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ENERGY USE FOR BUILDING CONSTRUCTION

by

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FINAL REPORT

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ABSTRACT

Total (direct and indirect) energy requirements of the construction industry for 1967 were determined in order to examine the potential for energy savings. The Energy Input/Output Model developed at the Center for Advanced Computation, University of Illinois was expanded to include 49 building and non-building construction sectors (new and maintenance). Total energy intensities were determined for these sectors, as well as energy requirements to final demand. Overall, the construction industry required about 6000 trillion Btu, or about 9% of the total U.S. energy requirement in 1967. About 20% of this requirement was for direct energy. Energy requirements were further broken down according to goods and services purchased by individual construction sectors, and energy distribution patterns were determined within each construction sector.

Energy cost per unit for various building materials were calculated, as well as 1967 energy cost per square foot for building sectors. Laboratories required the most energy per square foot (2,074,056 Btu/SF), while Farm Service required the least (149,071 Btu/SF).

Comparative interchangeable building assemblies were evaluated for their energy costs, including initial construction and lifetime maintenance energy. Tradeoffs between construction and operational energy costs were determined for a selected wall frame assembly with different exterior finishes and varying degrees of insulation.

A study was initiated to determine industries in which direct energy use led to a significant amount of the energy embodied in New Building Construction for 1967. The resulting Energy Flow Chart is included.

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INTRODUCTION

INTRODUCTION

The construction industry, consisting of new and maintenance activity on building and non-building facilities, accounted for more than 9 percent of the total U.S. energy requirement in 1967. If inter-industry transactions are included, this figure is increased to over 10¼ percent. Less than 20 percent of construction energy use was direct i.e., fuels consumed at jobsites. The bulk of it was indirect - embodied in material inputs. Although these relationships describe conditions in 1967, construction activity continues to play a major role in U.S. energy consumption. To understand how the construction industry uses energy and to determine potential for energy savings, both direct and indirect energy use must be considered. The average figures must be broken down by building type, by the industry sector which supplies the materials and by components within each sector.

Researchers at the Center for Advanced Computation (CAC) of the University of Illinois and Richard G. Stein and Associates (RGS&A), Architects, teamed up to conduct such a study. Our research, described in this report, made use of a large Energy Input/Output Model developed at CAC and augmented by construction industry data from the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. This model describes energy flows throughout the U.S. economy in 1967, a relatively stable year.

The economic data obtained from the BEA were translated into building and energy units based on construction figures from the Dodge Corporation and weighted analyses based on construction procedures.

An input/output model such as this, allows determination of total, i.e., direct and indirect energy costs of various industrial activities and is, therefore, essential for analyzing energy use by the construction industry.

The apportioned contribution of all sectors of the economy selling to the final purchaser at the building site, the contractor, permits an analysis of general patterns of energy flow. By further breakdown of the final category, differences in energy use patterns from one building type to another were determined. Knowledge of these specific patterns permits selection from alternate energy choices with maximum conservation benefits.

Adding expertise in architectural construction to the basic model results, Richard G. Stein and Associates conducted several detailed prototypical sub-studies on energy use in construction, with emphasis on new building facilities. In addition to presenting an overview of energy distribution patterns and energy cost per square foot of construction, we have considered two approaches to energy conservation in this area:

- Substitution of components and assemblies. Selected building materials and assemblies which satisfied given performance criteria determine where and to what extent energy could be saved by substitution of equivalent components. Also considered were life-cycle energy costs (as opposed to the usual dollar cost analyses), including tradeoffs between energy used in initial construction and operational energy costs.

  In order to make comparisons, energy values per construction unit developed as part of the report were applied. The method of energy estimating is expandable to a complete energy-estimating format for all building construction.

- Conservation in key supply industries. Richard G. Stein and Associates has developed the basis for tracing the flow of energy from primary resources through the economic system until it finally winds up embodied in new buildings. This approach will allow pinpointing transaction points in the system which are critical to the energy cost of new buildings.

Another approach would be investigation of the use of less material to do the same amount of work, such as through more efficient structural design.

The remainder of this document describes our research and results. We hope the identification of the magnitude of the problem and the data and approaches presented will lead to a rapid growth in this new area of energy conservation in building construction.

II THE EXPANDED INPUT/OUTPUT MODEL

II. The Expanded Energy Input/Output Model

In order to examine total (direct and indirect) energy use by the entire building construction industry, a highly disaggregated BEA breakdown containing 49 construction sectors was used in conjunction with the CAC Energy Input/Output (I/O) Model.[1] The insertion of these additional sectors, which include 32 new construction and 17 maintenance construction categories, into the CAC Model resulted in an expanded 399-industry model. This expanded model, with its detailed construction industry segment, provides a "snapshot" of the entire U.S. economy in 1967 and forms the basis for the analyses presented later in this document.

A detailed description of the development of the expanded model can be found in Appendix B, along with all relevant tables in full. What follows here are the basic results of the model with respect to energy use by the construction industry in 1967. These initial findings lay the groundwork for the various construction energy use studies conducted by RGSA and described in the following section.

The 49 sectors which comprise the construction industry segment of the expanded I/O model are listed in Table 1. (Tables referred to in this section appear directly after the text. For the most part, they are abridged for ease of display; full tables are given in Appendix B.) As a result of their insertion into the standard CAC I/O Model, these sectors wind up in positions 23 through 71, inclusively, and are associated with those indices throughout this report.

Direct energy use by the construction industry in 1967, i.e., purchases from the Coal, Crude Petroleum, Refined Petroleum, Electricity, and Natural Gas sectors, are summarized in Table 2. The data collection performed by RGSA which led to these results was crucial in implementing the expanded model. (See Appendix B for details.) As Table 2 indicates, the construction industry purchased 1484.7 trillion Btu of direct energy in 1967, the great bulk of which took the form of Refined Petroleum Products. (Construction sectors made no direct coal or crude petroleum purchases in 1967.) The numbers in parentheses in Table 2 are percentages of row, or energy use, totals. They indicate that the pattern of direct energy use varies between building and non-building segments of the construction industry. This type of occurrence will show up again in later sections of this report when total energy use is closely examined.

The incorporation of direct energy use data into the expanded model allowed computation of energy intensities for the construction sectors. (Reference 1 describes the CAC Energy I/O Model in detail.) Table 3 shows the ten most energy intensive construction sectors in terms of total primary energy intensity, i.e., direct and indirect primary* energy in Btu required per dollar of output. Most intensive are New Construction of Petroleum Pipelines (147,197 Btu/$) and New Construction of Gas Utilities (140,038 Btu/$; this sector also involves pipeline construction).** This is probably due to the use of heavy construction equipment and large amounts of raw materials (steel, pipe, etc.).

Table 3 also displays overall average energy intensities for New Construction (74,122 Btu/$) and Maintenance Construction (56,182 Btu/$), indicating the significantly higher energy cost of New Construction activity.

Energy intensities for the construction sectors can be used with total final demand data (from BEA) to determine the total energy required by these sectors for sales to final demand. Table 4 shows the ten construction sectors which required the most total energy to final demand in 1967. Also shown is the percent of each requirement which represented direct energy.

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*Total primary energy intensity is formed from the Coal, Crude Petroleum, and hydro and nuclear portions of Electricity intensities.

**This figure was referred to in hearings conducted by the Federal Power Commission, Bureau of Natural Gas, on "Staff Proposed Displacement Alternative to Arctic Gas Project Western Lateral to California," July 1976.

New Highway Construction required the largest portion of energy: 1035.87 trillion Btu, with nearly 40% of this for direct energy. Interestingly, New Residential 1-Family Construction was second, requiring 780.98 trillion Btu, but with less than 10 percent direct. Overall the construction industry required 6301.94 trillion Btu for final demand delivery in 1967, representing nearly 9-1/2 percent of the total U.S. energy requirement for that year. Less than 20 percent of the construction industry energy requirement was direct.

To set the stage for further analysis of energy use by the construction industry, the total energy required by each sector for production of its total 1967 output was determined. Each sector's total energy requirement was allocated among its direct purchases from all other sectors in the model and corresponding input energy fractions were also developed. The resulting tables are huge (nearly 40,000 figures) and are not included here. They do, however, allow for relatively easy identification of the major embodied energy contributors to the construction industry. (Appendix B contains a summary table showing the total energy requirements of each sector.) Note that the total energy requirement for all construction in 1967 (7235.55 trillion Btu) is larger than the total final demand energy requirement (6301.94 trillion Btu). This is because certain Maintenance Construction sectors do not sell to final demand, but do interact with other sectors.

To facilitate later analysis of energy use in the New Building segment of the construction industry, an aggregate New Building Construction sector was formed by combining sectors 23 through 38, 48 and 49. (See Table 1.) Table 5 summarizes energy use by this aggregate sector, which accounted for over 5 percent of the total U.S. energy requirement in 1967. A breakdown of this sector's energy use by direct purchases is given in Appendix B.

The various results of the Energy I/O Model described above enabled RGSA to conduct several in-depth energy use studies on the Building Construction industry. These studies, along with relevant tables, are described in the following section.

TABLE 1. CONSTRUCTION INDUSTRY SECTORS OF EXPANDED ENERGY I/O MODEL

SECTOR	399-ORDER INDEX
New Construction	
Residential single family housing, non-farm	23
Residential two-four family housing	24
Residential garden apartments	25
Residential high-rise apartments	26
Residential alterations & additions	27
Hotels & Motels	28
Dormitories	29
Industrial Buildings	30
Office Buildings	31
Warehouses	32
Garages & Service Stations	33
Stores & Restaurants	34
Religious Buildings	35
Education Buildings	36
Hospital Buildings	37
Other Non-farm Buildings	38
Telephone & Telegraph Facilities	39
Railroads	40
Electric Utility Facilities	41
Gas Utility Facilities	42
Petroleum Pipelines	43
Water Supply Facilities	44
Sewer Facilities	45
Local Transit Facilities	46
Highways	47
Farm Residential Buildings	48
Farm Service Facilities	49
Oil & Gas Wells	50
Oil & Gas Exploration	51
Military Facilities	52
Conservation & Development Facilities	53
Other New Non-Building Facilities.	54
Maintenance & Repair Construction	
Residential	55
Other Non-Farm Buildings	56
Farm Residential	57
Farm Service Facilities	58
Telephone & Telegraph Facilities	59
Railroads	60
Electric Utility Facilities	61
Gas Utility Facilities	62
Petroleum Pipelines	63
Water Supply Facilities	64
Sewer Facilities	65
Local Transit Facilities	66
Military Facilities	67
Conservation & Development Facilities	68
Highways	69
Oil & Gas Wells	70
Other Non-Building Facilities	71

TABLE 2. DIRECT ENERGY PURCHASES BY CONSTRUCTION SECTORS - AGGREGATE CATEGORIES (1967, TRILLION BTU)

(Numbers enclosed in parentheses are percent of row totals)

	ENERGY TYPE			
	REFINED PETROLEUM	ELECTRICITY	NATURAL GAS	TOTAL
NEW CONSTRUCTION:				
Buildings	415.15 (96.6)	4.28 (1.0)	10.39 (2.4)	429.78 (100.0)
Non-Buildings	785.27 (99.1)	2.18 (0.3)	5.28 (0.6)	792.72 (100.0)
MAINTENANCE CONSTRUCTION:				
Buildings	61.85 (96.6)	.63 (1.0)	1.58 (2.4)	64.06 (100.0)
Non-Buildings	197.09 (99.4)	.54 (0.3)	.54 (0.3)	198.16 (100.0)
TOTAL	1459.36 (98.3)	7.64 (0.5)	17.71 (1.2)	1484.71 (100.0)

NOTE: Rows and columns may not sum exactly to totals due to round off.

