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URBANA ILLINOIS 61801

CAC Document No. 178

DIRECT AND INDIRECT REQUIREMENTS FOR A PROJECT INDEPENDENCE SCENARIO

by

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This work was supported by the National Science Foundation.

ABSTRACT

This report evaluates the total (direct and indirect) construction requirements for the energy program proposed in the President's 1975 State of the Union Message. Using a linear model of the U.S. economic system, the total material, energy, manpower, and capital requirements are evaluated. It is shown that indirect requirements for material and manpower exceed direct inputs in most cases, so focusing on direct requirements alone can lead to serious underestimates in resource requirements. Since the proposed program involves an acceleration of capital investment in the energy sector, the impact of diverting these funds from other activities is also discussed.

ACKNOWLEDGMENT

The authors would like to express their sincere thanks to the computer programming assistance of Nadine Abbott and the typing effort by Lynn Rose.

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1. Introduction

Construction of energy supply facilities to meet the U.S. policy goals of energy self-sufficiency will require substantial commitments of several scarce resources: capital, certain types of materials and manpower, and energy itself. Examination of direct requirements alone may lead to serious underestimates and incomplete identification of possible constraints. The purpose of this report is to quantify the total (direct and indirect) requirements using a linear model of the U.S. energy-economic system. This permits a full accounting of (say) engineers required indirectly to design purchased components of energy facilities, in addition to those needed directly to design the facility itself. An appendix is included describing the calculational procedures.

1.1 Background

One of the immediate federal responses to the 1973 OPEC oil embargo was to initiate a policy of future independence from foreign supplies of energy. Project Independence was originally formulated to effect U.S. energy self-sufficiency by 1980. Questions raised concerning the exigency of energy independence as well as the prodigious domestic impacts of such a policy resulted in a reappraisal of these goals.[1]

In 1974 the National Academy of Engineering (NAE) evaluated the 1985 domestic supply-demand imbalance resulting from a program to increase domestic energy supplies and to reduce demand through conservation. They concluded that a 61% increase in domestic production by 1985 was achievable. However, great stress would be put on capital, water, and manpower resources, as well as the environment. Even with successful conservation programs, the NAE expected a continued (but decreased) reliance on imported oil in 1985.

Recently the Energy Research and Development Administration (ERDA) investigated the effects of six future scenarios for energy consumption. Their "improved efficiency in end use" scenario resulted in the lowest energy requirements for 1985, but only a scenario which included both improved efficiencies and the application of a number of new technologies significantly reduced imports in 1985. The ERDA report concluded that potential constraints would be resolved by normal market adjustments. However, increased demand for water and certain raw materials were a cause for concern.

1.2 Project Independence

A recent NSF-sponsored study by the Bechtel Corporation (Carasso 1975) evaluated the direct manpower, materials and capital required to construct the President's energy supply and transportation system as described in the Federal Energy Administrations's (FEA) "Draft Environmental Impact Statement of the Energy Independence Act of 1975." Characteristics of the forecasted 1985 U.S. energy system are compared with actual 1973 characteristics in Table 1. This scenario for energy supply development satisfies these characteristics for 1985, but obviously does not represent a unique path to the forecasted 1985 requirements.

Between 1973 and 1985, the U.S. is projected to increase its total energy consumption from 75.4 to 101.4 quads (10^{15} Btu). More intensive use of electricity is expected with electricity generation requiring over 41% of the 1985 energy use as compared to 28% in 1973. Nuclear generated electricity is expected to increase from 6% of the total in 1973 to 30% in 1985 while electricity generated from natural gas decreases from 21% to 6% of the total. This scenario achieves only a slight absolute reduction in imported oil: over 10% of the 1985 total energy requirements are met by imports. The 1985 total energy demand is quite similar to the NAE report. However, greater reliance on imports results from the FEA projecting a 41% increase in domestic supplies as compared to the NAE's 61% increase. The scenario considered by

