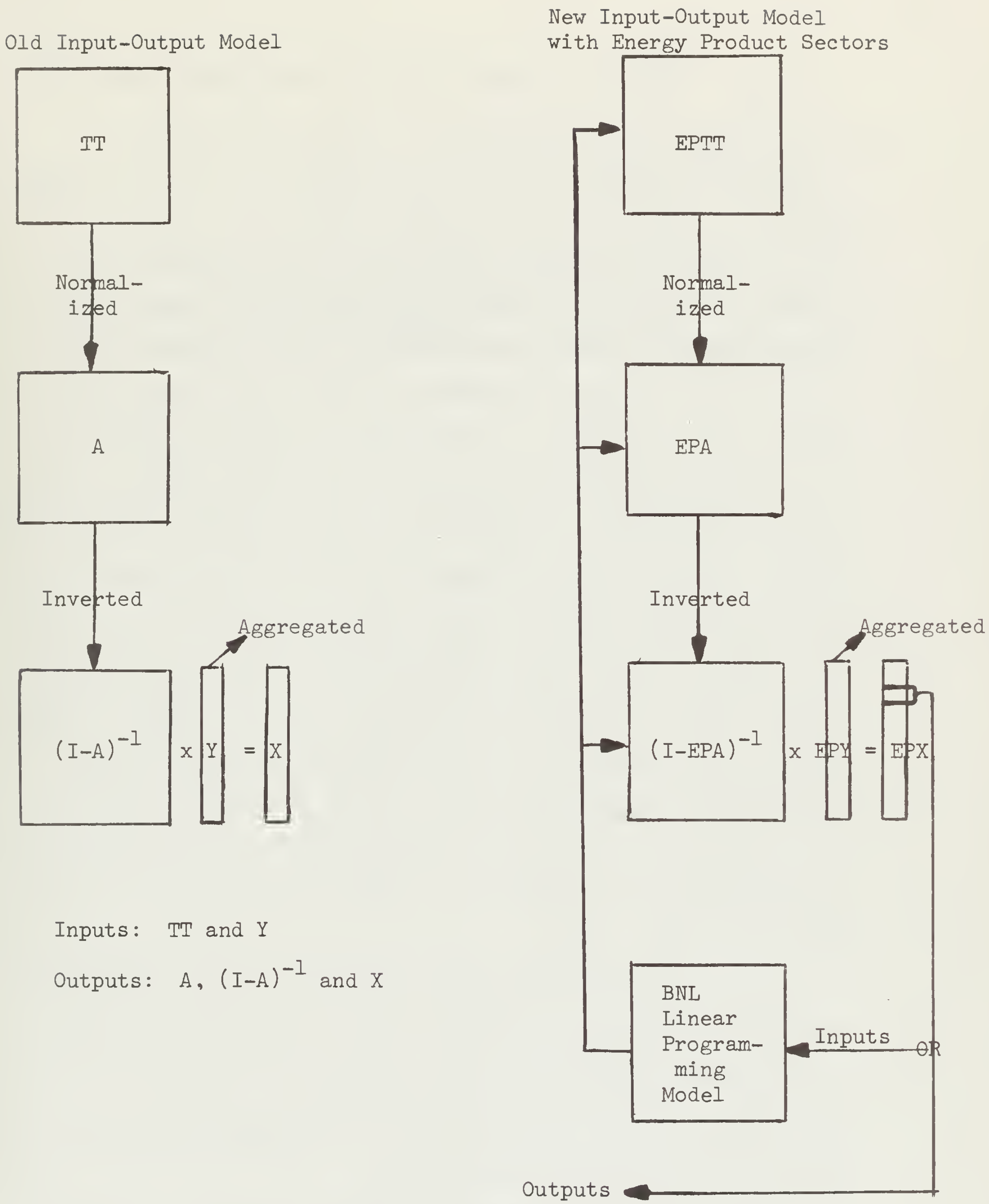
<u>Energy Product Sectors (Defined in Section 2.2):</u>

Coke and Ore Reduction Feedstocks
Other Feedstocks
Motive Power
Miscellaneous Thermal and Process Heat
Water Heat
Space Heat
Air-Conditioning
Electric Power

supply sectors because in this scheme there are still some transactions among the energy supply sectors, such as the flow of crude oil from the crude oil and gas extraction sector to the refined petroleum products manufacturing sector. Besides their allocations of energy product inputs and their allocations of energy supplies and fuels from other energy supply sectors, the energy supply sectors also continue to receive the same non-energy inputs they were allocated in the old model. The net transactions among any non-energy sector and the energy (product and supply) sectors taken as a group are the same as they were in the old model: each non-energy sector still gives the same real inputs to the energy supply sectors that it provided in the old model; and each sector still receives substantially the same energy inputs that it got previously from the energy supply sectors, but now gets them in a different form, energy products instead of fuels and energy supplies, and not directly from the energy supply sectors, but indirectly from them through the energy product sectors. Transactions from non-energy sectors to non-energy sectors are the same in the new model as they were in the old model.

1.4 COMBINING THE MODELS

To see the mechanics of how the new I-O model and the LP model are linked and to see how the combined model facilitates the use of non-constant energy technologies in I-O modeling, examine the schematic diagrams in Figure 2. The old modeling procedure begins with a transactions matrix, TT, showing all the real transactions between sectors [1]. (Energy sector rows are given in units of 10^6 Btu and non-energy sector rows are given in dollars.) Next this matrix is normalized to give the matrix A defined by eq. (1.2), which is then substituted into eq. (1.3) to solve for gross outputs as a function of exogeneously specified final demands.



Inputs: EPTT and Y

Outputs: EPA, (I-EPA)$^{-1}$,
X and new EPTT

Figure 2. Combined Model Operation

$$A_{i,j} = \frac{TT_{i,j}}{X_j} \tag{1.2}$$

$$X = (I - A)^{-1} \cdot Y \tag{1.3}$$

In the new modeling procedure, we form the new (or energy product) I-O model in the same manner and then we link this new matrix with the LP model and execute the pair iteratively. So, first we form EPTT, the transactions matrix with energy product sectors, then normalize it to get EPA, the technologies matrix with energy product sectors. From this, we form $(I\text{-}EPA)^{-1}$, the direct and indirect requirements matrix with energy product sectors. The multiplication of $(I\text{-}EPA)^{-1}$ by an aggregated final demand vector, EPY, with energy product sectors, gives us a total output vector, EPX, with energy product sectors. In particular, we are interested here in the total output demanded from the energy product sectors. The Brookhaven LP model was constructed to take as input a vector of energy product demands (certain elements of EPX) and give as its output a matrix of optimal allocations of the various fuels and energy supplies to each other (e.g. - coal to electric utilities) and to the energy products, for a given set of constraints. This is exactly the upper left corner (8 x 16 sub-matrix) of EPTT.

The modeling procedure begins by using I-O outputs as inputs to the LP. The resulting optimal energy technology (fuel use pattern) is then substituted into the I-O model A matrix and a new set of energy product demands obtained, as described in ref. [28]. Experience has demonstrated that the method converges in three to five iterations. A formal convergence proof is being developed [4] and [29].

Several efficient computing algorithms have been developed to minimize costs of using the model in this way [5]. They are also applicable to estimating effects of changes in other technological coefficients.

1.5 METHOD FOR CREATING THE NEW TRANSACTIONS MATRIX

Our method for creating the EPTT and disaggregated EPY matrices was to create submatrices as shown in Figure 3 and then assemble these into EPTT and EPY matrices. The next ten sections of this document describe in complete detail the creation of the energy products submatrix (EP67) shown in Figure 3. The final section describes briefly the other submatrices and the assembly.

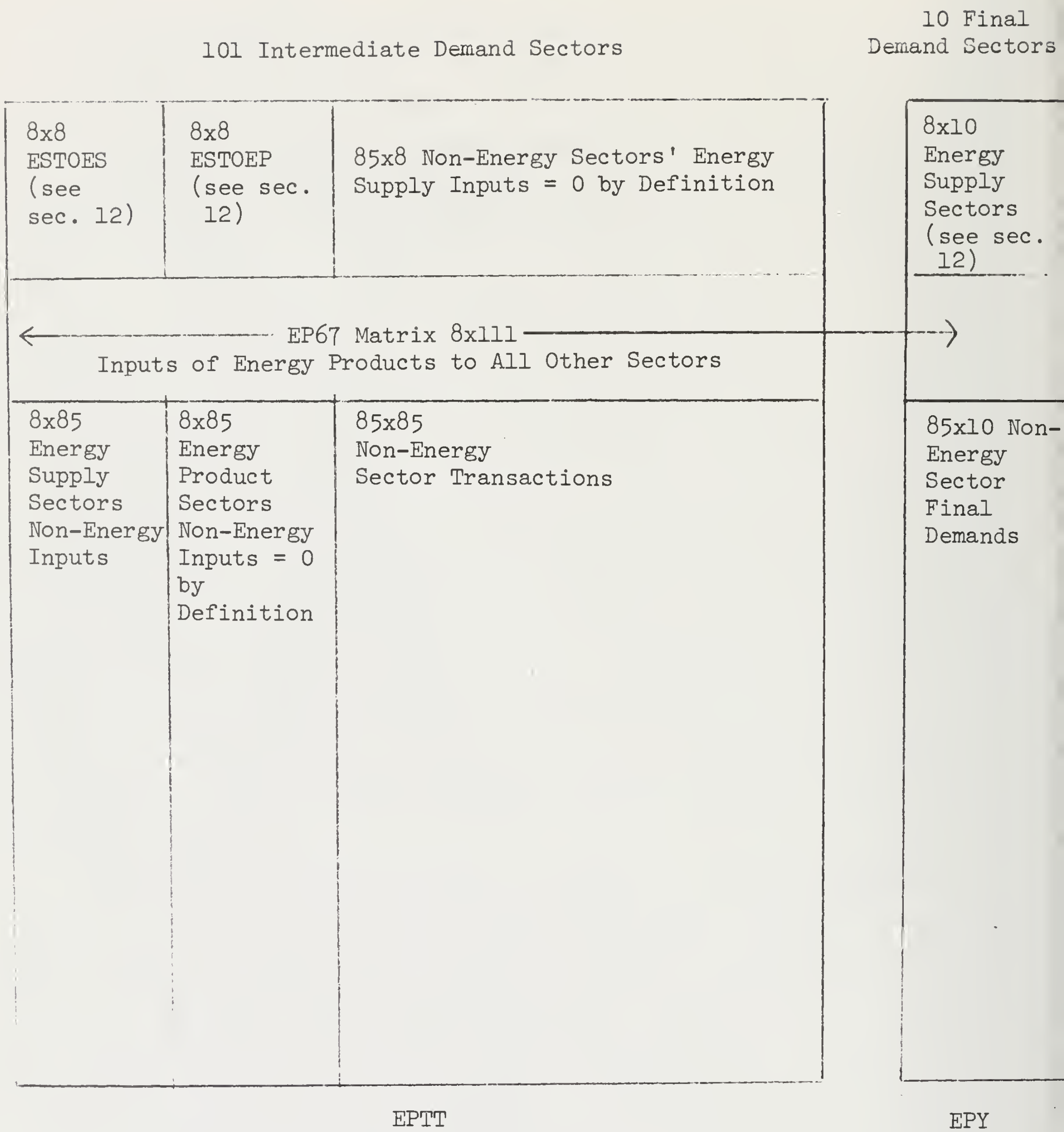


Figure 3. Assembling the EPTT Matrix
and Disaggregated EPY

2.0 GENERAL DESCRIPTION OF METHOD

The first step in constructing EP67, the energy products matrix, was to develop two matrices of energy use for a very simple (i.e., highly aggregated) four sector model. One matrix, two-dimensional, shows the use of each of the eight energy products by each of four sectors, to which we will refer as "supersectors." The other matrix, a three-dimensional array, shows the use of each of the five kinds of energy supplies (from our original energy and employment policy model) for each of the eight energy products by each of the four supersectors. We then developed for each product and each supersector a method for disaggregating the energy product and supply totals and spreading them among the sectors in EPTT within each supersector. These methods for disaggregating the supersector control totals are the subject of sections 3-11 of this document; principal sources for that effort were our own data [6] and the 1967 Census of Manufacturers [7].

This section describes the creation of the two aggregated matrices just mentioned. A four-supersector model was chosen because some data for such a model for the year 1968 were available from Patterns of Energy Consumption (PEC), a 1972 report prepared for the Federal Office of Science and Technology by Stanford Research Institute [8]. While the PEC data was not presented in an I-0 format, it was, to our knowledge, the first research attempt to develop the concept of energy products. Reference [2] uses a variation of the PEC structure for describing the energy system to present projections of the state of the system in future years. PEC and reference [6] were our primary sources of relevant end use data for energy. In this report, we proceed to integrate the energy product concept into an I-0 model of the economy.

This was possible because we were able to convert the PEC 1968 data into the four supersector model data. Using this with 1967 I-0 data from our own model [3], we were able to develop the two matrices we needed, starting with two other matrices.

The precise method for deriving these from the two sources is described in section 2.4, and the results of this method are presented in section 2.5. First, however, sections 2.1, 2.2, and 2.3 present our notation and definitions.

2.1 NOTATION

Figure 4 shows schematically the process of constructing EP67. In Figure 3, EP67 is also shown as being the concatenation of the ninth through sixteenth rows of the EPTT matrix from section 1 of this document, with the ninth through sixteenth rows of the 1967 disaggregated (ten-sector) final demand matrix for the 111-sector I-O model. Each entry is given in millions of Btu's for this matrix and all others, except the ETA-matrix of section 2.1.8.

2.1.1 DET67

To get EP67, we started with two other matrices. One, from the CAC 100-sector I-O model, is the DET67 matrix, a 5 x 100 matrix with subscripts K and j, which we converted to a 5 x 111 matrix before using it and which shall be considered a 5 x 111 matrix throughout the remainder of this document. The entries in this matrix are the energy supply transactions by energy supply sector (K = 1-5, as described in Table 1) to each sector (j = 1-101 for intermediate sectors and j = 102-111 for final demand sectors, as described in Table 2). The DET67 matrix is also a concatenation of a matrix of transactions to the producing (or intermediate demand) sectors and a matrix of demands by the final demand sectors. Section 2.4.1 provides details of the transformation of the original 100-sector DET matrix into the 111-sector DET67 matrix.

2.1.2 E68

The other matrix with which we started was E68, a 5 x 8 x 4 matrix with subscripts K, P, and S. The elements of this matrix

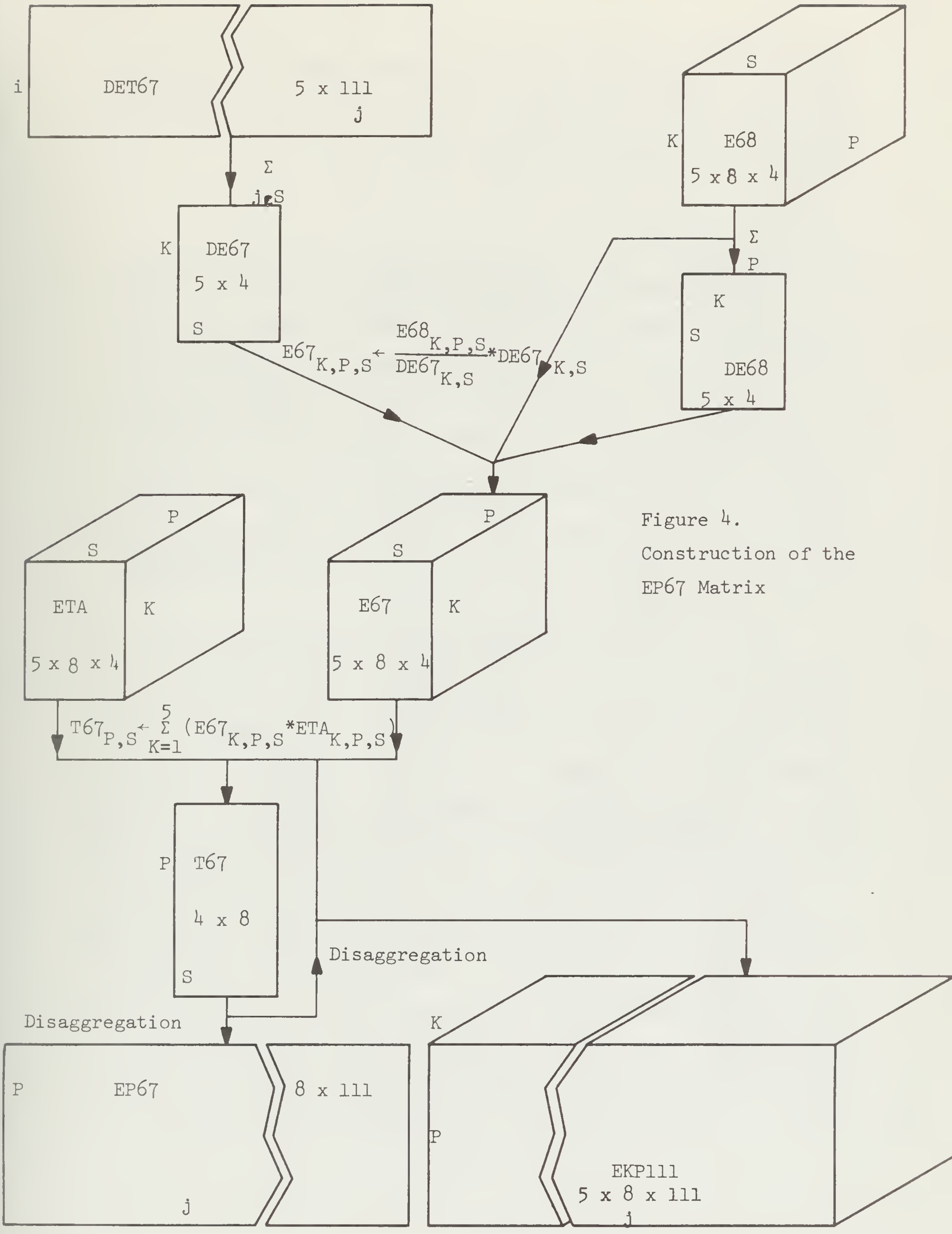


Figure 4.
Construction of the
EP67 Matrix

are the 1968 PEC allocations of each energy supply (K = 1-5) to each energy product (P = 1-8, as described in Table 1) for each PEC supersector (S = 1-4, as described in Table 1). Derivation of the entries for this matrix is given in section 2.4.3.

2.1.3 Subscripts

Table 1 identifies titles in the range of each of the subscripts, K, P and S. The numbers 1 through 5, when used in place of the subscript K, denote the set of energy supplies or sectors in the order listed. The numbers 1 through 8, when used in place of the subscript P, denote our set of energy products in the order listed. The numbers 1 through 4, when used in place of the subscript S, denote the PEC-based supersectors in the order listed. Definitions for the energy supply sectors are found in reference [6] and those for the energy product sectors and the PEC-based supersectors in section 2.3 of this document.

Table 2 identifies the sector titles corresponding to the subscripts i and j, which are interchangeable; generally we use i as a row subscript and j as a column subscript. The numbers 1 through 101, when used in place of the subscripts i or j, denote the intermediate or non-final demand I-O sectors in the order specified in the first column of Table 2. Table 2 also shows the correspondence between the DET67 sectors and the PEC-based supersectors. Note that the numbers 9 through 16, when used in place of the subscript i or j, refer to exactly the same set of energy products (or fictional sectors) which are denoted by the numbers 1 through 8 when they are used in place of the subscript P. The numbers 102 through 111, when they are used in place of the subscript i or j, denote the ten final demand sectors of the disaggregated final demand matrix of the 111-sector I-O model. These sectors are listed at the end of Table 2. Definitions of the energy supply sectors are given in

Energy Supplies	K
Coal	1
Crude Petroleum and Gas Products	2
Refined Petroleum Products	3
Electric Utilities	4
Natural Gas Utilities	5

Energy Products	P
Coke (Ore Reduction Feedstocks)	1
Feedstocks (other than ore reduction)	2
Motive Power	3
Miscellaneous Thermal Applications	4
Water Heat	5
Space Heat	6
Air Conditioning	7
Miscellaneous Electric Power	8

Supersectors	S
Industrial	1
Transportation	2
Commercial and Government	3
Residential	4

Table 1.

ENERGY SUPPLIES, ENERGY PRODUCTS AND SUPERSECTORS

J. Sequence No.	Old I-O Sequence No.	BEA I-O Code	Industry Name	PEC Super-sector	J. Sequence No.	Old I-O Sequence No.	BEA I-O Code	Industry Name	PEC Super-sector
1	1	7	Coal mining	I	57	46	42	Other fabricated metal products	I
2	2	8	Crude petroleum and natural gas	I	58	47	43	Engines and turbines	I
3	-	-	Converted Coal	-	59	48	44	Farm machinery	I
4	3	31.01	Petroleum refining and related products	I	60	49	45	Construction, mining, oil field machinery, equipment	I
5	5	68.02	Gas utilities	C	61	50	46	Materials handling machinery and equipment	I
6 }	} 4	{ 68.01	Fossil electric utilities }	} C	62	51	47	Metalworking machinery and equipment	I
7 }	} 4	{ 68.01	Nuclear electric utilities }	} C	63	52	48	Special industry machinery and equipment	I
8 }	} 4	{ 68.01	Renewable electric utilities }	} C	64	53	49	General industrial machinery and equipment	I
9	-	-	Coke (ore-reduction) feedstocks	-	65	54	50	Machine shop products	I
10	-	-	Other feedstocks	-	66	55	51	Office, computing and accounting machines	I
11	-	-	Motive power	-	67	56	52	Service industry machines	I
12	-	-	Miscellaneous thermal	-	68	57	53	Elec. transmission & dist. equip. & elec. insul. apparatus	I
13	-	-	Water heat	-	69	58	54	Household appliances	I
14	-	-	Space heat	-	70	59	55	Electric lighting and wiring equipment	I
15	-	-	Air conditioning	-	71	60	56	Radio, television and communication equipment	I
16	-	-	Electric power	-	72	61	57	Electronic components and accessories	I
17	6	1	Livestock and livestock products	C	73	62	58	Miscellaneous electrical machinery, equipment and supplies	I
18	7	2	Other agricultural products	C	74	63	59	Motor vehicles and equipment	I
19	8	3	Forestry and fishery products	C	75	64	60	Aircraft and parts	I
20	9	4	Agricultural, forestry and fishery services	C	76	65	61	Other transportation equipment	I
21	10	5	Iron and ferroalloy ores mining	I	77	66	62	Professional, scientific & controlling instruments & supp.s	I
22	11	6	Nonferrous metal ores mining	I	78	67	63	Optical, ophthalmic, & photographic equipment & supplies	I
23	12	9	Stone and clay mining and quarrying	I	79	68	64	Miscellaneous manufacturing	I
24	13	10	Chemicals and fertilizer mineral mining	I	80	69	65.01	Railroads and related services	T
25	14	11	New construction	C	81	70	65.02	Local, suburban & interurban highway passenger transpor.	T
26	15	12	Maintenance and repair construction	C	82	71	65.03	Motor freight transportation and warehousing	T
27	16	13	Ordnance and accessories	I	83	72	65.04	Water transportation	T
28	17	14	Food and kindred products	I	84	73	65.05	Air transportation	T
29	18	15	Tobacco manufactures	I	85	74	65.06	Pipe line transportation	T
30	19	16	Broad and narrow fabrics, yarn and thread mills	I	86	75	65.07	Transportation services	T
31	20	17	Miscellaneous textile goods and floor coverings	I	87	76	66	Communications except radio and television broadcasting	C
32	21	18	Apparel	I	88	77	67	Radio and TV broadcasting	C
33	22	19	Miscellaneous fabricated textile products	I	89	78	68.03	Water and sanitary services	C
34	23	20	Lumber and wood products, except containers	I	90	79	69	Wholesale and retail trade	C
35	24	21	Wooden containers	I	91	80	70	Finance and insurance	C
36	25	22	Household furniture	I	92	81	71	Real estate and rental	C
37	26	23	Other furniture and fixtures	I	93	82	72	Hotels & lodging; pers. & repair serv., except auto repair	C
38	27	24	Paper and allied products except containers and boxes	I	94	83	73	Business services	C
39	28	25	Paperboard containers and boxes	I	95	84	75	Automobile repair and services	C
40	29	26	Printing and publishing	I	96	85	76	Amusements	C
41	30	27	Chemicals and selected chemical products	I	97	86	77	Medical, educational serv. and nonprofit organizations	C
42	31	28	Plastics and synthetic materials	I	98	87	78	Federal government enterprises	C
43	32	29	Drugs, cleaning and toilet preparation	I	99	88	79	State and local government enterprises	C
44	33	30	Paints and allied products	I	100	89	81	Business travel, entertainment and gifts	C
45	34	31.02	Paving mixtures and blocks	I	101	90	82	Office supplies	C
46	35	31.03	Asphalt felts and coatings	I	102	91	96.60	Personal consumption expenditures	P
47	36	32	Rubber and miscellaneous plastics products	I	103	92	96.70	Gross private fixed capital formation	-
48	37	33	Leather tanning and industrial leather products	I	104	93	96.80	Net inventory change	-
49	38	34	Footwear and other leather products	I	105	94	96.90	Net exports	-
50	39	35	Glass and glass products	I	106	95	97.10	Federal government purchases, defense	C
51	40	36	Stone and clay products	I	107	96	97.20	Federal government purchases, other	C
52	41	37	Primary iron and steel manufacturing	I	108	97	98.60	State and local government purchases, education	C
53	42	38	Primary nonferrous metals manufacturing	I	109	98	98.70	State and local government purchases, health, welf. & sanit.	C
54	43	39	Metal containers	I	110	99	98.80	State and local government purchases, safety	C
55	44	40	Heating, plumbing and fabricated structural metal products	I	111	100	98.90	State and local government purchases, other	C
56	45	41	Screw machine prods., bolts, nuts, etc. & metal stampings	I					

Table 2.

Sector Definition Correspondence Among 111-Sector Model, 100 Sector Model, BEA I-0 Sectors, and PEC-Based Supersectors.

section 2.4.1 of this document, definitions of the energy product sectors in section 2.2 and definitions of the non-energy sectors and the final demand sectors in reference [6].

2.1.4 DE67

From the two matrices with which we started, DET67 and E68, we construct two intermediate and parallel matrices. The first of these is DE67, a 5 x 4 matrix with subscripts K and S. It is simply an aggregated version of DET67 out of which certain parts of the DET67 energy supply transactions have been subtracted because they do not correspond to energy product allocations. The precise aggregation method and the exact deletions from the DET67 matrix before aggregation are discussed in section 2.4.2. Thus, the entries in DE67 are energy supply transactions (K = 1-5) for 1967 to each of the PEC-based supersectors (S = 1-4), but only that portion of those transactions which is used for production of energy products.

2.1.5 DE68

Parallel to the DE67 matrix is the DE68 matrix, also a 5 x 4 matrix with subscripts K and S. There the entries are defined the same as those in the DE67 matrix, except that those in the DE68 matrix are for the year 1968. The entries in the DE68 matrix were obtained by a straightforward aggregation of E68 elements. Mathematically, this is expressed:

$$DE68_{K,S} \leftarrow \sum_{P=1}^{8} E68_{K,P,S}, \quad 1 \leq K \leq 5 \quad \text{and} \quad 1 \leq S \leq 4. \qquad (2.1)$$

Note that there is no need here to modify any portions of the basic data, because the energy allocations taken from PEC for the E68 were all the energy supplies which were converted to energy products and only those energy supply allocations were counted. Those which were not converted to energy products were not included, with one exception discussed in sections 2.2.6 and 2.4.3.

2.1.6 SELFUS

SELFUS is a 5 x 8 matrix with subscripts K and j in which the entries are the amounts subtracted out of the DET67 matrix before it is aggregated to give DE67. (These deductions are confined to the first eight of the 101 sectors.) An entry in SELFUS is an amount of an energy supply (K = 1-5) which is subtracted from the transaction to an energy supply sector (j = 1-8) because that portion of the energy supplied from source K does not get used by sector j to make energy products. Instead it is converted to another energy supply form or wasted. The derivation of the entries in the SELFUS matrix is given in section 2.4.2.

2.1.7 E67

Using DE67, E68 and DE67 we created E67, a 5 x 8 x 4 matrix with subscripts K, P and S, which is defined exactly analogously to E68. Thus, the elements of this matrix are the 1967 allocations of each energy supply (K = 1-5) to each energy product (P = 1-8) for each PEC-based supersector (S = 1-4). Derivation of this matrix is given in section 2.5.1.

2.1.8 ETA

ETA is a 5 x 8 x 4 matrix with subscripts K, P and S which is the matrix of conversion efficiencies from fuels or energy supplies to energy products. Each entry is the efficiency of converting an energy supply (K = 1-5) to an energy product (P = 1-8) in a given supersector (S = 1-4) in 1967. Values of the efficiencies were taken from reference [9]. Values of ETA were taken to be indicative of actual base year (1967) efficiencies. Table 3 displays the ETA matrix. The entries of this matrix are dimensionless.

K		P	S=1	S=2	S=3	S=4
K=1	P	1	0.67	0.67	o.67	0.67
		2	0.65	0.65	0.65	0.65
		3	0.06	0.06	0.06	0.06
		4	0.70	0.70	0.70	0.70
		5	0.0	0.0	0.0	0.0
		6	0.70	0.70	0.70	0.70
		7	0.0	0.0	0.0	0.0
		8	0.0	0.0	0.0	0.0
K=2	P	1	0.0	0.0	0.0	0.0
		2	0.0	0.0	0.0	0.0
		3	0.0	0.0	0.0	0.0
		4	0.0	0.0	0.0	0.0
		5	0.0	0.0	0.0	0.0
		6	0.0	0.0	0.0	0.0
		7	0.0	0.0	0.0	0.0
		8	0.0	0.0	0.0	0.0
K=3	P	1	0.0	0.0	0.0	0.0
		2	1.00	1.00	1.00	1.00
		3	0.20	0.20	0.20	0.20
		4	0.68	0.68	0.68	0.68
		5	0.70	0.70	0.70	0.70
		6	0.76	0.76	0.76	0.63
		7	0.0	0.0	0.0	0.0
		8	0.0	0.0	0.0	0.0
K=4	P	1	0.0	0.0	0.0	0.0
		2	0.0	0.0	0.0	0.0
		3	0.0	0.0	0.0	0.0
		4	1.00	1.00	1.00	1.00
		5	1.00	1.00	1.00	1.00
		6	0.0	0.0	0.0	1.58
		7	3.00	3.00	3.00	2.10
		8	1.00	1.00	1.00	1.00
K=5	P	1	0.0	0.0	0.0	0.0
		2	1.00	1.00	1.00	1.00
		3	0.0	0.0	0.0	0.0
		4	0.64	0.64	0.64	0.64
		5	0.70	0.70	0.70	0.57
		6	0.77	0.77	0.77	0.75
		7	1.00	1.00	1.00	1.00
		8	0.0	0.0	0.0	0.0

Table 3. Fuel Conversion Efficiencies, the ETA Matrix

2.1.9 T67

In a manner described in section 2.5.2 we created T67, an 8 x 4 matrix with subscripts P and S. Each entry is the total allocation of energy product (P = 1-8) to supersector (S = 1-4) in 1967.

2.1.10 EP67

Our ultimate output in this part of the project was EP67, an 8 x 111 matrix with subscripts P and j. EP67 is, generally speaking, a disaggregated T67; each entry is the total allocation of an energy product (P = 1-8) to a sector (j = 1-111) in 1967. EP67 includes not only the allocations of energy products to intermediate demand sectors (j = 1-101), but also to final demand sectors (j = 102-111). The derivation of EP67 from the intermediate matrices defined above is the subject of sections 2-11 of this report.

2.1.11 EKP111

A very important by-product of creating EP67 from E67 and T67 was the EKP111, a 5 x 8 x 111 matrix with subscripts K, P and j. EKP111 is, generally speaking, a disaggregated E67; each entry is the allocation of an energy supply (K = 1-5) for use in producing a given energy product (P = 1-8) in a given sector (j = 1-111) in 1967. EKP111 also includes not only the allocations of energy supplies to energy products for the intermediate demand sectors (j = 1-101), but also for the final demand sectors (j = 102-111). EKP111 is derived along with EP67 in sections 2-11.

2.1.12 LABOR

An important tool for disaggregating T67 and E67 into EP67 and EKP111, respectively, was the 111-sector LABOR vector for 1967, which uses the subscript j. Each entry in this vector is the full-time equivalent of labor employed for a year by each sector (j = 1-101 for intermediate sectors and j = 102-111 for final demand sectors). The derivation of this vector from the existing CAC 100-sector LABOR vector is given in section 2.4.4.

2.2 ENERGY PRODUCT SECTOR DEFINITIONS

The primary criteria used for specifying the energy product sectors were consistency with the LP model demand categories, non-substitutability among these sectors, and availability of disaggregation information and data, for development of coefficients. Consistency with the LP model demand categories required product sectors which are straightforward aggregations of the LP demand categories or the LP categories themselves. Any such aggregations should have avoided loss of information such as might occur if space heat and water heat demands were aggregated into one sector. The different costs and efficiencies of these two categories would result in differing patterns of energy consumption and aggregation would lose this substitution information which is provided by the LP model. However, any two or more demand categories in which efficiencies are the same and costs are at least proportional, if not equivalent, in the LP objective function could be aggregated to correspond to just one energy product sector in the 111-sector I-O model without loss of information. The non-substitution criterion simply reflects the requirement of I-O analysis that each sector have a fixed coefficient production function so that no substitution exists between inputs. This implies that our product sectors must be unambiguous, comprehensive and mutually exclusive. Any possible energy supply substitutions had to be included as part of the LP model and not carried over into the I-O model. The data criterion, referred to as "spreadability", relates to spreading or allocating across all 111 sectors the total Btu's of a particular product which are available. The requirement here was that the data exist in at least some form and, if possible, that it exist in a form which is readily spreadable. Possible aggregation schemes for PEC end use categories were compared with LP model demand categories and each possibility was examined in detail with respect to the related LP model constraint equations, coefficients and costs, and the nature of demands by the I-O model sectors of primary concern for each product. Names were then selected for each product, as shown in Table 4. In sections 2.2.1-2.2.8 these energy products are discussed further.

2.2.1 Coke (Ore Reduction Feedstocks)

Initially, this energy product or sector was equivalent to the LP model demand category labeled Iron. The name was changed to more accurately reflect the nature of the demand (ore reduction can be done with natural-gas-based and petroleum-based feedstocks) and the fact that this product is used by sectors other than just primary iron and steel.

2.2.2 Feedstocks (Other Than Ore-Reduction Feedstocks)

Initially, this energy product or sector was equivalent to the LP model petrochemical demand category. The name change was made to reflect the facts that some feedstocks inputs to chemical industries are natural gas and coal and that not all feedstocks are used by the chemicals industries. In the industrial sectors, feedstock inputs are coal, natural gas and petroleum products used as materials inputs in production of products; in the commercial sectors, feedstocks are refined petroleum products used as materials inputs for paving oils and asphalts. (Note that this is in addition to paving oils and asphalts purchased from the paving oils and asphalt sectors of the industrial supersectors.) Finally, the PEC totals for feedstocks used by the transportation supersector include all greases and lubricants used by any sector in the economy for the sector's motive power needs. So this total is not just a total for the I-O model transportation supersector, but for the whole economy. (This is apparent from the fact that PEC allocated no transportation fuel to the industrial, commercial and government, or personal consumption supersectors.)

2.2.3 Motive Power

This energy product is equivalent to the three LP model demand categories listed in Table 4. The name was chosen to reflect the fact that in the PEC "transportation" category, like the feedstocks category, includes all refined petroleum products used by any sector for the sector's motive power needs. This total is not just a total for the I-O model transportation supersector, but for the whole economy. Sections 4, 5, and 2.4.3 explain how this peculiar usage by PEC was handled in our spreading of motive power and feedstocks allocations to the sectors. Use of other fuels and energy supply sources for motive power, except electricity for railroads and urban mass transit, apparently was assumed by PEC to be negligibly small, since none is shown. Electricity for railroads and urban mass transit was considered a miscellaneous electric use and is covered in sections 2.2.8 and 10.2. Liquified petroleum gases used as fuels are considered refined petroleum products, consistent with the LP model and the DET67 matrix.