TABLE 3. TEN MOST ENERGY INTENSIVE CONSTRUCTION SECTORS IN 1967

SECTOR WITH INDEX	TOTAL PRIMARY ENERGY INTENSITY (Btu/$)
43. New* Petroleum Pipelines	147,197
42. New Gas Utilities	140,038
47. New Highways	123,745
63. Maintenance**- Petroleum Pipelines	117,158
50. New Oil & Gas Wells	116,895
70. Maintenance - Oil & Gas Wells	109,103
58. Maintenance - Farm Service	96,288
68. Maintenance - Conservation & Development	92,963
51. New Oil & Gas Exploration	92,941
54. New Other Non-Building	89,466
WEIGHTED*** AVERAGES:	
All New Construction (32 sectors)	74,122
All Maintenance Construction (17 sectors)	56,182

* Stands for "New Construction."

**Stands for "Maintenance and Repair Construction."

***Total energy intensities are weighted by Gross Domestic Output of each sector. See Appendix B.

TABLE 4. TEN CONSTRUCTION SECTORS REQUIRING THE MOST TOTAL ENERGY TO FINAL DEMAND IN 1967.

	SECTOR WITH INDEX	TOTAL ENERGY TO FINAL DEMAND (TRILLION BTU)	PERCENT DIRECT
47.	New* Highways	1035.87	39.60
23.	New Residential 1-Family	780.98	9.94
30.	New Industrial Buildings	463.38	8.23
36.	New Education Buildings	437.36	15.48
41.	New Electric Utilities	303.94	12.69
27.	New Residential Alterations & Additions	261.85	2.87
31.	New Office Buildings	258.66	17.80
50.	New Oil & Gas Wells	235.54	30.56
38.	New Other Non-Farm Buildings	231.07	17.50
69.	Maintenance**- Highways	220.00	43.57
	All Construction Sectors	6301.94***	19.52

*Stands for "New Construction."

**Stands for "Maintenance & Repair Construction."

***Represented 9.42% of total U.S. energy requirement in 1967.

TABLE 5. SUMMARY OF 1967 ENERGY USE IN NEW BUILDING CONSTRUCTION AGGREGATE (SECTORS 23-38, 48 & 49)

Direct Energy Use:	429.78 trillion Btu (96.6% Refined Petroleum)
Total Primary Energy Intensity:	62,671 Btu/$
Total Energy Requirement to Final Demand*	3,421.6** trillion Btu (12.6% direct)

*For New Building Construction, this is identical to Total Energy Requirement, since all new construction in the I/O Model is sold to final demand.

**Represents 5.1% of total U.S. energy requirement in 1967.

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III

ENERGY-USE SUB-STUDIES

III. ENERGY USE SUB-STUDIES

This section includes the following sub-studies of energy use in the construction industry in 1967:

A. Energy Distribution Patterns, which examines energy embodiment in the various construction sectors in terms of the patterns of materials use typical to each sector.

B.1 Embodied Energy per Unit of Material, which examines those materials making a major contribution to the energy embodied in new building construction and which translates the measure of embodiment from Btu/$ to Btu/physical unit. The physical units chosen are those used in standard building cost estimating.

B.2 Comparative Studies, which examines thirteen other independent studies of energy embodied in building materials. The energy values derived in all studies, including this one, are compared.

C. Energy Use per Square Foot of New Building, which examines the energy embodied in each of eighteen New Building Construction sectors with reference to the square footage of construction built in 1967, to arrive at a Btu value per square foot for each type of building.

D.1 Energy in Typical Building Assemblies, which compares the energy embodied in three alternate floor structures typical of high-rise office building construction and also two alternate wall sections typical of 1-family residential construction.

D.2 Energy Cost Life-Cycle, which examines the major components of the outside surface of a typical 1-family residence (walls, roof, doors and windows) in terms of not only energy embodied in the materials, but also the operational energy demanded by alternate assemblies for space heating over periods of one year and twenty years.

E. Energy Flow Model, which examines the flow of energy embodiment from energy resource in the ground, through the energy industries to the manufacturing sectors, and from the manufacturing sectors to building construction.

III A

Energy Distribution Patterns

A. ENERGY DISTRIBUTION PATTERNS

Tables A1-3 show the division of direct and embodied energy requirements of each of the 49 construction sectors in relation to the entire 1967 Construction Industry. It is important to note that in these tables, as well as in the rest of this section, direct energy use refers to the total energy embodied in direct fuels purchased. In other words, the direct energy requirements shown include the energy content of the fuels purchased plus the energy cost of producing those fuels.

Tables A1-3 indicate the following:

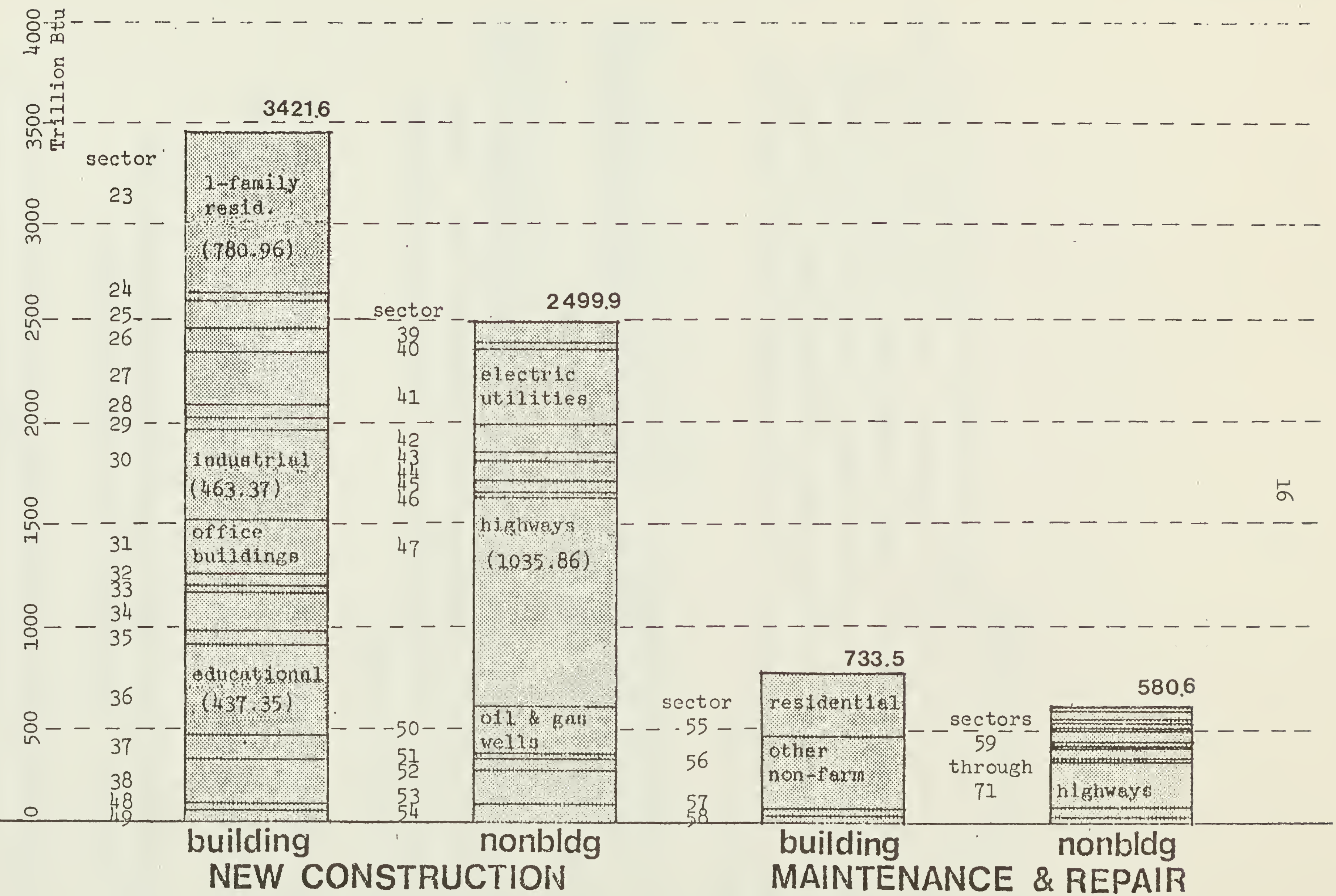
1. In all, construction required 7,235.6 trillion Btu in 1967, representing 10.82 percent of overall U.S. energy use in that year.

2. Of this, New Building Construction (Sectors 23-38, 48 and 49) used 3,421.6 trillion Btu (47.3 percent of the Construction use). Nearly 1/3 of this (1,107.9 trillion) went to the various small residential sectors. (23, 24, 27, 28)

3. New Non-building Construction Sectors, 38-47 and 50-54 used 2,499.9 trillion Btu (34.6 percent of the construction use). Over 40 percent of this (1,035.9 trillion) went to New Highway Construction alone.