Table 1

SELECTED CHARACTERISTICS OF THE U.S. ENERGY SYSTEM IN 1973 AND 1985

Fuel	Total Energy System Requirements (10^{15}Btu) 1973	Total Energy System Requirements (10^{15}Btu) 1985	Energy for Electric Power Generation (10^{15}Btu) 1973	Energy for Electric Power Generation (10^{15}Btu) 1985
Coal	13.1 (17.4)[a]	23.3 (23.0)[a]	8.6 (40.8)[a]	16.2 (38.6)[a]
Oil	34.4 (45.6)	40.8 (40.2)	3.6 (17.1)	5.9 (14.0)
Gas	23.5 (31.2)	20.0 (19.7)	4.5 (21.3)	2.6 (6.2)
Nuclear	1.3 (1.7)	12.5 (12.3)	1.3 (6.2)	12.5 (29.8)
Geothermal and Hydro	3.1 (4.1)	4.8 (4.7)	3.1 (14.7)	4.8 (11.4)
TOTAL	75.4	101.4	21.1 (28.0)[b]	42.0 (41.4)[b]

Source: Federal Energy Administration (1974).

Notes: a) Percent of column sum in parentheses.
b) Percent of total system energy requirements in parentheses.

Bechtel assumes a 3.2% average annual increase in domestic energy production up to 1985; the average for the last decade was 2.8%.[2]

2. Results

To calculate the total resource requirements we employ a linear model of the U.S. economic system. It is a modified economic input-output model that explicitly accounts for the fact that energy is sold to different users at different prices, and energy embodied in imported goods. A more complete description is given by Bullard and Herendeen (1975).

2.1 Material Requirements

Using the Bechtel results for direct material requirements, we have calculated the total requirements from each sector of the economy.[3] Table 2 shows the total (direct and indirect) requirements from those sectors supplying a significant fraction of their output to the proposed construction scenario. Note that in all cases, less than half the total material inputs were required directly at the construction site. At this level of aggregation, indirect inputs dominate in all sectors, emphasizing the importance of considering these effects in analyses for constraint identification.

Table 2 also gives the average annual output over the 1976-1985 time period as a percentage of each industry's actual gross domestic output for 1972.[4] This gives a measure of the relative demands on an industry due to the building of energy supply systems. However, some industries already rely to a great extent on the existing demand from energy-supply construction activities. For example in 1963, 65% of the "engines and turbines" sector and 49% of the "electric transmission and distribution

Table 2

TOTAL MATERIAL REQUIREMENTS FROM SEVERAL SECTORS[a] OF THE ECONOMY

Bureau of Economic Analysis Industry Sector	Percent Required Directly at Construction Site	1976-1985 Average Annual Requirements (millions of 1974 dollars)		Average Annual Percent Increase in Sector Output
Iron and ferroalloy ores mining	0.	235.	(21.6)[b]	1.1
Nonferrous metal ores mining	0.	248.	(13.0)	.7
Lumber and wood products except containers	36.	1068.	(7.3)	.3
Asphalt felts and coating	37.	35.	(5.1)	.5
Stone and clay products	38.	1042.	(8.7)	.6
Primary iron and steel manufacturing	22.	5504.	(19.1)	1.6
Primary nonferrous metals manufacturing	26.	4571.	(20.3)	1.2
Heating, plumbing and fabricated metal products	48.	6867.	(49.0)	3.6
Screw machine products, bolts, nuts, etc., and metal stampings	0.	344.	(5.2)	.3
Other fabricated metal products	32.	1274.	(9.2)	.6
Engines and turbines	46.	3514.	(70.1)	3.4
Construction, mining, oil field machinery equipment	46.	3637.	(53.9)	2.8
Materials handling machinery and equipment	37.	265.	(9.8)	.4
General industrial machinery and equipment	34.	1511.	(19.9)	1.8
Machine shop products	0.	228.	(6.8)	.4
Electric transmission and distribution equipment and electrical industrial apparatus	44.	4531.	(44.4)	2.2
Professional, scientific and controlling instruments, and supplies	44.	1304.	(19.3)	1.1
Railroads and related services	32.	993.	(8.0)	.4