ENERGY PRODUCT NAMES	LINEAR-PROGRAMMING MODEL DEMAND CATEGORIES	PEC END USES	P	j
Electric Power	Miscellaneous Electric (Base, Intermediate & Peak Load) Rail	Electric Drive Electrolytic Processes Other (Residential, Commercial & Industrial Regrigeration (Residential and Commercial) Miscellaneous Thermal (The electrically-powered portion - Industrial)	8	16
Miscellaneous Thermal	Miscellaneous Thermal	Direct Heat Process Steam Cooking (Residential and Commercial)	4	12
Motive Power (Transportation)	Air Transport Truck and Bus Auto	Fuel (Transportation)	3	11
Feedstocks	Petrochemicals	Feedstocks (Commercial and Industrial) Raw Materials (Transportation)	2	10
Coke (Ore-Reduction Feedstocks)	Iron	Direct Heat	1	9
Water Heat	Water Heat	Water Heat	5	13
Space Heat	Space Heat	Space Heat	6	14
Air Conditioning	Air Conditioning	Air Conditioning	7	15

Table 4.. CAC I-O Model Energy Product Sectors and Corresponding LP Model and PEC Categories

2.2.4 Miscellaneous Thermal Applications

This sector or energy product is equivalent to the LP model category of the same name and it includes direct process heat and steam heat (but not coke) end uses reported by PEC for the industrial sectors, plus use for cooking in the commercial and residential sectors, also reported by PEC. In section 9.1 of this paper, we compute independently figures for another component of this energy product, heat for laundry drying in the commercial and residential sectors. In that section, we also show where the fuels for this energy product are hidden in PEC data. The LP model miscellaneous thermal category includes this use, but PEC totals do not. Future work on refinement of the 111-sector I-O model and coupling that model to the LP model should attempt to disaggregate this sector, and then electric power, feedstocks and motive power. The PEC figures for this product end use include fuel uses for space heat and water heat in the industrial supersector. In sections 2.7.1 and 2.7.2 we separate these. For a number of reasons explained in section 10.1, PEC amounts for miscellaneous thermal applications in the industrial supersector which are supplied by electricity were considered use of the electric power energy product discussed in section 2.2.8.

2.2.5 Water Heat

This energy product is equivalent to the LP model category of the same name and it corresponds in the PEC commercial and residential supersectors to the PEC end-use category of the same name. As mentioned above, PEC includes the amount for this end-use in the industrial supersector in its total for miscellaneous thermal applications there. PEC also includes the amounts for this end-use in its transportation supersector in its total for natural gas use. See section 8.2 for the separation of these.

2.2.6 Space Heat

This energy product is equivalent to the LP model category of the same name and it corresponds in the PEC commercial and residential supersectors to the PEC end-use category of the same name. As mentioned in section 2.2.4, PEC includes the amounts for this end-use in the industrial supersector in its total for miscellaneous thermal applications there. In its transportation supersector, PEC also includes in its total for space heat end-use the amount for water heat there, as mentioned in section 2.2.5. But the total that PEC gives for use of natural gas in the transportation supersector (which we assumed to be used for space heat and water heat) includes the amount of natural gas that is consumed by leakage or to run compressors of gas by the natural gas utilities sector. Since we have included this activity among our self-use amounts subtracted out from DET67 in defining DE67, and since this is not a space heat usage, we have subtracted it from the PEC total before forming E68 and DE68 from the PEC figures. (See section 2.4.3 for this.)

2.2.7 Air-Conditioning

This energy product is equivalent to the LP model category of the same name and it corresponds in the PEC commercial and residential supersectors to the PEC end-use category of the same name. PEC apparently assumes that use of this energy product in the transportation supersector is negligible, since it gives no total there, and we agree. But PEC also shows no use of this energy product in the industrial supersector and we disagree. In section 6.1 we compute an amount for air-conditioning use in the industrial supersector and show where the fuels used for this product are hidden in the PEC totals.

2.2.8 Electric Power

This energy product is equivalent to the LP model category, "miscellaneous electric", except in one place. In the local transportation sector, this energy product also accounts for the electricity used for motive power in electric mass transit, so this energy product or sector overall is equivalent to the LP model categories, "miscellaneous electric" and "rail". This energy product category includes five PEC end-use categories, as shown in Table 4: electric drive; electrolytic processes; other electric; refrigeration; and miscellaneous thermal applications supplied by electricity. Electrolytic processes are industrial supersector applications and refrigeration and other electric are commercial and residential supersector applications. As mentioned in section 2.2.4, PEC amounts for industrial supersector miscellaneous thermal applications which are supplied by electricity are considered by us as use of the electric power energy product and are so accounted in section 2.4.4. As discussed more at length in sections 7.1 and 10.1 of this document, this can be done principally because fuel or energy supply substitution can be ruled out in that case and because some early runs of the combined model show that this application of electricity will not be greatly important in the future anyway. Using this accounting is very functional to our spreading process, section 10.1 also shows. The PEC electric power totals we used were those for conversion of fossil fuels to electricity at 3413 Btu per kilowatt-hour. However, we deflated all of these figures by a factor of nine percent because PEC allocated transmission and distribution of electricity among the consuming sectors, and we want the 111-sector I-O model electric power sector to show only allocations of usable Btu's of the electric power energy product to the consuming sector. (In section 2.4.3 one can see the nine percent difference in our numbers for E68 and the PEC numbers in Figures 5-13.)

2.3 SUPERSECTOR DEFINITIONS

The supersector definitions also merit some further explanation. The explanations below are taken from PEC. See again Table 2 for the correspondence between these supersectors and I-O sectors. Note in Table 2 that sectors 102-104 do not fit in any of the four supersectors since they are merely accounting sectors and use no energy products. Also, as noted in section 1.3, the energy products sectors do not use energy product inputs and so they are not included in any supersector.

2.3.1 Industrial Supersector

PEC lists twenty Standard Industrial Classification Manual [10] groupings, 20-39, as being included in its industrial supersector. These are the manufacturing sectors and they are equivalent to Bureau of Economic Analysis [11] sectors 13-64 or our sectors 3, 4 and 27-79. Mining is not explicitly specified as being in this supersector, but, by a process of elimination (since it is certainly not in the transportation or residential supersectors and since, as noted in section 2.3.3, PEC specifically excludes it from the commercial supersector) it is included here. Mining covers our sectors 1, 2, and 21-24.

2.3.2 Transportation Supersector

This is not explicitly defined by PEC, but the size of their totals for this supersector and the structure of their reporting make it clear that this supersector covers not only the usual transportation sectors (sectors 80-86 in our model) but all uses of motive power and feedstock (greases and lubricants) required by motive power uses as noted in sections 2.2.2 and 2.2.3. PEC reports no motive power uses by the other three supersectors, including, especially, the residential sector. (See Figures 5 - 13 in section 2.4.4 for verification of this.) We considered all other PEC energy product and supply totals for this supersector to be totals only for our sectors 80-86.

2.3.3 Commercial and Government Supersector

According to PEC, this includes all sectors "that are not classified as mining, manufacturing, transportation, and residential", including "commercial farms, fisheries, construction contractors, wholesale and retail trade, finance and insurance companies, real estate and law offices, hotels and restaurants, repair services, health services, schools, museums, art galleries, and all governmental institutions." By elimination from the industrial and transportation supersectors, this also includes electric and natural gas utilities, so it includes our sectors 5-8, 17-20, 25, 26, 87-101 and 106-111.

2.3.4 Residential Supersector

According to PEC (page 39), their residential totals are based on numbers of appliances in use, according to the Census of Housing, plus a fraction of the domestic sales (i.e., to final demand) of appliances. This sector corresponds only to the personal consumption expenditures sector (102) of our model.

2.4 SOURCE DATA AND MODIFICATIONS

In this section we describe first the DET data from reference [6] and the modifications we made to produce the 111-sector

DET67 matrix. Next we develop the SELFUS matrix and from this and DET67 we derive the DE67 matrix. Then we turn to our other basic source of data, PEC [8] and show the development of the E68 and DE68 matrices from their data. Finally, we trace the modifications made to the LABOR data from reference [12] to construct our 111-sector vector for use in spreading our totals.

2.4.1 Development of the DET67 Matrix

The Direct Energy Transactions (DET) matrix was created from the TT matrix and the disaggregated Y matrix to show in physical units (Btu's) the transactions from the five energy supply sectors to all sectors in the CAC I-O model. Thus, it is a 5 x 100 matrix with row subscript K and for a column subscript a set of sectors, shown in Table 5, similar to the set for j. The first ninety of these sectors are intermediate demand sectors and the last ten are the same set of final demand sectors corresponding to the subscript j in Table 2. Each entry in the matrix is the use in Btu's by a sector of one of the five energy supplies in 1967.

We needed a 111-sector DET67 to facilitate the spreading algorithms used in sections 3-10 and to modify the definitions of the energy supply sectors to more accurately describe the energy system in future years. To meet the first requirement, the receiving sectors in the DET matrix had to be changed to the same 111 sectors in Table 2. To meet the second requirement, this list had to replace the old five energy supply sectors with a new set of eight and add into the list the energy product sectors.

2.4.1.1 New Energy Supply Sectors - The new definitions of the energy supply sectors retained four of the five old sectors, disaggregated the other one into three new sectors and added one new sector.

DIRECT ENERGY TRANSACTIONS MATRIX
IN BILLIONS OF BTUS

SECTOR	COAL	CRUDE	REFINED	ELECTRIC	GAS	SECTOR	COAL	CRUDE	REFINED	ELECTRIC	GAS
1	11640	0	17370	1975	1672	51	3683	0	9755	9423	20172
2	1625	989699	23730	32020	758099	52	3455	0	8925	4654	9123
3	22510	23169984	1442999	51540	968799	53	7958	0	10690	9088	21768
4	7183997	0	576699	382599	2841999	54	2056	0	5448	6774	15100
5	14960	17869984	13784	5631	597399	55	3275	0	3058	4918	4827
6	21132	0	394599	16132	13680	56	4286	0	3261	3907	10395
7	4334	0	573913	16509	12270	57	8612	0	8261	17106	24745
8	0	0	43547	35	526	58	11422	0	4248	7134	19185
9	2167	0	6099	179	2104	59	4010	0	4349	5159	13802
10	1625	0	9079	10630	36000	60	6350	0	11422	15662	15343
11	3251	0	11134	13104	26005	61	2570	0	8306	14269	15384
12	11370	0	37190	11980	40580	62	3649	0	3586	4085	9366
13	1625	0	6920	9773	95400	63	80994	0	19610	43673	79825
14	0	0	1030744	7120	15605	64	10811	0	17528	28860	32071
15	0	0	234314	1075	2103	65	9024	0	13836	7598	12046
16	13546	0	31959	14025	14377	66	979	0	6349	4569	10991
17	196997	0	185797	92340	450518	67	0	0	8426	3475	5175
18	9410	0	3485	2515	2782	68	4698	0	11785	7412	14974
19	59583	0	47974	56608	60570	69	30860	0	552499	3989	21570
20	6095	0	14734	6068	18623	70	1625	0	170000	11180	4208
21	7960	0	23169	15938	20058	71	16797	0	428799	2009	11220
22	6726	0	1366	2852	10521	72	12050	0	608999	2475	3857
23	10261	0	76562	24405	76221	73	2167	0	1119999	2134	8767
24	541	0	933	676	2279	74	541	0	25006	11406	20670
25	6439	0	5357	5404	6763	75	1083	0	0	215	350
26	3101	0	2436	2457	9008	76	2167	0	79288	16804	36470
27	361190	0	294689	80582	374151	77	1625	0	610	5954	12800
28	2850	0	16340	7365	25100	78	28718	0	8416	8393	53830
29	2357	0	20036	19263	38457	79	14098	0	1510799	301828	699909
30	439251	108000	208137	283594	1711412	80	7586	0	111979	42581	93275
31	184131	0	224104	30535	117900	81	0	0	144792	24606	120800
32	19570	0	31648	9153	26710	82	29301	0	283485	43091	115377
33	1029	0	27750	2125	10000	83	3251	0	159796	13517	159030
34	17339	0	219800	1202	17250	84	1625	0	212126	12280	10700
35	3460	0	186300	882	13190	85	1083	0	21712	10507	21920
36	59353	0	32927	34811	57098	86	53643	0	258601	177538	397738
37	6296	0	6833	1040	5857	87	1083	0	53550	9706	35590
38	2100	0	4409	2975	6103	88	11378	0	50256	25920	292799
39	8321	0	13775	17214	199510	89	0	0	0	0	0
40	313706	0	117948	50154	504051	90	0	0	0	0	0
41	2441042	0	242508	177501	917499	91	656182	0	10669994	1173999	4364999
42	61755	0	47291	196073	345538	92	0	0	0	0	0
43	1501	0	2310	3925	16353	93	487299	75650	293799	0	191300
44	6210	0	15948	14431	59239	94	1313159	233400	493199	14840	84470
45	15354	0	11631	14628	27053	95	196692	0	1145285	42307	54530
46	13646	0	41256	15603	54136	96	35762	0	169920	4071	29630
47	9140	0	9810	4160	6531	97	83445	0	177849	131819	429599
48	16010	0	3497	3570	16230	98	7586	0	41961	13560	37700
49	12708	0	9162	8051	20099	99	5418	0	39888	8158	22790
50	1908	0	1884	1546	4628	100	23841	0	96243	80470	124100

Table 5. 100-Sector DET67 Matrix

The four sectors retained were "coal mining" (old sector 1), "crude oil and natural gas products" (old sector 2), "refined petroleum products" (previously sector 3) and "natural gas utilities" (old sector 5). The coal, crude, and natural gas sectors kept the same places on the list, but refined petroleum is now designated as sector 4. Inserted as new sector 3 is "converted coal products", which in its initial formulation includes gasified coal products using a high-Btu coal gasification process. Since this was not a real sector in 1967, its DET67 input column for the DET67 was a string of five zeroes. We disaggregated our old electric utilities fuel supply sector (previously sector 4) into three new sectors on the basis of the kind of energy used to generate the electricity. These three new electric sectors are "fossil fuel electric" (new sector 6), "nuclear electric" (new sector 7) and "renewable electric" (new sector 8); the first includes all electricity generated by burning of coal, petroleum products or natural gas, the second includes all electricity generated by nuclear fusion or fission and the third includes all electricity generated by solar and geothermal energy and by hydropower. As a first approximation for DET67 input column entries we assigned all of the fossil fuel inputs (K = 1, 3, and 5) from old sector 4 to be the same transactions to new sector 6 and new sectors 7 and 8 were assigned no fossil fuel inputs. Old sector 4 had no inputs from the crude sector (K = 2), so none of the new sectors 6, 7 or 8 do either. Finally, the inputs of electricity (K = 4) to old sector 4 were divided among new sectors 6, 7 and 8 in proportion to the total of electric power output in 1967 for which each sector accounted. The fraction of the total output of electric power generated in 1967 by each of these sectors was obtained from data in reference [13] and the fractions are: f = .8113 (sector 6), n = .0063 (sector 7) and r = .1824 (sector 8). Modifications were later made to the fossil fuel input allocations as described in sections 9.4 and 10.3 to allow for the use of some of these energy supplies for energy products such as space heat for electric utility office buildings.

2.4.1.2 <u>Energy Product Sectors</u> - The eight energy product sectors were inserted as sectors 9-16 into the DET67 matrix following the eight energy supply sectors. Since these are fictional sectors, there were no direct energy transactions to them and each was assigned a DET67 input vector consisting of a string of five zeroes. The insertion of eight energy product sectors and the splitting of five energy supply sectors into eight meant, of course, that the non-energy and final demand sectors were moved over eleven places; previously they carried subscript numbers 6-100 and now they carry subscripts 17-111.

2.4.1.3 <u>Crude Oil and Gas Adjustment</u> - To maintain consistency with the LP model treatment, all natural gas and petroleum products must be processed through the natural gas or refined petroleum products sectors; none moves directly from the crude sector to other sectors, other than sectors 4 and 5, at least hypothetically. This was also necessary in order to establish a reasonable set of production technology coefficients for the transactions from the energy supply and fuel sectors to the energy product sectors. As a matter of fact, only one non-final demand sector gets any input from the crude petroleum and gas products sector, according to the DET matrix. This is our sector 41, chemical products, and it gets only natural gas products from that supply sector for use as a feedstock, according to reference [7]. Since this is inconsistent with the inputs mixture for the feedstocks energy product in the rest of the industrial super-sector and the economy, we zeroed the allocation of crude petroleum and gas products to the chemicals sector in the DET67 matrix. Then we added to the allocation of natural gas to the chemicals sector 91 percent of the previous crude allocation and added the full amount of the previous crude allocation to the allocation of crude oil and gas products to the natural gas sector. The nine percent loss accounts for waste and efficiencies of processing, transportation, etc. The final demand allocations for inventory changes and net exports of crude petroleum and gas products, though, were left unchanged. Mathematically, the above reduces to:

$$DET67_{2,5} \leftarrow DET67_{2,5} + DET67_{2,41} ; \quad (2.2)$$

$$DET67_{5,41} \leftarrow DET67_{2,41} * .91 \text{ ; and} \quad (2.3)$$

$$DET67_{2,41} \leftarrow 0 \text{ .} \quad (2.4)$$

Table 6 displays the DET matrix, DET67, before this modification was made. Table 8 shows DET67 with this modification and modifications described in section 2.4.2

2.4.2 <u>Development of SELFUS and DE67 Matrices</u>

In section 2.5.1 we use the DE67, E68 and DE68 matrices to create E67 and from this we create T67, EP67 and EKP111. In order to convert E67 into these last three matrices, which contain allocations of energy products only, it was necessary to construct E67 with entries that represent only the allocations of fuels to supersectors which are converted to energy products. To construct E67 that way, it was necessary to modify the data from references [6] and [8] to yield DE67, E68 and DE68 matrices in which the entries represent only the portions of the allocations of fuels to supersectors which are converted to energy products. The DET67 matrix modifications were made by subtracting each entry in the SELFUS matrix from the corresponding entry in the DET67 matrix before aggregating the DET67 matrix to get the DE67 matrix. In this section we first develop the SELFUS matrix and subtract it out of the DET67 matrix and then form the DE67 matrix. In the next section we present the PEC data and our modifications to it.

2.4.2.1 <u>Defining SELFUS Entries</u> - The term "SELFUS" is used broadly to cover all non-energy-product flows of energy supplies in the energy supply sectors. These fall into three categories: conversion of one fuel to another or to electricity; waste; and real "self-use", a non-substitutable use by a sector of its own output. (Even if this kind of "self-use" involves the producing of an energy product from a fuel, we would want to show the energy input as a fuel or energy supply in order to preclude the substitution possibilities that are introduced by showing it as an energy product input.)

1967
DIRECT ENERGY TRANSACTIONS MATRIX
IN BILLIONS OF BTUS

SECTOR	COAL	CRUDE	REFINED	ELECTRIC	GAS	SECTOR	COAL	CRUDE	REFINED	ELECTRIC	GAS
1	11639	0	17369	1974	1671	57	13645	0	41256	15605	54136
2	1625	989699	23729	32019	758098	58	9139	0	9509	4159	6530
3	0	0	0	0	0	59	16009	0	3496	3569	16229
4	22509	23169984	1442998	51539	968798	60	12708	0	9162	8051	20098
5	14859	17869958	13763	5631	597399	61	1908	0	1884	1546	4628
6	7183990	0	976699	310299	2841998	62	3683	0	9754	9422	20171
7	0	0	0	2409	0	63	3455	0	8924	4654	9123
8	0	0	0	69889	0	64	7958	0	10590	9057	21767
9	0	0	0	0	0	65	2055	0	5447	6773	15099
10	0	0	0	0	0	66	3275	0	3058	4918	4827
11	0	0	0	0	0	67	4286	0	3261	3907	10395
12	0	0	0	0	0	68	8612	0	5260	17105	24745
13	0	0	0	0	0	69	11422	0	4248	7133	19185
14	0	0	0	0	0	70	4010	0	4348	5156	13801
15	0	0	0	0	0	71	6350	0	11421	15652	15342
16	0	0	0	0	0	72	2570	0	8305	14258	15583
17	21132	0	394599	16131	13679	73	3648	0	3586	4085	9366
18	4334	0	573812	16509	12269	74	60994	0	19610	43673	79224
19	0	0	43547	35	525	75	10810	0	17527	28850	32070
20	2167	0	6099	179	2103	76	9024	0	13836	7598	12046
21	1625	0	9078	10529	35999	77	979	0	6349	4569	10991
22	3251	0	11133	13103	26004	78	0	0	8425	3474	5175
23	11369	0	37179	11879	40579	79	4698	0	11785	7412	14974
24	1625	0	5919	9772	95399	80	30859	0	552499	3988	21569
25	0	0	1030743	7120	15604	81	1625	0	159999	11179	4207
26	0	0	234814	1076	2103	82	16797	0	425799	2008	11219
27	13545	0	31959	14025	14377	83	12049	0	605999	2474	3556
28	196995	0	135796	92340	450517	84	2167	0	1119999	2134	8765
29	9409	0	3484	2515	2781	85	541	0	25016	11405	20669
30	59583	0	47974	56508	60570	86	1083	0	0	215	350
31	6095	0	14734	6068	18623	87	2167	0	79288	16804	36469
32	7959	0	23168	15937	20057	88	1625	0	659	5954	12799
33	6725	0	1866	2852	10520	89	28718	0	8416	8393	53829
34	10261	0	76562	24405	76221	90	14088	0	1510798	301828	699908
35	541	0	983	676	2278	91	7585	0	111979	42581	93274
36	6438	0	5356	5404	6763	92	0	0	144792	24605	120799
37	3101	0	2496	2456	9008	93	29801	0	283484	43091	115376
38	361190	0	294588	80562	374151	94	3251	0	159795	13515	159030
39	2849	0	15839	7564	25099	95	1625	0	212125	12279	10699
40	2867	0	20056	19263	38457	96	1083	0	21712	10506	21919
41	439250	107999	208137	283594	1711410	97	53643	0	255600	177538	397738
42	184130	0	224104	30534	117899	98	1083	0	53547	9705	35589
43	19570	0	31547	9152	26710	99	11378	0	50256	25919	292799
44	1028	0	27749	2124	9999	100	0	0	0	0	0
45	17339	0	219799	1201	17249	101	0	0	0	0	0
46	3459	0	185299	882	13169	102	656181	0	10669985	1173999	4364996
47	59352	0	32926	34811	57098	103	0	0	0	0	0
48	6295	0	5832	1040	5856	104	487299	75649	293799	0	191299
49	2100	0	4409	2975	6102	105	1313199	238399	493199	14839	84469
50	8320	0	13774	17213	199509	106	196691	0	1145285	42307	54529
51	313705	0	117948	50153	504050	107	35762	0	169920	4071	29629
52	2441040	0	242508	177500	917498	108	83445	0	177849	131818	429599
53	61794	0	47291	196078	345537	109	7585	0	41961	13559	37699
54	1500	0	3310	3925	16352	110	5418	0	39887	8157	22789
55	6210	0	15948	14431	59238	111	23841	0	95243	80459	124099
56	15353	0	11630	14627	27052						

Table 6. 111-Sector DET67 Matrix Before Modification

Waste was considered to be significant in the crude oil and gas sector, and includes that oil and gas which is flared off, or wasted, and is never converted to a usable energy product. The rest of the allocation of crude to crude in the DET matrix is used in "lease condensate", a "self-use", according to reference [6]. The coal sector was treated the same way to account for waste and losses. So, mathematically we defined:

$$SELFUS_{1,1} \leftarrow DET67_{1,1} \; . \qquad (2.5)$$

$$SELFUS_{2,2} \leftarrow DET67_{2,2} \; . \qquad (2.6)$$

Waste and "self-use" also occur in the natural gas utilities sector where some natural gas is lost during pipeline transport. Reference [6] attributes this use of natural gas to the natural gas utilities sector and as a first approximation we defined the amount of this waste and "self-use" to be the total allocation in DET67 of natural gas by the natural gas utilities. Mathematically, this was expressed:

$$SELFUS_{5,5} \leftarrow DET67_{5,5} \; . \qquad (2.7)$$

This approximation is modified in sections 9.2 and 9.3.

Another "self-use" occurs in the electrical utilities sectors, where some electricity is consumed as transmission and distribution losses. Reference [6] also attributes this use of electricity to the three electric power producing sectors. As another first approximation we defined the amount of this "self-use" to be the total allocation in DET67 of electricity by the electric power utilities. Mathematically, this was expressed:

$$SELFUS_{4,j} \leftarrow DET67_{4,j}, \; 6 \leq j \leq 8 \; . \qquad (2.8)$$

This approximation is modified in sections 9.4 and 10.3.

There are two sets of conversions of energy supplies to other energy supplies. In the first instance, there is the conversion of crude oil and gas products to refined petroleum products and to natural gas. We considered all the crude oil and gas products listed in the DET67 matrix as consumed by the refined petroleum products and natural gas sectors to be used by conversion. So, mathematically, we defined:

$$SELFUS_{2,4} \leftarrow DET67_{2,4} \text{ ; and} \qquad (2.9)$$

$$SELFUS_{2,5} \leftarrow DET67_{2,5} \text{ .} \qquad (2.10)$$

In the other instance, there is conversion of the three fossil fuels, coal, refined petroleum products and natural gas, to electricity. We considered all the coal, refined petroleum products and natural gas listed in the DET67 matrix as consumed by the fossil fuel electricity sector to be used by conversion. So, mathematically, we defined:

$$SELFUS_{1,6} \leftarrow DET67_{1,6} \text{ ;} \qquad (2.11)$$

$$SELFUS_{3,6} \leftarrow DET67_{3,6} \text{ ; and} \qquad (2.12)$$

$$SELFUS_{5,6} \leftarrow DET67_{5,6} \text{ .} \qquad (2.13)$$

This also is a first approximation and it is modified in sections 9.4 and 10.3. The SELFUS matrix is displayed in Table 7.

2.4.2.2 <u>The DE67 Matrix</u> - To form DE67, SELFUS was first subtracted out of DET67. Mathematically, this was expressed:

$$DET67_{K,j} \leftarrow DET67_{K,j} - SELFUS_{K,j}, \; 1 \leq K \leq 5 \text{ and } 1 \leq j \leq 8. \qquad (2.14)$$

This modified DET67 was also useful in spreading the supersector energy product totals to the sectors, as shown in parts of sections 3-10. This final, modified DET67 matrix is displayed in Table 8.

This version of the DET67 matrix was then summed directly to yield DE67 by using the correspondences given among sectors

J

	1	2	3	4	5	6	7	8
1	11.64	0	0	0	0	7184	0	0
2	0	989.7	0	23170	17978	0	0	0
3	0	0	0	0	0	976.7	0	0
4	0	0	0	0	0	310.3	2.41	69.89
5	0	0	0	0	597.4	2842	0	0

Table 7. The SELFUS Matrix in Trillions of Btu

1967
DIRECT ENERGY TRANSACTIONS MATRIX
IN BILLIONS OF BTUS

SECTOR	COAL	CRUDE	REFINED	ELECTRIC	GAS	SECTOR	COAL	CRUDE	REFINED	ELECTRIC	GAS
1	0	0	17369	1974	1671	57	13645	0	41256	15603	54136
2	1625	0	23729	32019	756098	58	9139	0	9809	4159	6530
3	0	0	0	0	0	59	16009	0	3496	3569	16229
4	22509	0	1442998	51539	968795	60	12708	0	9162	8051	20093
5	14859	0	13783	5531	1077	61	1908	0	1884	1546	4525
6	40249	0	37335	17232	0	62	3653	0	9754	4422	20171
7	312	0	289	134	0	63	3455	0	5924	4654	9123
8	9049	0	8393	3855	0	64	7958	0	10690	9047	21767
9	0	0	0	0	0	65	2055	0	5447	6773	15099
10	0	0	0	0	0	66	3275	0	3058	4918	4527
11	0	0	0	0	0	67	4256	0	3261	3907	10395
12	0	0	0	0	0	68	8612	0	5260	17106	24745
13	0	0	0	0	0	69	11422	0	4248	7133	19185
14	0	0	0	0	0	70	4010	0	4348	5158	13801
15	0	0	0	0	0	71	5550	0	11421	15662	15342
16	0	0	0	0	0	72	2570	0	3305	14268	15385
17	21132	0	394599	16131	13679	73	3648	0	3586	4085	9365
18	4334	0	573812	16509	12269	74	80994	0	19610	43873	79124
19	0	0	43547	55	525	75	10810	0	17527	28850	32070
20	2167	0	6099	179	2103	76	9024	0	13636	7598	12046
21	1625	0	9078	10529	35999	77	979	0	6349	4569	10591
22	3251	0	11133	13103	25004	78	0	0	8425	3474	5175
23	11369	0	37179	11879	40579	79	4698	0	11785	7412	14974
24	1625	0	5919	9772	95399	80	30859	0	552499	3958	21569
25	0	0	1030743	7120	15504	81	1625	0	159999	11179	4207
26	0	0	234814	1076	2105	82	16797	0	428799	2008	11219
27	13545	0	31959	14025	14377	83	12049	0	655999	2474	3456
28	196995	0	185796	92340	450517	84	2157	0	1119999	2134	6766
29	9409	0	3484	2515	2781	85	541	0	25005	11406	20669
30	59583	0	47974	56608	60570	86	1083	0	0	215	350
31	6095	0	14734	6068	18623	87	2167	0	79288	16804	36469
32	7959	0	23168	15937	20057	88	1625	0	609	5954	12799
33	6726	0	1866	2852	10520	89	28718	0	8416	8393	53829
34	10261	0	76562	24405	76221	90	14088	0	1510798	301828	699908
35	541	0	983	576	2278	91	7565	0	111979	42531	93274
36	6438	0	5356	5404	6763	92	0	0	144792	24606	120799
37	3101	0	2496	2456	9008	93	29801	0	283484	43091	115376
38	351190	0	294588	80532	374151	94	3251	0	159795	13516	159030
39	2849	0	16839	7354	25099	95	1625	0	212126	12279	10899
40	2867	0	20056	19253	38457	96	1083	0	21712	10506	21919
41	439250	0	208137	283594	1809590	97	53643	0	258600	177538	397738
42	184130	0	224104	30534	117899	98	1083	0	53549	9705	35589
43	19570	0	31547	9152	26710	99	11378	0	50255	25919	292799
44	1028	0	27749	2124	9999	100	0	0	0	0	0
45	17339	0	219799	1201	17249	101	0	0	0	0	0
46	3459	0	185299	582	13189	102	650181	0	10659985	1173999	4364996
47	59352	0	32926	34811	57093	103	0	0	0	0	0
48	6295	0	5832	1040	3856	104	487299	75649	293799	0	191299
49	2100	0	4409	2975	6102	105	1313199	238399	493199	14839	84469
50	8320	0	13774	17213	199509	106	196691	0	1145215	42307	54529
51	313705	0	117948	50153	504050	107	35762	0	169920	4071	29629
52	2441040	0	242508	177500	917498	108	83445	0	177849	131818	429599
53	61794	0	47291	196078	345537	109	7585	0	41961	13559	37699
54	1500	0	3310	3925	15352	110	5418	0	39827	6157	22759
55	6210	0	15948	14431	59235	111	23841	0	95243	80459	124099
56	15353	0	11630	14627	27052						

Table 8. Modified DET67 Matrix

		S			
		1	2	3	4
	1	4531	65.13	551.3	656.2
	2	0	0	0	0
K	3	3770	14050	4245	2266
	4	1532	33.41	1020	1174
	5	7603	70.64	2795	4365

Table 9. The DE67 Matrix in Trillions of Btu's

and supersectors in Table 2. Mathematically, this sum is expressed:

$$DE67_{K,S} \leftarrow \sum_{j \varepsilon S} DET67_{K,j} \;,\; 1 \le K \le 5 \text{ and } 1 \le S \le 4 \;. \qquad (2.15)$$

For S = 1, j = 1-4, 21-24 and 27-79; for S = 2, j = 80-86; for S = 3, j = 5-8, 17-20, 25, 26, 87-101 and 106-111; and for S = 4, j = 102.

Next we modified DE67 to reflect the PEC definition of the transportation supersector and make DE67 exactly congruent to DE68. To do this, it was necessary to add allocations of refined petroleum that went to motive power fuels in non-transportation sectors and greases and lubricants in non-transportation sectors into $DE67_{2,2}$, the allocation of refined petroleum to the transportation supersector. It was also necessary to subtract from the other supersectors the amounts of these fuels and feedstocks they used. The amounts of fuels were computed from data in section 4.2: 122.363 x 10^{12} Btu for the industrial supersector; 2592.71 x 10^{12} Btu for the commercial and government supersector; and 8319.1724 x 10^{12} Btu's for the residential sector to account for feedstocks as well, we multiplied these totals by 1.010162, which is the ratio in PEC of motive power fuels to the sum of motive power fuels and motive power feedstocks, as mentioned in section 4.2. Table 9 displays the modified DE 67 matrix.

2.4.3 Creation of the E68 and DE68 Matrices

Figures 5-13 are photocopied from PEC. They summarize the basic data in that source in flow chart form. E68 was derived from these charts; Table 10 displays the E68 matrix. Table 11 shows the DE68 matrix as aggregated from E68 and it also presents the other two row-sum aggregation matrices derived from E68 for cross-checking purposes. With only eight exceptions, the figures in Table 10 have been lifted directly from the charts; the exceptions follow:

1. Coal allocated to use as coke is determined in section 3.1 and is subtracted from PEC's total for the industrial supersector's use of coal as a "fuel"; the remainder of the coal used by the industrial supersector as a fuel is allocated to the miscellaneous thermal uses total.