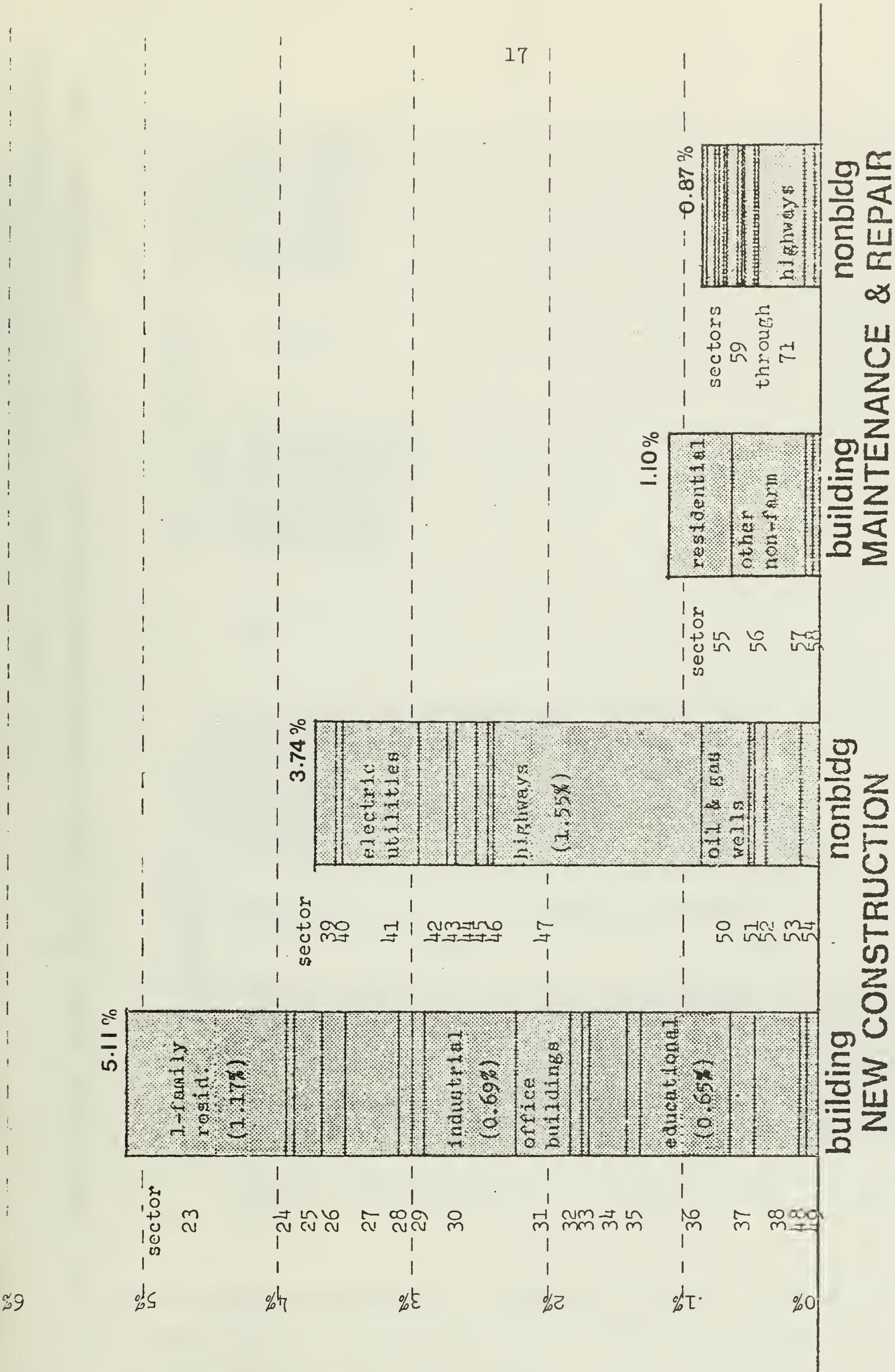
4. Building Maintenance and Repair Construction (Sectors 55-58) used 733.5 trillion Btu (10.1 percent of the Construction use.)

5. Non-building Maintenance and Repair Construction (Sectors 59-71) used 580.6 trillion Btu (8.0 percent of the Construction use, about half of which (227.2 trillion) went to Highway Maintenance and Repair).



In 1967 the Construction Industry required a total of 7,235.6 trillion Btu to produce its total output.

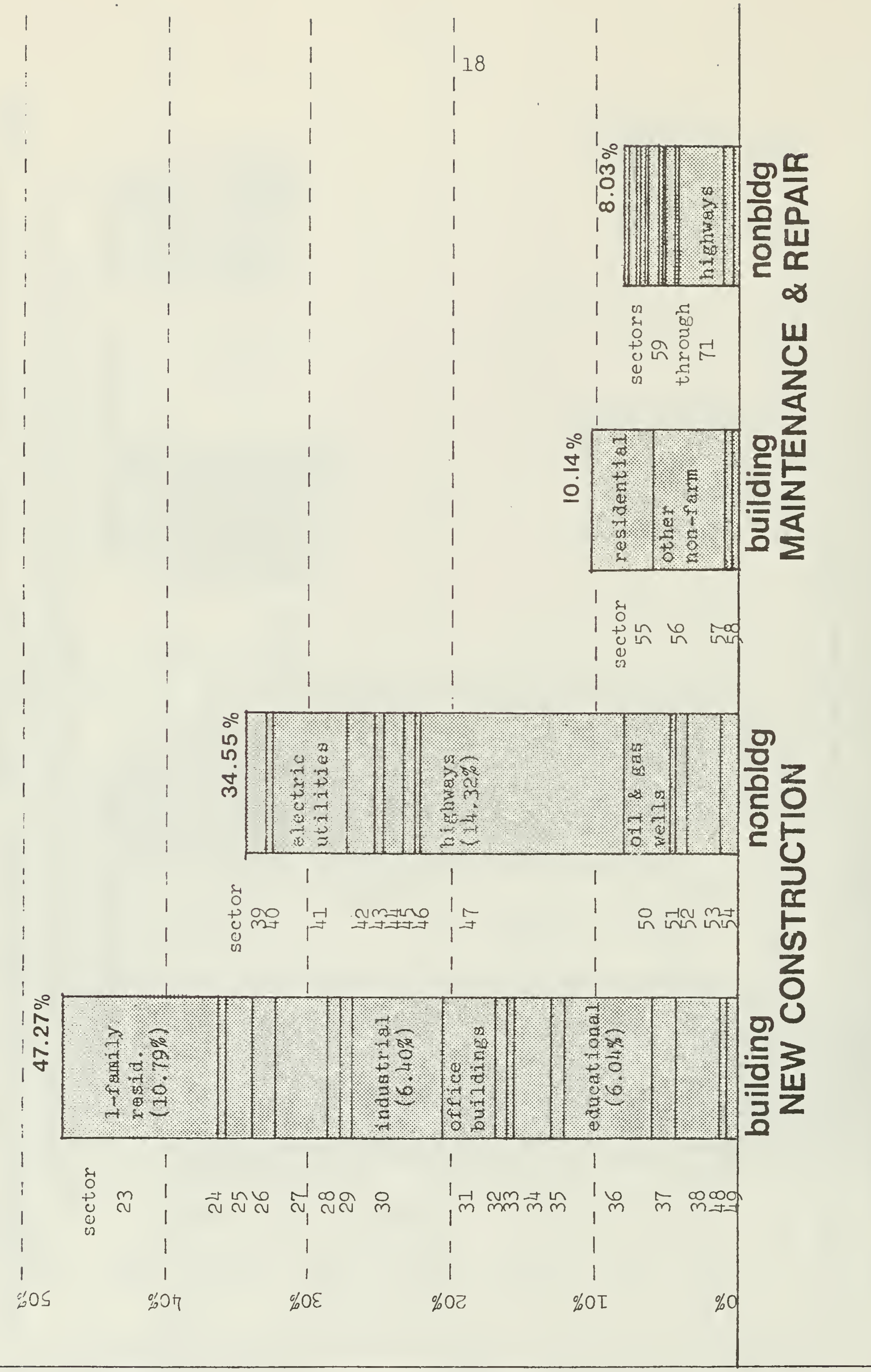
49 CONSTRUCTION SECTORS – breakdown by major sector groupings – 1967
trillion Btu



Altogether, the 49 Construction Sectors accounted for 10.82% of total U.S. energy consumption. (See page 19 of the text for some cautions on interpreting these figures.)

49 CONSTRUCTION SECTORS – breakdown by major sector groupings – 1967

% of total United States consumption



49 CONSTRUCTION SECTORS – breakdown by major sector groupings – 1967
% of total Construction Industry consumption

Referring to Point 1 above, it should be noted that the figures represent the total energy required by the Construction Industry to produce its total output in 1967. Some of the output in the Maintenance and Repair Construction Sectors, however, is not normally assigned to the Construction Industry, but rather to the industries which receive such output. For example, the energy cost of repairing a steel mill roof would normally be assigned to the Steel Industry. Because this type of activity is in fact construction activity, we have added the energy requirements it generates to the total of the Construction Industry. If total energy requirements were calculated in this manner for several industries and then summed and/or compared to the U.S. energy use total, the potential overlap of activities would produce duplication. In a study such as this one, however, in which a single industry is considered, this overlapping segment must be included. Thus, the total output of the Construction Industry represents 10.82 percent of the total U.S. energy requirement for 1967, while that portion of construction sold for final consumption represents only 9.42 percent of total energy use. The remaining portion is sold to other industries.

Tables A4-13 show the percentage division within each construction sector (and within the aggregate Sector: New Building Construction) of the entire direct and majority of the embodied energy represented by each of the 399 sectors contributing to the subject sector. In the charts the 399 sectors have been aggregated to the 90-level, and only the most significant contributors have been identified at the 399 level. (Related Sectors have been aggregated by CAC to form a compatible 90-level matrix. See Table B1-1, Appendix B for correspondence between 90 and 399 level sectors.) A study of the percentage divisions within each construction sector allows one to see the variations in the patterns of energy embodiment inherent in each construction sector or group of sectors.

It is immediately apparent that the patterns typical of building construction differ significantly from those of non-building construction.

Most new building construction sectors follow similar patterns in their use of energy and materials. (It is important to note that these are the <u>average</u> uses of materials by the different building type categories and may differ sharply from any individual example within the category. There are sharper variations within a category than between categories.) The exceptions to this are the small residential sectors 23, 24, 27 and 48, which use a much larger percentage of wood and wood products and a smaller percentage of direct fuel than the other categories and New Farm Service Facilities (Sector 49), in which energy embodied in direct fuel use accounts for only about 5-1/2 percent of all energy use and which shows a pattern of energy use consistent with a specialized use of materials. In Sector 49, over 20 percent of the total energy use comes through 399-level Sector 245, Miscellaneous Metal Work, which includes reinforcing steel, plastering accessories, and metal curtain walls. The extensive use of the products of this sector for farm service buildings is accounted for largely by the use of corrugated metal roofs, and metal siding commonly used in construction of barns, silos, storage buildings, etc. Including this one major exception, in general, in new building construction, the same 28 input sectors out of 399 account for approximately 70 to 80 percent of the total direct and embodied energy allocated to each new building construction sector.*

While there is much greater similarity between building sectors than between building and non-building sectors, there are important differences which must be noted as well. Many of these contain the opportunities for energy conservation through substitutions of materials and assemblies or through changes in construction methods. For example:

** Energy embodied in fuel purchased for direct use by the contractor varies from 12.22 percent of the total energy embodied in 1-Family Residences to 22.51 percent in Dormitory Construction and 23.10 percent in stores and restaurants. Application of these figures to the figures on Btu per square

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* These selected input sectors are: Sawmills, Millwork, Veneer Plywood, Prefabricated Wood Structures, Paint Products, Paving, Asphalt (Products and Coatings), Cement, Bricks, Concrete Blocks, Concrete Products, Ready-Mix Concrete, Gypsum Products, Asbestos Products, Mineral Wool, Non-Clay Refractories, Plumbing Fittings, Heating Equipment, Fabricated Structural Steel, Metal Doors, Fabricated Plate Work, Sheet Metal Work, Architectural Metal Work, Miscellaneous Metal Work, Railroad and Motor Freight Transport, and Wholesale and Retail Trade.

foot (see Table C-1) indicates that the total quantity of Btu embodied in direct fuel purchases* for these three categories in 1967 was:

1-Family Residences required	.1222	x	702,047	=	85,790 Btu/SF
Dormitory Construction required	.2251	x	1,430,724	=	322,056 Btu/SF
Stores and Restaurants required	.2310	x	941,353	=	217,453 Btu/SF

** In High-rise Residential Construction, concrete represents 17.9 percent of total energy embodiment and Fabricated Structural Steel, 2.5 percent. In Office Buildings, however, concrete represents 7.5 percent and Fabricated Structural Steel, 9.7 percent.