Notes: a) Included are sectors whose 1976-1985 average required outputs exceed five percent of the sector's 1972 gross output.

b) Equivalent percent of 1972 gross domestic output.

equipment and electrical industrial apparatus" sector outputs were sold directly (as capital goods) to the utilities sector.[5] Thus, the very high demand on several sectors in Table 2 is not very surprising. Therefore, an estimate of each sector's average annual growth rate after 1975 resulting only from the demands of the scenario's building program was also included (see Appendix for details). These results imply that the "heating, plumbing and fabricated metal products" sector and the "engines and turbines" sector will experience the greatest pressure for expansion because of Project Independence. Just to meet the scenario's demands, both sectors will have to increase output by about 3.5% annually.[6]

Construction of energy-related facilities will itself require energy.[7] Total energy requirements, computed in the same way as total material requirements, amount to 16 quads during the ten-year period. Thus, only about 1.5%-2.0% of total U.S. energy use will be channeled into the energy supply expansion program. New facilities coming on line during that period will produce a total of about 140 quads. These figures state simply that for every nine Btu of energy produced by new energy facilities, one Btu of that is needed to pay the "energy costs" of the construction program. These results indicate that the net energy impact of the scenario is quite favorable, but a complete analysis would require assessment of operating energy inputs as well.

2.2 Manpower Requirements

Between 1976 and 1985 the average number of jobs required directly and indirectly to build the energy-related facilities is equivalent to 2.3% of the total number of U.S. jobs in 1972.[8] The number of jobs indirectly related to the construction is over twice the number required directly. Table 3 gives several characteristics of those occupational categories that average over 2% of their respective 1972 total jobs. A significant fraction of the U.S. engineers and construction craftsmen will be involved, directly and indirectly, with the Project Independence construction program.

Table 3

TOTAL EMPLOYMENT IN SEVERAL LABOR CATEGORIES[a]

Category	Percent Required Directly	1976-1985 Average Total Jobs (Thousands)	1976-1985 Average Total Jobs as a Percent of 1972 Total Jobs	1976-1985 Increase in Number of Jobs (Thousands)
Engineers, technical	71	119	10.6	59
Engineers, science technicians	54	63	6.8	30
Supervisors, managers, foremen	11	156	2.1	72
Construction, metalworking and other craftsmen	68	466	8.1	200
Semiskilled metalworkers	23	129	9.8	67
Semiskilled packing, inspecting	0	43	2.9	21
Transport equipment operatives	0	64	2.0	29
Teamsters and laborers	32	416	3.6	200
TOTAL[b]	32	2,001	2.3	931

Notes: a) Included are categories whose 1976 to 1985 average number of jobs exceed two percent of the 1972 total.

b) Includes all categories not in Table as well.

Increased employment from constructing these facilities might be interpreted as favorable in light of current unemployment rates. While this is probably true for certain types of construction workers, it is not true for technical manpower. For example, the increased requirement for engineers is nearly four times those unemployed in 1974 (BLS 1975). Consideration of requirements for operating these new facilities and comparison with expected growth of supply in these categories would be necessary to quantify the true extent of the shortage.

Another result is that the peak requirements for all job categories will be 70-80% greater than that required for constructing energy-related facilities in the 1974-1975 period.[9] In general, the peak demand from the various occupational categories occurs around 1983. However, for the scenario considered, the total demand for engineers is still increasing in 1985. This is probably a result of the increasing reliance on nuclear power plants assumed by Bechtel. It requires four times the total number of engineering man-hours per MWe capacity to construct a light water reactor as a gas-fired power plant (.97 man-years/MWe versus .24 man-years/MWe). Because nuclear-generated electricity requires other high technology facilities (e.g., uranium enrichment and fuel reprocessing plants) the overall system reliance on engineers is even greater.