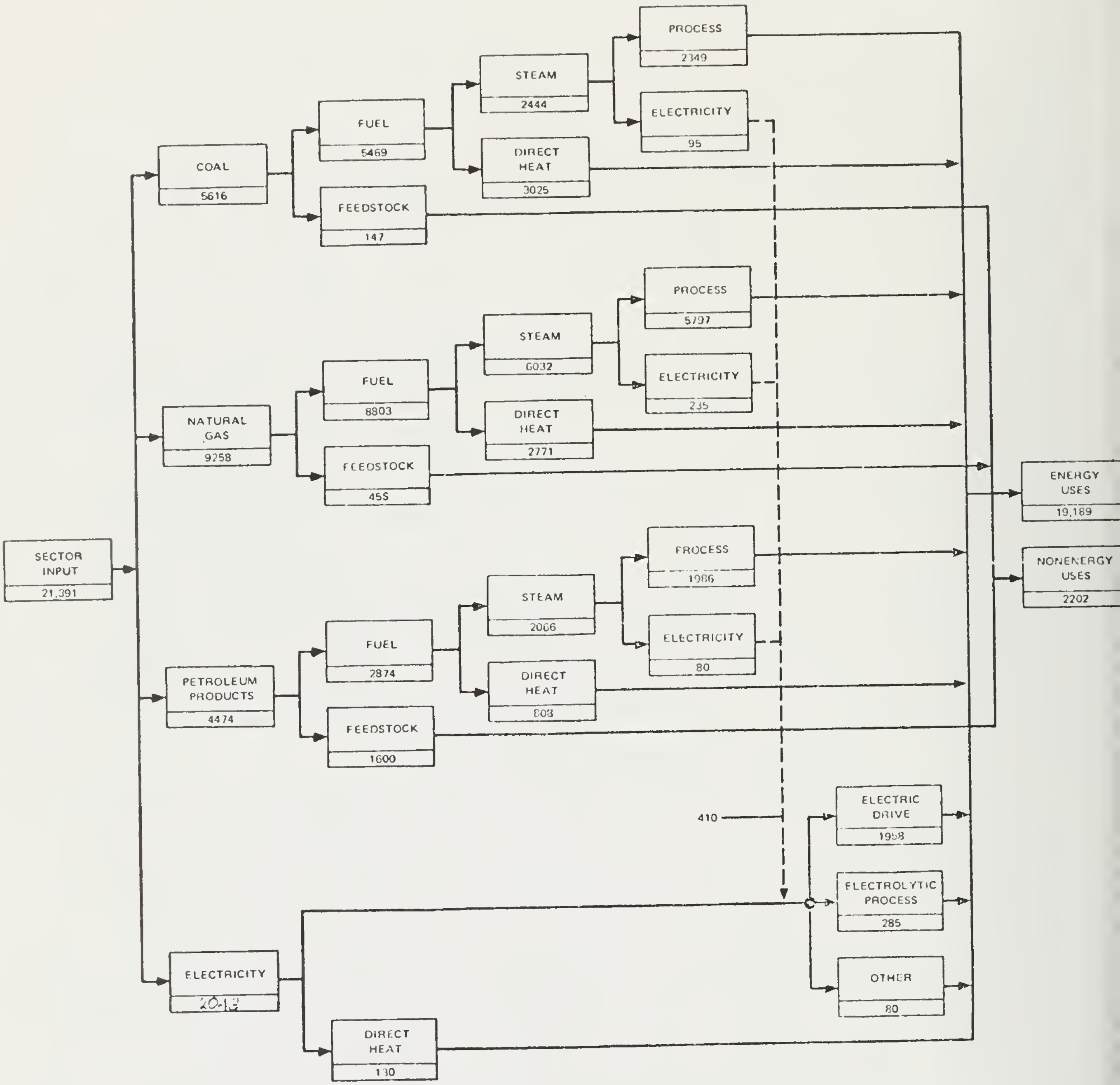


Figure 5. 1968 INDUSTRIAL CONSUMPTION OF ENERGY (Trillions of Btu)

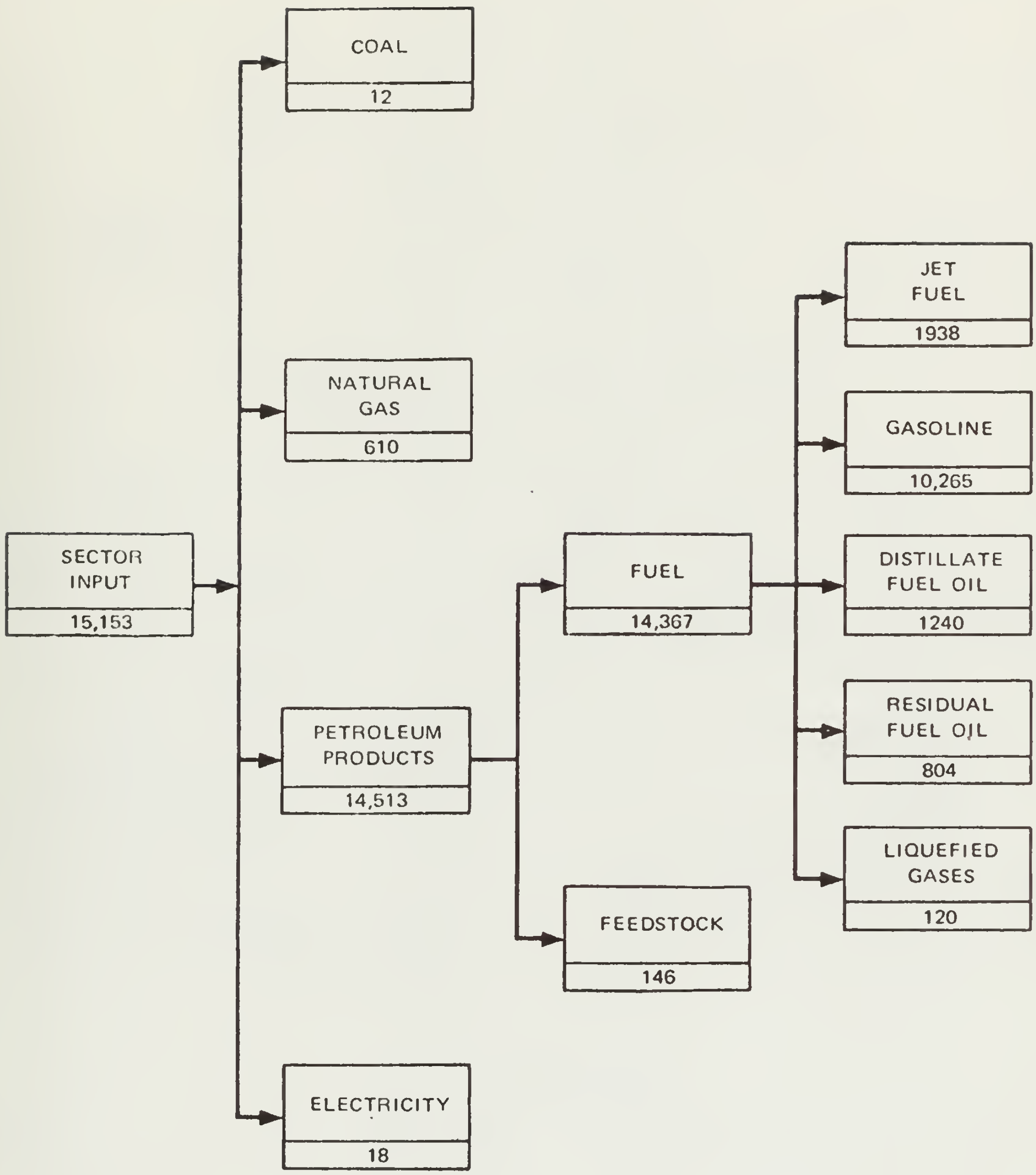


Figure 6. 1968 TRANSPORTATION CONSUMPTION OF ENERGY (Trillions of Btu)

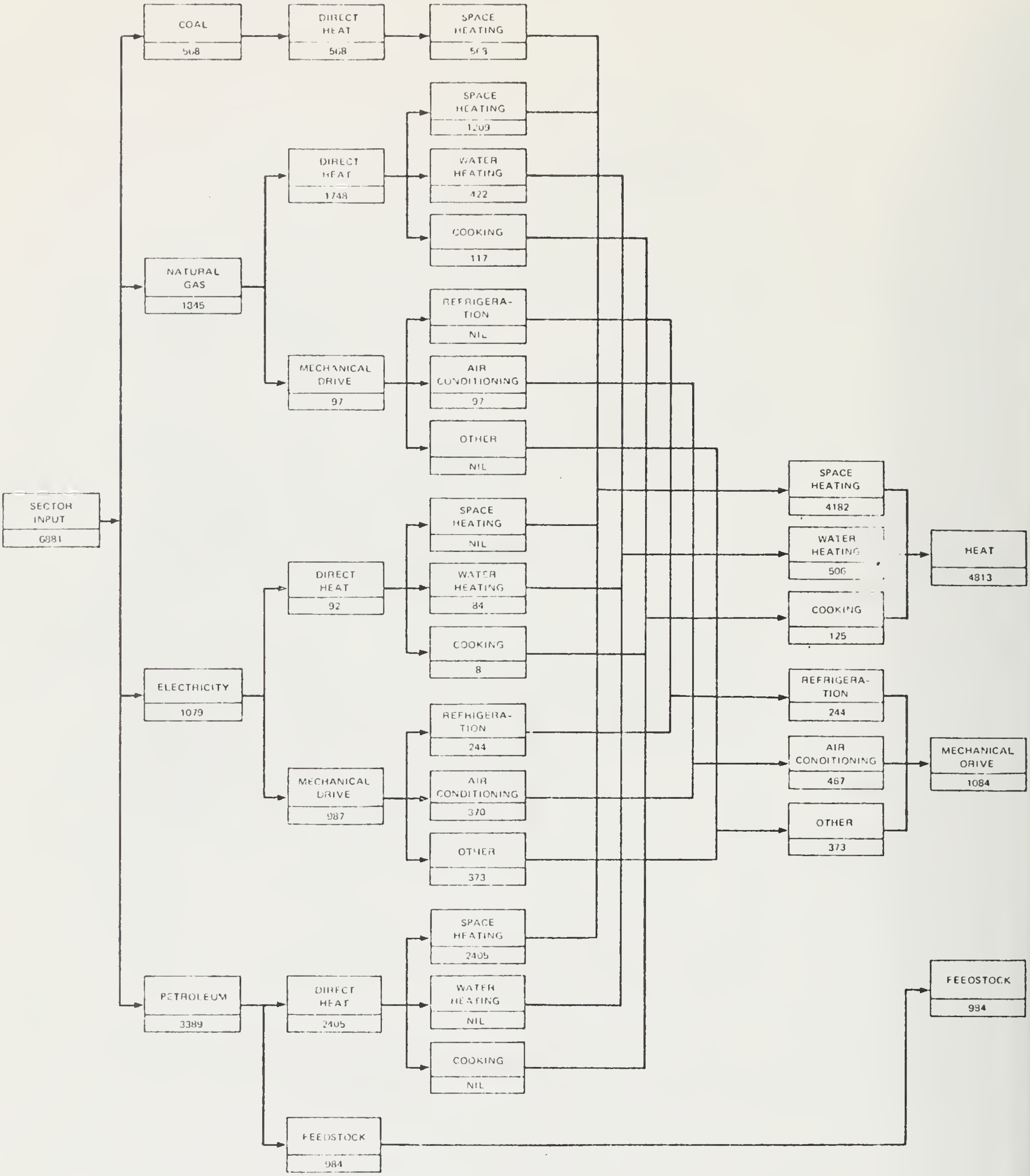


Figure 7. 1968 COMMERCIAL CONSUMPTION OF ENERGY (Trillions of Btu)

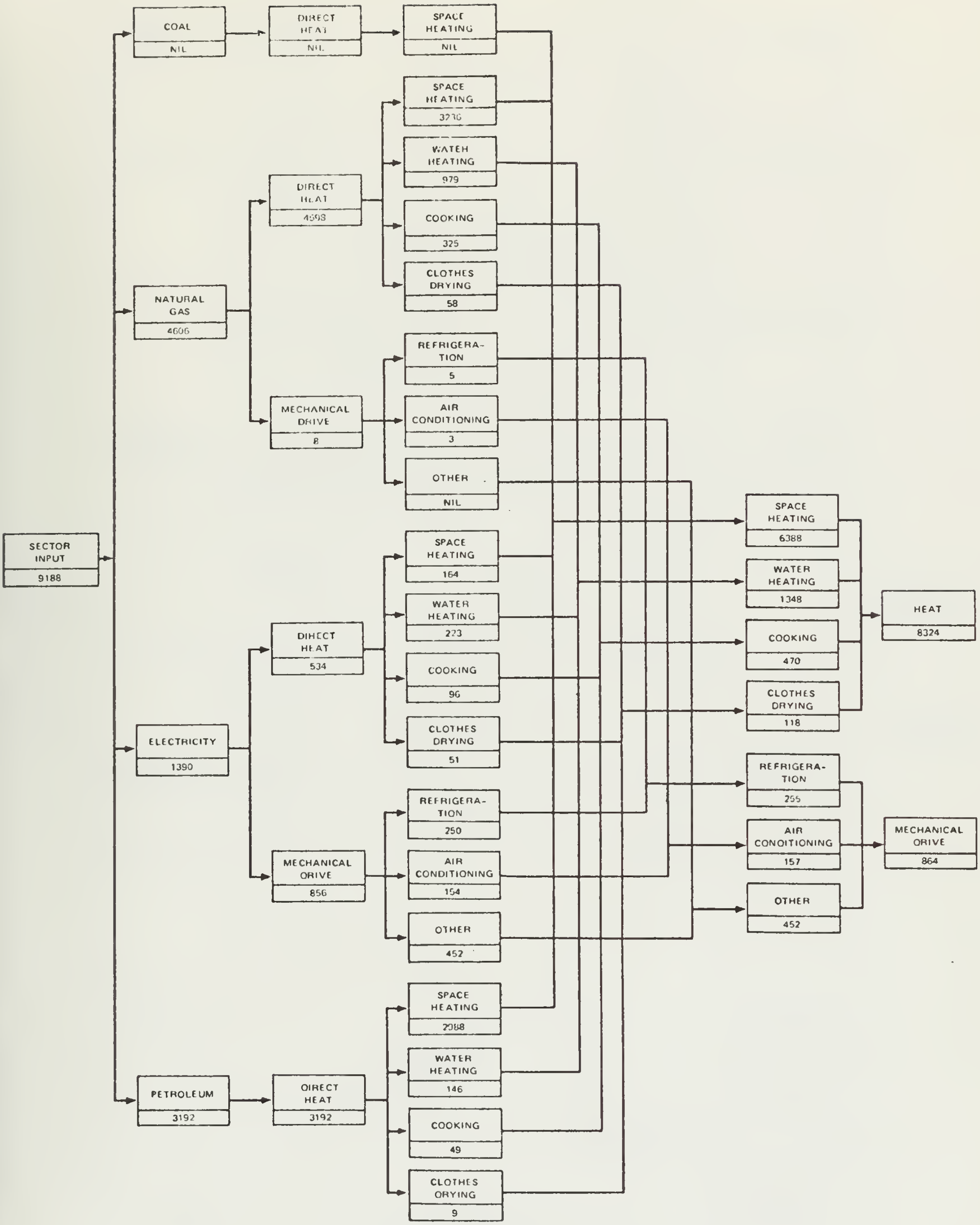


Figure 8. 1968 RESIDENTIAL CONSUMPTION OF ENERGY (Trillions of Btu)

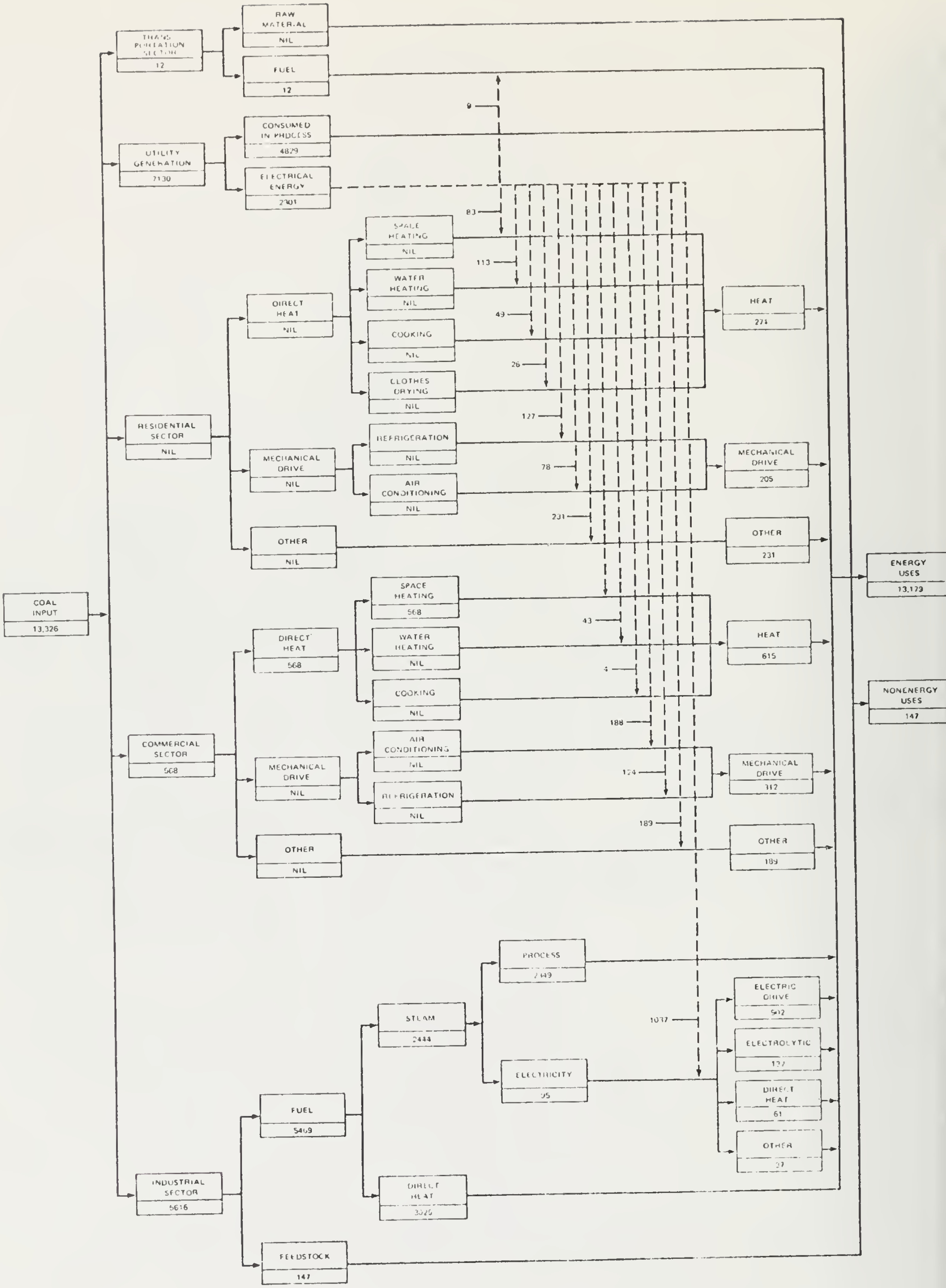


Figure 9. 1968 CONSUMPTION OF ALL TYPES OF COAL (Trillions of Btu)

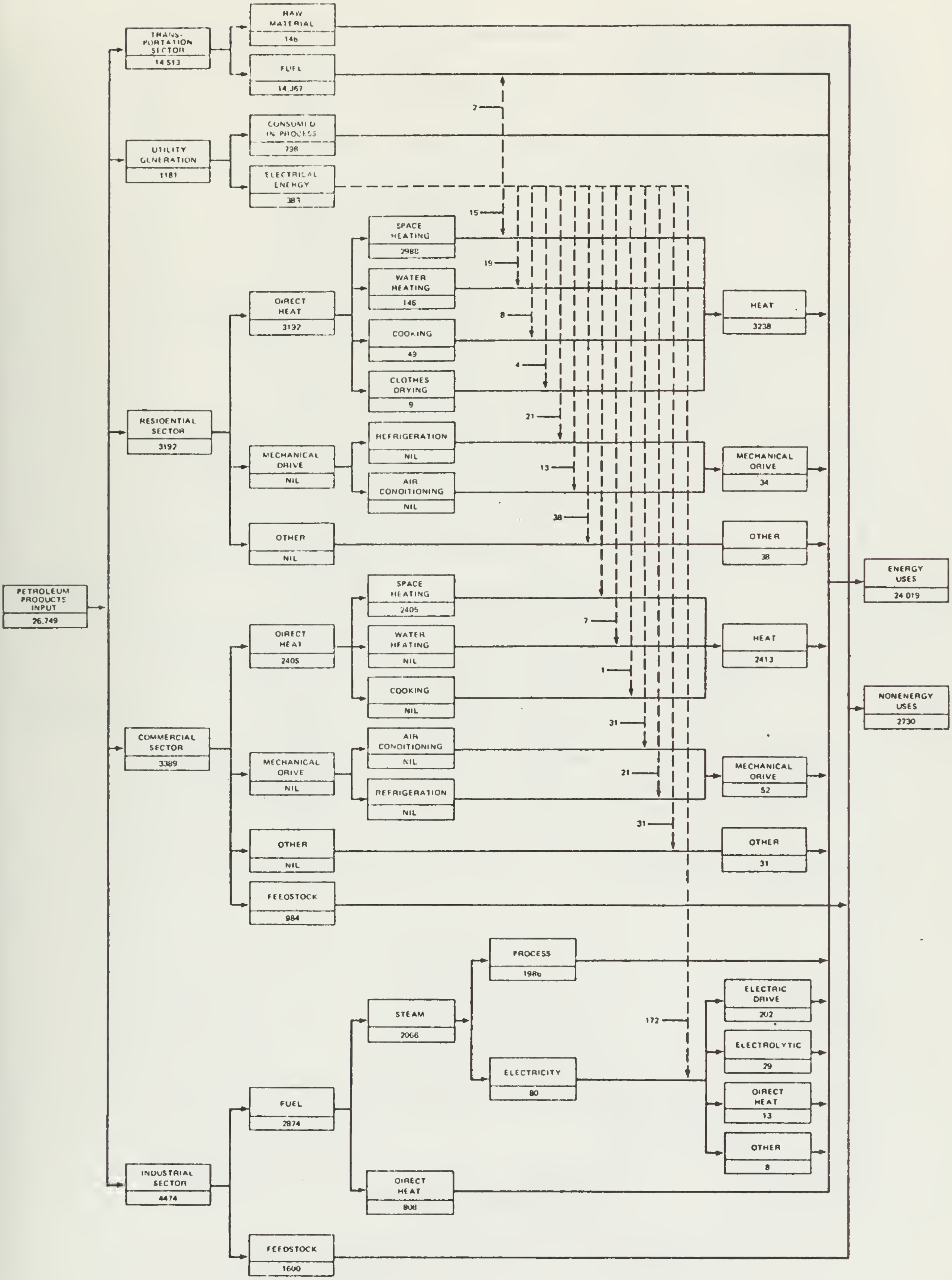


Figure 10. 1968 CONSUMPTION OF PETROLEUM PRODUCTS (Trillions of Btu)

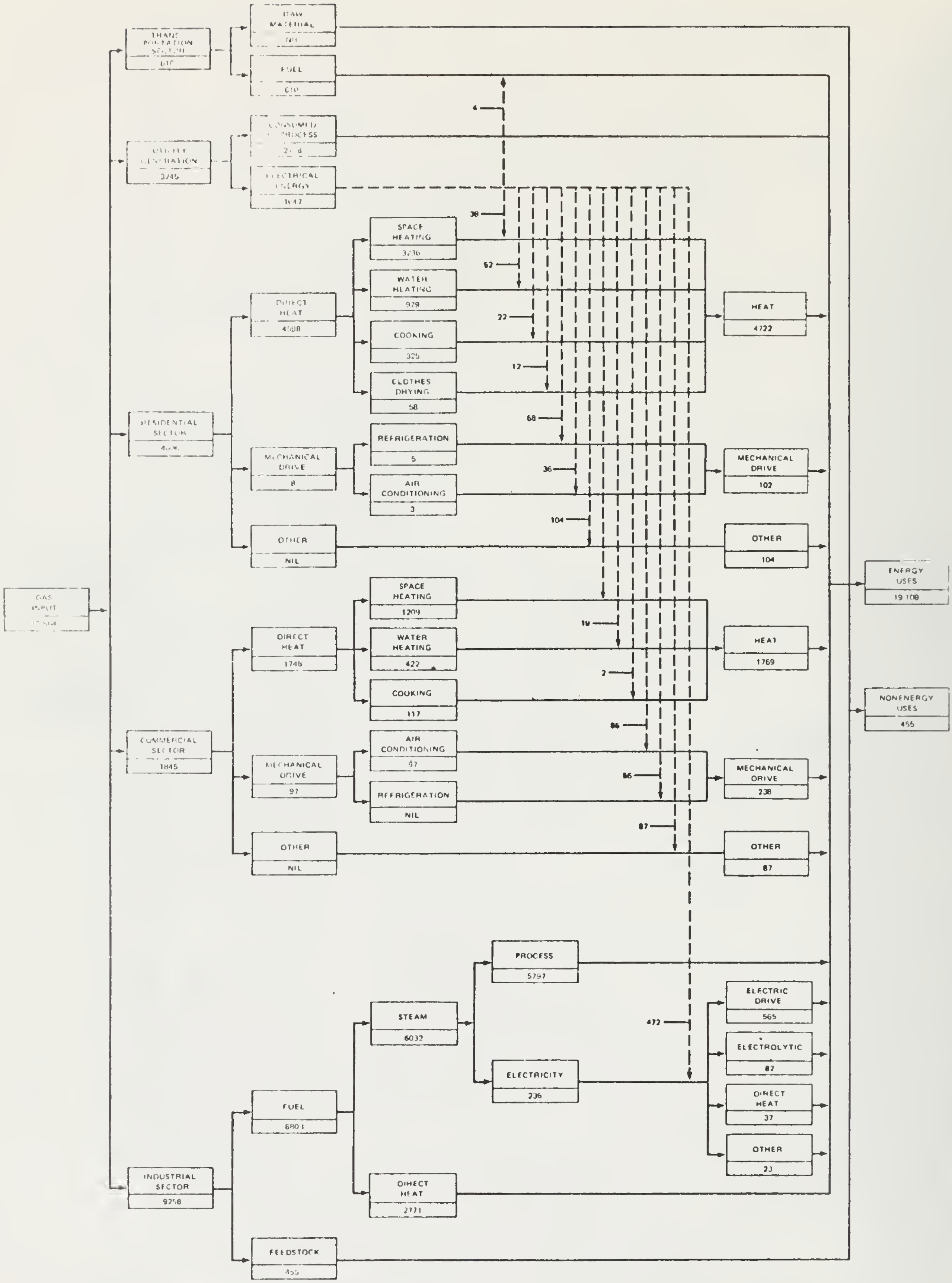


Figure 11. 1968 CONSUMPTION OF DRY NATURAL GAS (Trillions of Btu)

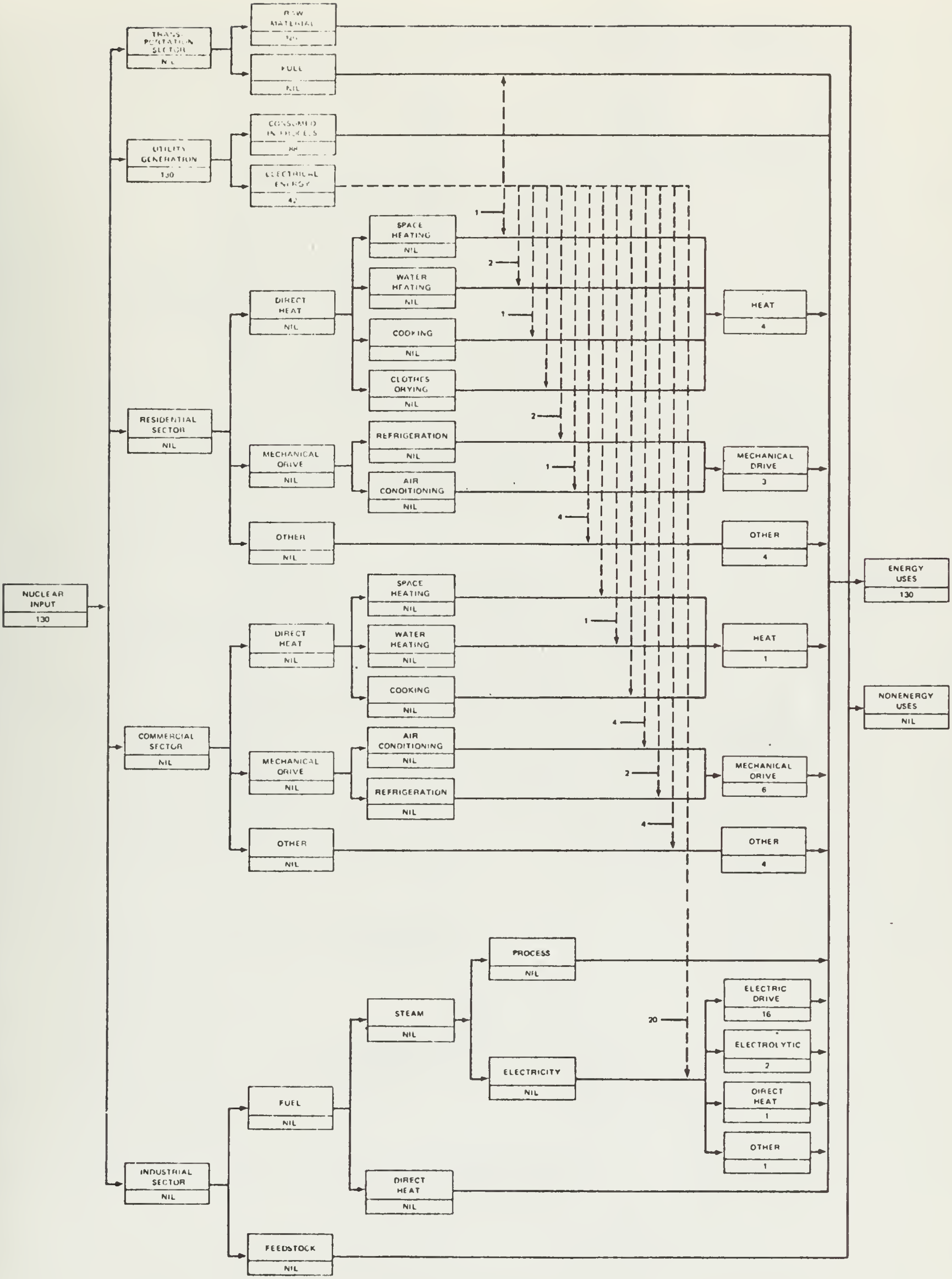


Figure 12. 1968 CONSUMPTION OF NUCLEAR POWER (Trillions of Btu)

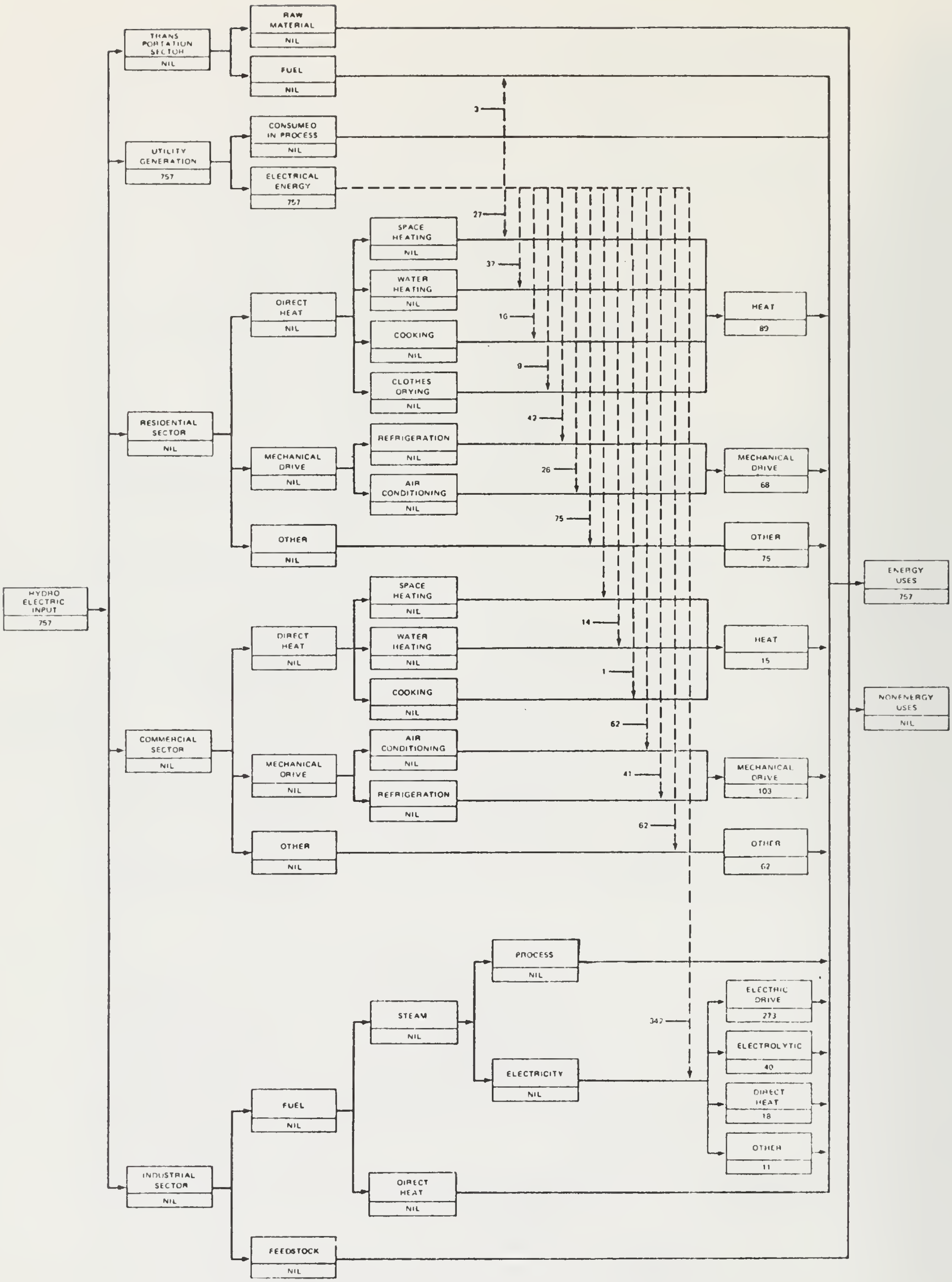


Figure 13. 1968 CONSUMPTION OF HYDROPOWER (Trillions of Btu)

Subscripts	Total	Subscripts	Total	Subscripts	Total	Subscripts	Total	Subscripts	Total
1,1,1	2,327	2,1,1	0	3,1,1	0	4,1,1	0	5,1,1	0
1,1,2	0	2,1,2	0	3,1,2	0	4,1,2	0	5,1,2	0
1,1,3	0	2,1,3	0	3,1,3	0	4,1,3	0	5,1,3	0
1,1,4	0	2,1,4	0	3,1,4	0	4,1,4	0	5,1,4	0
1,2,1	147	2,2,1	0	3,2,1	1,600	4,2,1	0	5,2,1	455
1,2,2	0	2,2,2	0	3,2,2	146	4,2,2	0	5,2,2	0
1,2,3	0	2,2,3	0	3,2,3	984	4,2,3	0	5,2,3	0
1,2,4	0	2,2,4	0	3,2,4	0	4,2,4	0	5,2,4	0
1,3,1	0	2,3,1	0	3,3,1	0	4,3,1	0	5,3,1	0
1,3,2	0	2,3,2	0	3,3,2	14,367	4,3,2	0	5,3,2	0
1,3,3	0	2,3,3	0	3,3,3	0	4,3,3	0	5,3,3	0
1,3,4	0	2,3,4	0	3,3,4	0	4,3,4	0	5,3,4	0
1,4,1	3,142	2,4,1	0	3,4,1	2,874	4,4,1	0	5,4,1	8,803
1,4,2	0	2,4,2	0	3,4,2	0	4,4,2	0	5,4,2	0
1,4,3	0	2,4,3	0	3,4,3	0	4,4,3	7	5,4,3	117
1,4,4	0	2,4,4	0	3,4,4	58	4,4,4	134	5,4,4	388
1,5,1	0	2,5,1	0	3,5,1	0	4,5,1	0	5,5,1	0
1,5,2	0	2,5,2	0	3,5,2	0	4,5,2	0	5,5,2	0
1,5,3	0	2,5,3	0	3,5,3	0	4,5,3	77	5,5,3	422
1,5,4	0	2,5,4	0	3,5,4	146	4,5,4	202	5,5,4	979
1,6,1	0	2,6,1	0	3,6,1	0	4,6,1	0	5,6,1	0
1,6,2	12	2,6,2	0	3,6,2	0	4,6,2	0	5,6,2	387
1,6,3	568	2,6,3	0	3,6,3	2,405	4,6,3	0	5,6,3	1,289
1,6,4	0	2,6,4	0	3,6,4	2,988	4,6,4	149	5,6,4	3,236
1,7,1	0	2,7,1	0	3,7,1	0	4,7,1	0	5,7,1	0
1,7,2	0	2,7,2	0	3,7,2	0	4,7,2	0	5,7,2	0
1,7,3	0	2,7,3	0	3,7,3	0	4,7,3	100	5,7,3	17
1,7,4	0	2,7,4	0	3,7,4	0	4,7,4	140	5,7,4	3
1,8,1	0	2,8,1	0	3,8,1	0	4,8,1	1,859	5,8,1	0
1,8,2	0	2,8,2	0	3,8,2	0	4,8,2	16	5,8,2	0
1,8,3	0	2,8,3	0	3,8,3	0	4,8,3	798	5,8,3	0
1,8,4	0	2,8,4	0	3,8,4	0	4,8,4	639	5,8,4	0

Table 10. E68, Derived from PEC

Table 11. DE68, Derived from PEC, and Other Row-Sum Matrices from E68

$$DE68_{K,S} = \sum_{P} E68_{K,P,S} \longrightarrow$$

K \ S	1	2	3	4	
	21,207	14,928	6,784	9,062	
1	5,616	12	568	0	6,196
2	0	0	0	0	0
3	4,474	14,513	3,389	3,192	25,568
4	1,859	16	982	1,264	16,096
5	9,258	387	1,845	4,606	4,121

K: 1	2	3	4	5	i	P
2,327	0	0	0	0	9	1
147	0	2,730	0	455	10	2
0	0	14,367	0	0	11	3
3,142	0	2,932	141	9,308	12	4
0	0	146	279	1,401	13	5
580	0	5,393	149	4,912	14	6
0	0	0	240	20	15	7
0	0	0	3,312	0	16	8

i	S: 1	2	3	4	
9	2,327	0	0	0	2,327
10	2,202	146	984	0	3,332
11	0	14,367	0	0	14,367
12	14,819	0	124	580	15,523
13	0	0	499	1,327	1,825
14	0	399	4.262	6,373	11,034
15	0	0	117	143	260
16	1,859	16	798	639	3,312

2. All PEC allocations of electricity supplies have been deflated by nine percent, as noted above, because the PEC totals include in their allocations of electricity to the supersectors that electricity which is consumed in transmission and distribution.