** In 1-Family Residences, wood and wood products represent 16.4 percent of the sector's total energy embodiment. When the low energy intensity of wood is realized (see Tables D-4 and D-5 for a comparison of a wood stud wall with wood exterior finish and with brick veneer), the low energy embodiment per square foot for 1-Family Residences is explained.

** In hospitals, specialty items (from input sectors other than those included in the 28 selected for comparison across all construction sectors) account for about 40 percent of energy embodiment, in contrast with about 25 percent in most other categories.

In the new Building Category, the sectors, starting with the greatest energy user - One-Family Residential - and following in diminishing order of energy embodiment are as follows:

(For comparison, the percent of total area of new building represented by each sector is also shown.)

*Figure does not include delivery of fuel to jobsite. This factor has been included in Table C-2, raising the total about 1.5%

SECTOR	TRILLION BTU ($BTU \times 10^{12}$)	PERCENT OF NEW BUILDING ENERGY	PERCENT OF TOTAL U.S. ENERGY	PERCENT OF** TOTAL NEW BUILDING AREA
23 1-family Residential	780.96	22.8	1.174	30.2
30 Industrial Building	463.37	13.5	.697	12.9
36 Education Buildings	437.35	12.8	.658	8.6
27 Residential Alt. & Add.	261.85	7.7	.394	-
31 Office Buildings	258.66	7.6	.389	4.3
38 Other Non-farm Buildings	231.07	6.8	.347	4.3
34 Stores & Restaurants	197.01	5.8	.296	5.7
25 Residential-Garden Apts.	147.75	4.3	.222	6.2
26 Residential High Rise	117.96	3.4	.177	4.4
37 Hospitals	117.21	3.4	.176	1.8
28 Hotels/Motels	69.05	2.0	.104	1.7
35 Religious Buildings	68.61	2.0	.103	1.5
49 Farm Service Buildings	57.88	1.7	.087	10.5
29 Dormitories	57.82	1.7	.087	1.1
32 Warehouses	57.78	1.7	.087	2.8
24 2-4 Family Residences	34.83	1.0	.052	1.5
33 Garage & Service Stations	34.24	0.9	.051	1.1
48 Farm Residential	30.22	0.9	.045	1.5
1967 TOTAL ENERGY ATTRIBUTED TO NEW BUILDING CONSTRUCTION	3,421.62	100.0	5.146	100.0

**Derived from Table C-1

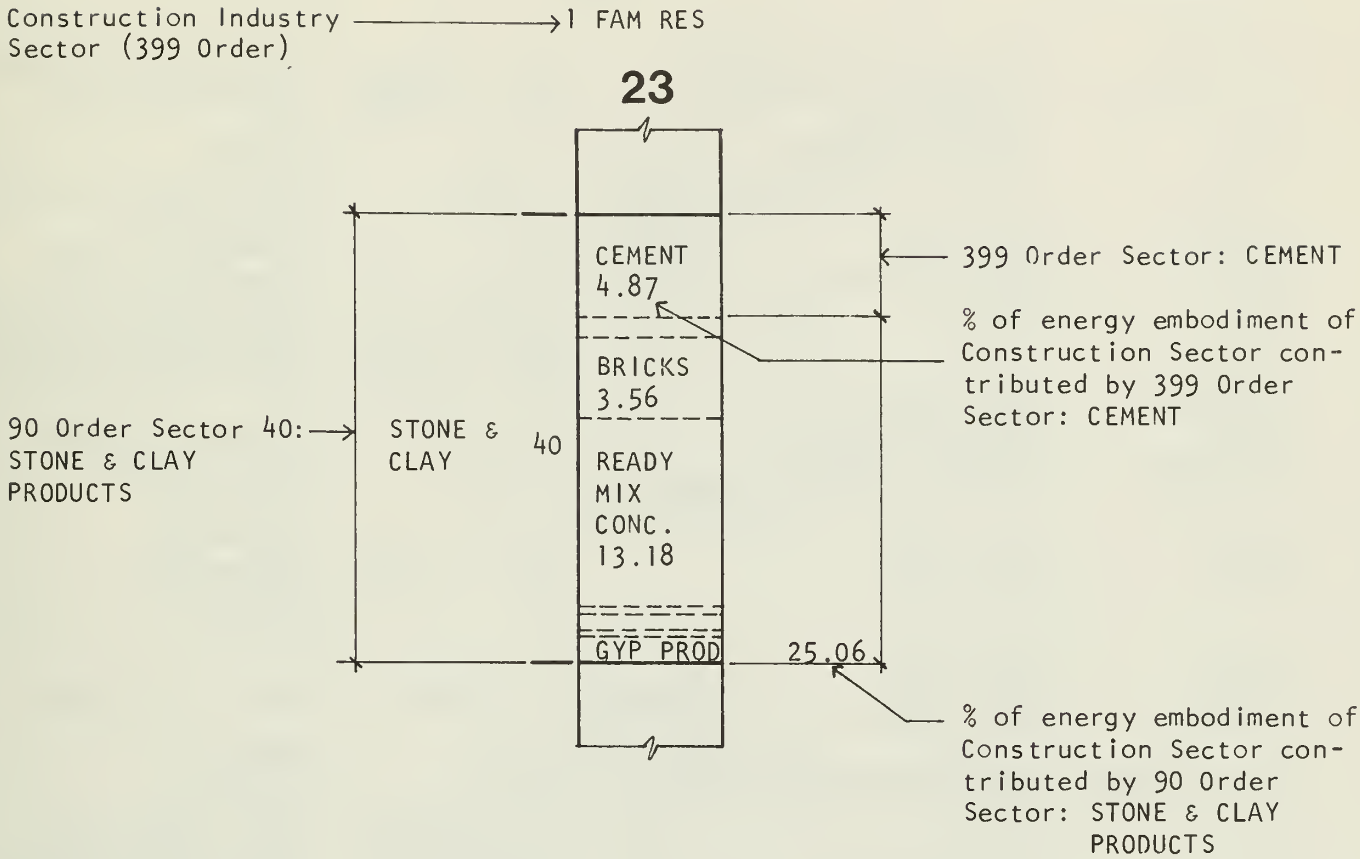
The impact of any construction sector on the total energy attributable to all construction varies with both the energy intensity inherent in the construction type and also the quantity of that type of construction completed in the year studied. Thus, in 1967, One-Family Residential Construction, which incorporates 702,214 Btu/SF of Construction accounted for nearly three times the total energy attributable to Office Buildings which are over twice as energy-intensive (1,641,440 Btu/SF).

Similarly, the differences in energy intensity between sectors is also attributable to variations between quantity and energy intensity of the materials inherent to the sector as well as variations in direct fuel consumption.

In Sector 23, One-Family Residential, which uses relatively little heavy equipment and virtually no temporary heat in the construction process, energy embodied in direct fuel use accounts for only 12-1/4 percent of its total energy (85,790 Btu per square foot*), wood products (in itself a low-energy-intensity industry) accounts for about 16-1/2 percent.

*Figure does not include delivery of fuel to jobsite. This factor has been included in Table C-2, raising the total about 1.5%.

KEY to TABLES A5 - A13



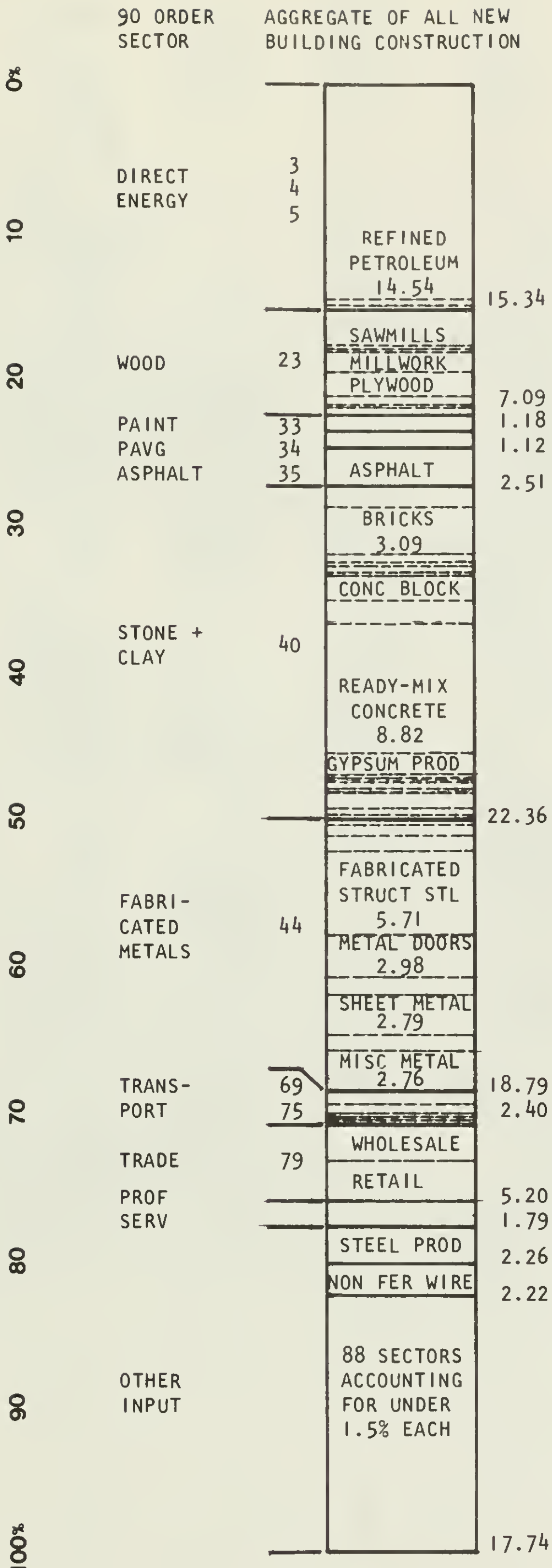
NOTES

1. "Direct Energy" as noted on tables A5 - A13 includes both the energy content of the fuels used and the energy cost of producing those fuels.

CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801 and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791 Subject Energy Input Fractions by Construction Sector	by **CAC** **RGS & A**	date 30 Dec 76 file **A4a**

ABBREVIATIONS

ARCH MTL	ARCHITECTURAL METAL WORK
ADD & ALTS	RESIDENTIAL ADDITIONS & ALTERATIONS
ASB	ASBESTOS PRODUCTS
ASPH	ASPHALT & ASPHALT COATINGS
BLDGS	BUILDINGS
BLK	CONCRETE BLOCKS
BRK	BRICKS
CEM	CEMENT
CLAY PROD	CLAY PRODUCTS
CONC	READY-MIX CONCRETE
CONC PROD	CONCRETE PRODUCTS
CONS DEV	CONSERVATION DEVELOPMENT
DORM	DORMITORIES
DRS	METAL DOORS
EDUC	EDUCATIONAL
ELEC	ELECTRICAL
EXPLOR	EXPLORATORY
FAB MTL PROD	FABRICATED METAL PRODUCTS
FAM	FAMILY
GYP	GYPSUM PRODUCTS
HTG/HTG EQPT	HEATING EQUIPMENT
INDUST	INDUSTRIAL
INS	MINERAL WOOL INSULATION
M + R	MAINTENANCE & REPAIR
MILW	MILLWORK
MISC/MISC MTL	MISCELLANEOUS METAL WORK
N-C REFR	NON-CLAY REFRACTORIES
NON FER WIRE	NON-FERROUS WIRE
PAVG	PAVING
PL/FAB PL	FABRICATED PLATE WORK
PETR	PETROLEUM
PLB	PLUMBING FITTINGS
PNT	PAINT PRODUCTS
PREFAB	PREFABRICATED WOOD STRUCTURES
PROF SERV	PROFESSIONAL SERVICES
PWD	VENEER, PLYWOOD
REF PET	REFINED PETROLEUM
REFR	REFRACTORIES
RELIG	RELIGIOUS
RES	RESIDENTIAL
REST	RESTAURANTS
RET	RETAIL TRADE
RR	RAILROAD
R/TV PROD	RADIO + TV PRODUCTS
SAWM	SAWMILLS
SERV	SERVICE
SHT MTL	SHEET METAL WORK
STL FNDY	IRON + STEEL FOUNDRY PRODUCTS
STR STL	FABRICATED STRUCTURAL STEEL
SVC STA	SERVICE STATIONS
TELE + TELEG	TELEPHONE + TELEGRAPH
TRANSP	TRANSPORT
TRK	TRUCK TRANSPORT
UTIL	UTILITIES
WD PRES	WOOD PRESERVING
WH	WHOLESALE TRADE
WIRG DEV	WIRING DEVICES



AGGREGATE OF ALL NEW BUILDING CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION
University of Illinois Urbana IL 61801

and

RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS
588 Fifth Avenue New York NY 10036

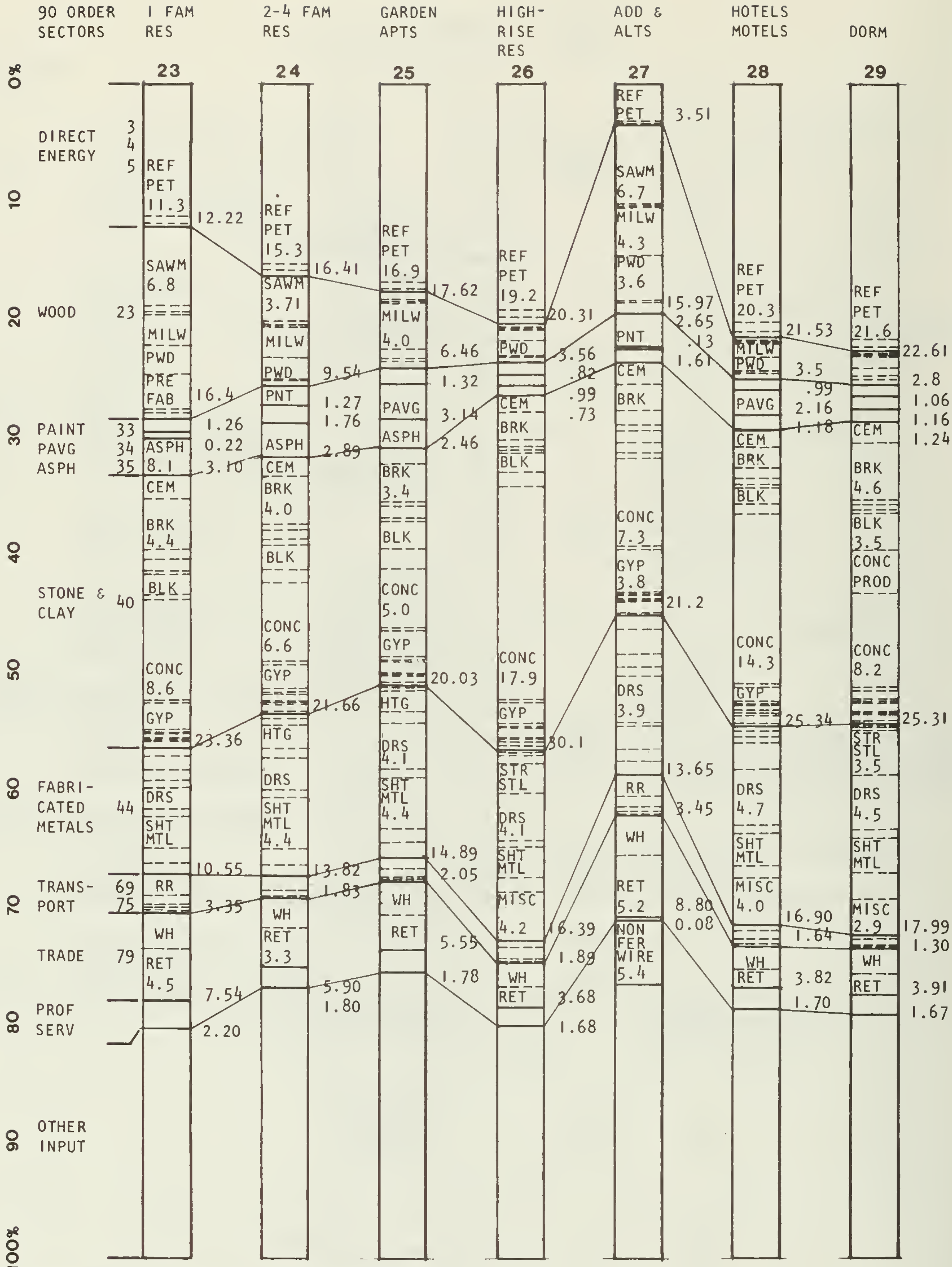
ENERGY IN BUILDING CONSTRUCTION
ERDA Contract No. E (11-1)-2791

date 30 Dec 76

Subject: Energy Input Fractions By Construction Sector

by: CAC / RGS & A

file: **A5**



NEW BUILDING CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION
University of Illinois Urbana IL 61801

and

RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS
588 Fifth Avenue New York NY 10036

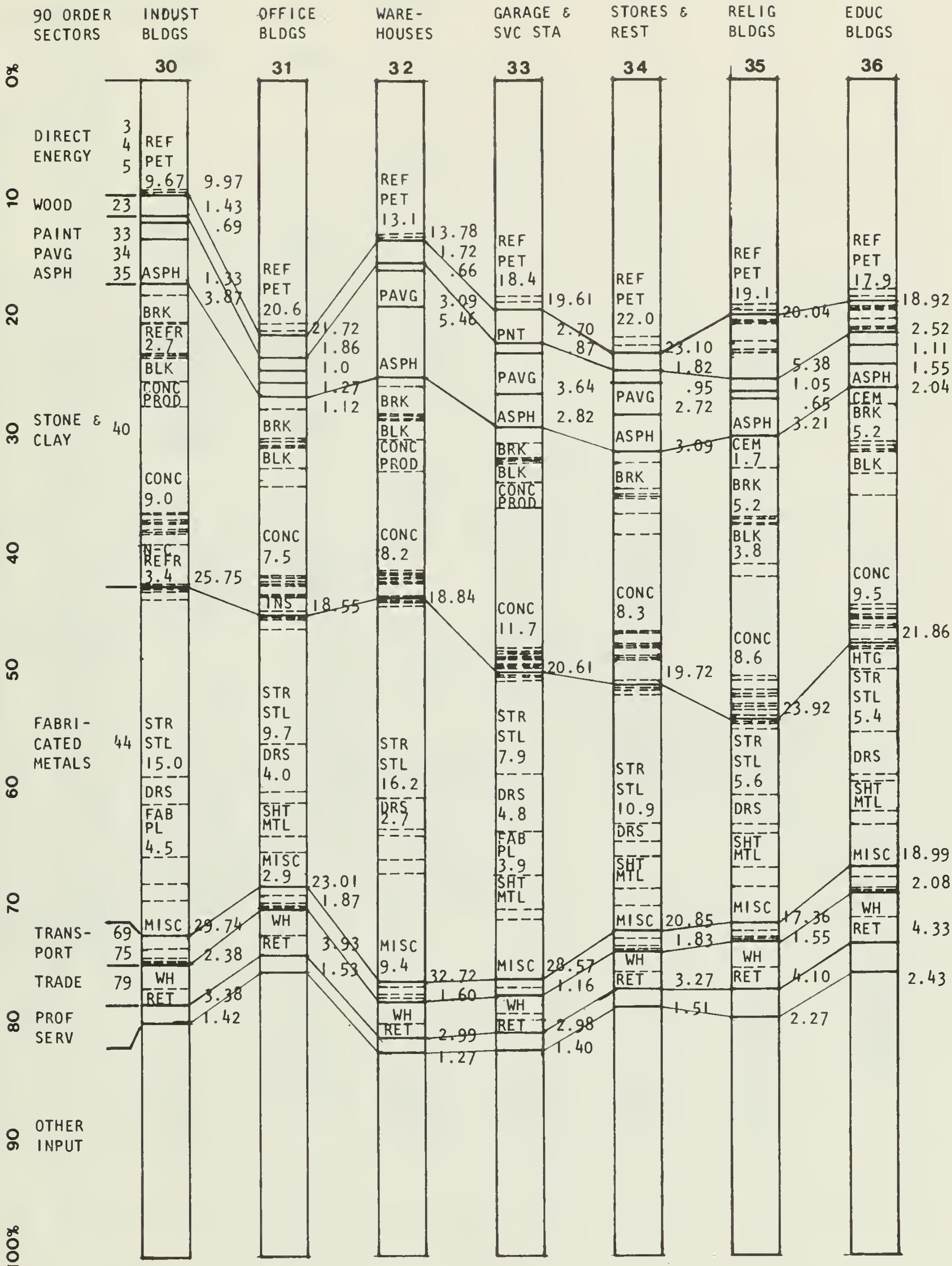
ENERGY IN BUILDING CONSTRUCTION
ERDA Contract No. E (11-1)-2791