2.3 Capital Requirements

The direct capital needed to build the energy supply and transportation facilities will amount to $559 billion (1974 dollars) over the 1976 to 1985 period. Additional capital will be indirectly required as supply industries expand to meet their increased demands. On the average, it requires $0.80 of capital equipment per dollar of material requirements for the scenario. Total annual material requirements increase by $42 billion between now and 1983. Therefore, if the supplying industries are currently operating at capacity, an indirect capital requirement of about $34 billion will be necessary for growth in the supplying industries.

3. Discussion

It has been suggested by ERDA (1975) that the anticipated increase in energy investment, with its resultant demands for manpower and materials, could be accomodated by normal market forces. This conclusion, however, was based on consideration of direct impacts alone; but as we have shown, indirect impacts are not negligible. The energy independence program might indeed be constrained by the large direct and indirect demands for capital, scientific and technical manpower, and certain types of heavy equipment.

Exacerbating these potential problems is the presence of another concurrent large readjustment of the economic system precipitated by the 1973 embargo and subsequent rise in energy prices. In order for industrial, commercial, and residential energy users to conserve energy and effectively respond to the situation, they will need access to some of the same scarce resources--capital, engineers and technicians--that the energy supply sectors are competing for.

The dilemma presented for the energy policy maker is an interesting one. His intervention is needed because normal market forces may not be able to allocate scarce resources to energy supply development due to constraints aggravated by competition from other programs. And, the other programs affected have the same objective: to close the gap between domestic energy supply and demand. The danger is that if the energy problem is viewed only as a supply shortage, policies to accelerate energy development may divert needed resources away from (perhaps) more effective conservation programs.[10]

Competition for capital provides an instructive focal point for highlighting the tradeoffs to be considered. The growth portion of energy supply investments between 1976 and 1985 amounts to $479 billion to increase the nation's output by 24.6 quads by 1985, or about $19.5 billion per quad.[11] Investments in energy conservation, on the other hand, can reduce energy demand substantially. The Ford Foundation's Energy Policy Project (1974) estimates about half as much capital investment is required to save that amount of energy.[12] In fact, the Ford Foundation results imply that a conservation investment of about $150 billion will be required to hold 1985 energy demand to the level assumed in the President's scenario.

It is clear, therefore, that the total capital needed to effect this energy independence scenario substantially exceeds the direct investment in supply facilities. If these capital costs per quad for energy supply and conservation programs are indicative of life-cycle costs, we would expect the conservation investments to be made first.[13] In fact, the large cost differential implies that even more energy conservation investments could displace some supply development in the President's program, significantly reducing total capital costs.

Note that occasionally capital may substitute for energy (e.g., insulation) but historically they have been highly complementary.[14] Thus the most capital intensive industries are likely to be the most energy intensive and, therefore, most responsive to energy price increases. It is the capital replacement in such sectors that could exacerbate a capital shortage, and failure to obtain the necessary capital could cause severe economic disruption due to the rigid complementarity of energy with in-place capital equipment.

Any intervention into the capital market to divert funds to energy supply development must be carefully planned to insure that this does not occur at the expense of legitimate efforts on the part of consumers to reduce energy demand. An ill-conceived program would result in a serious misallocation of resources that could lead to unnecessary plant shutdowns, and inflationary pressures due to aggravation of certain manpower and material constrain

FOOTNOTES

1. See for example, Adelman, et al., (1974) and Federal Energy Administration (1975).

2. Actual import prices are higher than those assumed in this scenario. FEA (1975) predicts this would result in an even higher growth in domestic energy production.

3. The modified 90-sector energy input-output model used is described by Bullard and Herendeen (1975). Sectors in this version correspond generally to the 2-digit industry definitions of the Bureau of Economic Analysis, U.S. Department of Commerce (1967).

4. The 1972 gross domestic output by industry is given in Schroeder (1974).

5. See Young, et al., (1971) for capital flows.

6. Since these sectors are defined at an aggregated level, the 3.5% actually underestimates the growth rate to be experienced by specific parts of these sectors producing certain energy-related equipment.

7. Concern for these costs has been focused on the so-called "net energy problem." For a discussion of the key aspects of this issue see the Proceedings of the NSF Workshop (1975) or Bullard (1975).