3. The PEC total for natural gas in the transportation supersector has been decreased by an amount we calculated as the total consumed in pipeline transport of natural gas, as mentioned earlier; that amount was calculated as follows:

$489{,}877 \times 10^6$ ft^3	- natural gas losses to gas producers and distributors according to reference [14]
$-274{,}300 \times 10^6$ ft^3	- producers' waste according to reference [15]
$215{,}577 \times 10^6$ ft^3	- consumed in pipeline transport
* 1,035 Btu/ft^3	- conversion factor
~ 223×10^{12} Btu	- consumed in pipeline transport.

PEC does not show energy products to which their total for natural gas use in the transportation supersector should be allocated, but we allocated it to space heat and then modified this assumption in section 8.1.

4. PEC allocated 130 trillion Btu's of electricity to industrial supersector miscellaneous thermal uses for 1968. We considered this to be a miscellaneous electric use as explained in sections 2.2.4, 7.0, and 10.1.

5. Included in PEC's allocation of electricity to the transportation supersector is that portion of motive power that was powered by electricity (mostly electric railroads and urban mass transit). We considered this to be a miscellaneous electric use for reasons explained in sections 2.2.3, 8.0, and 10.2. PEC does not show energy products to which their electricity total for the transportation supersector should be allocated, but we assumed it all went to miscellaneous electric under this broader definition.

6. PEC also does not show energy products to which their coal total for the transportation supersector should be allocated, but we assumed it all went to space heat. See again section 8.0.

7. The DET 67 matrix shows substantial amounts of coal used by the personal consumption sector of the 111-sector I-O model, the equivalent of the PEC residential sector. PEC assumed zero use of coal by this sector, apparently because the authors had only unsatisfactory data on it; this use was then apparently included in the PEC coal use totals for the commercial supersector. After the E68 and DE68 matrices were created we used the following assignment statements to compute a 1968 residential sector use of coal and subtract this use from the allocation of coal to the commercial supersector:

$$DE68_{1,4} \leftarrow DE68_{1,3} * DE67_{1,4} / (DE67_{1,3} + DE67_{1,4}); \quad (2.16)$$

$$DE68_{1,3} \leftarrow DE68_{1,3} - DE68_{1,4}; \quad (2.17)$$

$$E68_{1,6,3} \leftarrow DE68_{1,3}; \text{ and} \quad (2.18)$$

$$E68_{1,6.4} \leftarrow DE68_{1,4}. \quad (2.19)$$

These assignments assume first that the ratio of coal use by each of these two sectors was constant over the 1967-68 period. They also assume that the residential supersector, like the commercial supersector, uses coal only for space heating.

8. Stanford research Institute, authors of PEC, has informed Brookhaven National Laboratory that certain numbers in Figures 5-13 were incorrect [30]. They now estimate that only 110 trillion Btu's of electricity and 17 trillion Btu's of natural gas were used in 1968 by the commercial supersector for "air-conditioning." This means also, they reported, that 533 trillion Btu's of electricity were used for "other mechanical drive" and 1289 trillion Btu's of natural gas were used for "space heating." Our treatment of these electricity figures, of course, was subject to the qualification of item 2 in this section.

2.4.4 Modifications to the 1967 LABOR Vector

The LABOR vector for 1967 was taken from reference [11] as a vector of 90 entries, each the 1967 full-time employee-year equivalents of labor for an intermediate sector in the CAC 100-sector I-O model. We rearranged the entries in this vector in a manner almost entirely parallel to the modifications made in section 2.4.1 to the DET matrix to get DET67. We carried old sectors 1, 2, 3, 5, and 6-90 forward to become new sectors 1, 2, 4, 5, and 17-101. New sectors 3 and 9-16 were assigned zeroes for the same reasons the DET67 input columns for these sectors were zeroed. We used f, n, and r, the electricity generation fractions from section 2.4.1 to allocate old sector 4 among new sectors 6, 7 and 8 in the same manner that $DET_{4,4}$ was allocated to $DET67_{4,6}$, $DET67_{4,7}$, and $DET67_{4,8}$. Zeroes were allocated to sectors 102-105 since they are not real producing sectors. Government employment was not disaggregated in reference [11] so we had to find other data for sectors 106-111. Amounts in sectors 106 and 107, federal government, were taken from page 250 of reference [17]. Entries in sectors 108-111, state and local government, were obtained by using data from page 430 of the same source. First we obtained a total for sector 108, then a total for sectors 109-111 combined; this second total was allocated among these three sectors by using percentages of the sum that went to each in 1969, since direct data for that year was given on the same page. Table 12 displays the LABOR vector and new set of subscripts.

2.5 CREATION OF E67 AND T67 MATRICES

Our method for creating E67 used DE67, E68, and DE68. We assumed the 1968 PEC fractions for use of each fuel for the set of energy products within a supersector also held for 1967. This also implied an assumption that the technology for producing energy products was nearly constant throughout the economy for a year, which seemed reasonable. Combining the data in this way yielded a set of totals for fuels allocated to each energy product in each

1.	147000	29.	87000	57.	462000	85.	17460
2.	298000	30.	605000	58.	104000	86.	96025
3.	0	31.	124000	59.	153000	87.	852000
4.	148647	32.	1483000	60.	188000	88.	123000
5.	158753	33.	173000	61.	88000	89.	41830
6.	429999	34.	634116	62.	367000	90.	16160000
7.	3339	35.	40884	63.	208000	91.	2780989
8.	96674	36.	334000	64.	295000	92.	613098
9.	0	37.	143000	65.	247000	93.	2851000
10.	0	38.	466000	66.	239000	94.	2824827
11.	9	39.	214000	67.	129000	95.	529000
12.	0	40.	1113000	68.	418000	96.	758000
13.	0	41.	468000	69.	175000	97.	5423000
14.	0	42.	205000	70.	204000	98.	829405
15.	0	43.	258000	71.	667000	99.	322000
16.	0	44.	68000	72.	385000	100.	0
17.	1792276	45.	15756	73.	114000	101.	0
18.	2067724	46.	18597	74.	817000	102.	0
19.	113000	47.	519000	75.	836000	103.	0
20.	223000	48.	33000	76.	302000	104.	0
21.	29000	49.	320000	77.	299000	105.	0
22.	52000	50.	177000	78.	155000	106.	4606000
23.	109591	51.	465000	79.	452000	107.	1661000
24.	13409	52.	936000	80.	754061	108.	3658000
25.	3314164	53.	394000	81.	469523	109.	1440582
26.	666836	54.	78000	82.	1077591	110.	877107
27.	317000	55.	497000	83.	197143	111.	1479311
28.	1799086	56.	350000	84.	310197		

Table 12. LABOR Vector 1967 (Number of Jobs)

supersector for 1967. Using some more particular data from the CAC model, from PEC, and from other sources, we disaggregated the supersector totals into totals for each of our 111 sectors. We also accounted for the efficiencies of conversion of each energy supply source to each energy product in each supersector. Aggregating the totals for each energy product over the various energy supplies yielded the energy product inputs to each sector. Actually these last two steps, disaggregation of the supersector totals for the energy products and application of conversion efficiency coefficients, were not such well-defined sequential steps, but were in fact done together at times and in the opposite order, and with variations in methods, as will be seen in sections 3-10. All of this and all of the above are made explicit below.

Mathematically, the assumption of constant percentages was stated:

$$\frac{E67_{K,P,S}}{DE67_{K,S}} = \frac{E68_{K,P,S}}{DE68_{K,S}}, \quad K = 1\text{-}5,\ P = 1\text{-}8,\ \text{and } S = 1\text{-}4. \tag{2.20}$$

This says, for example, that the natural gas used in the commercial supersector for water heat as a proportion of the total amount of natural gas used in that supersector was invariant over the period of a year. This equation was rearranged into more useful form:

$$E67_{K,P,S} = \frac{E68_{K,P,S}}{DE68_{K,S}} * DE67_{K,S}, \quad K = 1\text{-}5,\ P = 1\text{-}8,\ \text{and } S = 1\text{-}4. \tag{2.21}$$

In this form, it was used as an assignment statement to define the entries in the E67 matrix. Table 13 displays the E67 matrix.

Next, we created the T67 matrix discussed above by applying efficiencies of conversion of energy supplies to energy products to the entries of the E67 matrix and then aggregating these products over the energy supplies. To put that mathematically, we defined:

$$T67_{P,S} \leftarrow \sum_{K=1}^{5} (E67_{K,P,S} * ETA_{K,P,S}), \quad P = 1\text{-}8 \text{ and } S = 1\text{-}4. \tag{2.22}$$

			S			
			1	2	3	4
K=1	P	1	1878	0	0	0
		2	118.6	0	0	0
		3	0	0	0	0
		4	2535	0	0	0
		5	0	0	0	0
		6	0	65.13	551.3	656.2
		7	0	0	0	0
		8	0	0	0	0
K=2	P	1	0	0	0	0
		2	0	0	0	0
		3	0	0	0	0
		4	0	0	0	0
		5	0	0	0	0
		6	0	0	0	0
		7	0	0	0	0
		8	0	0	0	0
K=3	P	1	0	0	0	0
		2	1348	141.4	1233	0
		3	0	13910	0	0
		4	2421	0	0	41.18
		5	0	0	0	103.7
		6	0	0	3012	2121
		7	0	0	0	0
		8	0	0	0	0
K=4	P	1	0	0	0	0
		2	0	0	0	0
		3	0	0	0	0
		4	0	0	7.269	124.5
		5	0	0	79.96	187.6
		6	0	0	0	138.4
		7	0	0	103.8	130
		8	1532	33.41	828.7	593.5
K=5	P	1	0	0	0	0
		2	373.7	0	0	0
		3	0	0	0	0
		4	7229	0	177.2	367.7
		5	0	0	639.3	927.8
		6	0	70.64	1953	3067
		7	0	0	25.75	2.843
		8	0	0	0	0

Table 13. E67, Derived from DET67 and PEC - in Trillions of Btu's

This yielded a matrix of 1967 allocations of each energy product to each supersector. Table 14 displays the T67 matrix. Sections 3-11 of this document describe how these supersector totals were disaggregated to yield 1967 allocations of each energy product to each individual sector, the entries in the EP67 and EKP111 matrices.

Figure 14 is another representation of the T67 matrix, showing it divided into submatrices. Each submatrix is considered as a unit in the following sections (3-11) in the order indicated in Figure 14. In each section, the supersector totals in the corresponding submatrix are spread among the appropriate sectors to yield the EP67 matrix and the corresponding supersector totals in the E67 matrix are spread among the appropriate sectors to yield the EKP111 matrix. Modifications which were made to these algorithms are discussed in section 11.2.

P \ S	1	2	3	4
1	1,258	0	0	0
2	1,799	141.4	1233	0
3	0	2,782	0	0
4	8048	0	120.7	387.8
5	0	0	527.4	789
6	0	99.98	4,179	4,315
7	0	0	357.9	275.9
8	1,532	33.41	828.7	593.5

Table 14. T67, Derived from E67 - in trillions of Btu's

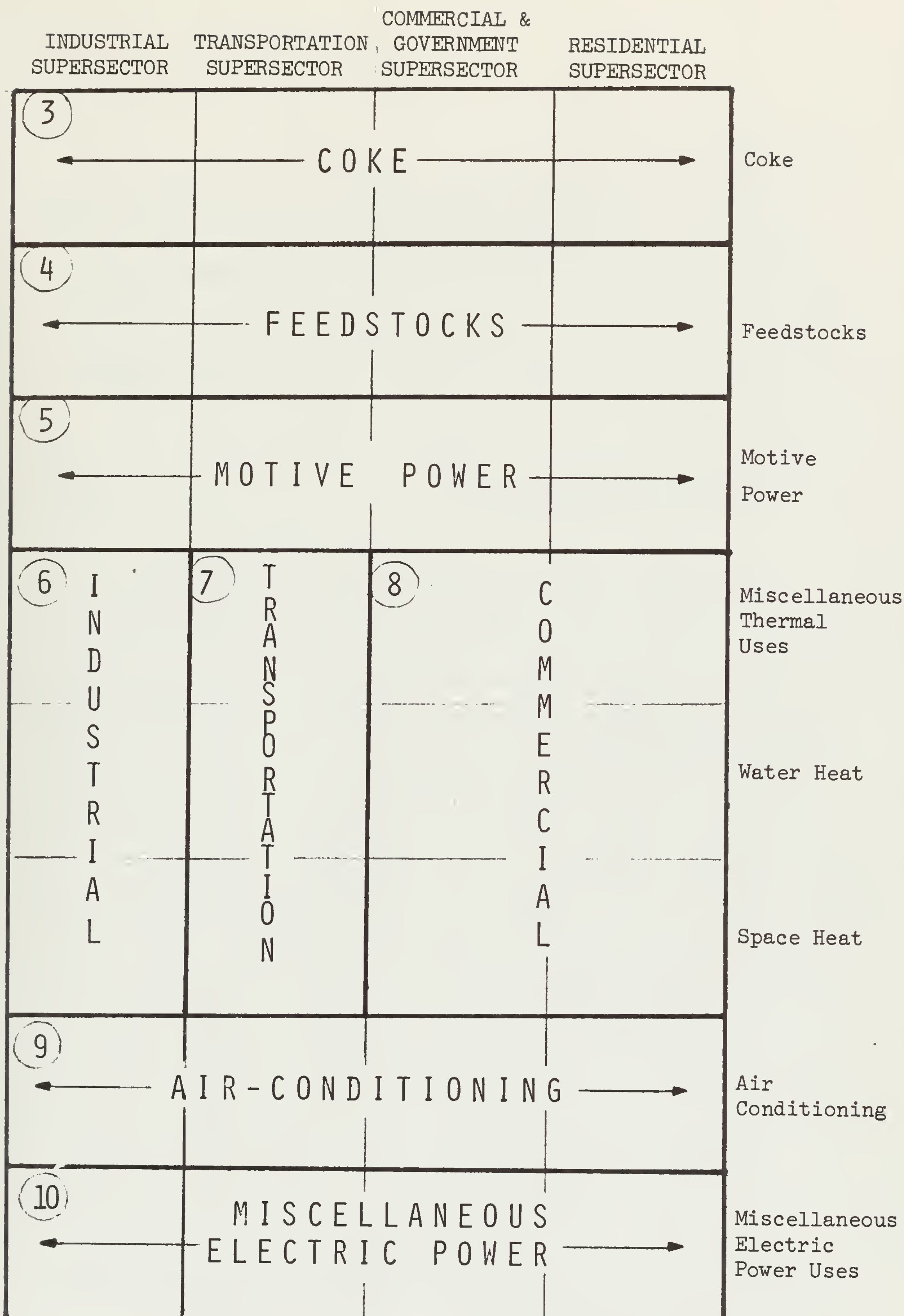


Figure 14. - BREAKDOWN OF T67 MATRIX INTO UNITS (Submatrices) FOR SECTIONS 3-11

◯ Encircled numbers refer to sections of this report.

3.0 COKE (ORE REDUCTION FEEDSTOCKS)

Data for use of this energy product was found only for the industrial sectors and we assumed that the other supersectors used no coke. In reference [6] all coal for making coke was allocated directly to each of the coke-using sectors. It was assumed there that the primary iron and steel sector does not function as an energy supply sector. We preserved those conventions here.

3.1 INDUSTRIAL SUPERSECTOR

PEC (pages 89-93) gives figures for coke use only in the primary iron and steel sector, but notes that other sectors do use small amounts and that there is buying and selling of this energy product among the sectors that use it. The <u>1967 Census of Manufacturers</u> (COM) [7] gives coke purchase data on a sector-by sector basis for other coke-using sectors. For 1967 PEC lists use of coal in the primary iron and steel sector at 56,435 thousand net tons (which it converts to 2306×10^{12} Btu of coke) and COM lists the net buying of coke by other sectors at 949.23 thousand short tons of coke, screenings, and breeze (Volume I, Table 7A, pp. 6-27 to 6-196 and "Fuels and Electric Energy Consumed" summary, Table 4, pp. 14-27), which we converted to 21.358×10^{12} Btu, following ref. [6]. Table 15 displays these allocations of Btu's of coal for coking to the non-energy sectors. COM also gives figures for use by our sector 41 ("Chemicals and chemical products") of coal to make coke which is then used as a materials feedstock, rather than for ore reduction energy. We did not list this use in Table 15 because we consider it a use of coal as a feedstock and it is covered in section 5.1. Mathematically, we made the direct assignment allocations of coal for coke to each sector this way:

$$EP67_{1,j} \leftarrow AMOUNT_j * ETA_{1,1,1};\tag{3.1}$$

$$EKP111_{1,1,j} \leftarrow AMOUNT_j ,\tag{3.2}$$

for j = 28, 51-53, 55, 57-60, 63-65, 71, and 74;

$$EP67_{1,j} \leftarrow 0; \text{ and}\tag{3.3}$$

$$EKP111_{1,1,j} \leftarrow 0 ,\tag{3.4}$$

for j = 3, 4, 27, 29-50, 54, 56, 61, 62, 66-70, 72, 73 and 75-79. $AMOUNT_j$ is the amount of coal allocated to coke use by sector j in Table 14.

A direct assignment-based value can now be computed for $E67_{1,1,1}$ (the allocation of coal to coke in the industrial supersector) by summing the allocations to the individual sectors. The total is 2327.358 trillion Btu. Since we here circumvented our basic procedure by computing a new value for $E67_{1,1,1}$, we had to make some adjustments to other figures to maintain consistency. Since coal is applied to only one other energy product in the industrial supersector (except for feedstocks, in which the allocations are made in sector 5.1 by direct assignment), miscellaneous thermal applications (which includes amounts for coal used in space heat and water heat in this supersector), we simply subtracted from $E67_{1,4,1}$(coal allocated to miscellaneous thermal applications in the industrial supersector) the amount which had been added to $E67_{1,1,1}$. Then we recomputed $T67_{1,1}$ (coke used by the industrial supersector) and $T67_{4,1}$ (miscellaneous thermal energy used by the industrial supersector), since the numbers on which they were based have been changed. Mathematically, all of the above reduces to:

$$ENET \leftarrow 2327.358 \text{ trillion Btu} - E67_{1,1,1}\tag{3.5}$$

$$E67_{1,1,1} \leftarrow 2327.358 \text{ trillion Btu} ;\tag{3.6}$$

[illegible] NUMBER [illegible] NAME	THOUSAND SHORT TONS OF COKE, SCREENINGS & BREEZE**	"[illegible]" ENERGY EQUIVALENT - 10^6 BTU's
- [illegible]		
[illegible] Canned Specialties	D	
2034 Dehydrated Food Products*	NA	
206[illegible] Beet Sugar*	56.4	
20[illegible] Soybean Oil Mills	D	
[illegible]95 Roasted Coffee*	NA	
20[illegible] Manufactured Ice*	NA	
	56.4	1252000
3[illegible] - Fabric and Mills		
[illegible]1 Yarn mills, except wool*	NA	
[illegible] Throwing mills and winding mills*	NA	
[illegible]3 Wool yarn mills*	NA	
	0	0
[illegible] - Textile Goods		
22[illegible] Tufted carpets and rugs*	NA	
[illegible]96 Tire cord and fabric*	NA	
	0	0
[illegible]		
[illegible]11 Men's and boys' suits and coats*	NA	
232 Men's and boys' furnishings*	NA	
[illegible]335 Women's and misses' dresses*	NA	
[illegible]37 Women's and misses' suits and coats*	NA	
[illegible] Women's and children's undergarments*	NA	
[illegible]35 Hats, caps, and millinery*	NA	
[illegible]36 Children's Outerwear*	NA	
[illegible] Fur goods*	NA	
23[illegible] Miscellaneous Apparel and Accessories	NA	
	0	0
3[illegible] - Fabricated Textile Products		
239[illegible] House Furnishings, N.E.C.*	NA	
	0	0
- [illegible] Products		
[illegible] [illegible]ware*	NA	
	0	0
[illegible] - [illegible] Containers		
[illegible] [illegible] containers*	NA	
	0	0
[illegible] - [illegible]hold Furniture		
[illegible] Upholstered Household Furniture*	NA	
	0	0
[illegible] - Other Furniture and Fixtures		
[illegible] Office Furniture*	NA	
[illegible] Public Building Furniture*	NA	
[illegible] Partitions and Fixtures*	NA	
2[illegible] Miscellaneous Furniture and Fixtures*	NA	
	0	0
[illegible] - Paper Products		
[illegible] Paper Mills, Except Building	0	
[illegible] Pressed and Molded Pulp Goods*	NA	
	0	0
[illegible] Printing and Publishing		
[illegible] Periodicals*	NA	
[illegible] Book Publishing*	NA	
279 Bookbinding and Bookbinding*	NA	
[illegible] Printing Trade Services*	NA	
	0	0
[illegible] and Selected Chemical Products**		
[illegible] Agricultural Chemicals, N.E.C.*	NA	
	0	0
[illegible] Synthetic Materials		
[illegible] Plastics, Materials and Resins	D	
	0	0
[illegible] - [illegible] Cleaning and [illegible] Preparations		
[illegible] [illegible] Preparations	NA	
	0	0
[illegible] Other Leather Products		
[illegible] Personal Leather Goods*	NA	
	0	0

Table 15. Industrial Coke Use

51 - Stone and Clay Products		
3281 Cut Stone and Stone Products*	NA	
3296 Mineral Wool	48.5	
	48.5	1077000
52 - Primary Iron and Steel Manufacturing***	----	2306000000
53 - Primary Nonferrious Metals		
3331 Primary Copper	12.8	
3332 Primary Lead	153.9	
3333 Primary Zinc	197.4	
3339 Primary Nonferrous Metals, N.E.C.	3.3	
3341 Secondary Nonferrous Metals	19.6	
3351 Copper Rolling and Drawing	D	
3362 Brass, Bronze, Copper Castings	3	
	390.0	8658000
55 - Heating, Plumbing		
3431 Metal Sanitary Ware	34.9	
3433 Heating Equipment, Except Electric	20.9	
3441 Fabricated Structural Steel	4.5	
3442 Metal Doors, Sash and Trim	.2	
3443 Fabricated Platework (Boiler Shops)	4.6	
3444 Sheet Metalwork	.7	
	65.8	1461000
57 - Fabricated Metal Products		
3423 Hand and Edge Tools, N.E.C.	D	
3429 Hardware, N.E.C.	1.9	
3494 Valves and Pipe Fittings	45.8	
3499 Fabricated Metal Products, N.E.C.	0	
	47.7	1059000
58 - Engines, Turbines		
3519 Internal Combustion Engines, N.E.C.	15.1	
	15.1	335000
59 - Farm Machinery		
3522 Farm Machinery	94.5	
	94.5	2098000
60 - Construction, Mining Equipment		
3531 Construction Machinery	14.8	
3532 Mining Machinery*	3.8	
3533 Oilfield Machinery	NA	
	18.6	413000
63 - Special Industry Machinery		
3552 Textile Machinery	NA	
3559 Special Industry Machinery, N.E.C.	6.5	
	6.5	144000
64 - General Industrial Machinery		
3561 Pumps and Compressors	17.1	
3562 Ball and Roller Bearings	1 1	
3564 Blowers and Fans*	1.3	
3566 Power Transmission Equipment	5.9	
3569 General Industrial Machinery, N.E.C.	NA	
	22.53	562000
65 - Machine Shop Products		
3599 Miscellaneous Machinery, Except Electrical	5.7	
	5.7	127000
68 - Electrical Industrial Apparatus		
3611 Electric Measuring Instruments*	NA	
3612 Transformers*	NA	
3613 Switchgear and Switchboard Apparatus*	NA	
3622 Industrial Controls*	NA	
	0	0
69 - Household Appliances		
3633 Household Laundry Equipment*	NA	
3634 Electric Housewares and Fans*	NA	
	0	0
70 - Electric Lighting and Wiring Equipment*		
3641 Electric Lamps*	NA	
3644 Noncurrent Carrying Wiring Devices	9.8	
	9.8	218000
71 - Radio, Television and Communications Equipment		
3651 Radio and TV Receiving Sets*	NA	
	0	0

Table 15, (cont.)

73 - Miscellaneous Electrical Machinery, Equipment and Supplies		
3691 Storage Batteries*	NA	
3694 Engine Electrical Equipment*	NA	
	0	0
74 - Motor Vehicles and Equipment		
3711 Motor Vehicles	D	
3714 Motor Vehicles Parts and Accessories	57.4	
	178.1	3954000
76 - Transportation Equipment		
3731 Ship Building and Repairs*	S	
3732 Boat Building and Repairs*	S	
3742 Railroad and Street Cars*	S	
379 Miscellaneous Transportation Equipment*	NA	
	0	0
77 - Professional, Scientific and Controlling Instuments and Supplies		
3811 Engineering and Scientific Instruments*	NA	
3821 Mechanical Measuring Devices*	NA	
384 Medical Instruments and Supplies*	NA	
	0	0
78 - Optical Supplies		
3861 Photographic Equipment and Supplies	Z	
	0	0
79 - Miscellaneous Manufacturing		
391 Jewelry, Silverware and Plated Ware*	NA	
3941 Games and Toys*	NA	
3949 Sporting and Athletic Goods, N.E.C.*	NA	
395 Pens, Pencils, Office, and Art Supplies*	NA	
396 Costume Jewelry and Notions*	NA	
3993 Signs and Advertising Displays*	NA	
3999 Manufactures, N.E.C.*	NA	
	0	0
TOTAL		2,327,358,000.

Notes:

D - Withheld by COM "to avoid disclosing figures for individual companies."

S - Withheld by COM "because the figure did not meet publication standards either to avoid disclosing figures of individual companies or on the basis of a consistency review.

NA - "Not Available," according to COM.

* - From COM: Fuels and Electric Energy Consumed; other entries from COM.

** - These inputs all carry the SIC designation 331212 and/or 331213.

*** - See text for notes on these sectors.

Table 15, (cont.)

$$E67_{1,4,1} \leftarrow E67_{1,4,1} - ENET \;; \qquad (3.7)$$

$$T67_{1,1} \leftarrow E67_{1,1,1} \text{ *}ETA_{1,1,1}$$ (since coal was in 1967 the only source of coke); and (3.8)

$$T67_{4,1} \leftarrow E67_{1,4,1} \text{ *}ETA_{1,4,1} + E67_{3,4,1} \text{ *}ETA_{3,4,1}$$

$$+ E67_{4,4,1} \text{ *}ETA_{4,4,1} + E67_{5,4,1} \text{ *}ETA_{5,4,1}. \qquad (3.9)$$

3.2 TRANSPORTATION SUPERSECTOR

PEC gives no figures for use of coke in the transportation supersector and it seems reasonable to assume that use of this energy product by the transportation sectors is negligible. So we assigned zero allocations of coke to the transportation sectors of the 111-sector EP67 matrix:

$$EP67_{1,1} \leftarrow 0, \; 80 \leq j \leq 86 \;. \qquad (3.10)$$

3.3 COMMERCIAL AND GOVERNMENT SUPERSECTOR

PEC gives no figures for use of coke in the commercial supersector and it seems reasonable to assume that use of this energy product by the commercial sectors is negligible. So we assigned zero allocations of coke to the commercial sectors of the 111-sector EP67 matrix:

$$EP67_{1,j} \leftarrow 0, \; j = 5\text{-}8, 17\text{-}20, 25, 26, \; 87\text{-}101, \; 106\text{-}111. \qquad (3.11)$$

3.4 RESIDENTIAL SUPERSECTOR

PEC gives no figures for use of coke in the residential sector and it seems reasonable to assume that use of this energy product is negligible:

$$EP67_{1,102} = 0. \qquad (3.12)$$

4.0 MOTIVE POWER

PEC totals for this energy product are entangled in a definition problem which must be explained before we can make use of the totals. The problem is simply as follows. PEC allocations of refined petroleum products to the PEC transportation category are the only fuels for motive power applications, with two small exceptions noted below. PEC allocations of other energy supplies to their transportation category are given only for uses other than motive power (e.g. - Coal used by railroads for motive power was assumed in PEC to be negligible.), and are treated in sections 8 and 10.2 of this report. The PEC transportation super sector totals for refined petroleum products used in motive power applications, on the one hand, are totals not just for the transportation sectors of the EP67 matrix, but for all sectors; the PEC transportation super sector totals for the other energy supplies used in non-motive power applications, on the other hand, are totals just for the transportation sectors of the EP67 matrix.* One exception to the above definitions is that PEC does give totals for electricity used for motive power, but these totals cover only that used by the transportation sectors of the EP67 matrix (since the urban mass transit sector is the only sector which makes significant use of this energy supply source for motive power). This application, though, was not included by us in our motive power applications energy product category, but in our electric power energy product category and it is covered in sections 2.2, 2.3.4, and 10.2. The other exception is that some refined petroleum products allocated by PEC to their transportation category actually are used for greases and lubricants (feedstocks) in

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*These facts are never stated explicitly in PEC, but they are obvious for two reasons. The first is that PEC does not list any allocations of motive power to its other three super sectors, including especially the residential demand category, which uses substantial amounts of this energy product. The second reason is that the PEC total for transportation super sector use is close to totals given by other references [6] for total transportation uses by all sectors and the PEC totals for non-motive power applications in the transportation super sector are close to the same figures given by other references.

conjunction with the production of motive power. However, these feedstocks are not only used by the transportation sectors, but they are used by each sector of the economy in proportion to the motive power needs of the sector. So, the PEC total allocation of refined petroleum products to their transportation category is still a total for use of non-electric motive power fuels and feedstocks by the whole economy and not just the transportation sectors. Section 5.2 covers the allocation of the refined petroleum products used as greases and lubricants by the various sectors in the EP67 matrix and this section covers only the allocation of refined petroleum products used as fuels for motive power.

4.1 INDUSTRIAL SUPER SECTOR

PEC gives no figures for use of motive power in the industrial supersector. The use of motive power in the industrial supersector is subsumed in the totals for motive power allocated to the transportation super sector, as mentioned above. In the next section (4.2) some amounts from the total allocated to the transportation supersector are assigned to the industrial sectors of the EP67 matrix.

4.2 TRANSPORTATION SUPER SECTOR

As stated above, PEC figures given for use of refined petroleum products for motive power applications by this supersector do not include only the uses by the transportation sectors of the 111-sector model, but rather include all sectors. So our algorithms must spread these PEC totals over all sectors. Again, note that only refined petroleum products are used in non-negligible amounts for motive power applications. The five principal refined petroleum products which are burned for motive power applications are: gasoline; distillates (diesel fuels); residual oils (ships and trains); jet fuel; and liquified petroleum. See Figure 6 in section 2.4, which is taken from PEC. This figure shows the amounts of each of these fuels used by all sectors of the economy in 1968 for motive power applications. Our method for allocating our 1967 totals for energy supplies to motive power applications involves four factors: 1.) allocating demands by fuel from the 1967 overall total in proportion to the percentage of the 1968 PEC overall total that was supplied by each fuel; 2.) making direct assignments of some use totals that we were able to document from other sources; 3.) spreading some residuals among many non-transportation sectors in proportion to the labor employed by each sector; and 4.) calculating the personal consumption sector use as the residual amount of gasoline after other allocations were made. Below, on a fuel-by-fuel basis, the allocations of the amounts of fuel used by each sector for motive power applications are detailed. Then, for each sector in the EP67 matrix, the five allocations (one for each fuel type) are summed to yield the total fuel consumed by that sector for motive power applications.

4.2.1 Gasoline

The direct allocations of gasoline to motive power applications are shown in Table 16.

Sector	Amount_j	
Agriculture - crop farming (sector 18)	360.31×10^{12} Btu.	[18]
Local transport - school buses (sector 81)	33.02×10^{12} Btu.	[19]
Local transport - taxis (sector 81)	31.65×10^{12} Btu.	[6]
Water transport vessels (sector 83)	62.67×10^{12} Btu.	[19]
Personal consumption expenditures aviation gas (sector 102)	166.10×10^{12} Btu.	[19]
Federal government, defense (sector 106)	14.40×10^{12} Btu.	[21]

Table 16. Direct Allocations of Gasoline

Mathematically, this was expressed:

$EP67_{3,j} \leftarrow AMOUNT_j * ETA_{3,3,8}$, j = 18, 102, and 106, where for j = 18 or 106, S=3; and for j = 102, S=4; and (4.1)

the values for $AMOUNT_j$ are taken from Table 16. No allocations of particular petroleum products were made to the commercial transportation sectors, as discussed at the end of this section.

We also made direct allocations of gasoline to motive power in government non-defense sectors (sectors 98, 99 and 107-111), utilities sectors (sectors 5-8 and 89) and commercial sectors (sectors 87, 88, 90-97, 100 and 101) in the EP67 matrix. These allocations were made in proportion to the labor employed by each sector, as given in the LABOR vector, we assumed that such institutions use .04 autos per employee, with each auto driven approximately 25,000 miles per year and using gasoline at the rate of 15 miles per gallon. These assumptions are based on our analyses of fuel consumption and employment data for state and local governments. The gasoline used by sector j, one of these sectors, then, is calculated assuming conversion factors of 42 gallons per barrel and 5.253×10^6 Btu. per barrel:

$$EP67_{3,j} \leftarrow 25{,}000 \text{ miles/car} * .04 \text{ car/employee} \div 15 \text{ miles/gallon} \div 42 \text{ gallons/barrel} * 5.253 \times 10^6 \text{ Btu.} * LABOR_j * ETA_{3,3,2} \qquad (4.2)$$

or, more simplified:

$$EP67_{3,j} \leftarrow 8.34 \times 10^6 * LABOR_j * ETA_{3,3,2}, \; j=5\text{-}8,\ 87\text{-}101, \text{ and } 107\text{-}111. \qquad (4.3)$$

Note that sector 106, federal government, defense, is not included here because a direct allocation was made above to that sector.

Non-agricultural off-highway uses of gasoline were allocated directly among the construction sectors (sector 25 and 26) and mining sectors (sectors 1, 2 and 21-24) in proportion to $LABOR_j$, the labor employed in sector j. Total off-highway use of gasoline in 1967 was 438.2×10^{12} Btu [19] and (from Table 16) agricultural use was 360.31×10^{12} Btu, leaving

77.99×10^{12} Btu to be assigned among the mining and construction sectors. Mathematically, this assignment was made this way:

$$EP67_{3,j} \leftarrow 77.99 \times 10^{12} * ETA_{3,3,1} * LABOR_j \;/\; \sum_{j=1,2,21-26} LABOR_j \qquad (4.4)$$

for j=1, 2, and 21-24; and

$$EP67_{3,j} \leftarrow 77.99 \times 10^{12} * ETA_{3,3,3} * LABOR_j \;/\; \sum_{j=1,2,21-26} LABOR_j \qquad (4.5)$$

for j=25 and 26.

Statistics on use of gasoline for on highway trucking by various groups of sectors in the EP67 matrix were found in the 1967 Census of Transportation (COT) [21] and these statistics are presented in Table 17. Below we describe how the entries in this table were obtained from COT and how they were spread among the sectors in each group in proportion to $LABOR_j$, the labor employed in each sector j.

Sector Group	Million truck-miles-from COT	Million truck-miles-diesel Table 18	Million truck-miles-gas Column 2-Column 3	Percent of total gas. miles used by this sector group	Trillion Btu gas used by non-panel & non-pick-up trucks
Agriculture	7662	984.1	6672.7	12.08	85.93
Construction	6480	923.1	5556.7	10.05	71.49
Manufacturing	5582	1492.8	4089.1	7.40	52.64
Wholesale & retail	8241	3356.3	14884.7	26.93	191.15
Utilities	1909	259.0	1650.	2.99	21.27
Services	2357	335.0	2022.	3.66	26.04
For Hire	22898	8222.8	14675.2	26.55	188.87
Lease	1031	333.7	677.3	1.26	8.96
Forestry & lumber	1818	329.3	1488.7	2.69	19.14
Mining	989	167.3	821.7	1.49	10.60
Other	3263	558.5	2704.5	4.89	34.79
			55268.1		710.88

Table 17. 1967 Gasoline Used for All Trucks by Sector Groups

Sector Group	Million truck miles from COT (1)	Percent long range from COT	Percent short range from COT	Percent local from COT	Million truck miles diesel (3)	Percent of total miles	Trillion Btu (2)
Agriculture	7622	.1	6	93	984.08	5.80	26.56
Construction	6480	.6	10.6	88.8	923.13	5.44	24.91
Manufacturing	5582	11.4	22.2	66.4	1492.81	8.80	40.29
Wholesale & Retail trade	18241	2.8	17.3	79.9	3356.30	19.79	90.58
Utilities	1909	.1	9.8	90.1	259.05	1.53	6.99
Services	2357	.9	9.9	89.2	335.02	1.98	9.04
For Hire	22898	22.6	24.	53.4	8222.75	48.48	221.92
Short term lease	1031	23.4	12.8	63.8	333.68	1.97	9.01
Forestry & Lumber	1818	1.2	19.8	79.0	329.29	1.94	8.89
Mining	989	.4	18.2	81.4	167.26	.98	4.51
Other	3263	3.6	12.2	84.2	558.49	3.29	15.07
					16961.86	100.	457.77

(1) Excludes pick-ups and panel trucks
(2) Based on Total Btu value obtained on DET worksheet, D. Simpson, CAC [6].
(3) According to COT, trucking used the two fuel types in the following proportions:

	GASOLINE	DIESEL AND LP GAS
Local	90.14%	9.86%
Short	53.56%	46.94%
Long	14.25%	85.75%

Table 18. 1967 Diesel Fuel Used For All Trucks by Sector

For 1967, COT reports that 4,711,000 trucks other than panel trucks and pick-up trucks were used by these sectors. (Panel trucks and pick-up trucks were all assumed to run on gasoline and we assumed the gasoline used to run them to be included in the other allocations of gasoline to these sectors.) 516,000 of this number ran on diesel fuel and liquified petroleum gas and 133,000 were not classified as running on gasoline or one of these other two fuels. We assumed that a reasonable breakdown for this unclassified group would be the same as the breakdown among those that were classified. So, 11.3 percent of all non-panel and non-pickup trucks were assumed to run on diesel fuel and liquified petroleum gas and 88.7 percent on gasoline. COT also shows (see Table 18) a breakdown of fuels used by non-panel and non-pickup trucks depending on the range of use of each vehicle and a breakdown of trucks used by each sector grouping in Table 17, depending on vehicle range. We used this data to derive the entries in the third column in Table 17.