date 30 Dec 76

Subject
Energy Input Fractions By Construction Sector

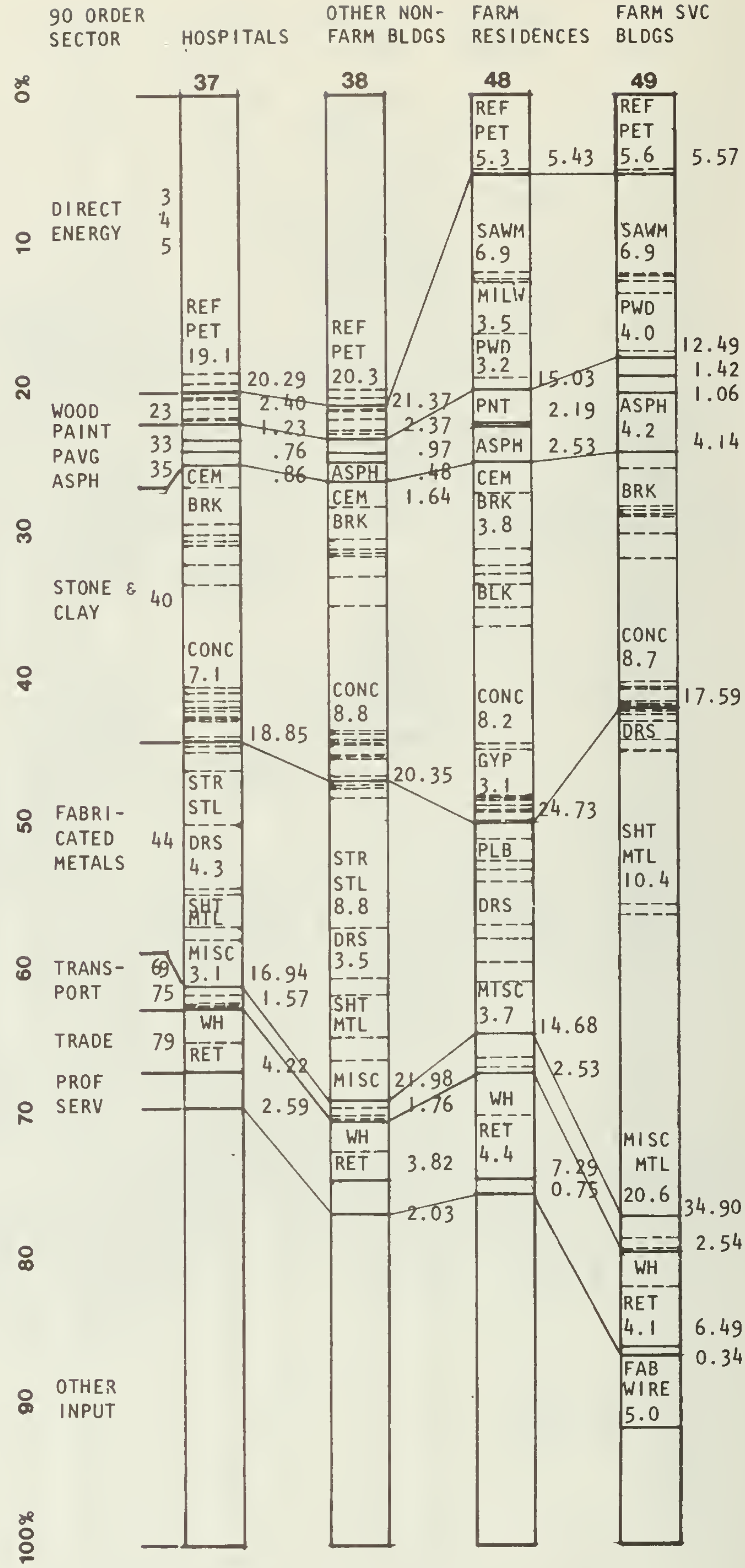
by
CAC
RGS & A

file **A6**



NEW BUILDING CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801 and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791		date 30 Dec 76
	Subject Energy Input Fractions By Construction Sector	by **CAC** **RGS & A**	file **A7**



NEW BUILDING CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION
University of Illinois Urbana IL 61801

and

RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS
588 Fifth Avenue New York NY 10036

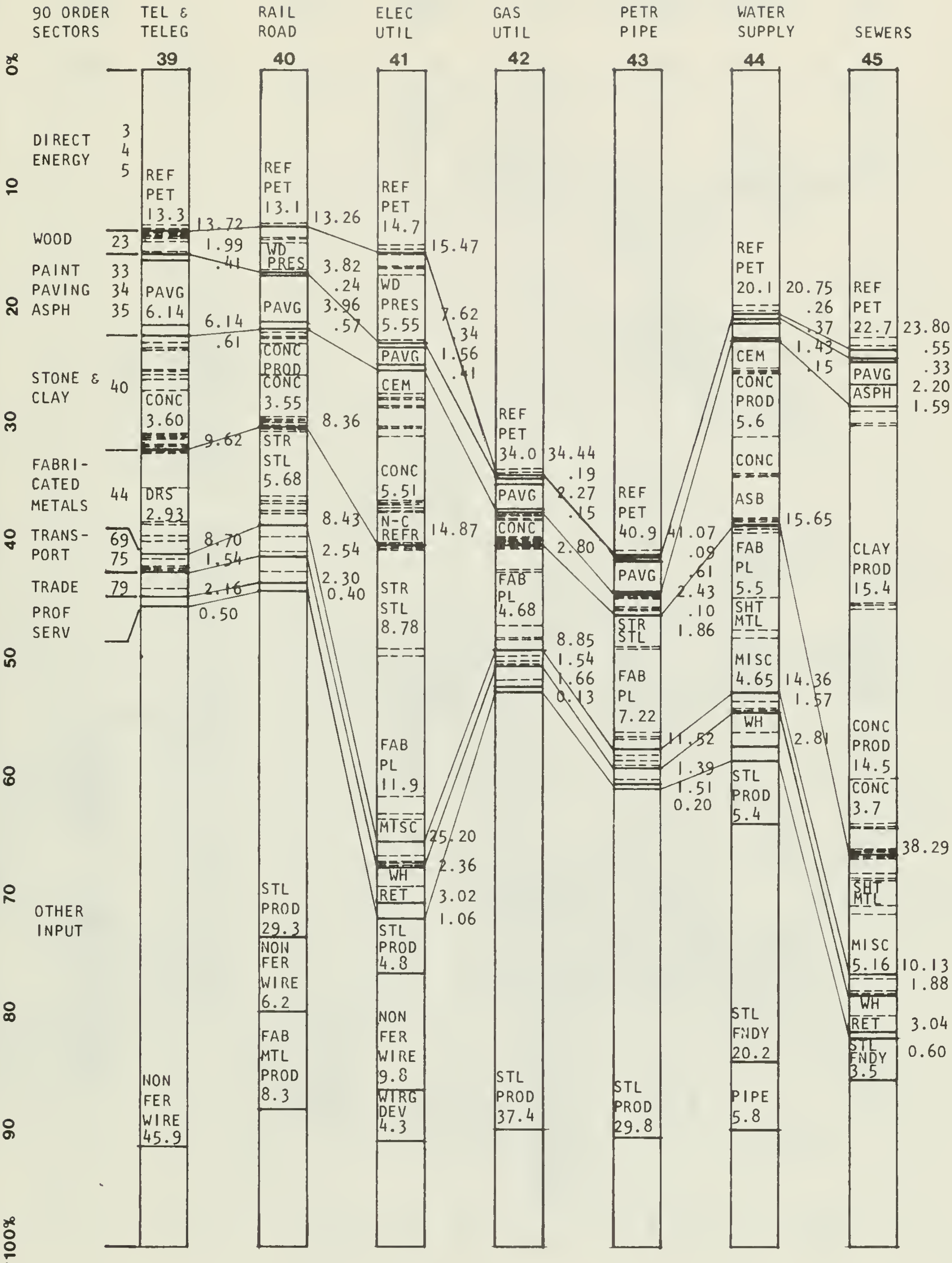
ENERGY IN BUILDING CONSTRUCTION
ERDA Contract No. E (11-1)-2791