8. Total jobs for 40 occupational categories were compiled by Merrill (1975). For our analysis these were aggregated to 31 categories.

9. This statement assumes that the Bechtel estimates for the 1974-1975 period accurately reflect current direct requirements of the energy industry.

10. For example, a proposal from the Domestic Council headed by Vice President Rockefeller, calls for establishment of a quasipublic corporation to channel up to $100 billion to the development of new domestic energy supplies. The corporation could make high-risk loans, financing energy projects where funds would not likely come from "traditional private capital sources in the traditional manner." See *Oil and Gas Journal* (1975).

11. Depending on the assumed lifetime of existing facilities, the U.S. will be replacing about 2 quads of supply facilities per year over the Project Independence time horizon. Therefore, about one seventh of the capital costs are for maintenance of existing supply facilities at current levels.

12. Based on figures from the Energy Policy Project (1974) assuming uniform annual capital expenditures for conservation schemes, and inflating to 1974 dollars, we obtain $10.5 billio per quad.

13. Other factors such as the relatively longer lead time of suppl development options and the difference between producers' and purchasers' prices of energy, also work to the advantage of conservation. A counterpoint, however, is that residential co sumers and small businessmen have historically had to pay more for capital than the energy industry, and are not as well informed of the costs and benefits of conservation.

14. See Berndt and Wood (1974).

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APPENDIX

A. Input-Output Analysis

Input-Output analysis provides the tool with which indirect material and requirements can be calculated. Bullard and Herendeen (1975) give a detailed description of the method employed in this analysis. A brief description of the technique is included here.

The Bureau of Economic Analysis (BEA) provides detailed information on the dollar value of interindustry transactions (flows) of goods and services. The latest year for which these data are available is 1967 (BEA 1974). Simpson and Smith (1975) converted dollar flows from energy sectors to physical units explicitly accounting for differing prices. The 90-order matrix used in our analysis has been updated to reflect the direct energy use technology as of 1971 (Knecht and Bullard 1975)

Using this data, a matrix of technological coefficients, A_{ij}, is defined as the amount of industrial sector i's output sold to sector j per unit of j's output. The total output of industry i (X_i) consists of that sold to other industries and that sold to final demand (Y_i). Mathematically, this can be represented as

$$X_i = \sum_j A_{ij} X_j + Y_i$$

Or, in matrix notation,

$$\underline{X} = \underline{\underline{A}}\, \underline{X} + \underline{Y}$$

For a given final demand vector, the total requirements can be obtained through matrix inversion,

$$\underline{X} = (\underline{\underline{I}} - \underline{\underline{A}})^{-1} \underline{Y}$$

where $\underline{\underline{I}}$ is the identity matrix.

Analogously, total energy requirement for a bill of goods is obtained from the energy sector requirements when the $\underline{\underline{A}}$ matrix includes physical data on energy flows. This matrix has been generated at the Center for Advanced Computation, University of Illinois, for several levels of BEA classification. The data used in this report required the CAC 90-order A matrix to calculate both the indirect energy and material requirements.

B. Labor Requirements

Total labor requirements for constructing any facility include the direct construction requirements and that labor necessary to provide the material requirements for the facility. Most of this section deals with the direct and indirect labor requirements implicitly contained in the construction materials. The reader should be aware of the distinction between direct construction labor and direct labor requirements for providing the necessary materials.

Total 1972 labor requirements disaggregated to 40 classes, for each industry (90-sector) are obtained from Merrill (1975). Table A-1 shows the occupational categories employed by the Bureau of Labor Statistics (BLS). Direct labor requirements are obtained from the 1967 dollar value of each industry's gross domestic output in 1972 (Schroeder 1975). Therefore, direct labor coefficients, L_{ij} are obtained as follows:

$$L_{ij} = \frac{LABOR_{ij}}{GDO_j} \qquad (i=1,40;\ j=1,90)$$

where L_{ij} = 1972 requirements of type i labor per unit of industry j's gross domestic output in 1967 dollars.