The entries in the third column from the right in Table 18 were obtained by multiplying the total truck miles for each sector group by the sum of three products, where each product was given by multiplication of each range percentage for that group and the corresponding diesel and LP gas percentage for that range.

The total gasoline allocation for on-highway trucking to each sector group in Table 17 was sub-allocated among the sectors in each group in proportion to $LABOR_j$, the labor employed in each sector j. The gasoline allocated to the "other" grouping for on-highway trucking use includes the amount previously allocated by us to military use (sector 106), 14.40×10^{12} Btu. and an overall residual amount of 20.39×10^{12} Btu, which we allocated among all the sector groups in proportion to their listed use in Table 17. Mathematically, all of this was done with the following sets of equations:

MINING -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 10.6 \times 10^{12} * (1 + C1) * ETA_{3,3,1} * LABOR_j / \sum_{j=1,2,21-24} LABOR_j \quad (4.6)$$

for j=1,2, and 21-24;

MANUFACTURING -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 52.64 \times 10^{12} * (1 + C1) * ETA_{3,3,1} * LABOR_j / \sum_{j=3,4,27-79} LABOR_j \quad (4.7)$$

for j=3,4, and 27-79;

UTILITIES -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 21.27 \times 10^{12} * (1 + C1) * ETA_{3,3,3} * LABOR_j / \sum_{j=5-8,89} LABOR_j \quad (4.8)$$

for j=5-8 and 89;

AGRICULTURE -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 85.93 \times 10^{12} * (1 + C1) * ETA_{3,3,3} * LABOR_j / \sum_{j=17,18,20} LABOR_j \quad (4.9)$$

for j=17, 18, 20;

FORESTRY AND LUMBER -

$$EP67_{3,19} \leftarrow EP67_{3,19} + 19.4 \times 10^{12} * (1 + C1) * ETA_{3,3,3} \quad (4.10)$$

CONSTRUCTION -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 71.49 \times 10^{12} * (1 + C1) * ETA_{3,3,3} * LABOR_j / \sum_{j=25}^{26} LABOR_j \quad (4.11)$$

for j=25 and 26;

SERVICES -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 26.04 \times 10^{12} * (1 + C1) * ETA_{3,3,3} * LABOR_j / \sum_{j=87,88,91-97,100,101} LABOR_j \quad (4.12)$$

for j= 87,88,91-97,100 and 101;

WHOLESALE AND RETAIL TRADE -

$$EP67_{3,90} \leftarrow EP67_{3,90} + 191.15 \times 10^{12} * (1 + C1) * ETA_{3,3,3}; \quad (4.13)$$

C1 = 20.39/676.09 is the fraction of the total allocated to these sector groups which is allocated as a residual to the "other" grouping. The total 676.09 x 10^{12} Btu is obtained by subtracting 34.79 x 10^{12} Btu from 710.88 x 10^{12} Btu in Table 17. Note that the incremental assignment of these new totals ($EP67_{3,j} \leftarrow EP67_{3,j} + \ldots$) is used in order not to erase assignments previously made to these totals.

Note that no gasoline was allocated directly to the commercial transportation sectors, 80 - 86. Since the data here for other types of refined petroleum is incomplete we have chosen to let our $DET67_{3,j}$ value represent total refined petroleum for motive power uses in these sectors. This assignment will be made in section 4.2.6. However we do use the direct gasoline allocations to these sectors to compute personal consumption use as a residual. COT gives the total gasoline usage in 1967 as 9961.1 x 10^{12} Btu and from this we must subtract the portions previously allocated to other sectors and then add the remainder to sector 102.

$$EP67_{3,102} \leftarrow EP67_{3,102} + \{[9961.1 - (1 + C1) * (188.87 + 8.96) + 33.02 + 31.65 + 62.67] \times 10^{12} - \sum_{j=1,111} EP67_{3,j}/ETA_{3,3,2}\} * ETA_{3,3,4} \quad (4.14)$$

4.2.2 Distillates

The direct allocations of distillates to motive power applications were made according to Table 19.

SECTOR	AMOUNT	
Agriculture - tractors (sector 18)	115.74 x 10^{12} Btu	[18]
Forestry and Lumber - trucking (sector 19)	8.89 x 10^{12} Btu	[18]
Railroads (sector 80)	516.61 x 10^{12} Btu	[19]
Commercial buses (sector 81)	83.30 x 10^{12} Btu	[19]
Motor freight (sector 82)	230.93 x 10^{12} Btu	[19]
Water transport vessels (sector 83)	101.81 x 10^{12} Btu	[19]
Water and sanitary utilities - trucking (sector 89)	6.99 x 10^{12} Btu	[21]
Federal government, defense (sector 106)	100.92 x 10^{12} Btu	[21]

Table 19. Direct Allocations of Distillates

Mathematically, this assignment process was done as follows:

$$EP67_{3,j} \leftarrow EP67_{3,j} + AMOUNT_j * ETA_{3,3,3}, \; j=18,19,89 \text{ and } 106 \qquad (4.15)$$

Note again that we used the incremental form of the assignment statement ($EP67_{3,j} \leftarrow EP67_{3,j} + \ldots$) to preserve assignments already made to the energy product totals in the EP67 matrix for gasoline use. Multiplication by the efficiency factor from the ETA matrix changes $AMOUNT_j$ from a fuel supply total to an energy product total.

Some of the direct allocations above were made from the allocations in Table 18 in the section 4.2.1 and we spread the remaining sector group totals for trucking from that table to the sectors in each group in proportion to $LABOR_j$ the labor employed by each sector j. The diesel fuel and liquified petroleum gases allocated in that table to use by "other" sectors for trucking motive power applications (15.07 x 10^{12} Btu), we allocated to the other sector groups in the table in proportion to the use the table lists for them for those fuels. Of course, as above, in order to convert these allocations of fuels to energy product use, we must multiply the fuel totals by the efficiency of conversion factor taken from the ETA matrix. Then, using the incremental form of the assignment statement, we add these allocations to the allocations previously made in the EP67 matrix for this energy product. Mathematically, all of the above is expressed below, using the sector group allocations from Table 19:

MINING -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 4.51 \times 10^{12} * (1 + C2) * ETA_{3,3,1} * LABOR_j / \sum_{j=1,2,21-24} LABOR_j \text{ , for } j=1,2 \text{ and } 21\text{-}24; \qquad (4.16)$$

MANUFACTURING -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 40.29 \times 10^{12} * (1 + C2) * ETA_{3,3,1} * LABOR_j / \sum_{j=3,4,27-79} LABOR_j \text{ , for } j=3,4 \text{ and } 27\text{-}79; \qquad (4.17)$$

AGRICULTURE -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 26.56 \times 10^{12} * (1 + C2) * ETA_{3,3,3} * LABOR_j / \sum_{j=17,18,20} LABOR_j, \quad (4.18)$$

for j=17,18 and 20;

FORESTRY AND LUMBER -

$$EP67_{3,19} \leftarrow EP67_{3,19} + 8.89 \times 10^{12} * (1+C2) * ETA_{3,3,3}; \quad (4.19)$$

CONSTRUCTION -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 24.91 \times 10^{12} * (1 + C2) * ETA_{3,3,3} * LABOR_j / \sum_{j=25,26} LABOR_j, \quad (4.20)$$

for j = 25 and 26;

SERVICES -

$$EP67_{3,j} \leftarrow EP67_{3,j} + 9.04 \times 10^{12} * (1 + C2) * ETA_{3,3,3} * LABOR_j / \sum_{j=87,88,91-97,100,101} LABOR_j, \quad (4.21)$$

for j=87,88,91-97,100 and 101

WATER AND SANITARY SERVICES UTILITIES -

$$EP67_{3,89} \leftarrow EP67_{3,89} + 6.99 \times 10^{12} * (1+C2) * ETA_{3,3,3}; \text{ and} \quad (4.22)$$

WHOLESALE AND RETAIL TRADE -

$$EP67_{3,90} \leftarrow EP67_{3,90} + 90.58 \times 10^{12} * (1 + C2) * ETA_{3,3,3}, \quad (4.23)$$

where C2 = 15.07/442.7 is, as in the previous section a fraction for allocating the residual or "other" category to the other sector groups. No allocations were made to transportation sectors, as mentioned in section 4.2.1.

4.2.3 Residual Fuel Oil

The direct allocations of residual fuel oils to motive power applications were made according to Table 20.

SECTOR	$AMOUNT_j$	
Railroads (sector 80)	34.54×10^{12} Btu	[19]
Water transportation vessels (sector 83)	507.24×10^{12} Btu	[19]
Federal government, defense (sector 106)	254.40×10^{12} Btu	[21]

Table 20. Direct Allocations of Residual Fuel Oil

(We assumed that all residual fuel oil used by the federal government defense sector was used for motive power applications.) Multiplying these energy supply totals by the efficiency of conversion factor taken from the ETA matrix, the product was an energy product total, which we then added to the appropriate previous entries for this energy product in the EP67 matrix. Mathematically, all of this was expressed:

$$EP67_{3,106} \leftarrow EP67_{3,106} + AMOUNT_{106} * ETA_{3,3,3}. \qquad (4.24)$$

Again, no allocations were made to transportation sectors, as mentioned in section 4.2.1.

4.2.4 Jet Fuel

The direct allocations of jet fuels to motive power applications were made according to Table 21.

SECTOR	$AMOUNT_j$
Air transportation (sector 84)	1054×10^{12} Btu
Federal government, defense (sector 106)	597.3×10^{12} Btu

Table 21. Direct Allocations of Jet Fuels

These figures were obtained by summing total production and net imports and subtracting net stock changes for naptha-type fuels (for military use) and kerosine-type fuels (for commercial use) and converting these use figures at the rate of 5.355×10^6 Btu per barrel for naptha-type fuels and 5.57×10^6 Btu per barrel for kerosine-type fuels. [20]

JET FUEL TYPE:	NAPTHA-TYPE	KEROSINE-TYPE
Total production	$109{,}694 \times 10^3$ Bbl	$163{,}535 \times 10^3$ Bbl
Imports	$5{,}450 \times 10^3$ Bbl	$26{,}941 \times 10^3$ Bbl
Exports	$-(1{,}804 \times 10^3$ Bbl)	$-(217 \times 10^3$ Bbl)
Net stocks change	$-(1{,}802 \times 10^3$ Bbl)	$-(1{,}035 \times 10^3$ Bbl)
	$111{,}538 \times 10^3$ Bbl	$189{,}224 \times 10^3$ Bbl
Conversion	$\times\ 5{,}355 \times 10^6$ Btu/Bbl	$\times\ 5.57 \times 10^6$ Btu/Bbl
	597.3×10^{12} Btu	1054×10^{12} Btu

Multiplying these energy supply totals by the efficiency of conversion factor taken from the ETA matrix, gives an energy product total, which we then added to the appropriate previous entries for the motive power energy product in the EP67 matrix. Mathematically, all of this was expressed:

$$EP67_{3,106} \leftarrow EP67_{3,106} + AMOUNT_{106} * ETA_{3,3,3}. \qquad (4.25)$$

Here, too, no allocations were made to transportation sectors, as stipulated in section 4.2.1.

4.2.5 Liquified Petroleum Gas

We calculated liquified petroleum gas usage for 1967 from PEC totals for 1968 uses of fuels for motive power applications. We did this by assuming that in 1967 the proportion of the fuels allocated to motive power uses which were liquified petroleum gas was the same as that for 1968. The total use in 1968 of fuels for motive power applications and the total for use of liquified petroleum gas for motive power applications in 1968 are both taken from Figure 6 in section 2.4 as 14367×10^{12} Btu and 120×10^{12} Btu, respectively. So the proportion is: .0084. This factor was multiplied by $T67_{3,2}$, the allocation of motive power to the transportation super sector. We assigned the full amount here to sector 18, the sector which includes grain agriculture, on the assumption that it is the only sector using liquified petroleum gas for motive power. Mathematically, this was expressed:

$$EP67_{3,18} \leftarrow EP67_{3,18} + .0084\ T67_{3,2}. \tag{4.26}$$

Note that again we used the incremental form ($EP67_{3,18} \leftarrow EP67_{3,18} + \ldots$) of the assignment statement to avoid wiping out previous allocations of motive power applications to the entries in the EP67 matrix.

4.2.6 Commercial Transportation Sectors

In these sectors we simply allocated all refined petroleum from the DET67 matrix for motive power use, allowing 1 percent of this total for feedstocks and 99 percent for fuels. According to PEC, 1 percent was the fraction used for greases and lubricants overall in 1968. Therefore:

$$EP67_{3,j} \leftarrow .99 * DET67_{3,j} * ETA_{3,3,2},\ j=80\text{–}86;\ \text{and} \tag{4.27}$$

$$EP67_{2,j} \leftarrow .99 * DET67_{3,j} * ETA_{3,2,2},\ j=80\text{–}86. \tag{4.28}$$

Mathematically, we defined the EKP111 matrix totals for refined petroleum fuels to motive power for all sectors as follows:

$$EKP111_{3,3,j} \leftarrow EP\ 67_{3,j}/ETA_{3,3,2},\ j = 1\text{–}111;\ \text{and} \tag{4.29}$$

$$EKP111_{3,2,j} \leftarrow EP67_{2,j}/ETA_{3,2,2},\ j=80\text{–}86. \tag{4.30}$$

4.3 COMMERCIAL AND GOVERNMENT SUPERSECTOR

PEC gives no figures for use of motive power in the commercial and government supersector, but as mentioned above, uses by these sectors are subsumed in the totals for motive power applications allocated to the transportation supersector. In the previous section some amounts from the total allocated to the transportation supersector were assigned to the commercial and government sectors of the EP67 matrix.

4.4 RESIDENTIAL SUPERSECTOR

PEC gives no figures for use of motive power by the personal consumption super sector, but as mentioned above, uses by this sector are subsumed in the totals for motive power applications allocated to the transportation super sector. In section 4.2 above, some amounts from the total allocated to the transportation supersector were assigned to the personal consumption sector in the EP67 matrix.

5.0 FEEDSTOCKS

We defined the energy product category, "feedstocks", to include all uses of fossil fuel materials (coal, petroleum products and natural gas) not as a fuel or the source of electric energy, but used as a material input to production. Figures given in this category by PEC for the industrial and commercial supersectors include all inputs used as raw materials (in paints, chemicals, plastics, asphalts and road oils, etc., but, with one exception in section 5.1 specifically not coke - see also section 2.2). Figures given in this category by PEC for the transportation supersector include all inputs used as greases and lubricants in all sectors of the economy (in the same way that PEC figures for transportation include motive power uses by all sectors); we assumed that all but a negligible portion of these are consumed in motive power uses and allocated none to fixed machinery. Since it is derived from PEC figures our total, $T67_{2,2}$ (feedstocks energy products allocated to the transportation supersector), includes all inputs of lubricants and greases for all transportation uses in all sectors (see section 2.2.2 and 4.2). So, $T67_{2,2}$ had to be spread over industrial, commercial and government and personal consumption sectors of the EP67 matrix as well as transportation sectors. The next four sections describe for the EP67 matrix the direct allocation of feedstocks materials inputs in the industrial supersector, the spreading of the transportation supersector total for feedstocks inputs (greases and lubricants) to all sectors, and the direct allocation of feedstock inputs in the commercial and government supersector. Each section also details the fuel source breakdown for the feedstocks allocation to each sector.

5.1 INDUSTRIAL SUPERSECTOR

First we allocated the feedstocks (materials inputs) in the industrial supersector directly to six sectors on the basis of use of these inputs reported for these sectors by the COM [7]. COM provides summary tables of materials used by each manufacturing sector (Volume I, Table 7A, pp. 6-27 to 6-196 and "Fuels and Electric Energy Consumed" summary, Table 4, pp. 14-27) and from their tables we obtained the entries in Table 22. (We assumed the mining sectors used none of the materials inputs.) The table shows the SIC code for each using sector, each feedstocks product used as a material input, the quantity used by the sectors, the Btu equivalent of that quantity of the product. To compute the EP67 allocations of feedstocks materials to the industrial sectors we merely assigned to each sector except sector 41 the product of its $AMOUNT_j$ and the efficiency of conversion of refined petroleum products to feedstocks. Sector 41 was the only sector using non-petroleum feedstocks and we obtained its entry in the feedstocks row by summing the product of each of its entries in Table 22 and the efficiency of conversion. Entries in the EKP111 matrix were obtained directly from Table 22. Mathematically, all this was expressed:

$$EP67_{2,j} \leftarrow AMOUNT_j * ETA_{3,2,1}, \; j=4,38,42, \text{ and } 44\text{-}46; \quad (5.1)$$

$$EP67_{2,41} \leftarrow AMOUNT_{coal41} * ETA_{1,2,1} + AMOUNT_{rpp41} * ETA_{3,2,1} + AMOUNT_{ngas41} * ETA_{5,2,1}; \quad (5.2)$$

$$EP67_{2,j} \leftarrow 0, \; j = 1\text{-}3, 21\text{-}24, 27\text{-}37, 39, 40, 43 \text{ and } 47\text{-}79; \quad (5.3)$$

$$EKP111_{3,2,j} \leftarrow AMOUNT_j, \; j = 38, 42, \text{ and } 44\text{-}46; \quad (5.4)$$

$$EKP111_{1,41} \leftarrow AMOUNT_{coal41}; \quad (5.5)$$

$$EKP111_{3,2,41} \leftarrow AMOUNT_{rpp41}; \quad (5.6)$$

$$EKP111_{5,2,41} \leftarrow AMOUNT_{ngas41}; \text{ and} \quad (5.7)$$

$$EKP111_{3,2,j} \leftarrow 0, \; j = 1\text{-}3, 21\text{-}24, 27\text{-}37, 39, 40, 43, \text{ and } 47\text{-}79. \quad (5.8)$$

Table 22. Industrial Feedstocks Use

INPUT PRODUCT (SIC CODE AND NAME)	QUANTITY USED	Btu x 10^{12} EQUIVALENT - "AMOUNT"
SECTOR 4 - REFINED PETROLEUM PRODUCTS - SIC 3103		
Liquified petroleum gases[e]	176900000 bbl.	709.5
SECTOR 38 - PAPER PRODUCTS - SIC 261-264 and 266		
291106 petroleum wax[a]	143.5 mil.lbs.	3.3
SECTOR 41 - CHEMICAL PRODUCTS - SIC 281, 286, 287, and 289		
coal[b](anthracite, bituminous and lignite)	1073 thousand short tons	28.1
coke, screenings and breeze[b]	1390 thousand short tons	30.9
		59.0
natural gas[c]	502753 mil. cu. ft.	502.8
131302 natural gas[c]	104366.5 mil. cu. ft.	104.4
		607.2
291101 fuel oil[d]	10,406,700 bbl. (10,380,100 - 42 gal. bbl.)	60
291101 fuel oil[d]	(less than $50,000)	____
291101 fuel oil[d]	N/A	____
Liquified petroleum gases[c]	21466000 bbl.	74.4
		134.4
SECTOR 42 - PLASTICS - SIC 282		
291165 ethylene[f]	2049.9 mil. lbs.	45.7
291167 (1.5)butadiene[g]	185.0 mil. lbs.	6.7
291167 butadiene[g]	1825.2 mil. lbs.	66.0
291168 other (including isoprene propylene, butylene, etc.)[h]	3253.4 mil. lbs.	55.0
291171 extender oils of petroleum origin[i]	562.1 mil. lbs.	13.0
291171 extender oils of petroleum origin[i]	S	7.3
		193.7
SECTOR 44 - PAINTS - SIC 285		
291105 petroleum thinner (naptha)[j]	172.7 mil. gal.	21.0
SECTOR 45 - PAVING - SIC 2951		
291191 asphalt-less than 200 penetration[k]	4761.4-Thou. short tons	173.9
291195 asphalt-200 or more penetration[l]	S	23.9
		197.8
SECTOR 46 - ASPHALT - SIC 2952		
291191 asphalt-less than 200 penetration[k]	3213.6thou. short tons	117.4
291195 asphalt-200 or more penetration[l]	9.1 mil. bbl.	60.0
		177.4
	Total	2103.3

Notes:

D - COM withheld total to avoid disclosing figures for individual companies.

NA - Not available, according to COM.

S - COM withheld total because estimate did not meet publication standards, either on the basis of the associated standard error of estimate or on the basis of a consistency review.

a - Petroleum wax energy content was figured on the basis of 5520000 Btu/bbl. and 238.26 lbs./bbl.

b - Anthracite, bituminous, and lignite energy content was figured on the basis 26,200,000 Btu/short ton. The amount listed and product description were taken from "Fuels and Electric Energy Consumed," a COM summary pamphlet, Table 6, pp. 30-31. Coke description and figures were also taken from that source and converted at 22,200,000 Btu/short ton. In both cases it was assumed by us that the summary covered a number of (usually incomplete) entries in the main COM volume cited in the text and used for this table.

c - Natural gas energy content was figured at 1000 Btu/cu. ft. and the first of the two figures was again taken from the pamphlet source of note "b" and considered to cover many (usually incomplete) entries in the COM main volume.

d - Fuel oil energy content was figured on the basis of 5,825,000 Btu/42-gallon barrel.

e - Liquified petroleum gases energy content was figured on the basis of 4,011,000 Btu/barrel and, as in "b" and "c" above was taken from the secondary source and assumed to cover a number of (usually incomplete) listings in the main source. In the chemicals sector, the use total could not be found directly in the table. But an amount of 27894000 bbl. was found for 1962 at a value of $16 million and the value of the 1967 amount was given at $35.4 million. To account for inflation we took the 1962 and 1967 figures -- 160846000 bbl. at $363 million and 176900000 bbl. at $462 million, respectively -- and computed a multiplier of .8641 for the dollars-to-Btu conversion factor. Then we figured the 1967 Btu amount using the 1967 dollar amount. the 1962 dollars-to-Btu conversion rate in the chemicals sector and the multiplier.

f - Ethylene energy content was figured on the basis of 4,011,000 Btu/barrel and 1 barrel = 180 lbs.

g - Butadiene energy content was figured on the basis of 4,284,000 Btu/barrel and 1 barrel = 238.26 lbs.

h - "Other (including isoprene, propylene, butylene, etc.)" energy content was figured on the basis of 4,011,000 Btu/barrel and 1 barrel = 238.26 lbs. (isoprene: 1 barrel = 206.69 lbs.; propylene: 1 barrel = 217.2 lbs.; butylene: 1 barrel = 245.23 lbs.).

i - Extender oils energy content was figured on the basis 5,588,000 Btu/barrel and 1 barrel = 238.26 lbs. COM lists the cost of the 562.1 million lbs. of these products at $11 million and the cost of the withheld amount at $6.2 million and we estimated the energy content of the withheld amount in direct linear proportion to the cost and energy content of the other amount. So the amount $\approx$ 6.2 million * 13 trillion/11 million = 7.3 trillion Btu.

j - "Naptha petroleum thinner" energy content was figured on the basis of 5,245,000 Btu/barrel and 1 barrel = 42 gallons.

k - "Asphalt less than 200 penetration" energy content was figured on the basis of 6,640,000 Btu/barrel and 5.5 barrels = 1 ton.

ℓ - "Asphalt - 200 or more penetration" energy content was figured on the basis of 6,640,000 Btu/barrel. COM lists the cost of the 9.1 million barrels of this product at $27.6 and the cost of the withheld amount at $11 million and we estimated the energy content of the withheld amount in direct linear proportion to the cost and energy content of the other amount. So, the amount withheld $\approx$ 11 million * 60 trillion/27.6 million = 23.9 trillion Btu.

In making these allocations by direct assignment, we have deviated from the procedure we outlined in section 2.5 for obtaining supersector totals and then spreading these among the sectors. Here, we obtained the sectors' allocations by direct assignment and we may sum all those allocations to get a better supersector total. We summed the entries in the EKP111 matrix to obtain a new set of entries in the E67 matrix feedstocks-to-industrial supersector row. Then we had to adjust other entries in the E67 matrix to reallocate the differences in the new and previous entries in that row of the E67 matrix. This reallocation was straightforward, however, since each of the three fossil fuels computes miscellaneous thermal energy uses (including water heat and space heat) in the industrial supersector as a residual, or the amount of the given fuel remaining after all direct assignment uses have been subtracted from the total use of that fuel in the supersector. So we merely changed the allocation of the given fuel to the miscellaneous thermal sector in a manner complementary to the change in the allocation to feedstocks. Mathematically, all of this was expressed:

$$E67^{new}_{K,2,1} \leftarrow \sum_{j \varepsilon I} EKP111_{K,2,j}, \quad K = 1, 3, \text{ and } 5 \text{ ; and} \qquad (5.9)$$

$$E67_{K,4,1} \leftarrow E67_{K,4,1} + (E67^{old}_{K,2,1} - E67^{new}_{K,2,1}), \quad K = 1, 3, \text{ and } 5. \qquad (5.10)$$

The notation $j \varepsilon I$ indicates that subscript j is summed over the industrial sectors, as shown in Table 2 in section 2.1.

5.2 TRANSPORTATION SUPERSECTOR

As stated in section 5.0, we assume that all but a negligible portion of the greases and lubricants ($T67_{2,2}$ feedstocks allocated to the transportation supersector) are consumed in motive power uses and none of this total will be allocated to fixed machinery. However, because the PEC definition of the transportation supersector includes all uses of motive power in all sectors and because our total, $T67_{2,2}$, was derived from those PEC totals, we had to spread $T67_{2,2}$ not just among the transportation sectors, but to all sectors in the EP67 matrix. Since greases and lubricants are required in producing motive power and because we have found no other workable assumption, we assumed that demand by any sector for these products varies linearly with the amount of the motive power energy product used by that sector. So we allocated to each sector in the EP67 matrix a portion of the greases and lubricants total, $T67_{2,2}$, which is calculated to be the same percent of that total as the allocation of motive power energy products to the given sector is of the total use of motive power in the economy. Mathematically this was expressed:

$$EP67_{2,j} \leftarrow EP67_{2,j} + (EP67_{3,j}/T67_{3,2})*T67_{2,2},\ j = 1\text{-}111\ . \quad (5.11)$$

$EP67_{3,j}$ is, of course, the 1967 allocation of the motive power energy product to sector j and $T67_{3,2}$ is the total use of motive power energy products in the PEC transportation supersector (and thus in the whole economy). These numbers are computed in sections 2.5 and 4.2. The format of this assignment is incremental rather than direct because we do not want to wipe out the amounts already allocated in section 5.1 to sectors 4, 38, 41, 42, 44, 45, and 46; we want to add an amount to the allocation already there.

The new entries in the EKP111 matrix are also computed incrementally. To compute the increments, we merely divide the EP67 increments by $ETA_{3,2,2}$, the efficiency factor for converting refined petroleum products to feedstocks in the transportation (motive power) sector. This is possible because all these feedstocks are made from refined petroleum products and so all the increments are added to that input. Mathematically, these assignments were made as follows:

$$EKP111_{3,2,j} \leftarrow EKP111_{3,2,j} + (EP67_{3,j}/T67_{3,2}) * E67_{3,2,2},$$

$$j = 1\text{-}111. \qquad (5.12)$$

For the commercial transportation sectors, a slight variation of the above algorithm was used, yielding the same results as the algorithm outlined above. See section 4.2.6 for the variation on the algorithm.

5.3 COMMERCIAL AND GOVERNMENT SUPERSECTOR

The PEC allocation of feedstocks to its commercial and government supersector is itemized to include only asphalt and paving oils. We have made three assumptions about this total: a) all of these products went to the construction sectors in the EP67 matrix; b) these inputs all come from petroleum products; and c) in particular, all of this allocation is from the refined petroleum products sector of the EP67 matrix, sector 4, and is an addition to inputs of finished asphalt and paving products which the construction sectors get from the paving oils sector, sector 45, and asphalt sector, sector 46. (These last two products are, indeed, feedstock inputs to the construction sectors, but the energy content embodied in them is accounted for first in the energy or Btu transactions in our I-O model from sector 4 to sectors 45 and 46 and second in the dollar transactions from sectors 45 and 46 to the construction sectors; the energy content is passed on and counted.)

With these assumptions, we computed the allocations of feedstocks in the commercial and government supersector to be zero in the non-construction sectors of the EP67 matrix to be direct assignments of amounts in the construction sectors. To compute the amounts of these direct assignments for sectors 25 and 26 we first obtained a total for 1967 for use by both sectors. Then we spread this between them in proportion to the amount of refined petroleum products used by each for all uses, as given in DET67. The total given by PEC for 1967 was 917×10^{12} Btu. Mathematically, this was expressed:

$$EKP111_{3,2,25} \leftarrow EKP111_{3,2,25} + 917 \times 10^{12} * DET67_{3,25} / (DET67_{3,25} + DET67_{3,26}); \quad (5.13)$$

$$EKP111_{3,2,26} \leftarrow EKP111_{3,2,26} + 917 \times 10^{12} * DET67_{3,26} / (DET67_{3,25} + DET67_{3,26}); \text{ and} \quad (5.14)$$

$$EP67_{2,j} \leftarrow EKP111_{3,2,j} * ETA_{3,2,3}, \; j = 25 \text{ and } 26. \quad (5.15)$$

Note again that we used the incremental assignment to preserve previous allocations. Eq. 5.15 can be written without taking other fuels into consideration because in the commercial and government supersector only refined petroleum is used for feedstocks. Again we have changed our supersector totals by using direct allocations. But in this case there is no energy product use in the PEC numbers which corresponds to the residual amounts of the refined petroleum products allocated by DET67 to our consuming sectors. Assuming the direct allocations to each sector will sum to less than the DET67 refined petroleum allocations to each sector, we have a DET67 residual to be allocated to some energy product. This is done in section 11. Mathematically, we reassigned the commercial and government supersector totals for use of feedstocks this way:

$$E67_{3,2,3} \leftarrow 917 \times 10^{12} \text{ Btu; and} \quad (5.16)$$

$$T67_{2,3} \leftarrow E67_{3,2,3} * ETA_{3,2,3} . \quad (5.17)$$

Again, the latter equation is possible because the commercial and government supersector uses only refined petroleum products to make feedstocks.

5.4 RESIDENTIAL SUPERSECTOR

PEC gives no figures for use of feedstocks in the residential sector and, except for the allocation of lubricants and greases made to the personal consumption sector in section 5.2, it seemed reasonable to us to assume there is none.

6.0 AIR-CONDITIONING ALLOCATIONS

6.1 INDUSTRIAL SUPERSECTOR

PEC gives no figures for air-conditioning use by the industrial supersector. We assumed that air-conditioning use is negligible in the mining sectors of the EP67 matrix, but not in the manufacturing sectors. Below, we show how we used data from other sources to compute a total air-conditioning demand for the manufacturing sectors and to spread this total among those sectors in the EP67 matrix.

Reference [7] gives figures for total water use, including recirculated water, for air-conditioning in each of the manufacturing sectors. From their table of water use by purpose in manufacturing sectors, we have taken the entries in our Table 23, Water Use for Air-Conditioning in the Manufacturing Sectors. Only because we were unable to develop any other assumption, we assumed that each manufacturing sector employed the same percentages of air-cooled and water-cooled air-conditioning capacity as every other sector (and thus the same percentage as is used by the supersector taken as a whole). This assumption allowed us to allocate air-conditioning use to the manufacturing sectors in proportion to their individual water use totals for air-conditioning. To do this we merely multiplied $T67_{7,1}$, the total industrial supersector use of the air-conditioning energy product computed below, by $ACH2O_j$ for each manufacturing sector, j. $ACH2O_j$ is the portion of the total for water use for air-conditioning in the industrial supersector that is used by sector j, and these fractions are computed in Table 23.

To compute $T67_{7,1}$, we assumed an 11.2°F temperature change through a cycle for water-cooled air-conditioning units [22]. We also assumed that 75 percent of the air-conditioning cooling capacity in use in 1967 was supplied by water-cooled units and 25 percent by air-cooled units [23]. From Table 23, we took the total water use in 1967 for air-conditioning in the industrial sectors as 1108.6 billion gallons. We used standard conversions of 7.5 gallons and 62.4 lbs. per cubic foot to find the total cooling capacity in Btu's of this water usage:

1108.6	billion gallons
÷ 7.5	gallons/cubic foot
147.8	billion cubic feet
x 62.4	pounds/cubic foot
9222.7	billion pounds
x 11.2	^{o}F
103,294	billion Btu (water-cooled)
x 1.33	(for water- and air-cooled)
137	trillion Btu

This energy product total was spread to the manufacturing sectors by multiplying the total by $ACH2O_j$ for each sector j, but we also had to account for these usage amounts with fuel allocations in each sector. We assigned to $E67_{5,7,1}$ (the allocation of natural gas to air-conditioning in the industrial supersector) the quotient of one-fourth of the total and the efficiency of conversion $ETA_{5,7,1}$ (natural gas for air-conditioning in the industrial supersector). We assigned to $E67_{4,7,1}$ (the allocation of electric power to air-conditioning in the industrial supersector) the quotient of three-fourths of the total and the efficiency of conversion, $ETA_{4,7,1}$ (electric power to air-conditioning in the industrial supersector). Having added these new allocations to our E67 matrix, we also had to subtract the same amounts from the entries in the E68 matrix to which they were originally allocated based on our interpretation of PEC in section 2.4. We inferred that these two amounts were included in the catch-all allocations, $E68_{5,4,1}$ (natural-gas to miscellaneous thermal applications in the industrial supersector), and $E68_{4,8,1}$ (electricity to electric power in the industrial supersector). So, we subtracted the $E67_{5,7,1}$ allocation from $E67_{5,4,1}$ and the $E67_{4,7,1}$ allocation from $E67_{4,8,1}$.