date: 30 Dec 76

Subject: Energy Input Fractions By Construction Sector

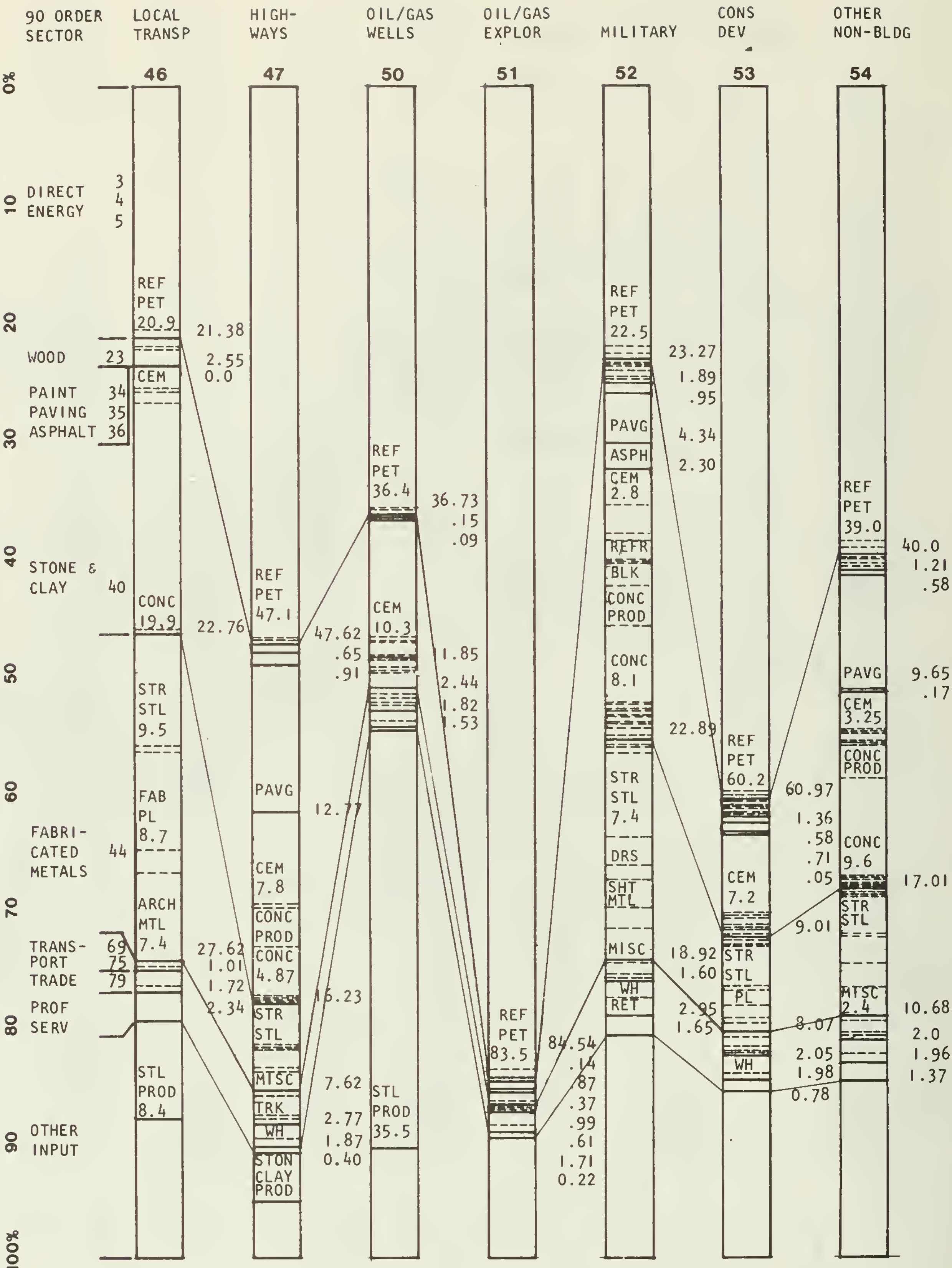
by: CAC / RGS & A

file: **A8**

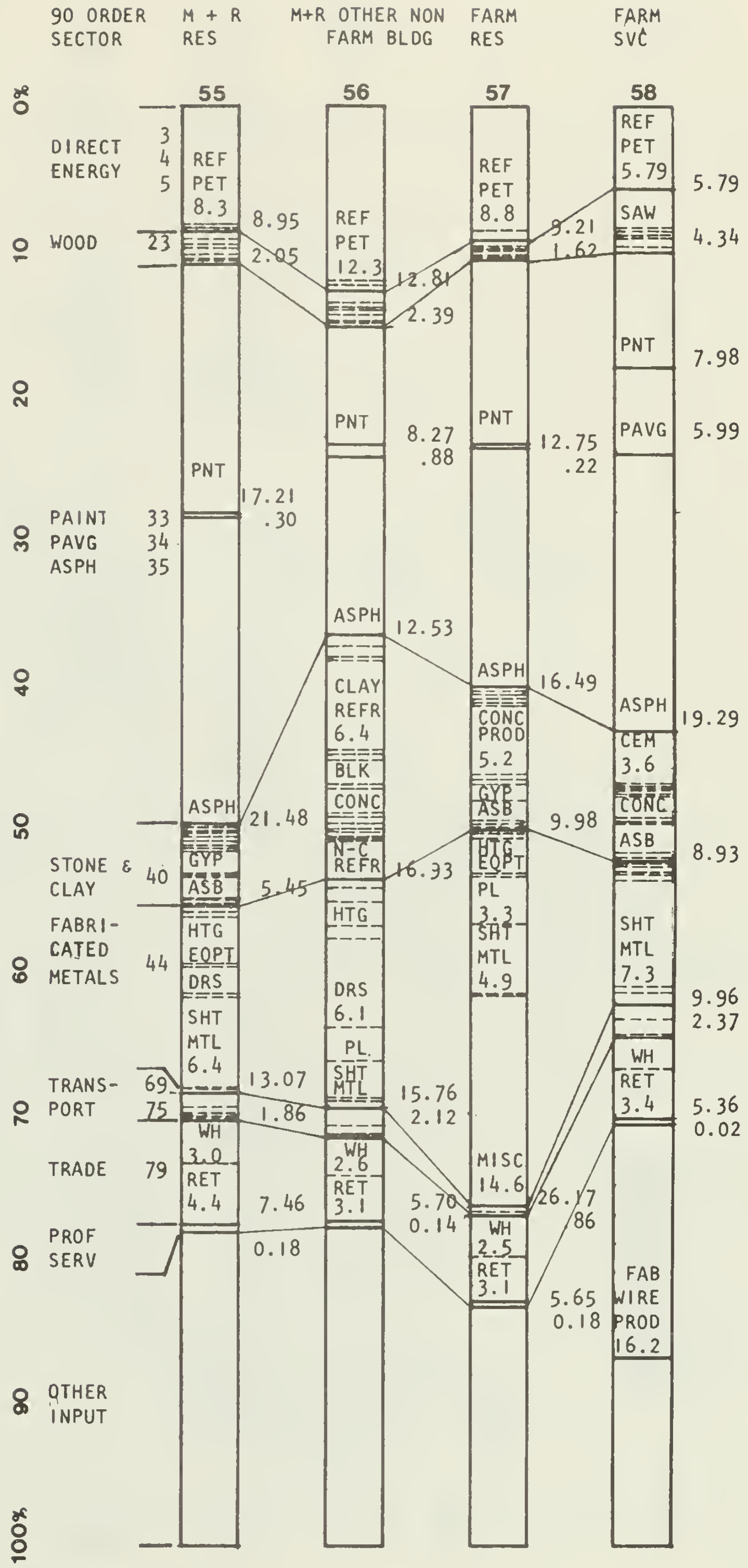


NEW NON-BUILDING CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791	date 30 Dec 76
and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	Subject Energy Input Fractions By Construction Sector by: **CAC** / **RGS & A**	file **A9**

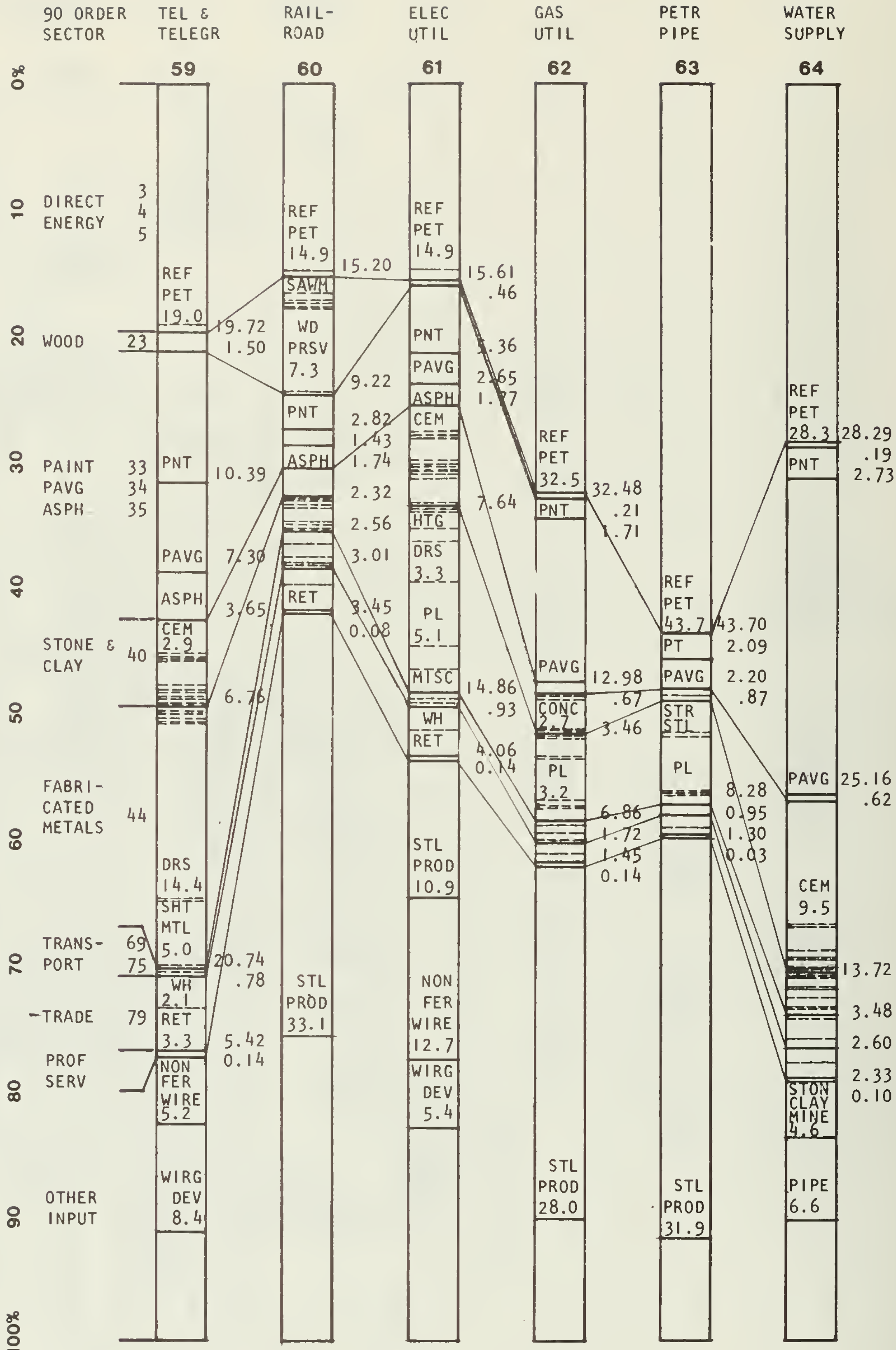


NEW NON-BUILDING CONSTRUCTION



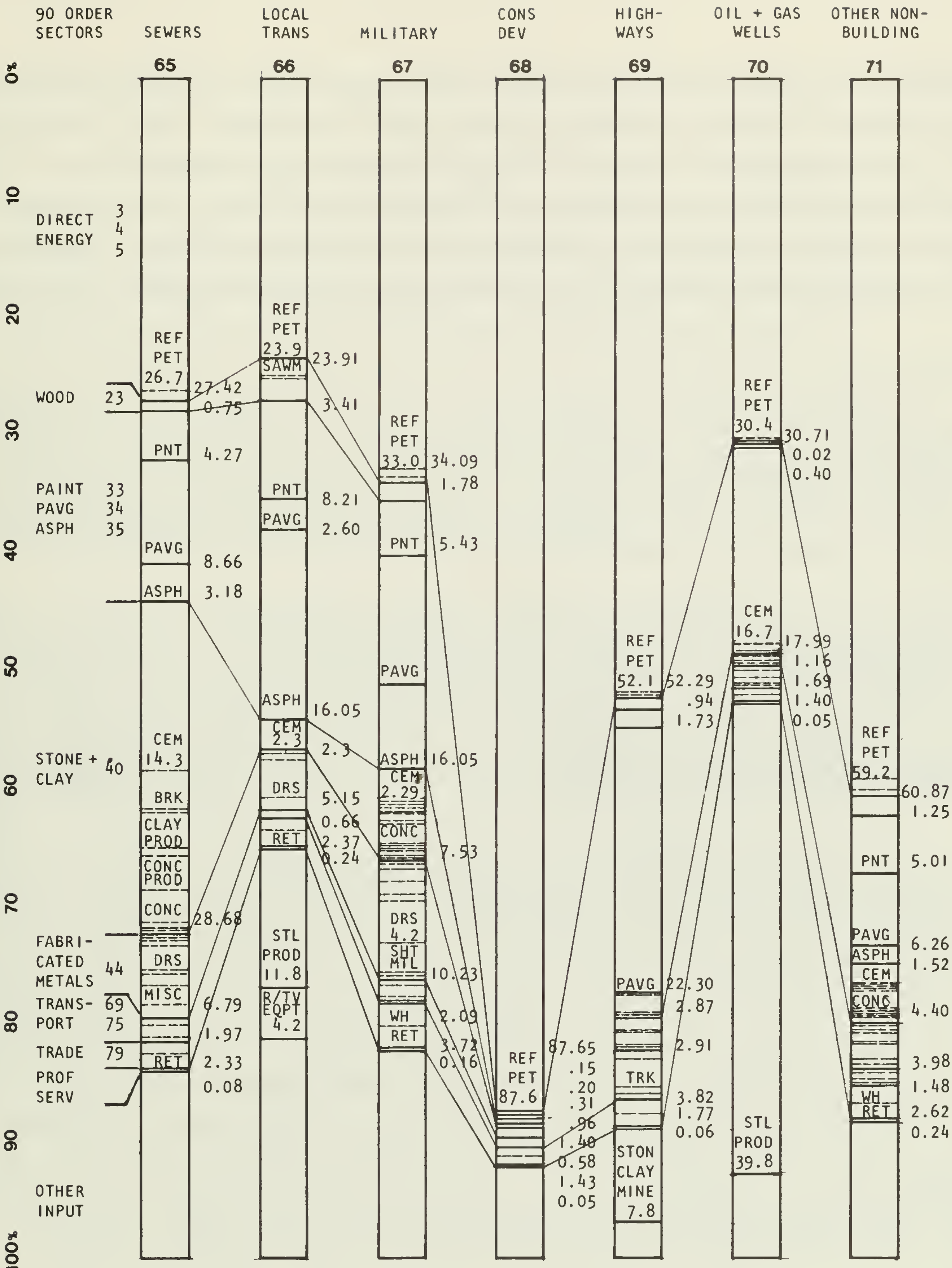
BUILDING MAINTENANCE & REPAIR CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801 and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791 Subject Energy Input Fractions By Construction Sector	by CAC RGS & A	date 30 Dec 76 file **A11**