$LABOR_{ij}$ = direct requirements of type i labor in sector j for 1972.

GDO = gross domestic output for 1972 in 1967 dollars.

The labor coefficients matrix, L_{ij}, gives the type i labor required directly per unit of output (in 1967 dollars) from

Table A-1

40-LEVEL BLS LABOR CLASSES AND AGGREGATION GROUPS

Engineers, technical*	
Life and physical scientists	
Mathematical specialists	
Engineers, science technicians*	
Medical workers, except technicians	
Health technologist and technicians	
Technicians, except health	
Computer specialists	
Social scientists	
Teachers	
Writers, artists, entertainers	
Other professional, technical	non-technical, non-manual*
Buyers, sales, loan managers	
Administrators, public inspectors	
Stenos, typists, secretaries	
Office machine operators	
Other clerical	
Other managers, officials, proprietors	Supervisors, managers, and foremen*
Foremen	
Sales Workers	
Construction craftsmen	Construction, metalworkers, and other craftsmen*
Metalworking craftsmen, except mechanics	
Other craftsmen, kindred workers	
Mechanics, repairmen, installers	
Printing trade craftsmen	
Transportation, public utility craftsmen	
Semiskilled metalworkers*	
Semiskilled textile	
Semiskilled packing, inspecting	
Other operatives, except transportation	teamsters and laborers*
Laborers, except farm	

Table A-1 Continued

Transportation equipment operators
Cleaning service workers
Food service workers
Health service workers
Personal service workers
Protective service workers
Private household workers
Farmers and farm managers
Farm laborers, farm foremen

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*Direct requirements given by Bechtel

sector j for 1972 technology. Labor is also indirectly required for output from one sector because that sector relies on inputs from other sectors. The total requirements (direct and indirect) from each of the j sectors per unit of output from sector k to final demand is $(I - A)^{-1}_{jk}$ where I is the identity matrix and A is the "technology" matrix (A is the direct requirements per unit of total domestic output). Therefore, the direct and indirect labor requirements per unit of output to final demand, λ, is obtained from the matrix product

$$\lambda = L * (I-A)^{-1}$$

or,

$$\lambda_{ik} = \sum_{j=1,90} L_{ij} * (I-A)^{-1}_{jk} \qquad (i=1,40;\ k=1,90)$$

where λ_{ik} = direct and indirect labor of type i required per unit of output from sector k to final demand.

For each year, matrix multiplication of λ and the material requirements gives the direct and indirect labor necessary to produce the material inputs for the construction of each energy supply facility.

Total labor requirements (direct construction requirements, as well as the direct and indirect labor for materials) are calculated at 31-class level of aggregation. This is due to differences in Bechtel labor classes and the 40-class level of labor aggregation in Table A-1. Table A-1 includes the aggregation assumed to make the labor classification compatible. These classifications are judgmental, based on on an understanding of the various classes. For example, the classification "other professional, technical" is included in the aggregated "non-technical, non-manual" classification. This results from Bechtel's "non-technical, non-manual" classification including "staff from finance and accounting, personnel, and labor relations..." while the BLS category "other professional, technical" includes accountants" and "personnel labor relations." The assumed correspondence between labor categories is given below.

The direct requirements from the BLS category "engineers, science technicians" are assumed the same as Bechtel's "designers and draftsmen." Betchtel's "supervisors and managers" category includes foremen, hence the aggregation to "supervisors, managers, and foremen." The direct manpower in the aggregated "construction, metalworking, and other craftsmen" include Bechtel's "pipefitters," "electricians," "boilermakers," "iron workers," "carpenters," "other major skills," "other craftsmen," and "operating engineers." Both Bechtel welding categories "pipefitter/welder" and "boilermaker/welder" are included in the BLS "semiskilled metalworkers" category.

C. Material Requirements

Bechtel's direct material requirements are given (in 1974 purchaser's prices) as a function of time for a 20-sector economy. The requirements from one sector, refined petroleum, are given in the physical unit of tons. To be compatible with the I-O model, these requirements are transformed to 90-sector requirements in units of 1967 producers prices (except the five energy producing sectors which are given in Btu's).