Table 23. Water Use for Air-Conditioning in Manufacturing Sectors

J, OUR SECTOR NO.	SIC CODE	GROSS WATER USED FOR A/C*	$ACH2O_j$**	J, OUR SECTOR NO.	SIC CODE	GROSS WATER USED FOR A/C*	$ACH2O_j$**
4	291,299	2.6-2.6+25.4 = 25.4	.023	53	333-336,3392	5.1-4.7+13.0 = 13.4	.012
27	19	------------	* * *	54	341,3491	0-0+.3 = .3	0
28	20	17.9-14.2+39.6 = 44.3	.040	55	343,344	.3-.2+1.2 = 1.3	.001
29	21	.5-.5+59.7 = 59.7	.054	56	345,346	.5-.3+5.8 = 6.0	.005
30	221-224,226,228	7.5-6.3+126.8 = 128.0	.116	57	342,347,348,3492-3499	2.8-2.6+5.2 = 5.4	.005
31	227-229	1.3-.9+10.1 = 10.5	.010	58	351	2.2-2.2+7.1 = 7.1	.006
32	225,231-238	1.0-.4+3.7 = 4.3	* * *	59	352	.9-.6+2.4 = 2.7	.002
33	239	-----------	* * *	60	3531-3533	1.3-1.3+8.5***** = 8.5	.008
34	241-243,249	.4-.4+.9 = .9	.001	61	3534-3537	.1-.1+.6***** = .6	.001
35	244	0-0+0 = 0	0	62	354	.9-.7+3.0 = 3.2	.003
36	251	.1-.1+.2 = .2	0	63	355	.3-.2+1.2 = 1.3	.001
37	252-254,259	.1-.1+.2 = .2	0	64	356	1.4-1.1+5.7 = 6.0	.005
38	261-264,266	17.3-16.9+33.4 = 33.8	.030	65	359	.3-.3+1.4 = 1.4	.001
39	265	.2-.1+3.9 = 4.0	.004	66	357	7.7-7.4+15.6 = 15.9	.014
40	27	-----------	* * *	67	358	.8-.8+4.6 = 4.6	.004
41	281,286,287,289	31.5-28.7+87.7 = 90.5	.082	68	361,362	2.3-1.8+14.8 = 15.3	.014
42	282	56.4-40.5+169.1 = 185.0	.167	69	363	1.5-1.3+6.5 = 6.7	.006
43	283,284	8.0-4.4+40.8 = 44.4	.040	70	364	.3-.2+1.1 = 1.2	.001
44	285	.3-.2+2.5 = 2.6	.002	71	365,366	4.0-3.8+75.4 = 75.6	.068
45	2951	.0-0+.1**** = .1	0	72	367	3.8-2.8+58.6 = 59.6	.054
46	2952	0-0+.1**** = .1	0	73	369	.4-.3+5.1 = 5.2	.005
47	30	6.2-6.0+14.6 = 14.8	.013	74	371	3.5-3.4+25.9 = 26.0	.023
48	311,312	.1-.1+.1 = .1	0	75	372	20.3-18.1+88.8 = 91.0	.082
49	313-317,319	0-0+0 = 0	0	76	373-375,379	.5-.3+3.7 = 3.9	.004
50	321-323	1.5-1.3+9.5 = 9.7	.009	77	381,382,384,387	.7-.5+5.4 = 5.6	.005
51	324-329	1.9-.9+1.6 = 2.6	.002	78	383,385,386	3.2-3.2+19.4 = 19.4	.018
52	331,332,3391,3399	26.1-25.3+28.0 = 28.8	.026	79	39	1.1-.2+2.7 = 3.6	.003
						249.4-209.6+1068.8 =1108.6	.970

Notes follow on next page.

Notes:

* The totals are given in billions of gallons. The first number in each sum is taken from pages (7-23) - (7-28) of Volume I of the 1967 Census of Manufacturers (COM), Table 2.A, "Water Intake by Purpose, Gross Water Used, and Water Discharged: 1968", the column entitled "Water Intake for Air-Conditioning". Each of these numbers, then, is the total amount of water taken in by all firms in the sector for air-conditioning use. (Many of these numbers were obtained by summing the appropriate entries in the COM table). The second number in each sum, the number which is subtracted in every case is taken from the same volume of COM, pages (7-68) - (7-71), Table 4.A, "Water Intake by Source and Purpose, Gross Water Used, and Water Discharged by Establishments Recirculating Water: 1968". Each of these numbers is the total amount of the water taken in by all firms in a sector and recycled for repeated use for air-conditioning. (Again, many of these numbers were obtained by summing the appropriate entries in the COM table). The difference between the first number for each sector and the second number represents the amount of water taken in, and thus used, by firms in the sector for air-conditioning, but not recycled for repeated use. The third number in each sum is taken from the same volume of COM, pages (7-80) - (7-83), Table 5.A, "Water Intake, Gross Water Used, and Water Discharged by Discharge Point for Establishments Recirculating Water: 1968". Each of these numbers is the total amount of water use, including amounts of water recycled for repeated use counted each time the water is re-used for air-conditioning for firms in each sector. (There, too, many of these numbers were obtained by summing the appropriate entries in this COM table). The sum of this third number, which represents the total use where water is recycled, and the difference between the first two numbers in each sector, which represents the total water used where the water is not recycled, is the total water used in the sector for air-conditioning. This sum is the final or right-most entry in the "GROSS/WATER USED FOR A/C" column.

** $ACH2O_j$ represents the fraction of the total water used for all industries which was used in sector j. $ACH2O_j$ was obtained by dividing the total water used by sector j, as listed in the third column from the left by the total computed at the bottom of that column. The total water used by all industries was computed using data on use by all industries from the three tables mentioned in the note above in the same way that the data from those tables was used to compute the total for each sector. The portions of this grand total use allocated in the table above sum only to 97 per cent of the total, as shown at the bottom of the $ACH2O_j$ column. Since be tables gave no figures on three major SIC industrial classifications, we assumed that the remaining amount should be allocated to those sectors. In the next note, that is discussed.

*** The tables referenced above gave no water use totals for SIC classes 19 (our sector 27, "ordinance and accessories"), 23 (part of which is part of our sector 32, "apparel", and the other part of which is all of our sector 33, "miscellaneous fabricated textile products"), and 27 (our sector 40, "printing and publishing"). However, the allocations the tables give for the other SIC classes add up to only 97 percent of the totals for all industries given by the tables. Because a partial direct assignment of .4 percent of the total for all industries was made from the data in the tables to our sector 32, this amount must first be taken from this remaining three percent. We divided the remaining 2.6 percent of the water use by all industries for air-conditioning among these four of our sectors in proportion to the labor employed in each sector. Labor totals were: SIC class 19 (our sector 27) - 317,000; SIC classes 231-238 (part of our sector 32) - 1,245,202; SIC class 239 (our sector 33) - 173,000; and SIC class 27 (our sector 40) - 1,113,000, or a total of 2,848,202 for all four groups. Allocating the 2.6 percent in these proportions meant that: sector 27 was assigned .3% of this total, sector 32, 1.1%; sector 33, .2%; and sector 40, 1.0%. In sector 32, this amount must be added to the amount which was found for the other components of this sector in the tables, namely .4% of the total for all industries. This gives a total allocation to sector 32 of 1.2%. So the $ACH2O_j$ values for these sectors were used as: sector 27, .003; sector 32, .015; sector 33, .001; and sector 40, .010.

**** The second and third tables referenced above did not give a breakdown of the totals for SIC class 295; our sectors 45 and 46, however, correspond separately to SIC classes 2951 and 2952, respectively. Because the totals for SIC classes in the first table were approximately equal, we decided to allocate the totals from the second and third tables in equal proportions to these two sectors. The matter ultimately, though, is inconsequential because the total for both sectors is insignificant.

***** Again, the second and third tables referenced above did not give a breakdown of the totals for SIC class 353, even though our sectors 60 and 61 correspond respectively to SIC classes 3531 - 3533 and 3534 - 3537. There, too, we broke the totals in the second and third tables down in proportion to the amounts allocated to these two sectors in the first table. The first table allocated .3 and .1, respectively, to these sectors and so the total, 9.1, from the third table was broken down to 8.5 and .6, respectively.

Table 23, (cont.)

Finally, for purposes of computing DET67 residuals in sections 7.3 and 10.1, we had to make the same kind of allocations by fuel for each sector. For lack of a basis for any other assumption, we assumed that air-conditioning in each sector was powered by the same fuel mix as applied to every other sector and, thus to the total. That is, we assumed that 25 percent of the air-conditioning cooling use in each sector was powered by natural gas and 75 percent by electricity.

Mathematically, all of the above reduces to:

$$T67_{7,1} \leftarrow 137 \text{ trillion Btu;} \quad (6.1)$$

$$E67_{5,7,1} \leftarrow .25 * T67_{7,1} \; / \; ETA_{5,7,1}; \quad (6.2)$$

$$E67_{4,7,1} \leftarrow .75 * T67_{7,1} \; / \; ETA_{4,7,1}; \quad (6.3)$$

$$E67_{5,4,1} \leftarrow E67_{5,4,1} - E67_{5,7,1}; \quad (6.4)$$

$$E67_{4,8,1} \leftarrow E67_{4,8,1} - E67_{4,7,1}; \quad (6.5)$$

$$EP67_{7,j} \leftarrow ACH20_{j} * T67_{7,1}, \; j = 3,4, \text{ and } 27\text{-}79 \text{ (manufacturing sectors)} \quad (6.6)$$

$$EKP111_{4,7,j} \leftarrow ACH20_{j} * E_{4,7,1}, \; j = 3, 4, \text{ and } 27\text{-}79 \quad (6.7)$$

$$EKP111_{5,7,j} \leftarrow ACH20_{j} * E_{5,7,1}, \; j = 3, 4, \text{ and } 27\text{-}79 \quad (6.8)$$

$$EP67_{7,j} \leftarrow 0, \; j = 1, 2, \text{ and } 21\text{-}24 \text{ (mining sectors} \quad (6.9)$$

$$EKP111_{4,7,j} \leftarrow 0, \; j = 1, 2, \text{ and } 21\text{-}24 \quad (6.10)$$

$$EKP111_{5,7,j} \leftarrow 0, \; j = 1, 2, \text{ and } 21\text{-}24 \quad (6.11)$$

6.2 TRANSPORTATION SUPERSECTOR

PEC also gives no figures for use of air-conditioning in the transportation supersector and it seems to us reasonable to assume that use of this energy product by the transportation sectors is neglibible. Vehicle air-conditioning is considered a motive power product because it cannot be separated. So we assigned zero allocations for air-conditioning to the transportation sectors of the EP67 and EKP111 matrices.

$$EP67_{7,j} \leftarrow 0, \; j = 80\text{-}86; \quad (6.12)$$

$$EKP111_{4,7,j} \leftarrow 0, \; j \; \varepsilon \; T; \text{ and} \quad (6.13)$$

$$EKP111_{5,7,j} \leftarrow 0, \; j \; \varepsilon \; T. \quad (6.14)$$

6.3 COMMERCIAL AND GOVERNMENT SUPERSECTOR

PEC does give figures for air-conditioning use in their commercial and government supersector, and we inferred from their text that the figures applied to only the wholesale and retail trade services, miscellaneous and government sectors and not to the agriculture and construction sectors. We assumed that use of air-conditioning in the agriculture and construction sectors of the EP67 matrix is negligible.

No really good method for allocating $T67_{7,3}$ (air-conditioning use in the commercial and government supersector) to the commercial and government sectors of the EP67 matrix was found. We found no use figures for particular sectors and while it might be reasonable to allocate air-conditioning use on the basis of floor-space and cooling-degree-days, we could not find adequate data to do so.

So for lack of an alternative, we will allocate $T67_{7,3}$ to the various commercial and government sectors using air-conditioning in proportion to $LABOR_j$, the labor employed by each sector j, with one exception. The exception is the "federal government, defense" sector (j=106), which in our scheme is a final demand sector; and which includes military personnel. We assumed that per-capita air-conditioning demand by military personnel is generally less than that for other sectors and we arbitrarily allocated air-conditioning use to military use at half the per-capita rate it was allocated to other commercial (non-agriculture and non-construction) and government sectors of the EP67 matrix.

Finally, we allocated fuels used as the sources of this energy product. PEC figures show that for their entire commercial and government supersector, 91.5 percent of the air-conditioning was electrically powered and 8.5 percent was powered by natural gas. (Actually, PEC reports that 110 trillion Btu of electricity were used for air-conditioning in the commercial and government sector and 17 trillion Btu of natural gas. Applying efficiencies of conversion of 3 for electricity to air-conditioning in this supersector and 1.8 for natural gas to air-conditioning in this supersector, we have 330 trillion Btu of air-conditioning cooling from electricity and 30.6 trillion Btu from natural gas. This gives us our 91.5/8.5 percent split.)

We assumed, again for lack of a better assumption, that all commercial and government sectors using air-conditioning powered it by the same two fuels in the same proportions as were employed for the whole supersecotr.

Mathematically, all of the above reduces to:

$$EP67_{7,j} = T67_{7,3} * LABOR_j/[\sum_j LABOR_j + LABOR_{106}/2],$$
$$j=5\text{-}8,\ 87\text{-}101,\ \text{and } 107\text{-}111; \quad (6.15)$$

$$EP67_{7,106} = T67_{7,3} *.5\ LABOR_{106}/[\sum_j LABOR_j + LABOR_{106}/2],$$
$$j=5\text{-}8,\ 87\text{-}101,\ \text{and } 107\text{-}111; \quad (6.16)$$

$$EP67_{7,j} = 0,\ j = 17\text{-}20,\ 25,\ \text{and } 26; \quad (6.17)$$

$$EKP111_{4,7,j} \leftarrow .864 * EP67_{7,j}/ETA_{4,7,3},\ j=17\text{-}20, 25, 26, 87\text{-}101,\ \text{and } 106\text{-}111;\ \text{and} \quad (6.18)$$

$$EKP111_{5,7,j} \leftarrow .136 * EP67_{7,j}/ETA_{5,7,3},\ j=17\text{-}20, 25, 26, 87\text{-}101,\ \text{and } 106\text{-}111. \quad (6.19)$$

EKP111 assignments of energy supplies for air-conditioning in the natural gas and electric utilities sectors are made in section 9.4.

6.4 RESIDENTIAL SUPERSECTOR

PEC gives a total residential demand for air-conditioning and PEC figures show that more than 98 percent of residential air-conditioning fuel is electricity (154 trillion Btu's of electricity are applied to residential air-conditioning, according to PEC, and only 3 trillion Btu's of natural gas). We assigned all of this usage, $T67_{7,4}$, directly to our residential sector. Mathematically, this is expressed:

$$EP67_{7,102} = T67_{7,4}\ \text{(residential)} \quad (6.20)$$

$$EKP111_{4,7,102} = E67_{4,7,4};\ \text{and} \quad (6.21)$$

$$EKP111_{5,7,102} = E67_{5,7,4}. \quad (6.22)$$

7.0 INDUSTRIAL MISCELLANEOUS THERMAL USES, WATER HEAT, AND SPACE HEAT

PEC does not give separate totals for industrial supersector use of the water heat and space heat energy products; rather, it assumes they are small and includes them in its total for miscellaneous thermal applications in this supersector. For this reason, the entries in our E68 matrix for water heat in the industrial supersector and for space heat used there are zero and so, then, are those same entries in the E67 matrix. In each case, the entries in the E matrix for miscellaneous thermal uses in this supersector includes these uses. So, the method outlined in the three sections below must allocate the totals $T67_{4,1}$ (miscellaneous thermal uses by the industrial supersector), $E67_{1,4,1}$ (coal to miscellaneous thermal uses in the industrial supersector), $E67_{3,4,1}$ (refined petroleum products to miscellaneous thermal uses in the industrial supersector) and $E67_{5,4,1}$ (natural gas to miscellaneous thermal uses in the industrial supersector) to all three energy product uses as well break them down among the various industrial sectors in the EP67 and EKP111 matrices.

Such a procedure, of course, makes the assumption that crude petroleum and gas products and electric power are not used in more than negligible amounts for these energy products by the industrial sectors. This appears to be the case for crude petroleum and gas, but PEC does list a substantial usage of electric power (130 trillion Btu in 1968) for miscellaneous thermal uses. We included this usage in the electric power energy product category in section 10.1 under the assumption that electricity is a non-substitutable source in the few applications in which it is used. (Otherwise, a more efficient, less expensive source would surely be employed.) This assumption seems adequate for the 1960's, but is questionable for the future; future work should seek a method to accommodate the assumption of substitutability here.

The two-dimensional spreading of the totals $T67_{4,1}$, $E67_{1,4,1}$, $E67_{3,4,1}$ and $E67_{5,4,1}$, to yield the entries in the EP67 and EKP111 matrices, is done indirectly. To do this, we first found by independent methods the usage totals for water heat and space heat for each industrial sector. Then we made an assumption to determine the mixtures of fuels used in the production of each of these energy product amounts. Finally, the fuel amounts thus allocated to water heat and space heat production in each sector were subtracted from the amounts of the fuels allocated to all three energy products in the sector, and the remainders were assumed to be the portions that were used in miscellaneous thermal uses. New values of T67 were then computed.

First we determined the amount of each fuel that was allocated to use for these three products as a group in each sector. This was done by starting with the DET67 allocations of each fuel to each sector, and then subtracting out the amounts of the fuels that go to the other five energy products in the sector. For coal, we find $COLNET_j$, the amount of coal which went to the three energy products in sector j, by subtracting out the amount of coal allocated in sector j to use as coke and to feedstocks, since those are the only other uses:

$$COLNET_j \leftarrow DET67_{1,j} - EKP111_{1,1,j} - EKP111_{1,2,j},\ j \epsilon I \qquad (7.1)$$

For refined petroleum products, we find $RPPNET_j$ by subtracting out the amounts of refined petroleum products allocated in the sector to feedstocks and to motive power, since those are the only other uses:

$$RPPNET_j \leftarrow DET67_{3,j} - EKP111_{3,2,j} - EKP111_{3,3,j},\ j \epsilon I \qquad (7.2)$$

For natural gas, we find $GASNET_j$ by subtracting out the amount of natural gas allocated to feedstocks and to air-conditioning in the sector, since those are the only other uses:

$$GASNET_j \leftarrow DET67_{5,j} - EKP111_{5,2,j} - EKP111_{5,7,j},\ j \epsilon I\ . \qquad (7.3)$$

7.1 WATER HEAT

We assumed that hot water in this supersector is used for employees' personal hygiene purposes only, and so water heat demand is proportional to the labor employed in a sector j, given by $LABOR_j$. To find a water heat per employee per year constant, a hot water use of three gallons per employee per day and a 100°F temperature rise in the water temperature in the water heater was allowed [24] and we assumed a work year of 260 days. Since water weighs approximately 8.3 pounds per gallon, we have:

$$EP67_{5,j} \leftarrow LABOR_j(\text{emp-yr}) * 260(\frac{\text{day}}{\text{yr}}) * 3(\frac{\text{gal}}{\text{day-emp}})$$

$$* \; 8.3(\frac{\text{lbs}}{\text{gal}}) * 100(°F) * 1(\frac{\text{Btu}}{°F\text{-lbs}}), \; j \varepsilon I, \qquad (7.4)$$

or:

$$EP67_{5,j} \leftarrow 647400 * LABOR_j, \; j \varepsilon I; \text{ and} \qquad (7.5)$$

the supersector total was obtained as follows:

$$T67_{5,1} \leftarrow \sum_{j \varepsilon I} EP67_{5,j} \; . \qquad (7.6)$$

Allocation of fuels for water heat in an industrial sector j in the EKP111 matrix is based on an assumption related to efficiency, cost and suitability in general of each fuel for this purpose. We assume, simply, that if the $GASNET_j$ allocation of natural gas to the sector is enough or more than sufficient to supply the sector's water heat needs, then all water heating in this sector was done with natural gas. If the $GASNET_j$ allocation of natural gas to the sector was not enough to supply the sector's water heat needs, we assume that all the $GASNET_j$ allocation of natural gas in that sector was used in water heating and define $WHTNET_j$ for the sector as the amount of water heat which was not fueled by natural gas. In all cases the $RPPNET_j$ allocation of refined petroleum products to the sector was enough or more than sufficient to supply the rest of the sector's water heat needs, then the $WHTNET_j$ portion of the water heat needs was satisfied with refined petroleum products. Mathematically, the above can be expressed for $j \varepsilon I$:

if $GASNET_j * ETA_{5,5,1} \geq EP67_{5,j}$:

$$EKP111_{5,5,j} \leftarrow EP67_{5,j}/ETA_{5,5,1}; \quad (7.7)$$

$$GASNET_j \leftarrow GASNET_j - EKP111_{5,5,j}; \quad (7.8)$$

$$EKP111_{3,5,j} \leftarrow 0; \text{ and} \quad (7.9)$$

$$EKP111_{1,5,j} \leftarrow 0; \quad (7.10)$$

if $GASNET_j * ETA_{5,5,1} < EP67_{5,j} \leq GASNET_j * ETA_{5,5,1} + RPPNET_j * ETA_{3,5,1}$:

$$EKP111_{5,5,j} \leftarrow GASNET_j; \quad (7.11)$$

$$WHTNET_j \leftarrow EP67_{5,j} - GASNET_j * ETA_{5,5,1}; \quad (7.12)$$

$$GASNET_j \leftarrow 0; \quad (7.13)$$

$$EKP111_{3,5,j} \leftarrow WHTNET_j/ETA_{3,5,1}; \quad (7.14)$$

$$RPPNET_j \leftarrow RPPNET_j - WHNET_j/ETA_{3,5,1}; \text{ and} \quad (7.15)$$

$$EKP111_{1,5,j} \leftarrow 0, \quad (7.16)$$

Supersector totals were obtained as follows:

$$E67_{K,5,1} \leftarrow \sum_{j \varepsilon I} EKP111_{K,5,j}, \; K = 1, 3, \text{ and } 5. \quad (7.17)$$

7.2 SPACE HEAT

The table and footnote on page 7 of PEC indicate that fuels used by industrial sectors for space heat were approximately 2.1 percent of all energy supplies used for all purposes in the U. S. economy in 1968; this amount is included in the 28.2 percent of the total energy supplies PEC allocated for 1968 to process steam and direct heat uses in the industrial supersector. We used an adaptation of these figures to calculate $T67_{6,1}$ the space heat enrgy product total for the industrial supersector. We assumed that in 1967 the industrial supersector use of the space heat energy product was 7.5 percent (from the estimates that 28.2% of total primary energy consumption goes to industrial miscellaneous thermal uses, space heat and water heat and about 2.1% of the total is for space heat) of the energy product total for miscellaneous thermal uses ($T67_{4,1}$), water heat and space heat in the supersector. (The total might be higher because efficiencies for producing space heat from a given fuel are generally higher than for miscellaneous thermal uses from that fuel.) Mathematically, we obtained $T67_{6,1}$ and deleted that amount and $T67_{5,1}$ from $T67_{4,1}$ (which was taken from PEC as the total for all three) as follows:

$$T67_{6,1} \leftarrow .075 * T67_{4,1} \qquad (7.18)$$

The industrial space heat total was allocated only among the manufacturing sectors, assuming that the mining sectors used a negligible amount. Allocation of the total among the manufacturing sectors in the EP67 matrix was made in proportion to the number of full time equivalent employee-years for each sector, as given by the LABOR vector. Mathematically, this was expressed as follows:

$$EP67_{6,j} \leftarrow T67_{6,1} * LABOR_j / {}_{j=3,4,27-79}LABOR_j, \; j = 3,4, \text{ and } 27\text{-}79 \; . \qquad (7.19)$$

Allocation of fuels for space heat in an industrial sector j in the EKP111 matrix is based on an assumption related to efficiency, cost and suitability in general of each fuel for this purpose, in precisely the same manner that fuels were allocated to water heat. In this case, we start with the $COLNET_j$, $RPPNET_j$ and $GASNET_j$ totals left after fuels are allocated to water heat. If the $COLNET_j$ allocation of coal to the sector is enough, or more than enough to supply the sector's space heat needs, then all space heating in this sector was done with coal. If the $COLNET_j$ allocation of coal to the sector was not enough to supply the sector's space heat needs, we assume that all the $COLNET_j$ allocation of coal in that sector was used in space heating and we define $SHTNET_j$ for the sector as the amount of space heat which was not fueled by coal. If the remaining $RPPNET_j$ allocation of refined petroleum products to the sector is enough or more than sufficient to supply the rest of the sector's space heat needs, then the $SHTNET_j$ portion of the space heat needs was satisfied with refined petroleum products. If the $RPPNET_j$ allocation of refined petroleum products to the sector was not enough to supply the $SHTNET_j$ portion of the sector's space heat needs, then we assume that all of the remaining $RPPNET_j$ allocation was also used in space heating and the rest of the space heating needs were satisfied by natural gas. (If the $GASNET_j$, $RPPNET_j$ and $COLNET_j$ to a sector are together insufficient to satisfy the space heat and water heat needs computed for the sector, then those requirements must be revised downwards since crude oil and gas and electric power are assumed to be so inefficient and costly for the quantities of water and air to be heated in industrial operation that none of them would ever be chosen. See also section 11. Mathematically, the above allocation can be expressed for j = 3, 4, and 27-79:

if $COLNET_j * ETA_{1,6,1} \leq EP67_{6,j}$:

$$EKP111_{1,6,j} \leftarrow EP67_{6,j} / ETA_{1,6,1}; \tag{7.20}$$

$COLNET_j \leftarrow COLNET_j - EKP111_{1,6,j};$ (7.21)

$EKP111_{3,6,j} \leftarrow 0;$ and (7.22)

$EKP111_{5,6,j} \leftarrow 0;$ (7.23)

If $COLNET_j{*}ETA_{1,6,1} < EP67_{6,j} \leq COLNET_j{*}ETA_{1,6,1} +$

$RPPNET_j{*}ETA_{3,6,1}:$

$EKP111_{1,6,j} \quad COLNET_j/ETA_{1,6,1};$ (7.24)

$SHTNET_j \leftarrow EP67_{6,j} - COLNET_j{*}ETA_{1,6,1};$ (7.25)

$GASNET_j \leftarrow 0;$ (7.26)

$EKP111_{3,6,j} \leftarrow SHTNET_j;$ (7.27)

$RPPNET_j \leftarrow RPPNET_j - SHTNET_j/ETA_{3,6,1};$ and (7.28)

$EKP111_{5,6,j} \leftarrow 0;$ (7.29)

And if $COLNET_j{*}ETA_{1,6,1} + RPPNET_j{*}\ ETA_{3,6,1} < EP67_{6,j}$

$\leq COLNET_j * ETA_{1,6,1} + RPPNET_j * ETA_{3,6,1} + GASNET_j{*}ETA_{5,6,1}:$

$EKP111_{1,6,j} \leftarrow COLNET_j;$ (7.30)

$EKP111_{3,6,j} \leftarrow RPPNET_j;$ (7.31)

$SHTNET_j \leftarrow EP67_{6,j} - COLNET_j{*}ETA_{1,6,1} - RPPNET_j{*}ETA_{3,6,1};$ (7.32)

$COLNET \leftarrow 0;$ (7.33)

$RPPNET_j \leftarrow 0;$ (7.34)

$$EKP111_{5,6,j} \leftarrow SHTNET_j/ETA_{5,6,1}; \text{ and} \tag{7.35}$$

$$GASNET_j \leftarrow GASNET_j - SHTNET_j/ETA_{5,6,1}; \tag{7.36}$$

In the mining sectors we merly assigned zeroes:

$$EP67_{6,j} \leftarrow 0, \ j = 1, 2, \text{ and } 21\text{-}24; \text{ and} \tag{7.37}$$

$$EKP111_{K,6,j} \leftarrow 0, \ j = 1, 2, \text{ and } 21\text{-}24 \text{ and } K = 1, 3, \text{ and } 5. \tag{7.38}$$

Supersector totals were obtained as follows:

$$E67_{K,6,1} \leftarrow \sum_{j \varepsilon I} EKP111_{K,6,j}, \ K = 1, 3, \text{ and } 5. \tag{7.39}$$

7.3 MISCELLANEOUS THERMAL USES

The amounts remaining in $COLNET_j$, $RPPNET_j$ and $GASNET_j$ at this point are assumed to be used in miscellaneous thermal applications in the sector j. We calculate the miscellaneous thermal energy product for the sector by multiplying the amounts of fuels by their respective efficiencies of utilization and summing:

$$EP67_{4,j} \leftarrow COLNET_j{*}ETA_{1,4,1} + RPPNET_j{*}ETA_{3,4,1} + GASNET_j{*}ETA_{5,4,1}, \ j \varepsilon I. \tag{7.40}$$

Fuels to supply this energy product in each sector are also taken from the residuals, as follows for $j \varepsilon I$:

$$EKP111_{1,4,j} \leftarrow COLNET_j; \tag{7.41}$$

$$EKP111_{3,4,j} \leftarrow RPPNET_j; \text{ and} \tag{7.42}$$

$$EKP111_{5,4,j} \leftarrow GASNET_j. \tag{7.43}$$

Supersector totals were obtained as follows:

$$E67_{K,4,1} \leftarrow \sum_{j \varepsilon I} EKP111_{K,4,1}, \ K = 1, 3, \text{ and } 5 \tag{7.44}$$

$$T67_{4,1} \leftarrow \sum_{K=1}^{5} E67_{K,4,1} * ETA_{K,4,1} \tag{7.45}$$

8.0 TRANSPORTATION MISCELLANEOUS THERMAL USES, WATER HEAT, AND SPACE HEAT

PEC gives a breakdown of the energy supply inputs to this supersector but no reporting of energy product uses of these energy supplies. We made the following assumptions about those fuel inputs: a) all but a negligible amount of the coal used in this supersector is burned for space heat; b) all but a negligible amount of the natural gas used in this supersector is burned for space heat and water heat (The allocation of natural gas to which we are referring here is not the full PEC allocation of natural gas to transportation sectors, but that full amount minus the portion consumed as pipeline losses in natural gas pipelines, since PEC chose to classify that kind of consumption as transportation and we did not. See section 2.4.3); c) all but a negligible portion of the refined petroleum products and liquified petroleum gas products allocated by PEC to the transportation supersector and to motive power uses of other sectors was burned for motive power; and d) all but a negligible portion of the electricity allocated by PEC to the transportation supersector was used for electrically-based motive power or other miscellaneous electric uses. See section 10.2. When E68 was derived from PEC data in section 2.4.3, the coal and natural gas amounts allocated by PEC to the transportation supersector were assigned by us nominally to space heat uses. In the next three sections, we will show how those were allocated more specifically.

8.1 MISCELLANEOUS THERMAL USES

PEC gives no figures for use of process heat, steam heat, cooking or laundry drying heat by the transportation supersector, and it seems reasonable to assume that use of these energy products by the transportation sectors is negligible. So we assigned zero allocations to the transportation sectors of the miscellaneous thermal product of the EP67 and EKP111 matrices:

$$EP67_{4,j} \leftarrow 0,\ j \varepsilon T; \text{ and} \tag{8.1}$$

$$EKP111K_{,4,j} \leftarrow 0, \; K = 1\text{-}5 \text{ and } j \varepsilon T. \tag{8.2}$$

8.2 WATER HEAT

PEC also gives no figures for use of water heat by the transportation supersector, but we assumed that while use of this energy product in this supersector is not large, it is significant. We used the per capita method we employed in section 7.3 to compute for each transportation sector of the EP67 matrix a total use for the water heat energy product there; then we assumed that all water heating in these sectors is fueled by natural gas in the EKP111 matrix.

$$EP67_{5,j} \leftarrow 647{,}400 * LABOR_j, \; j\varepsilon T; \text{ and} \tag{8.3}$$

$$EKP111_{5,5,j} \leftarrow EP67_{5,j}/ETA_{5,5,2}, \; j\varepsilon T. \tag{8.4}$$

Supersector totals here were calculated as follows:

$$T67_{5,2} \leftarrow \sum_{j\varepsilon T} EP67_{5,j}; \text{ and} \tag{8.5}$$

$$E67_{5,5,2} \leftarrow \sum_{j\varepsilon T} EKP111_{5,5,j}. \tag{8.6}$$

8.3 SPACE HEAT

The assumptions in section 8.0 dictate that space heat used by the transportation supersector was provided by only two fuels, coal and natural gas, and that there was only one alternative use for one of these fuels--water heat from natural gas, which has already been computed from each sector--and none for the other. So, we allocated space heat to the transportation sectors of the EP67 and EKP111 matrices by using residuals from the DET67 allocations for each of these fuels to the sectors. In the case of coal, the residual is the full DET67 allocation $DET67_{1,j}$ to any sector j, (since there are no alternative uses) and we get the energy product for the sector from this fuel allocation from the product of this fuel allocation and the efficiency of conversion, $ETA_{1,6,2}$ (coal to space heat in the transportation supersector). In the case of natural gas we must first subtract from $DET67_{5,j}$ the amount of natural gas used in sector j for heating water. This amount is the allocation of natural gas to the water heat energy product to sector j in the EKP111 matrix. The residual amount for sector j is then multiplied by the efficiency of converting natural gas to space heat in the transportation supersector, to yield the space heat energy product for sector j from burning natural gas. The total space heat energy product for sector j is the sum of the space heat energy product allocations from each fuel. Mathematically, all of the above reduces to:

$$EP67_{6,j} \leftarrow DET67_{1,j} * ETA_{1,6,2} + (DET67_{5,j} - EKP111_{5,5,j}) * ETA_{5,6,2},\ j \epsilon T; \quad (8.7)$$

$$EKP111_{1,6,j} \leftarrow DET67_{1,j},\ j \epsilon T; \text{ and} \quad (8.8)$$

$$EKP111_{5,6,j} \leftarrow DET67_{5,j} - EKP111_{5,5,j},\ j \epsilon T. \quad (8.9)$$

Due to the allocations to water heat in section 8.2, the supersector space heat totals were modified as follows:

$$E67_{5,6,2} \leftarrow E67_{5,6,2} - E67_{5,5,2}; \text{ and} \quad (8.10)$$

$$T67_{6,2} \leftarrow E67_{1,6,2} * ETA_{1,6,2} + E67_{5,6,2} * ETA_{5,6,2}. \quad (8.11)$$

9.0 COMMERCIAL AND GOVERNMENT SUPERSECTOR AND RESIDENTIAL SUPERSECTOR MISCELLANEOUS THERMAL USES, WATER HEAT, AND SPACE HEAT

9.1 COMMERCIAL AND GOVERNMENT MISCELLANEOUS THERMAL USES

In this supersector, "miscellaneous thermal uses" was defined by PEC as encompassing energy use for commercial, government, and institutional cooking and refrigeration. We chose, however, to include refrigeration (all of which in this sector was assumed in PEC to be electrically powered) energy uses in our miscellaneous electric power energy product category. At the same time, we also chose to include as a miscellaneous thermal use, commercial, government, and institutional laundry drying heat. The above definition was chosen to make our I-O model consistent with the Brookhaven LP model, to which it will be linked. In section 11.2 we expand this definition to include construction process heating and we develop data for that use there, too. In the future, it may be desirable to devise separate energy product categories for processes such as refrigeration.

Below a total fuel use for laundry drying heat is calculated to be added to $E67_{5,4,3}$ (natural gas to miscellaneous thermal uses in the commercial and government supersector) before $T67_{4,3}$ (miscellaneous thermal use to the commercial and government supersector) is recalculated. In this calculation, the cooking and laundry drying fuel was assumed to be natural gas in all cases, following PEC. In order to add this total to $E67_{5,4,3}$ the same amount must be subtracted out of some other entries in the E67 matrix. Since PEC calculated space heat use for this supersector using residual amounts of fuels left after allocations to other uses and since we do the same thing below (section 9.3) on a sector-by-sector basis, we subtracted the laundry drying fuel total from $E67_{5,6,3}$ (natural gas to space heat in the commercial and government supersector). The laundry drying fuel total is calculated as follows:

60.0	million households	[25]
x 11%	without washers	[25]
6.6	million households using commercial and institutional laundry drying facilities	
x 312	loads/year/household	[26]
2.06	billion loads/year	
x 12,144	Btu/load	[26]
~ 25	trillion Btu/year	
+ 5	trillion Btu/year in commercial laundering (estimated at 20 percent of laundromat total)	
30	trillion Btu/year for 1967.	

The laundry drying energy use is allocated to our sector 93 ("Hotels, ..., personal and repair services, ...") since this sector includes all establishments which would likely offer such a service. Mathematically, the above can be expressed:

$$E67_{5,4,3} \leftarrow E67_{5,4,3} + 30 \text{ trillion Btu}; \tag{9.1}$$

$$E67_{5,6,3} \leftarrow E67_{5,6,3} - 30 \text{ trillion Btu}; \tag{9.2}$$

$$T67_{4,3} \leftarrow T67_{4,3} + 30 \text{ trillion Btu} * ETA_{5,4,3}; \tag{9.3}$$

$$T67_{6,3} \leftarrow T67_{6,3} - 30 \text{ trillion Btu} * ETA_{5,6,3}; \text{ and} \tag{9.4}$$

$$EP67_{4,93} \leftarrow 30 \text{ trillion Btu} * ETA_{5,4,3}, \tag{9.5}$$

where $ETA_{5,4,3}$ is the efficiency of converting natural gas to miscellaneous thermal uses in the commercial and government supersector and $ETA_{5,6,3}$ is the efficiency of converting natural gas to space heat.

Our method for allocating the rest of the total, $T67_{4,3}$ - 30 trillion Btu * $ETA_{5,4,3}$ (the cooking portion of $T67_{4,3}$) was to assign certain percentages of the total directly to each of six commercial and government sectors on the basis of refrigeration use reported by PEC in these sectors in 1968 (assuming refrigeration needs in these sectors to be directly proportional to the cooking done); the small residual amount left after these assignments were made was allocated to sector 106, "federal government, defense," since no figures were found for military mess.

PEC gives detailed 1966 distributions for the allocation of refrigeration in this supersector, with 44% of the total going to supermarkets and their wholesale distributors. We assumed that 1967 commercial cooking could be allocated to the sectors in the EP67 and EKP111 matrices in the same proportions that the residual amount (56%) of the refrigeration use is allocated to them by PEC for 1966. So the PEC sectors were matched to our sectors in the EP67 and EKP111 matrices in Table 24 below and the PEC "other" category (which includes only a small amount) was allocated to sector 106.

Mathematically, the above was expressed for:

$$EP67_{4,j} \leftarrow PERCNT_j * (T67_{4,3} - RP67_{4,93}),$$

$$j = 90, 93, 96, 97, 106, 108, \text{ and } 109; \qquad (9.6)$$

$$EP67_{4,93} \leftarrow EP67_{4,93} + PERCNT_{93} * (T67_{4,3} - EP67_{4,93}); \qquad (9.7)$$

$$EP67_{4,j} \leftarrow 0,\ j=5\text{-}8,\ 17\text{-}20,\ 25,\ 26,\ 87\text{-}89,\ 91,\ 92,\ 94,\ 95,\ 98\text{-}101,\ 107,\ 110, \text{ and } 111; \text{ and} \qquad (9.8)$$

$$EKP111_{5,4,j} \leftarrow EP67_{4,j} / ETA_{5,4,3},\ j \epsilon C. \qquad (9.9)$$

Our Sector Title	j, Our Sector Number	Amount used (Adapted from PEC--millions of KWH, 1966	$PERCNT_j$, Amount as % of the Residual Total
"Wholesale & Retail Trade"	90	31129	65.7%
"Hotels...personal & repair services..."	93	3060	6.5%
"Amusements"	96	2400	5.1%
"Medical, Educational,..."	97	5371	11.3%
"State & local government ...health, welfare..."	109	2667	5.6%
"Other" to "Federal government, defense"	106	1608	3.3%
		47394	100.0%

Table 24. Refrigeration Uses, 1966, Except for Supermarkets and Their Wholesalers

9.2 COMMERCIAL AND GOVERNMENT WATER HEAT

Our method for allocating values to the water heat energy product category in the commercial and government sectors of the EP67 and EKP111 matrices was similar to the method of section 9.1: we assigned certain percentages of the total, $T67_{5,3}$ to various sectors directly. These percentages were determined below for 1968 (and assumed to be the same for 1967) for some sectors using our own independent techniques, PEC data and the residual portion was allocated in proportion to employment in each sector.

The portion of this supersector's water heat energy product consumed in commercial and institutional laundry washing (included in sector 93, "Hotels ..., personal services, ...") was calculated for 1968 as follows:

2.06	billion loads/year (See section 9.1)	
x 35000	Btu/load	[26]
72	Trillion Btu/year.	

The portion of this supersector's water heat consumed in hotels, motels, etc. (also included in sector 93) was calculated for 1968 as follows:

1348	trillion Btu/year - PEC residential hot water fuel use	
÷ 198.6	million people	[17]
6.7	million Btu/person water heat fuel used	
÷ 365	days/year	
18,600	Btu/person/day water heat fuel used	
5.415	billion-hotel, etc. income	[11]
÷ $10	paid/person/day (our estimate)	
541.5	million person-days	
x 18600	Btu/person/day (from above)	
10.1	trillion Btu, 1967	
x 1.04	to approximate 1967-68 growth	
10.5	trillion Btu	

The portion of this supersector's water heat consumed in commercial, governmental, and institutional dish washing was calculated for 1968 as follows:

198.6	million people	
x 3	meals/day/person	
595.8	million meals/day	
x 365	days/year	
217	billion meals/year	
x 17%	not eaten at home	[26]
37	billion meals eaten away from homes/year	
5000	Btu/meal-water heat for dishes	[26]
185	trillion Btu/year	

The total just calculated was allocated in the same manner as cooking fuel was in section 9.1. Table 25 shows the proportions for direct allocations of water heat for 1968 (which we assumed also to be valid for 1967):

Sector Number	Amount = 185 trillion Btu * $PERCNT_j$ + Other Direct Allocations	Percent of Supersector Total
90	121.545 trillion Btu	24.2%
93	(12.02 + 72 + 10.5) = 94.525 trillion Btu	18.8%
96	9.435 trillion Btu	1.9%
97	20.905 trillion Btu	4.2%
106	6.105 trillion Btu	1.2%
108	4.625 trillion Btu	.9%
109	10.36 trillion Btu	2.1%

Table 25. Direct Allocation of Water Heat to the Commercial and Government Sectors

The other 46.7% (235.5 trillion Btu of the supersector total of 503 trillion Btu in 1968) was allocated proportional to the labor employed in each commercial and government sector. To do this, we multiplied this percentage of the 1967 supersector total by the labor employed in each sector as a proportion of the total labor employed in the commercial and government supersector. By assuming the 1967 percentage breakdowns to be the same as those for 1968, we were able to use the above percentages to allocate $T67_{5,3}$ to the water heat energy product categories in the commercial and government sectors of the EP67 and EKP111 matrices.

Mathematically, the above was expressed:

$$EP67_{5,90} \leftarrow .242 * T67_{5,3} + .471 * T67_{5,3} * LABOR_{90} / \sum_{j \varepsilon C} LABOR_j; \qquad (9.10)$$

$$EKP111_{k,5,90} \leftarrow .242 * E67_{k,5,3} + .471 * E67_{k,5,3} * LABOR_{90} / \sum_{j \varepsilon C} LABOR_j, \quad k = 4 \text{ and } 5; \qquad (9.11)$$

$$EP67_{5,93} \leftarrow .184 * T67_{5,3} + .471 * T67_{5,3} * LABOR_{93} / \sum_{j \varepsilon C} LABOR_j; \qquad (9.12)$$

$$EKP111_{k,5,93} \leftarrow .184 * E67_{k,5,3} + .471 * E67_{k,5,3} * LABOR_{93} / \sum_{j \varepsilon C} LABOR_j, \quad k = 4 \text{ and } 5; \qquad (9.13)$$

$$EP67_{5,96} \leftarrow .019 * T67_{5,3} + .471 * T67_{5,3} * LABOR_{96} / \sum_{j \varepsilon C} LABOR_j; \qquad (9.14)$$

$$EKP111_{k,5,96} \leftarrow .019 * E67_{k,5,3} + .471 * E67_{k,5,3} * LABOR_{96} / \sum_{j \varepsilon C} LABOR_j; \quad k = 4 \text{ and } 5; \qquad (9.15)$$

$$EP67_{5,97} \leftarrow .042 * T67_{5,3} + .471 * T67_{5,3} * LABOR_{97} / \sum_{j \varepsilon C} LABOR_j; \qquad (9.16)$$

$$EKP111_{k,5,97} \leftarrow .042 * E67_{k,5,3} + .471 * E67_{k,5,3} * LABOR_{97} / \sum_{j \varepsilon C} LABOR_j, \quad k = 4 \text{ and } 5; \qquad (9.17)$$

$$EP67_{5,106} \leftarrow .012 * T67_{5,3} + .471 * T67_{5,3} * LABOR_{106} / \sum_{j \varepsilon C} LABOR_j; \qquad (9.18)$$

$$EKP111_{k,5,106} \leftarrow .012 * E67_{k,5,3} + .471 * E67_{k,5,3} * LABOR_{106} / \sum_{j \varepsilon C} LABOR_j, \quad k = 4 \text{ and } 5; \qquad (9.19)$$

$$EP67_{5,108} \leftarrow .009 * T67_{5,3} + .471 * T67_{5,3} * LABOR_{108} / \sum_{j \varepsilon C} LABOR_j; \qquad (9.20)$$

$$EKP111_{k,5,108} \leftarrow .009 * E67_{k,5,3} + .471 * E67_{k,5,3} * LABOR_{108} / \sum_{j \varepsilon C} LABOR_j, \quad k = 4 \text{ and } 5; \tag{9.21}$$

$$EP67_{5,109} \leftarrow .021 * T67_{5,3} + .471 * T67_{5,3} * LABOR_{109} / \sum_{j \varepsilon C} LABOR_j; \tag{9.22}$$

$$EKP111_{k,5,109} \leftarrow .021 * E67_{k,5,3} + .471 * E67_{k,5,3} * LABOR_{109} / \sum_{j \varepsilon C} LABOR_j, \quad k = 4 \text{ and } 5; \tag{9.23}$$

$$EP67_{5,j} \leftarrow .471 * T67_{5,3} * LABOR_j / \sum_{j \varepsilon C} LABOR_j, \quad j=5\text{-}8,17\text{-}20,25,26,87\text{-}89,91,92,94,95,98\text{-}101,107,110, \text{ and } 111; \text{ and} \tag{9.24}$$

$$EKP111_{k,5,j} \leftarrow .471 * E67_{k,5,3} * LABOR_j / \sum_{j \varepsilon C} LABOR_j, \quad k=4 \text{ and } 5 \text{ and } j=17\text{-}20,25,26,87\text{-}89,91,92,94,95,98\text{-}101,107,110, \text{ and } 111. \tag{9.25}$$

See section 9.4 for water heat use in the natural gas and electric utilities sectors.

9.3 COMMERCIAL AND GOVERNMENT SPACE HEAT

Following PEC, we assumed that all commercial and government supersector space heating was fueled by coal, light and heavy oils and natural gas; also, all coal and all light and heavy oil were assumed to be used in this supersector only for space heating, while natural gas was used also for water heating, cooking and air-conditioning, as well as for space heating. Our method for allocating space heat to the commercial and government sectors was to assume that the residual left after all other uses of a fuel were subtracted from the DET67 allocation of the fuel to a sector was applied to space heating. (Light and heavy oils were assumed to be the residuals left in the refined petroleum products allocation and were used exclusively for space heating.) Multiplying by an efficiency factor for each of the three residual fuel amounts thus determined and summing yielded the total space heat allocation for each sector.

In the case of coal, as was noted above, there were no other energy product uses for the fuel in this supersector. The DET67 allocation for a sector j was the residual amount and its space heat product was merely this amount multiplied by the efficiency factor, $ETA_{1,6,3}$.

In this supersector, some refined petroleum products were also used for motive power, greases, lubricants, and road oils. To account for the amounts of fuel these two uses consumed in sector j, we subtracted the allocations $EKP111_{3,3,j}$ and $EKP111_{3,2,j}$ from $DET67_{3,j}$, and assumed as indicated above, that the residual was all light and heavy oils and all used for space heating. To get the space heat product, we multiplied this residual by the efficiency of conversion, $ETA_{3,6,3}$.

Finally, the same procedure was employed for natural gas. This fuel was also used in this supersector for cooking heat, air conditioning and water heating. We subtracted amounts of fuels for these uses from $DET67_{5,j}$, the total natural gas allocated to the sector in the DET67 matrix and assumed that the residual amount was all used in space heating. To get the space heat product, we multiplied this residual amount by the efficiency of converstion, $ETA_{5,6,3}$.

Finally, we summed all of the partial space heat amounts computed above to get the space heat total for the sector. Mathematically, all this reduced to:

$$EP67_{6,j} \leftarrow DET67_{1,j} * ETA_{1,6,3} + (DET67_{3,j} - EKP111_{3,2,j} - EKP111_{3,3,j}) * ETA_{3,6,3} + (DET67_{5,j} - EKP111_{5,4,j} - EKP111_{5,5,j} - EKP111_{5,7,j}) * ETA_{5,6,3},\ j \varepsilon C; \qquad (9.26)$$

$$EKP111_{1,6,j} \leftarrow DET67_{1,j},\ j \varepsilon C; \qquad (9.27)$$

$$EKP111_{3,6,j} \leftarrow DET67_{3,j} - EKP111_{3,2,j} - EKP111_{3,3,j},\ j \varepsilon C; \text{ and} \qquad (9.28)$$

$$EKP111_{5,6,j} \leftarrow DET67_{5,j} - EKP111_{5,4,j} - EKP111_{5,5,j} - EKP111_{5,7,j},\ j \varepsilon C. \qquad (9.29)$$

The above assignments were made for all commercial and government sectors, except natural gas and electric utilities. See section 9.4 about these. Space heat was assumed zero in the construction sectors, and so residual refined pertroleum is assigned to miscellaneous thermal uses in section 11.2. Finally, note as a check on the $EP67_{6,j}$ and $EKP111_{k,6,j}$ values computed above, that the following should be true:

$$T67_{6,3} = \sum_{j\varepsilon C} EP67_{6,j}; \text{ and} \quad (9.30)$$

$$E67_{k,6,3} = \sum_{j\varepsilon C} EKP111_{k,6,j}, \; K = 1\text{-}5. \quad (9.31)$$

9.4 SPECIAL TREATMENT OF NATURAL GAS AND ELECTRIC UTILITIES SECTORS

We mentioned in sections 6.3, 9.2, and 9.3 that fuels for the natural gas and electric utilities' energy products were computed using algorithms different from the standard algorithms for the rest of the commercial and government sectors. This was necessary because DET67 entries for some energy supplies for these sectors were taken in section 2.4.2 to be non-energy product flows (as a first approximation) and were zeroed when the DET67 matrix was modified by the SELFUS matrix so that all non-energy product flows were deleted from DET67. The allocations which were deleted are: natural gas to all four utility sectors (j=5-8); and electricity, coal, and refined petroleum products to the three electric utility sectors (j=6-8). In the sections below, the non-standard algorithms are discussed. Note that each algorithm required modification to the DET67 and SELFUS matrices reflect the new usages. Note also that we made allocations of refined petroleum products for motive power and greases and lubricants, feedstocks, respectively, in sections 4.2 and 5.2, to the electric utilities sectors. So we start with the following modifications:

$$DET67_{3,j} \leftarrow EKP111_{3,2,j} + EKP111_{3,3,j}, \; j=6\text{-}8; \text{ and} \quad (9.32)$$

$$SELFUS_{3,j} = SELFUS_{3,j} - EKP111_{3,2,j} - EKP111_{3,3,j}, \; j=6\text{-}8. \quad (9.33)$$

9.4.1 Water Heat

The energy product amounts were calculated in section 9.2; all that remains is to assign the energy supply amounts and make modifications to the DET67 and SELFUS matrices. We assumed that all water heat for the natural gas utilities sector was supplied by burning natural gas and that all water heat for the electric utilities was electrically powered. Mathematically, we made the following assignments:

$$EKP111_{5,5,5} \leftarrow EP67_{5,5}/ETA_{5,5,3}; \tag{9.34}$$

$$DET67_{5,5} \leftarrow DET67_{5,5} + EKP111_{5,5,5}; \tag{9.35}$$

$$SELFUS_{5,5} \leftarrow SELFUS_{5,5} - EKP111_{5,5,5}; \tag{9.36}$$

$$EKP111_{4,5,j} \leftarrow EP67_{5,j}/ETA_{4,5,3},\ j=6\text{-}8; \tag{9.37}$$

$$DET67_{4,j} \leftarrow DET67_{4,j} + EKP111_{4,5,j},\ j=6\text{-}8;\ \text{and} \tag{9.38}$$

$$SELFUS_{4,j} \leftarrow SELFUS_{4,j} - EKP111_{4,5,j},\ j=6\text{-}8. \tag{9.39}$$

9.4.2 Space Heat

Generally, space heat was computed as a residual after all other products uses had been accounted for from the DET67 matrix. Coal and refined petroleum products residuals were available to the natural gas utilities sectors, but no natural gas residuals. So, we computed a natural gas residual by assuming that use of space heat in this sector was proportional to the same use in the refined petroleum products sector, based on labor employed. Then, using the two real residuals and this energy product amount, we calculated the natural gas "residual" and the modifications to the DET67 and SELFUS matrices. Mathematically, all of this was done as follows:

$$EP67_{6,5} \leftarrow EP67_{6,4} * LABOR_5/LABOR_4; \tag{9.40}$$

$$EKP111_{1,6,5} \leftarrow DET67_{1,5}; \tag{9.41}$$

$$EKP111_{3,6,5} \leftarrow DET67_{3,5} - EP67_{2,5}/ETA_{3,2,3} - EP67_{3,5}/ETA_{3,3,3}; \quad (9.42)$$

$$EPNET \leftarrow EP67_{6,5} - EKP111_{1,6,5} * ETA_{1,6,3} - EKP111_{3,6,5} * ETA_{3,6,3}; \quad (9.43)$$

If EPNET > 0, then

$$EKP111_{5,6,5} \leftarrow (EP67_{6,5} - EKP111_{1,6,5} * ETA_{1,6,3} - EKP111_{3,6,5} * ETA_{3,6,3})/ETA_{5,6,3}; \quad (9.44)$$

Otherwise

$$EP67_{6,5} \leftarrow EKP111_{3,6,5} * ETA_{3,6,3} + EKP111_{1,6,5} * ETA_{1,6,3}; \text{ and} \quad (9.45)$$

$$EKP111_{5,6,5} \leftarrow 0; \quad (9.46)$$

and, in either case

$$DET67_{5,5} \leftarrow DET67_{5,5} + EKP111_{5,6,5}; \text{ and} \quad (9.47)$$

$$SELFUS_{5,5} \leftarrow SELFUS_{5,5} - EKP111_{5,6,5}. \quad (9.48)$$

A pseudo-residual for each fossil fuel for space heat in each electric utilities sector was computed by assuming that use in each electric utilities sector was proportional to the same use in the natural gas utilities sector, based on labor employed. Then efficiencies were applied to these fuel allocations and they were aggregated to yield an energy product amount. Finally, modifications were made to the DET67 and SELFUS matrices. Mathematically, all of this was expressed:

$EKP111_{k,6,j} \leftarrow EKP111_{k,6,5} * LABOR_j/LABOR_5$, k=1, 3, and 5 and j=6-8; (9.49)

$EP67_{6,j} \leftarrow EKP111_{1,6,j} * ETA_{1,6,3} + EKP111_{3,6,j} * ETA_{3,6,3} + EKP111_{5,6,j} * ETA_{5,6,3}$, j=6-8; (9.50)

$DET67_{K,j} \leftarrow DET67_{K,j} + EKP111_{K,6,j}$, K=1, 3, and 5 and j=6-8; and (9.51)

$SELFUS_{K,j} \leftarrow SELFUS_{K,j} - EKP111_{K,6,j}$, K=1, 3, and 5 and j=6-8. (9.52)

9.4.3 Air-Conditioning

Air-conditioning use in the natural gas utilities sector was assumed to be powered by the same mix of fuels used in all other commercial and government sectors. See section 6.3 for this. This required the following modifications:

$DET67_{5,5} \leftarrow DET67_{5,5} + EKP111_{5,7,5}$; and (9.53)

$SELFUS_{5,5} \leftarrow SELFUS_{5,5} - EKP111_{5,7,5}$. (9.54)

Air-conditioning use in the electric utilities sectors was assumed to be powered exclusively by electricity. This dictated the following assignments in EKP111 and modifications:

$EKP111_{4,7,j} \leftarrow EP67_{7,j}/ETA_{4,7,3}$, j=6-8; (9.55)

$DET67_{4,j} \leftarrow DET67_{4,j} + EKP111_{4,7,j}$, j=6-8; and (9.56)

$SELFUS_{4,j} \leftarrow SELFUS_{4,j} - EKP111_{4,7,j}$, j=6-8. (9.57)

9.5 RESIDENTIAL MISCELLANEOUS THERMAL USES, WATER HEAT AND SPACE HEAT

Assigning energy supplies and energy product totals for personal consumption use of miscellaneous thermal uses (cooking and clothes drying) and water heat merely involved carrying forward the residential supersector totals from T67 and E67. Mathematically, this was done as follows:

$$EKP111_{K,P,102} \leftarrow E67_{K,P,4}, \text{ k=1-5 and P=4 and 5; and} \quad (9.58)$$

$$EP67_{P,102} \leftarrow T67_{P,4}, \text{ P = 4 and 5.} \quad (9.59)$$

Coal. Refined petroleum, and natural gas not assigned to other energy products were allocated to space heat use in the residential sector. This was done rather than direct assignment of E67 values $T67_{6,4}$, because the bariability of space heating requirements from year to year could induce some error into the 1967 control total computed from 1968 data in section 2. Electricity used for space heat were taken from E67 and no crude oil and gas products were used by sector 102. First the EKP111 values for energy supplies used for space heat in this sector were calculated and then the EP67 values were computed from these and the efficiencies of conversion. Mathematically, these assignments were made:

$$EKP111_{K,6,102} \leftarrow PET67_{K,102} - \sum_{p=1} E67_{K,P,102}, \text{ k=1, 3, and 4;} \quad (9.60)$$

$$EKP111_{K,6,102} \leftarrow E67_{K,6,102}, \text{ K=2 and 5; and} \quad (9.61)$$

$$EP67_{6,102} \leftarrow \sum_{k=1}^{5} EKP111_{K,6,102} * ETA_{K,6,4}. \quad (9.62)$$

10.0 MISCELLANEOUS ELECTRIC USES

10.1 INDUSTRIAL SUPERSECTOR

In the industrial supersector we calculated electricity use for air-conditioning (section 6.1). PEC assumed that electricity used to produce space heat and water heat is negligible and, of course, that no electric energy goes to motive power in this supersector or to coke or feedstocks. PEC, though, does list a 1968 usage of 130 trillion Btu of electricity for direct (process) heat in this supersector. We included this usage in the miscellaneous electricity category under the assumption that electricity is a non-substitutable source in the few applications in which it is used. (See section 2.2.) (Otherwise, a more efficient, less expensive source would surely be employed.) This assumption allowed us to apread the industrial electric power control totals to the electric power rows of the EP67 and EKP111 matrices merely by allocating to each sector of the EP67 the product of the conversion efficiency and the residual amount left in the same sector of the electricity row in the DET67 matrix after the energy for electrically-powered air-conditioning was subracted from the DET67 number. The DET67 residual itself was allocated directly to the EKP111 matrix. Mathematically, the above was expressed:

$$EP67_{8,j} \leftarrow (DET67_{4,j} - EKP111_{4,7,j}) * ETA_{4,8,1}, \quad j=3,\ 4,\ \text{and } 27\text{-}79;\ \text{and} \qquad (10.1)$$

$$EKP111_{4,8,j} \leftarrow DET67_{4,j} - EKP111_{4,7,j}. \qquad (10.2)$$

As a check, the amounts allocated to the various industrial sectors in the EP67 electric power row should sum to $T67_{8,1}$, the control total for this row and supersector.

10.2 TRANSPORTATION SUPERSECTOR

PEC assumed that a negligible amount or no electricity was used to produce space heat, water heat, coke, feedstocks, process heat or air-conditioning in this supersector. The PEC amount for electric use in the transportation supersector includes all of the electricity used by the transportation sectors for motive power. Again we assumed that electric power is a non-substitutable source in this application (mostly urban mass transit, where, if nothing else, the capital invested in subways and elevated rails dictates that they not be abandoned). This assumption required that we account for electrically-produced motive power in the electric power category with all the other electric power uses in the transportation sectors and that requirement allowed us to spread the transportation-electric power control total, $T67_{8,2}$, to the electric power row of the EP matrix merely by placing in each sector of that row the number which is the product of the conversion efficiency and the amount in the same sector of the electric power row in the DET67 matrix. Mathematically, the allocations in this supersector were described:

$$EP67_{8,j} \leftarrow DET67_{4,j} * ETA_{4,8,2}, \; j\epsilon T; \text{ and} \qquad (10.3)$$

$$EKP111_{4,8,j} \leftarrow DET67_{4,j}, \; j\epsilon T. \qquad (10.4)$$

Again, the obvious check on our algorithm was that the amounts allocated to the transportation sectors in the EP67 electric power row should sum to $T67_{8,2}$.

10.3 COMMERCIAL AND GOVERNMENT SUPERSECTOR

In this supersector PEC assumed that a negligible amount of electric power is used to produce coke, petro-chemical feedstocks, motive power and space heat. We allocated the commercial electric power control total, $T67_{8,3}$, in the same manner the industrial electric power control total was spread; we placed in each sector of the electric power row of the EP67 matrix the product of the conversion efficiency and the residual amount left in the same sector of the electric power row of the DET67 matrix after electricity applied as other energy products was subtracted from the DET67 number. In order to compute the residual, it was necessary to subtract the allocations of miscellaneous thermal uses, water heat and air-conditioning. The residual amount itself was allocated in the EKP111 matrix. Mathematically, the allocations in this supersector were made as follows for all commercial sectors except electric utilities:

$$EP67_{8,j} \leftarrow (DET67_{4,j} - EKP111_{4,4,j} - EKP111_{4,5,j} - EKP111_{4,7,j}) * ETA_{4,8,3},\ j\varepsilon C;\ \text{and} \quad (10.5)$$

$$EKP111_{5,8,j} \leftarrow DET67_{4,j} - EKP111_{4,4,j} - EKP111_{4,5,j} - EKP111_{4,7,j},\ j\varepsilon C. \quad (10.6)$$

Since, as a first approximation in section 2.4.2, all electricity allocated in DET67 to the electricity sectors was considered to be consumed in transmission and distribution losses, there is no DET67 residual to allocate here. We computed the EKP111 allocations of miscellaneous electric uses for the electricity sectors to be proportional on the basis of labor employed to the same use by the natural gas utilities sector and then we computed the EP67 entries from the EKP111 entries. It was then necessary to modify the DET67 and SELFUS matrices to be consistent with these new usages. Mathematically, all of this was expressed:

$$EKP111_{4,8,j} \leftarrow EKP111_{4,8,5} * LABOR_j/LABOR_5,\ j=6\text{–}8; \quad (10.7)$$

$$EP67_{8,j} \leftarrow EKP111_{4,8,j} * ETA_{4,8,3},\ j=6\text{–}8; \quad (10.8)$$

$$DET67_{4,j} \leftarrow DET67_{4,j} + EKP111_{4,8,j},\ j=6\text{–}8;\ \text{and} \quad (10.9)$$

$$SELFUS_{4,j} \leftarrow SELFUS_{4,j} - EKP111_{4,8,j},\ j=6\text{–}8. \quad (10.10)$$

Allocations of electric power to other energy products, including air-conditioning were done in section 9.4. The check on this algorithm is essentially the same as for the first two supersectors. The sum of the amounts allocated to the commercial and government sectors of the EP67 electric power should equal $T67_{8,3}$.

10.4 RESIDENTIAL SECTOR

To compute the EP67 and EKP111 entries for the personal consumption expenditures sector use of miscellaneous electricity, we simply carried forward entries in the T67 and E67 matrices. Mathematically, this was expressed:

$$EP67_{8,102} \leftarrow T67_{8,4}; \text{ and} \tag{10.11}$$

$$EKP111_{4,8,102} \leftarrow E67_{4,8,4}. \tag{10.12}$$

11.0 RESULTS AND CONSISTENCY CHECKS

11.1 ENERGY PRODUCT ALLOCATIONS

At this point we have completed development of the 8 x 111 matrix of energy product allocations, EP67, and the 5 x 8 x 111 matrix of fuels to energy products in each sector, EKP111. As explained in the preceding sections, construction of this matrix was not simply a matter of disaggregating national control totals. Many different data sources, sometimes complementary but occasionally contradictory, were employed. Some of these data sources provided the opportunity of consistency checks at various stages in the development of the final matrix.

The final results, the two matrices, are shown in Tables 26 and 27. Consistency checks and minor methodological modifications resulting from those checks are discussed next.

11.2 CONTROL TOTALS AND INTERNAL CONSISTENCY

Return to figure 4 in section 2.1.1 and recall that all the matrices in the lower half of the picture were carried throughout the analysis and continuously updated at every step. Tests repeated after execution of the assignments in each of sections 3 - 11 assured that the following conditions were satisfied at all times:

$$\sum_{K=1}^{5} E67_{K,P,S} * ETA_{K,P,S} = T_{P,S} \qquad (11.1)$$

$$\sum_{K=1}^{5} EKP111_{K,P,j} * ETA_{K,P,S} = T_{P,S} \quad j \varepsilon S; \text{ and} \qquad (11.2)$$

$$\sum_{j \varepsilon S} EKP111_{K,P,j} = E67_{K,P,S}; \qquad (11.3)$$

In the above equations all subscripts run over their full ranges:

K = 1-5, P = 1-8, S = 1-4, j = 1-111

As additional sector-by-sector checks, the following conditions were tested after the last step:

$$\sum_{K=1}^{5} EKP111_{K,P,j} * ETA_{K,P,S} = EP67_{P,j}; \text{ and} \tag{11.4}$$

$$\sum_{P=1}^{8} EKP111_{K,P,j} = DET67_{K,S}. \tag{11.5}$$

Here the right hand side is the modified DET67 derived in section 2.4.2 and contains only transactions for energy product uses.

Since the employment of so many diverse data sources overspecified the problem in some areas, it was expected that equations (11.4) and (11.5) would sometimes not be satisfied. It was encouraging to note that the equations were satisfied in all but 13 of the 555 cases. Each of these cases is discussed below with the action taken by us.

There were only three cases where our algorithms disagreed with DET67 entries derived in ref. [6] from direct fuel use measurements:

1) In the computing machines sector (66), natural gas use was computed to be slightly larger than ref. [6] reported, leaving no residual for miscellaneous thermal sector. We retained our natural gas use figure, but assumed miscellaneous thermal use zero in this sector because of the absence of heat-intensive production processes.
2) In the apparel sector (32) our algorithm overallocated fuels considerably. We therefore assumed per capita space heating requirements in this sector were about half the average for manufacturing employees because of the relatively dense working conditions and concentration of this labor intensive industry in the sourthern states where labor is less expensive and heat requirements lower.
3) In the leather products sector (48) a similar condition was encountered, and fixed by assuming per capita space heat requirements were 2/3 the national average due to the relatively dense working conditions, compared to other manufacturing sectors.

All other inconsistencies occurred for elements of DET67 derived in ref. [6] from dollar transactions and implied prices due to the absence of direct energy measurement data. Therefore in the following cases we tended to give preference to our algorithms over the fuel assignments.

EP67

K= 1									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8388E 05	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7216E 06	0.1545E 10	0.5801E 07	0.0	0.9789E 06	0.0	0.7095E 06	0.2244E 05	0.1406E 07	0.2767E 06
0.0	0.0	0.9648E 05	0.3765E 06	0.8509E 05	0.0	0.0	0.0	0.0	0.1461E 06
0.0	0.0	0.0	0.2649E 07	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									
K= 2									
0.6103E 05	0.1237E 06	0.0	0.7095E 09	0.6184E 05	0.1675E 06	0.1301E 04	0.3766E 05	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.5174E 06	0.6622E 07	0.2938E 06	0.6437E 05
0.1204E 05	0.2159E 05	0.4550E 05	0.5567E 04	0.7483E 09	0.1704E 09	0.1561E 05	0.8859E 05	0.4284E 04	0.2979E 05
0.6106E 04	0.7303E 05	0.8519E 04	0.3123E 05	0.2013E 04	0.1645E 05	0.7042E 04	0.3323E 07	0.1054E 05	0.5481E 05
0.7800E 09	0.1937E 09	0.1270E 05	0.2100E 08	0.1978E 09	0.1774E 09	0.2556E 05	0.1625E 04	0.1576E 05	0.8716E 04
0.2290E 05	0.4609E 05	0.1940E 05	0.3841E 04	0.2447E 05	0.1724E 05	0.2275E 05	0.5121E 04	0.7534E 04	0.9258E 04
0.4333E 04	0.1807E 05	0.1024E 05	0.1453E 05	0.1216E 05	0.1177E 05	0.6352E 04	0.2058E 05	0.8618E 04	0.1005E 05
0.3285E 05	0.1896E 05	0.5614E 04	0.4023E 05	0.4117E 05	0.1487E 05	0.1472E 05	0.7633E 04	0.2226E 05	0.1105E 07
0.3400E 06	0.8576E 06	0.1218E 07	0.2240E 07	0.5001E 05	0.0	0.9090E 05	0.1312E 05	0.1871E 05	0.4323E 07
0.2967E 06	0.6541E 05	0.3042E 06	0.3014E 06	0.5644E 05	0.8087E 05	0.5786E 06	0.7029E 05	0.2729E 05	0.0
0.0	0.8355E 08	0.0	0.0	0.0	0.9827E 07	0.1408E 06	0.3100E 05	0.1221E 06	0.7434E 05
0.1254E 06									
K= 3									
0.1201E 07	0.2435E 07	0.0	0.1441E 06	0.1217E 07	0.3296E 07	0.2560E 05	0.7411E 06	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.1018E 08	0.1303E 09	0.5782E 07	0.1267E 07
0.2370E 06	0.4249E 05	0.8955E 05	0.1096E 06	0.2772E 08	0.5577E 07	0.3072E 06	0.1744E 07	0.8432E 05	0.5863E 06
0.1202E 06	0.1437E 07	0.1677E 06	0.6146E 06	0.3962E 05	0.3237E 06	0.1386E 06	0.4516E 06	0.2074E 06	0.1079E 07
0.4536E 06	0.1987E 06	0.2500E 06	0.6590E 05	0.1527E 05	0.1802E 05	0.5030E 06	0.3198E 05	0.3101E 06	0.1715E 06
0.4507E 06	0.9071E 06	0.3818E 06	0.7559E 05	0.4817E 06	0.3392E 06	0.4478E 06	0.1008E 05	0.1483E 06	0.1822E 06
0.8529E 05	0.3557E 06	0.2016E 05	0.2859E 06	0.2394E 06	0.2316E 06	0.1250E 06	0.4051E 05	0.1696E 06	0.1977E 06
0.6464E 06	0.3731E 06	0.1105E 05	0.7918E 06	0.8102E 06	0.2927E 06	0.2898E 06	0.1502E 06	0.4381E 06	0.1094E 09
0.3366E 08	0.8490E 08	0.1206E 09	0.2218E 09	0.4951E 07	0.0	0.1789E 07	0.2583E 05	0.3683E 06	0.8507E 08
0.5839E 07	0.1287E 07	0.5986E 07	0.5932E 07	0.1111E 07	0.1592E 07	0.1139E 08	0.1383E 07	0.5371E 06	0.0
0.0	0.1644E 10	0.0	0.0	0.0	0.1934E 09	0.2771E 07	0.6102E 07	0.2403E 07	0.1463E 07
0.2467E 07									
K= 4									
0.8669E 07	0.4939E 09	0.0	0.1129E 10	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2952E 08	0.2500E 08	0.5607E 08	0.6652E 08	0.9785E 08	0.2482E 08	0.2943E 08	0.4889E 09	0.7068E 07	0.9074E 08
0.2180E 08	0.7541E 07	0.6762E 07	0.8736E 08	0.1202E 07	0.1707E 07	0.4971E 07	0.6739E 09	0.2254E 08	0.6334E 07
0.1069E 10	0.2159E 09	0.4290E 08	0.9476E 07	0.3759E 08	0.1627E 08	0.8236E 08	0.1038E 08	0.1292E 07	0.1366E 09
0.6055E 09	0.8139E 09	0.2767E 09	0.1121E 08	0.3623E 08	0.2379E 08	0.5602E 08	0.1334E 08	0.1718E 08	0.2110E 08
0.2681E 07	0.1046E 08	0.7442E 07	0.1651E 08	0.7004E 07	0.0	0.7459E 07	0.1359E 08	0.1703E 08	0.7819E 07
0.4276E 06	0.4690E 07	0.7080E 07	0.8979E 08	0.1248E 08	0.1324E 08	0.2825E 07	0.3959E 07	0.6528E 07	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7930E 08
0.0	0.0	0.2705E 08	0.0	0.0	0.6156E 07	0.1364E 08	0.0	0.0	0.0
0.0	0.3878E 09	0.0	0.0	0.0	0.3983E 07	0.0	0.3018E 07	0.6759E 07	0.0
0.0									

Table 26. Energy Product Allocations, 1967

(In millions of Btu's--Read across the rows.)