This transformation to the I-O input format is effected by a series of operations. Figure A-1 schematically outlines the five steps necessary to transform the Bechtel data. An explanation of each step is given below.

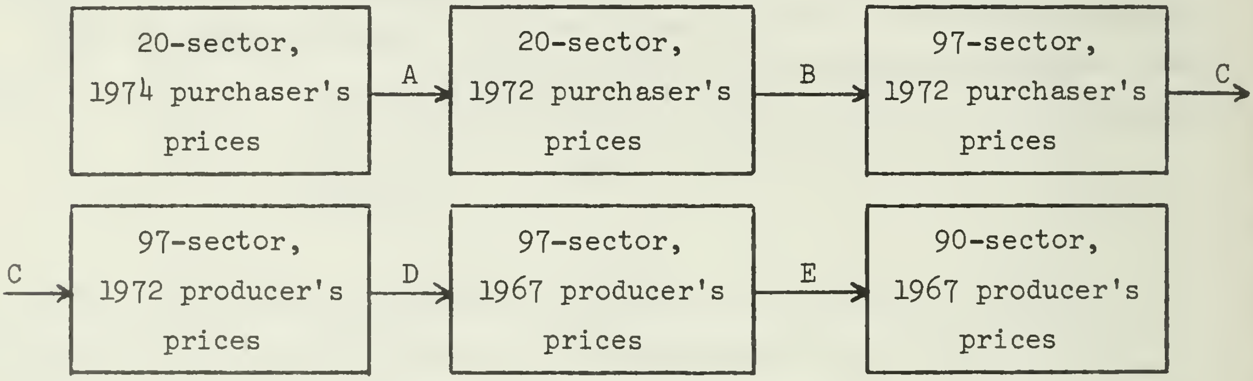

Figure A-1. Schematic of Data Transformation to I-O Format

Step A deflates the 1974 purchasers' prices to their values in 1972. Deflators provided by Bechtel are used for the 19 non-energy sectors. Refined petroleum is converted to energy units assuming 3.19×10^7 Btu/ton.

Table A-2 gives the 19 non-energy sectors for which the Bechtel construction requirements are given. The BEA four-digit classifications are given in parenthesis. Step B aggregates

Table A-2.

NON-ENERGY DIRECT MATERIAL REQUIREMENT SECTORS

Wood Products (20.00)
Chemical & Allied Products (27.00, 28.00, 30.00, 32.00)
Stone & Clay Products (36.00)
Primary Iron & Steel Products (37.00)
Primary Non-ferrous Metals (38.00)
HVAC Ductwork & Accessories (40.03)
Fabricated Structural Products (40.04)
Fabricated Plate Products (40.06)
Other Fabricated Products (42.00)
Turbines (43.00)
Construction, Mining & Oil Field Equipment (45.00)
Materials Handling Equipment (46.00)
Gas Welding Sets & Metal Working Equipment (47.00)
General Industry Equipment (49.00)
HVAC Heating & Cooling Units (52.03)
Electrical Equipment (53.04)
Electric Welding Sets (53.06)
Instrumentation & Controls (62.00)
Miscellaneous (Dummy sector)

and disaggregates these sectors (and refined petroleum to the 97-sector level shown in Table A-3. Eleven of the sectors in Table A-2 map directly to the two-digit BEA classifications in the 97-sector representation. Subsector 52.03 is assumed to be the total requirements from the BEA two-digit (52) sector. Aggregation to the two-digit BEA sectors 40 and 53 is accomplished by adding the given subsectors. It is assumed that this aggregation completely defines the requirements from these two-digit sectors.

Disaggregation of the chemical products and miscellaneous categories is more difficult. Chemical and allied products are disaggregated to their two-digit sectors by assuming the distribution purchased by the nonresidential construction industry (BEA 11.02) in 1967. For a particular year this distribution is obtained as follows:

$$X_i = \frac{T_i}{\sum\limits_{i \varepsilon (27,28,30,32)} T_i} * R$$

where X_i = material requirements for sector i (i=27,28,30 and 32).

T_i = sector 11.02 expenditures for sector i goods in 1967.

R = aggregated requirements for sectors 27, 28, 30 and 32.

The T vector is obtained by adding the direct allocations to the transportation, trade and insurance margins for the 11.02 sector. Therefore, the T vector represents inputs to the nonresidential construction sector in 1967 purchaser's prices.

Table A-3.
97 ORDER BEA SECTOR NUMBERS

1	100
2	200
3	300
4	400
5	500
6	600
7	700
8	800
9	900
10	1000
11	1100
12	1200
13	1300
14	1400
15	1500
16	1600
17	1700
18	1800
19	1900
20	2000
21	2100
22	2200
23	2300
24	2400
25	2500
26	2600
27	2700
28	2800
29	2900
30	3000
31	3101
32	3102
33	3103
34	3200
35	3300
36	3400
37	3500
38	3600
39	3700
40	3800
41	3900
42	4000
43	4100
44	4200
45	4300
46	4400
47	4500
48	4600
49	4700
50	4800
51	4900
52	5000
53	5100
54	5200
55	5300
56	5400
57	5500
58	5600
59	5700
60	5800
61	5900
62	6000
63	6100
64	6200
65	6300
66	6400
67	6501
68	6502
69	6503
70	6504
71	6505
72	6506
73	6507
74	6600
75	6700
76	6801
77	6802
78	6803
79	6900
80	7000
81	7100
82	7200
83	7300
84	7500
85	7600
86	7700
87	7800
88	7900
89	8001
90	8002
91	8100
92	8200
93	8300
94	8400
95	8500
96	8600
97	8700

The miscellaneous requirements sector is disaggregated to all sectors not previously mentioned. The assumed disaggregation is analogous to the chemical products disaggregation above for the remaining sectors.

Step C converts the 97-sector requirements in 1972 purchaser's prices to 1972 producer's prices. This is effected by subtracting the transportation, trade and insurance margins from the total requirements and adding them to their appropriate margin's sector. It is assumed that the fraction of margin's value to total value of each input is the same as that for inputs to sector 11.02 in 1967.

Step D deflates the requirements vector from 1972 to 1967 dollars. Except for the cases described below, deflators from Just (1975) are used. Just (1975) disaggregated the deflators for the two-digit sectors 70 and 73. For the aggregated sector j, deflators are calculated from the following relation:

$$\mathrm{DEFLATOR}_j = \frac{\sum_{i \varepsilon j} \mathrm{DEFLATOR}_i * \mathrm{DA}_{i \to 11.02}}{\sum_{i \varepsilon j} \mathrm{DA}_{i \to 11.02}}$$

where $\mathrm{DA}_{i \to 11.02}$ is the direct allocations from subsector i to sector 11.02 in 1967.

Transportation and utility two-digit sectors are disaggregated in the 97-sector model. For these subsectors, deflators from the Bureau of Labor Statistics are used.

In step E, energy dollar values are converted to Btu's (except refined petroleum which is already in energy units). The import sectors and the two-digit sectors above 82 are deleted. Energy sectors are moved to the first five rows making the requirements vector compatible with the 90-sector CAC model.

An estimate of the average increase in a sector's output is made for the following assumptions:

1) Bechtel direct requirements in 1974-1975 are the actual.
2) The 1974-1975 real gross domestic output from a sector is the same as in 1972.

For these two assumptions, the annually compounded total growth rate for output from a sector due only to energy-related construction becomes

$$r = [1 + F * (\frac{P}{A_{74-75}} - 1)]^{1/n} - 1$$

where r = average annual growth rate of sector output.

P = peak requirements demanded from sector between 1976-1985.

A_{74-75} = average of the 1974 and 1975 total requirements from sector for energy-related construction.

F = fraction of sector's 1972 gross domestic output to energy-related construction in 1974-1975 as implied by A_{74-75}.

n = Number of years after 1975 that peak demand occurs.