K= 5									
0.9517E 05	0.1929E 06	0.0	0.9623E 05	0.7178E 06	0.1944E 07	0.1510E 05	0.4371E 06	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.8103E 07	0.9349E 07	0.5109E 06	0.1008E 07
0.1877E 05	0.3366E 05	0.7095E 05	0.8681E 04	0.1320E 08	0.1930E 07	0.2052E 06	0.1165E 07	0.5632E 05	0.3917E 06
0.8028E 05	0.9601E 06	0.1120E 06	0.4105E 06	0.2647E 05	0.2162E 06	0.9258E 05	0.3017E 06	0.1385E 06	0.7206E 06
0.3030E 06	0.1327E 06	0.1670E 06	0.4402E 05	0.1020E 05	0.1204E 05	0.3360E 06	0.2136E 05	0.2072E 06	0.1146E 06
0.3010E 06	0.6060E 06	0.2551E 06	0.5050E 05	0.3218E 06	0.2266E 06	0.2991E 06	0.6733E 05	0.9905E 05	0.1217E 06
0.5697E 05	0.2376E 06	0.1347E 05	0.1910E 06	0.1599E 06	0.1547E 06	0.8351E 05	0.2706E 06	0.1133E 06	0.1321E 06
0.4318E 06	0.2492E 06	0.7380E 05	0.5289E 06	0.5412E 06	0.1955E 06	0.1936E 06	0.1003E 05	0.2926E 06	0.4882E 05
0.3040E 06	0.6976E 06	0.1276E 06	0.2008E 06	0.1130E 05	0.6217E 05	0.3852E 07	0.5561E 05	0.1891E 06	0.2007E 09
0.1257E 08	0.2772E 07	0.1121E 09	0.1277E 08	0.2392E 07	0.3427E 07	0.4667E 08	0.3750E 07	0.1456E 07	0.0
0.0	0.7890E 09	0.0	0.0	0.0	0.2715E 08	0.7510E 07	0.2129E 08	0.1759E 08	0.3966E 07
0.6688E 07									
K= 6									
0.0	0.0	0.0	0.4563E 07	0.1621E 08	0.4390E 08	0.3409E 06	0.9869E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.2786E 09	0.3758E 07	0.1090E 08	0.2196E 07
0.0	0.0	0.0	0.0	0.0	0.0	0.9730E 07	0.5522E 08	0.2670E 07	0.1857E 08
0.3806E 07	0.2276E 08	0.5310E 07	0.1946E 08	0.1255E 07	0.1025E 08	0.4389E 07	0.1430E 08	0.6569E 07	0.3416E 08
0.1436E 08	0.6292E 07	0.7919E 07	0.2087E 07	0.4836E 06	0.5708E 06	0.1593E 08	0.1013E 07	0.6548E 07	0.5433E 07
0.1427E 08	0.2873E 08	0.1209E 08	0.2394E 07	0.1525E 08	0.1074E 08	0.1418E 08	0.3192E 07	0.4696E 07	0.5770E 07
0.2701E 07	0.1126E 08	0.6384E 07	0.9055E 07	0.7581E 07	0.7336E 07	0.3960E 07	0.1283E 08	0.5371E 07	0.6262E 07
0.2047E 08	0.1182E 08	0.3499E 07	0.2508E 08	0.2566E 08	0.9270E 07	0.9178E 07	0.4758E 07	0.1387E 08	0.3767E 08
0.4044E 07	0.1963E 08	0.1126E 08	0.8047E 07	0.1628E 08	0.9602E 06	0.7919E 08	0.1045E 08	0.6635E 08	0.1090E 10
0.1274E 09	0.1954E 09	0.4643E 09	0.2108E 09	0.1640E 09	0.1769E 08	0.4364E 09	0.5985E 08	0.2681E 09	0.0
0.0	0.4379E 10	0.0	0.0	0.0	0.2773E 09	0.1589E 09	0.4768E 09	0.3260E 08	0.4213E 08
0.1693E 09									
K= 7									
0.0	0.0	0.0	0.3151E 07	0.1113E 07	0.3015E 07	0.2341E 05	0.6777E 06	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.4110E 06	0.5343E 07	0.7398E 07	0.1589E 08
0.1233E 07	0.2055E 07	0.2740E 06	0.1370E 06	0.0	0.0	0.0	0.4110E 07	0.5480E 06	0.1370E 07
0.1123E 08	0.2288E 08	0.5480E 07	0.2740E 06	0.0	0.0	0.1781E 07	0.0	0.0	0.1233E 07
0.2740E 06	0.3562E 07	0.1644E 07	0.0	0.1370E 06	0.6850E 06	0.6850E 06	0.8220E 06	0.2740E 06	0.1096E 07
0.1370E 06	0.4110E 06	0.1370E 06	0.6850E 06	0.1370E 06	0.1918E 07	0.5480E 06	0.1918E 07	0.8220E 06	0.1370E 06
0.9316E 07	0.7398E 07	0.6850E 06	0.3151E 07	0.1123E 08	0.5480E 06	0.6850E 06	0.2466E 07	0.4110E 06	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.5973E 07	0.8623E 06	0.2933E 06	0.1133E 09
0.1950E 08	0.4298E 07	0.1999E 08	0.1980E 08	0.3709E 07	0.5314E 07	0.3802E 08	0.5815E 07	0.2257E 07	0.0
0.0	0.2759E 09	0.0	0.0	0.0	0.1615E 08	0.1164E 08	0.2564E 08	0.1010E 08	0.6149E 07
0.1037E 08									
K= 8									
0.1975E 07	0.3202E 08	0.0	0.5075E 08	0.5292E 07	0.1433E 08	0.1113E 06	0.3223E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.1490E 08	0.1509E 08	0.3587E 05	0.2649E 05
0.1063E 08	0.1310E 08	0.1188E 08	0.9773E 07	0.4848E 07	0.6190E 06	0.1392E 08	0.9100E 08	0.6662E 06	0.5264E 08
0.5760E 07	0.1542E 08	0.2784E 07	0.2437E 08	0.6766E 06	0.5404E 07	0.2457E 07	0.7955E 08	0.7228E 07	0.1892E 08
0.2808E 09	0.2482E 08	0.7783E 07	0.2056E 07	0.1202E 07	0.8823E 06	0.3437E 08	0.1040E 07	0.2975E 07	0.1691E 08
0.5009E 08	0.1766E 09	0.1957E 09	0.3926E 07	0.1440E 08	0.1446E 08	0.1543E 08	0.3954E 07	0.3501E 07	0.7778E 07
0.1513E 07	0.9320E 07	0.4621E 07	0.8917E 07	0.6740E 07	0.4439E 07	0.3770E 07	0.1663E 08	0.6928E 07	0.5125E 07
0.1333E 08	0.1242E 08	0.3914E 07	0.4289E 08	0.2605E 08	0.7462E 07	0.4398E 07	0.2858E 07	0.7310E 07	0.3989E 07
0.1118E 08	0.2009E 07	0.2475E 07	0.2134E 07	0.1141E 08	0.2152E 06	0.1439E 08	0.5606E 07	0.8275E 07	0.2319E 09
0.3470E 08	0.2287E 08	0.1950E 08	0.6072E 07	0.1078E 08	0.7987E 07	0.1580E 09	0.7355E 07	0.2501E 08	0.0
0.0	0.5935E 09	0.0	0.0	0.0	0.3300E 08	0.3570E 07	0.1205E 09	0.3096E 07	0.5672E 07
0.7628E 08									

Table 26 (Con't.)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1252E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1077E 07	0.2306E 10	0.3658E 07	0.0	0.1461E 07	0.0	0.1059E 07	0.3355E 06	0.2098E 07	0.4130E 05
0.0	0.0	0.1440E 06	0.5620E 06	0.1270E 06	0.0	0.0	0.0	0.0	0.2130E 06
0.0	0.0	0.0	0.3954E 07	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=1 P=2 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5900E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=1 P=3 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=1 P=4 EKP111(K,P,J)=

0.0	0.1626E 07	0.0	0.1599E 08	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1626E 07	0.3251E 07	0.1137E 08	0.1626E 07	0.0	0.0	0.0	0.1169E 09	0.5595E 07	0.3305E 08
0.6578E 06	0.0	0.0	0.0	0.0	0.0	0.0	0.3438E 09	0.0	0.0
0.3597E 09	0.1751E 09	0.8258E 07	0.0	0.1665E 08	0.2645E 07	0.3660E 08	0.4849E 07	0.0	0.5598E 06
0.2922E 09	0.9400E 08	0.3586E 08	0.0	0.0	0.6966E 04	0.0	0.4245E 07	0.7203E 07	0.4052E 07
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3749E 07	0.0
0.0	0.0	0.0	0.4122E 08	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=1 P=5 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

Table 27. Fuel Allocations to Energy Products, 1967

(In millions of Btu's--Read across the rows.)

```
K=1        P=6        EKP111(K,P,J)=
   0.0         0.0         0.0         0.6518E 07  0.1486E 08  0.4025E 08  0.3125E 06  0.9349E 07  0.0         0.0
   0.0         0.0         0.0         0.0         0.0         0.0         0.2133E 08  0.4335E 07  0.0         0.2167E 07
   0.0         0.0         0.0         0.0         0.0         0.0         0.1355E 08  0.7589E 08  0.3815E 07  0.2653E 08
   0.5437E 07  0.7960E 07  0.5727E 07  0.1026E 08  0.5419E 06  0.5439E 07  0.3101E 07  0.2043E 08  0.2[illegible]E 07  0.2867E 07
   0.2052E 08  0.8989E 07  0.1131E 08  0.1029E 07  0.6909E 06  0.8155E 06  0.2276E 08  0.1447E 07  0.2101E 07  0.7761E 07
   0.2039E 08  0.4104E 08  0.1728E 06  0.1501E 07  0.4749E 07  0.1535E 08  0.1259E 08  0.4560E 07  0.6709E 07  0.8244E 07
   0.1908E 07  0.3684E 07  0.3311E 07  0.7397E 07  0.1929E 07  0.3275E 07  0.4287E 07  0.8612E 07  0.7674E 07  0.3792E 07
   0.6350E 07  0.2570E 07  0.3649E 07  0.3582E 08  0.1081E 08  0.9024E 07  0.9794E 06  0.0         0.4698E 07  0.3086E 08
   0.1626E 07  0.1680E 08  0.1205E 08  0.2167E 07  0.5419E 06  0.1084E 07  0.2167E 07  0.1626E 07  0.2872E 08  0.1409E 08
   0.7586E 07  0.0         0.2980E 08  0.3251E 07  0.1626E 07  0.1084E 07  0.5364E 08  0.1084E 07  0.1138E 08  0.0
   0.0         0.6562E 09  0.0         0.0         0.0         0.1967E 09  0.3576E 08  0.6345E 08  0.7586E 07  0.5419E 07
   0.2384E 08
K=1        P=7        EKP111(K,P,J)=
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0
K=1        P=8        EKP111(K,P,J)=
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0
K=2        P=1        EKP111(K,P,J)=
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0
K=2        P=2        EKP111(K,P,J)=
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
   0.0
```

Table 27 (cont.)

K=2	P=3	EKP111(K,P,J)=							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									
K=2	P=4	EKP111(K,P,J)=							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									
K=2	P=5	EKP111(K,P,J)=							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									
K=2	P=6	EKP111(K,P,J)=							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									
K=2	P=7	EKP111(K,P,J)=							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

Table 27 (cont.)

K=2 P=8 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=3 P=1 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=3 P=2 EKP111(K,P,J)=

0.6103E 05	0.1237E 06	0.0	0.7095E 09	0.6184E 05	0.1675E 06	0.1301E 04	0.3766E 05	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.5174E 06	0.6622E 07	0.2938E 06	0.6437E 05
0.1204E 05	0.2159E 05	0.4550E 05	0.5567E 04	0.7483E 05	0.1704E 09	0.1561E 05	0.8859E 05	0.4284E 04	0.2979E 05
0.6106E 04	0.7303E 05	0.8519E 04	0.3123E 05	0.2013E 04	0.1645E 05	0.7042E 04	0.3323E 07	0.1054E 05	0.5481E 05
0.1344E 09	0.1937E 09	0.1270E 05	0.2100E 08	0.1973E 09	0.1774E 09	0.2556E 05	0.1525E 04	0.1576E 05	0.5716E 04
0.2290E 05	0.4609E 05	0.1940E 05	0.3841E 04	0.2447E 05	0.1724E 05	0.2275E 05	0.5121E 04	0.7534E 04	0.9258E 04
0.4333E 04	0.1807E 05	0.1024E 05	0.1453E 05	0.1216E 05	0.1177E 05	0.6352E 04	0.2058E 05	0.8618E 04	0.1005E 05
0.3285E 05	0.1896E 05	0.5614E 04	0.4023E 05	0.4117E 05	0.1487E 05	0.1472E 05	0.7633E 04	0.2226E 05	0.5525E 07
0.1700E 07	0.4288E 07	0.6090E 07	0.1120E 08	0.2501E 06	0.0	0.9090E 05	0.1312E 05	0.1871E 05	0.4323E 07
0.2967E 06	0.6541E 05	0.3042E 06	0.3014E 06	0.5644E 05	0.8087E 05	0.5786E 06	0.7029E 05	0.2729E 05	0.0
0.0	0.8355E 08	0.0	0.0	0.0	0.9827E 07	0.1408E 06	0.3100E 06	0.1221E 06	0.7434E 05
0.1254E 06									

K=3 P=3 EKP111(K,P,J)=

0.6006E 07	0.1217E 08	0.0	0.7203E 06	0.6085E 07	0.1648E 08	0.1280E 06	0.3706E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.5091E 08	0.6516E 09	0.2891E 08	0.6335E 07
0.1135E 07	0.2124E 07	0.4477E 07	0.5478E 06	0.1386E 09	0.2788E 08	0.1536E 07	0.6718E 07	0.4216E 06	0.2932E 07
0.6009E 06	0.7186E 07	0.8355E 06	0.3073E 07	0.1981E 06	0.1618E 07	0.6929E 06	0.2258E 07	0.1037E 07	0.5393E 07
0.2268E 07	0.9934E 06	0.1250E 07	0.3295E 06	0.7635E 05	0.9012E 05	0.2515E 07	0.1599E 05	0.1551E 07	0.8577E 06
0.2253E 07	0.4536E 07	0.1909E 07	0.3780E 06	0.2408E 07	0.1696E 07	0.2239E 07	0.5040E 06	0.7414E 06	0.9110E 06
0.4264E 06	0.1778E 07	0.1008E 07	0.1430E 07	0.1197E 07	0.1158E 07	0.6251E 06	0.2026E 07	0.8480E 06	0.9865E 06
0.3232E 07	0.1866E 07	0.5524E 06	0.3959E 07	0.4051E 07	0.1463E 07	0.1449E 07	0.7511E 06	0.2190E 07	0.5470E 09
0.1683E 09	0.4245E 09	0.6029E 09	0.1109E 10	0.2476E 08	0.0	0.8945E 07	0.1291E 07	0.1841E 07	0.4254E 09
0.2920E 08	0.6437E 07	0.2995E 08	0.2956E 08	0.5554E 07	0.7958E 07	0.5694E 08	0.6917E 07	0.2585E 07	0.0
0.0	0.8222E 10	0.0	0.0	0.0	0.9670E 09	0.1385E 08	0.3051E 05	0.1201E 08	0.7315E 07
0.1234E 08									

K=3 P=4 EKP111(K,P,J)=

0.1130E 08	0.1143E 08	0.0	0.7328E 09	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7882E 07	0.8988E 07	0.3266E 08	0.6367E 07	0.1439E 09	0.3651E 08	0.3008E 08	0.1770E 09	0.3059E 07	0.4501E 08
0.1413E 08	0.0	0.2285E 06	0.5730E 08	0.0	0.0	0.0	0.2891E 09	0.9775E 07	0.0
0.7145E 08	0.2940E 08	0.3039E 08	0.4619E 07	0.2192E 08	0.8809E 07	0.3039E 08	0.6571E 07	0.0	0.1291E 08
0.1157E 09	0.2379E 09	0.4536E 08	0.1161E 07	0.0	0.9918E 07	0.3193E 08	0.9301E 07	0.2748E 07	0.5243E 07
0.0	0.0	0.2556E 07	0.4145E 07	0.0	0.0	0.1368E 07	0.0	0.3392E 07	0.0
0.0	0.0	0.1785E 07	0.1561E 08	0.0	0.8473E 07	0.0	0.1408E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.4118E 08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=3 P=5 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.1037E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=3 P=6 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.7637E 07	0.2069E 08	0.1606E 08	0.4551E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.3432E 09	0.0	0.1434E 08	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.3258E 06	0.0	0.0	0.0
0.0	0.1591E 08	0.7913E 06	0.1616E 08	0.7838E 06	0.3722E 07	0.1797E 07	0.0	0.6018E 07	0.1461E 08
0.0	0.0	0.0	0.1799E 07	0.0	0.0	0.0	0.0	0.2843E 07	0.0
0.0	0.0	0.0	0.1758E 07	0.1352E 08	0.0	0.7066E 07	0.0	0.0	0.0
0.1454E 07	0.7959E 07	0.5351E 07	0.5101E 07	0.4239E 07	0.1888E 07	0.1262E 07	0.6215E 07	0.0	0.3350E 07
0.8157E 07	0.6421E 07	0.1243E 07	0.0	0.1344E 08	0.3885E 07	0.4856E 07	0.6260E 07	0.9573E 07	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.7025E 08	0.0	0.6557E 07	0.1081E 10
0.8248E 08	0.1383E 09	0.2532E 09	0.1298E 09	0.2065E 09	0.1367E 08	0.2011E 09	0.4556E 08	0.4754E 08	0.0
0.0	0.2220E 10	0.0	0.0	0.0	0.1684E 09	0.1559E 09	0.1470E 09	0.2983E 08	0.3250E 08
0.8378E 08									

K=3 P=7 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=3 P=8 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=4 P=1 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

Table 27 (cont.)

```
K=4         P=2         EKP111(K,P,J)=
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0
K=4         P=3         EKP111(K,P,J)=
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0
K=4         P=4         EKP111(K,P,J)=
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.4776E 07
  0.0         0.0         0.4725E 06  0.0         0.0         0.3707E 06  0.8214E 06  0.0         0.0         0.0
  0.0         0.1245E 09  0.0         0.0         0.0         0.2399E 06  0.0         0.1517E 06  0.4571E 06  0.0
  0.0
K=4         P=5         EKP111(K,P,J)=
  0.0         0.0         0.0         0.0         0.0         0.1944E 07  0.1510E 05  0.4371E 06  0.0         0.0
- 0.0         0.0         0.0         0.0         0.0         0.0         0.1229E 07  0.1417E 07  0.0         0.1529E 06
  0.0         0.0         0.0         0.0         0.2272E 07  0.4571E 06  0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.5840E 06  0.8431E 05  0.2867E 05  0.3043E 06
  0.1906E 07  0.4202E 06  0.1699E 08  0.1936E 07  0.3626E 06  0.5196E 06  0.7076E 07  0.5635E 06  0.2207E 06  0.0
  0.0         0.1876E 09  0.0         0.0         0.0         0.4117E 07  0.1139E 07  0.3227E 07  0.2667E 07  0.6012E 06
  0.1014E 07
K=4         P=6         EKP111(K,P,J)=
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.1384E 09  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0
```

K=4 P=7 EKP111(K,P,J)=

0.0	0.0	0.0	0.7877E 06	0.3395E 06	0.1005E 07	0.7803E 04	0.2259E 05	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.1027E 06	0.1336E 07	0.1849E 07	0.5973E 07
0.3082E 06	0.5137E 06	0.6850E 05	0.3425E 05	0.0	0.0	0.0	0.1027E 07	0.1370E 07	0.3425E 06
0.2808E 07	0.5720E 07	0.1370E 07	0.6850E 05	0.0	0.0	0.4452E 06	0.0	0.0	0.3082E 06
0.6850E 05	0.8905E 06	0.4110E 06	0.0	0.3425E 05	0.1712E 06	0.1712E 06	0.2055E 06	0.5850E 05	0.2740E 06
0.3425E 05	0.1027E 06	0.3425E 05	0.1712E 06	0.3425E 05	0.4795E 06	0.1370E 06	0.4795E 05	0.2055E 06	0.3425E 05
0.2329E 07	0.1849E 07	0.1712E 06	0.7877E 06	0.2808E 07	0.1370E 06	0.1712E 06	0.6165E 05	0.1027E 06	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.1831E 07	0.2544E 05	0.5991E 05	0.3473E 08
0.5977E 07	0.1318E 07	0.6128E 07	0.6072E 07	0.1137E 07	0.1629E 07	0.1166E 08	0.1723E 07	0.6921E 06	0.0
0.0	0.1300E 09	0.0	0.0	0.0	0.4950E 07	0.3570E 07	0.7562E 07	0.3096E 07	0.1885E 07
0.3180E 07									

K=4 P=8 EKP111(K,P,J)=

0.1975E 07	0.3202E 08	0.0	0.5075E 08	0.5292E 07	0.1433E 08	0.1113E 06	0.3223E 07	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.1490E 08	0.1509E 08	0.3587E 05	0.2649E 05
0.1063E 08	0.1310E 08	0.1188E 08	0.9773E 07	0.4848E 07	0.6190E 06	0.1592E 08	0.9100E 08	0.6662E 06	0.5264E 08
0.5760E 07	0.1542E 08	0.2784E 07	0.2437E 06	0.6766E 06	0.5404E 07	0.2457E 07	0.7955E 08	0.7225E 07	0.1892E 09
0.2808E 09	0.2482E 08	0.7783E 07	0.2056E 07	0.1202E 07	0.8823E 06	0.3437E 08	0.1040E 07	0.2975E 07	0.1691E 06
0.5009E 08	0.1766E 09	0.1957E 09	0.3926E 07	0.1440E 08	0.1446E 08	0.1543E 08	0.5954E 07	0.3501E 07	0.7778E 07
0.1513E 07	0.9320E 07	0.4621E 07	0.8917E 07	0.6740E 07	0.4439E 07	0.3770E 07	0.1663E 08	0.6928E 07	0.5125E 07
0.1333E 08	0.1242E 08	0.3914E 07	0.4289E 08	0.2605E 08	0.7462E 07	0.4398E 07	0.2856E 07	0.7310E 07	0.3969E 07
0.1118E 08	0.2009E 07	0.2475E 07	0.2134E 07	0.1141E 08	0.2152E 06	0.1439E 08	0.5506E 07	0.8275E 07	0.2319E 09
0.3470E 08	0.2287E 08	0.1950E 08	0.6072E 07	0.1078E 08	0.7987E 07	0.1560E 09	0.7355E 07	0.2501E 08	0.0
0.0	0.5935E 09	0.0	0.0	0.0	0.3300E 08	0.3570E 07	0.1205E 09	0.3096E 07	0.5672E 07
0.7628E 08									

K=5 P=1 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=5 P=2 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6072E 09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

K=5 P=3 EKP111(K,P,J)=

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0									

Table 27 (cont.)

```
K=5          P=4          EKP111(K,P,J)=
  0.1536E 07  0.7578E 09  0.0         0.9682E 09  0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.3597E 08  0.2596E 08  0.4048E 08  0.9539E 08  0.0         0.0         0.1403E 08  0.4461E 09  0.1574E 07  0.5780E 08
  0.1834E 06  0.1176E 08  0.1032E 08  0.7552E 08  0.1876E 07  0.2668E 07  0.7765E 07  0.3731E 09  0.2483E 08  0.9896E 07
  0.1200E 10  0.1145E 09  0.2571E 08  0.9899E 07  0.1724E 08  0.1317E 06  0.5637E 08  0.3826E 07  0.2019E 07  0.1992E 09
  0.5036E 09  0.9161E 09  0.3449E 09  0.1628E 08  0.5661E 08  0.2663E 08  0.5361E 08  0.6321E 07  0.1605E 08  0.1977E 08
  0.4189E 07  0.1635E 08  0.8912E 07  0.2140E 08  0.1094E 08  0.0         0.1020E 08  0.2139E 08  0.1891E 08  0.1222E 08
  0.6682E 06  0.7328E 07  0.9166E 07  0.7863E 08  0.1950E 08  0.1169E 08  0.4413E 07  0.4690E 07  0.1020E 08  0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.1164E 09
  0.0         0.0         0.4152E 08  0.0         0.0         0.9039E 07  0.2003E 08  0.0         0.0         0.0
  0.0         0.3677E 09  0.0         0.0         0.0         0.5849E 07  0.0         0.4431F 07  0.9925E 07  0.0
  0.0
K=5          P=5          EKP111(K,P,J)=
  0.1360E 06  0.2756E 06  0.0         0.1375E 06  0.1025E 07  0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.9821E 07  0.1133E 08  0.5260E 06  0.1222E 07
  0.2682E 05  0.4809E 05  0.1014E 06  0.1240E 05  0.1560E 08  0.2104E 07  0.2932E 06  0.1554E 07  0.8046E 05  0.5595E 06
  0.1147F 06  0.1372E 07  0.1600E 06  0.5865E 06  0.3781E 05  0.3089E 05  0.1323E 06  0.4310E 05  0.1979E 06  0.1029E 07
  0.4328E 06  0.1896E 06  0.2386E 06  0.6289E 05  0.1457E 05  0.1720E 05  0.4800E 06  0.3052E 05  0.2960E 06  0.1637E 06
  0.4301E 06  0.8657E 05  0.3644E 05  0.7214E 05  0.4597E 06  0.3237E 05  0.4273E 06  0.9619E 05  0.1415E 05  0.1739E 05
  0.8139E 05  0.3394E 06  0.1924E 05  0.2728E 06  0.2264E 06  0.2210E 06  0.1193E 06  0.3866E 05  0.1618E 06  0.1587E 06
  0.6169E 05  0.3561E 05  0.1054E 05  0.7555E 06  0.7732E 06  0.2793E 06  0.2765E 06  0.1434E 05  0.4180E 06  0.5974E 06
  0.4342E 06  0.9966E 06  0.1823E 06  0.2659E 06  0.1615E 05  0.8881E 05  0.4669E 07  0.6740E 05  0.2292E 06  0.2453E 09
  0.1524E 08  0.3360E 07  0.1358E 09  0.1548E 08  0.2899E 07  0.4154E 07  0.5657E 08  0.4545E 07  0.1764E 07  0.0
  0.0         0.9278E 09  0.0         0.0         0.0         0.3291E 08  0.9102E 07  0.2580E 08  0.2132E 06  0.4806E 07
  0.8106E 07
K=5          P=6          EKP111(K,P,J)=
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.3859F 07  0.9393E 05  0.0         0.8820E 06
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.6619E 07  0.0         0.0         0.3636E 06  0.3787E 07  0.1108E 07  0.0         0.0         0.2734E 08
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.3786E 07  0.0
  0.0         0.0         0.0         0.0         0.2154E 07  0.0         0.0         0.0         0.0         0.0
  0.3365E 06  0.3425E 07  0.0         0.0         0.3909E 07  0.4686E 07  0.0         0.2699E 07  0.0         0.1377E 07
  0.1275E 08  0.6673E 07  0.0         0.0         0.1024E 08  0.0         0.6206E 07  0.0         0.4298E 07  0.2087E 06
  0.3774E 07  0.1022E 08  0.3675E 07  0.8480E 07  0.2065E 08  0.2619E 05  0.3153E 08  0.1209E 08  0.5359E 08  0.3352E 09
  0.7717E 08  0.1172E 09  0.3259E 09  0.1427E 09  0.7636E 07  0.8490E 07  0.3194E 09  0.3379E 08  0.2909F 09  0.0
  0.0         0.3070E 10  0.0         0.0         0.0         0.1505E 08  0.2001E 08  0.3982E 09  0.5006E 07  0.1771E 08
  0.1155E 09
K=5          P=7          EKP111(K,P,J)=
  0.0         0.0         0.0         0.4376E 06  0.5256E 05  0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.5708E 05  0.7421E 06  0.1027E 07  0.2207E 07
  0.1712E 06  0.2854E 06  0.3806E 05  0.1903E 05  0.0         0.0         0.0         0.5708E 05  0.7611E 05  0.1903E 06
  0.1560E 07  0.3178E 07  0.7611E 06  0.3806E 05  0.0         0.0         0.2474E 06  0.0         0.0         0.1712E 06
  0.3806E 05  0.4947E 06  0.2283E 06  0.0         0.1903E 05  0.9514E 05  0.9514E 05  0.1142E 06  0.3806E 05  0.1522E 06
  0.1903E 05  0.5708E 05  0.1903E 05  0.9514E 05  0.1903E 05  0.2664E 06  0.7611E 05  0.2664E 06  0.1142E 06  0.1903E 05
  0.1294E 07  0.1027E 07  0.9514E 05  0.4376E 06  0.1560E 07  0.7611E 05  0.9514E 05  0.3425E 06  0.5708E 05  0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.2663E 06  0.3844E 05  0.1307E 05  0.5051E 07
  0.8692E 06  0.1916E 06  0.8911E 06  0.8829E 06  0.1653F 06  0.2369E 06  0.1695E 07  0.2592E 06  0.1006E 06  0.0
  0.0         0.0         0.0         0.0         0.0         0.7198E 06  0.5191E 06  0.1143E 07  0.4502E 06  0.2741E 06
  0.4623E 06
K=5          P=8          EKP111(K,P,J)=
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         -0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
  0.0
```

1) In the new construction sector (25), the full water heat allocation would have exceeded that sector's natural gas usage. It seems reasonable that new construction would not use as much water heat per employee as other commercial sectors so we assumed water heat use was limited to that possible with the fuel allocated.

2) In two agricultural sectors (18,20) and the broadcasting sector (89), ref. [6] did not allocate sufficient refined petroleum to cover our motive power assignments. We retained our earlier motive power allocations.

3) In the forestry sector (19) the standard commercial sector water heat allocation would have required more natural gas than ref. [6] assigned. We limited our water heat use to that amount.

4) In the hotels and repair services sector (93) ref. [6] did not allocate enough natural gas to cover space heating. Noting in PEC that natural gas use for space heat was about 8 times that for (allocated) water heat in the commercial supersector we extended that assumption to sector 93 and gave a higher allocation of natural gas to that sector.

5) Our algorithms in the amusements and movies sector (96) left no natural gas for space heating. We therefore deleted the special water heating allocation for dishwashing (based on PEC's refrigeration data) assuming that disposable utensils would be used here. This left a nonzero amount for space heat in this sector. The figure is only as good as the natural gas use figure from ref. [6] which was derived only from dollar data and average prices.

6) Finally, the electricity use figures from ref. [6] were not adequate to cover electric power use in the business services sector (94) and two government sectors (107 and 109). Noting in PEC that electric power use in the commercial and government supersector approximately equalled the electricity used for air conditioning there, we extended that assumption to these sectors.

Together, these ex-post adjustments had a minimal effect on the national totals for energy use by type in 1967. Since our ultimate objective is the development of a matrix of technological coefficients (See section 12 we believe that further adjustments in other sectors to compensate for these minor control total inconsistencies might induce more error into the resulting energy product coefficients.* Rather than obsessing over such minor accounting inconsistencies, we believe future research should proceed to identify the most important coefficients and refine those figures as necessary.

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* "Coefficients" of the EPA matrix as opposed to "base year transactions" in the EP67 matrix.

12. TOTAL TRANSACTIONS AND TECHNICAL COEFFICIENTS

In this section we describe the development of the 101 order matrix of total transactions, EPTT, and then normalize it to obtain the matrix EPA of technical coefficients for the base year.

12.1 TOTAL TRANSACTIONS

It was convenient to partition the matrix as shown in figure 15 and let S, P, I denote energy supply, energy product and non-energy sectors respectively. We inserted the new energy product and supply data as described below.

The II partition was the simplest; all values were taken directly from reference [11].

As discussed in section 1.2, we assumed partitions SI, PP, and IP contain zeros. The only exception was in the SI matrix. We had non-zero elements in two final demand columns corresponding to net inventory changes and exports. These were not converted to energy products.

Values in the SS partition correspond directly to the SELFUS matrix, since they denote those energy transactions not converted to energy products. Electric utilities sectors transactions were split from the old sector 4 to new sectors 6, 7, and 8 by multiplying each old sector 4 total by the base year fractions of fossil (.8113), nuclear (.0063), and renewable (.1824), as discussed in section 2.4.1.

The elements of SP are obtained from the EKP111 matrix as row sums for all 111 sectors. These represent the total energy supply flows converted to energy products. As above, electricity transactions were placed in the converted coal row according to their base year fractions and zeros.

The base year data for partitions PS and PI were obtained directly from the EP67 matrix which was inserted intact.

Finally, the elements of the IS partition were taken from the original CAC energy and employment policy model for sectors 1, 2, 4 and 5, and the data for sectors 3 and 6-8 obtained from in reference [16].

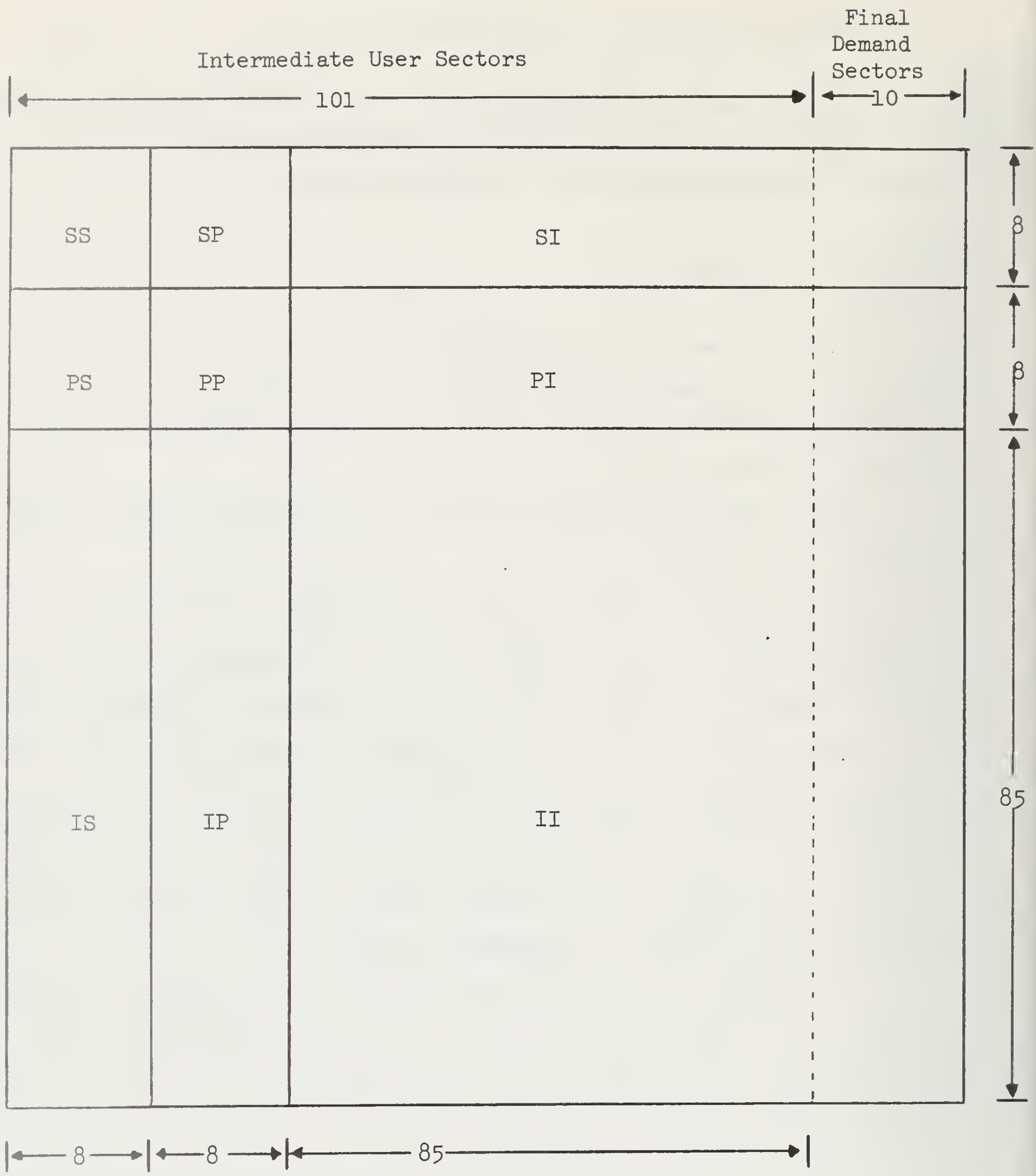

Figure 15. Partitions of the Total Transactions Matrix

12.2 TECHNOLOGICAL COEFFICIENTS

The derivation of the EPA matrix was straightforward, and followed the methods of conventional input-output analysis exactly. The entries in each column of EPTT were divided by the gross domestic output of that sector, given by

$$GDO_i = \sum_{j=1}^{111} EPTT_{i,j} - IMP_i \qquad (12.1)$$

where IMP is the vector of imports taken from reference [11]. The imports given by the source were only at the 90 sector level of detail, however, but expansion to 111 was straightforward. First since only energy supplies, not products, were imported, IMP_i was set equal to zero in the product sectors. Electricity imports [13] were split among the three sectors in the method described in section 12.1 and imports for the converted coal sector (3) were zero since it eas non-existent at that time.

Since there was no coal gasification in the base year 1967, that row and column of EPTT is zero. However, ref. [14] gives a vector of technical coefficients for that sector and it can be inserted into EPA as column 3 for problems where its output is nonzero.

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