NON-BUILDING MAINTENANCE & REPAIR CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801 and RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS 588 Fifth Avenue New York NY 10036	ENERGY IN BUILDING CONSTRUCTION ERDA Contract No. E (11-1)-2791	date 30 Dec 76
	Subject: Energy Input Fractions By Construction Sector — by: CAC / RGS & A	file A12



NON-BUILDING MAINTENANCE & REPAIR CONSTRUCTION

CENTER FOR ADVANCED COMPUTATION
University of Illinois Urbana IL 61801

and

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ENERGY IN BUILDING CONSTRUCTION
ERDA Contract No. E (11-1)-2791

date 30 Dec 76

Subject: Energy Input Fractions By Construction Sector

by: CAC / RGS & A

file: **A13**

In Sector 31, Office Buildings, which uses a good deal of heavy equipment and temporary heat, energy embodied in direct fuel use accounts for 21-1/2 percent of the total energy to the sector (352,975 Btu per square foot*), and Fabricated Metals Products and Stone and Clay Products (which incorporate the highest energy intensity input sectors in Building Construction) together account for an additional 55-1/2 percent. Wood Products account for only 1-1/2 percent.

In Non-building Construction, not only are the patterns of materials and energy use different from those of Building Construction (in general a much greater percentage of energy use is direct) but also, for the most part, there is a far greater degree of specialization in the non-building categories and hence, a greater amount of variation from one non-building category to another.

The 28 input sectors which account for approximately 70 to 80 percent of energy in the new building construction sectors account for only 40 to 50 percent of the energy in most new non-building sectors. The main exceptions to this statement, 47: Highway, 51: Oil Exploration and 53: Conservation Development show a high input of energy embodied in direct fuels. (47.62, 84.54 and 60.97 percent).

Almost half the energy embodied in Highways (46.7 percent) is applied directly to the construction process, reflecting not only the extensive amount of diesel powered equipment and the use of asphalt plants and spreaders in the construction process, but also the inclusion of asphalt paving in the direct fuel Refined Petroleum Sector. (See App B.2- p148 for details.) Oil Exploration (84.54 percent energy embodied in direct fuels) purchases and uses large quantities of fuel for the operation of deep drilling rigs. Conservation Development (60.97 percent energy embodied in direct fuels) includes dams and other large earthmoving projects which also use a great deal of mechanized equipment but incorporate comparatively little other material in the finished product.

The Maintenance and Repair Sectors show patterns of energy use which are again different from the New Construction Sectors, and within the Maintenance and Repair group, Building Sectors differ from Non-building Sectors. As might be expected, the building sectors show primarily a very large use of paint, asphalt, and asphalt coatings, and next, heating, air-conditioning and plumbing equipment.

*See note on page 22.

The Non-building Sectors each show a heavy dependency on the materials specific to the sector. (E.g. non-ferrous wire and wiring devices account for over 18 percent of the energy attributable to Electric Utility Maintenance and Repair Construction.) Those sectors which are dependent on a great deal of heavy equipment use with relatively little addition of material show a proportionately high percentage of energy embodied in direct fuel use (e.g. over 87 percent for Conservation Development Maintenance and Repair.)

An examination of the 399-order Sectors contributing to the Maintenance and Repair Sectors indicates that each Maintenance and Repair Construction Sector adds an increment of energy embodiment but no further square footage or bulk to the New Construction Category to which it pertains.

In 1967, the Building Maintenance and Repair Sectors accounted for 17.7 percent of all energy embodied in building construction. This is a significant amount. However, these sectors have been so greatly aggregated (there are only four Building Maintenance and Repair Sectors: Farm Residential; Farm Service; Other Residential; and Other) that it is not possible to apportion their energy embodiment to the appropriate New Building Construction Sectors. This is unfortunate, because maintenance and repair activities are becoming an increasingly important part of building construction activities. The last few years have witnessed a decline in the amount of new building and a corresponding increase in renovation work. To renovate, rather than to demolish and rebuild from the beginning serves to do more than simply extend the useful life of a building. In addition, by requiring smaller amounts of new materials and products, and less of a construction effort, to produce the end result than would a totally new building, renovation lessens the rate of consumption of non-renewable raw materials and saves energy as well as dollars. (While there is no comrehensive study of operational energy use of renovated buildings, there are numerous examples that indicate that carefully renovated, older buildings will operate as efficiently as most new buildings). Although the materials which contribute to Maintenance and Repair Construction will be investigated together with all construction materials (e.g., it would be possible to assign an energy cost to repainting an office interior), the

Maintenance Sectors as such will not be considered in greater detail in this study.

Industry reports with regard to the Maintenance and Repair Sectors remain unchanged in the 1972 Census (and the Census Bureau has no plans to expand these sectors in the future). Any detailed analysis of this area of building construction will not be possible through investigation of BEA data alone, even when more current information is available.

Because of their very specific nature, the New Non-building Construction Sectors cannot be combined with the New Building Sectors nor with each other, but should be studied individually.* In this study, however, our main concern is specific to the energy embodied in buildings.

*Highway Construction, which has already been the subject of a number of energy studies, is a particular case in point. Not only is it an energy-intensive category, but, in 1967, at least, it accounted for a large percentage of the dollar volume of construction (9½ percent of total dollar volume and nearly 20 percent of total construction energy for new construction and maintenance combined.) Between 1967 and now, there has continued to be a great deal of activity in Highway Construction, and the 1972 benchmark data can be expected to show a similar or even greater weighting of this sector. At this time, however, with most of the Interstate system complete, and with an apparent shift occurring in national construction priorities, we expect New Highway Construction to show a slackening off in importance.

III B.1

Embodied Energy per Unit of Building Material

B.1 ENERGY EMBODIMENT PER UNIT OF MATERIAL

Approximately 70 percent of the energy embodied in New Building Construction is attributable to manufacture of basic construction materials and components. The remaining 30 percent is divided among Direct Fuel Purchases (15 percent); Administration - i.e. Wholesale and Retail Trade; Miscellaneous Business and Professional Services, etc. - (11 percent); Transport of Materials (2.5 percent); Furnishings, (1 percent) and Construction Machinery and Equipment, (0.5 percent).

In this sub-study, we have subdivided certain of the 399-level manufacturing sectors (which correspond with Department of Commerce Standard Industrial Classification (SIC) 4-digit classification)into the SIC 5- and 7-digit classifications, corresponding to the 1967 Census of Manufacturers (CM) data[2]. For example, the 399-level Sector 138: Millwork, is based on the 4-digit SIC classification 2431: Millwork, which is subdivided into 5-digit classifications, e.g. 24311: Window Units, Wood, or 24314: Doors, wood, interior and exterior. These are further subdivided into 7-digit classifications, e.g. Wood windows are broken down into 24311 33: Conventional-double hung, 24311 36: Awnings and casement, and 24311 39: All other wood window units.

The sectors chosen for our detailed study represent over 50 percent of the embodied energy attributable to building construction materials.

With the 30 percent embodied in direct fuel purchases, administration, and margins, 80 percent of the energy embodied in New Building Construction is thus accounted for. The remaining 20 percent includes such items as miscellaneous plastics; paving; nonferrous wire; mechanical, plumbing and electrical equipment and fixtures; sheet metal work; metal doors and platework; miscellaneous and architectural metalwork, and 77 other input sectors, each contributing less than 1 percent of New Building Construction embodied energy. (Of 399 input sectors, only 140 make a direct contribution to New Building Construction.)

The 6-digit breakdown, shown by the CM for the output of all manufacturing sectors, begins to approach the type of unit breakdown necessary for a precise energy estimate of building materials and components. That is, industrial products are subdivided not only with respect to dollar of product, but also by quantities of production: e.g., number of board feet of lumber, divided into rough or dressed lumber, hardwood or softwood, etc. In most cases, corresponding dollar value is also given. To the unit price obtained from these figures,* we have applied the CAC figure for total energy intensity (Btu/$) of product, arriving at an average figure for embodied Btu/unit.

In all cases both dollar value and energy embodiment relate to "producer's dollar." In the materials and manufacturing sectors, the manufacturer or the supplier is the producer and the Contractor is the consumer.

The additional activity which transfers materials from producer to consumer is accounted for by eight "margin" sectors. Six of these sectors account for the transportation of materials from the producer to the consumer by different modes - rail, truck, air, etc. - and the remaining two, Retail Trade and Wholesale Trade, cover the operation of retail and wholesale establishments which sell the producer's material to the consumer. Transportation and Trade margins prior to this stage are included in the embodied energy value.

Tables B-1 to B-19 include the increment of Btu/unit of product to New Building Construction which accounts for these margins involved in the transfer of materials from the manufacturer or supplier to the Contractor. Derivation of this factor is described in Appendix C.

When the sectors are broken down into their component products, certain difficulties become apparent. The 399-level figures are average figures, each of which covers a large aggregation of building products. Since most of the 399 sectors (although not all) deal with similar industries, and the entire

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*Averge $/unit has been rounded off to 4 decimal places for units under $1.00 in value and to 2 decimal places for units over. Minor discrepancies are due to rounding off.

aggregation can be represented by dollars of product, the 399 breakdown and the average figures for each sector are valid in a study of economics. Where the sector is highly aggregated, that is, where it deals with only one product (e.g. Sector 206: Ready-Mix Concrete) or where the products within the sector are similar in terms of their use of process energy, the average figures are valid in a study of energy consumption as well. In many cases, however, where the components are not similar and are not comparable, the sectors must be investigated in further detail. For example, Sector 138: Millwork includes wood moldings per board foot; wood window and door frames, per unit; wood doors, per unit; etc. These subdivisions are further broken down by the CM; e.g., wood doors are divided into panel type, flush type hollow core and flush type solid core, and each door type is divided up further according to the type of wood in its composition.

The price variation between even similar units may be dependent not on the amount of energy in the manufacturing process, but on a variety of other factors: rarity of material, amount of material, labor intensity, etc. The average Btu/$ of manufacture figure applied at the 4-digit breakdown level at this scale of breakdown (SIC 7-digit) is the most refined figure now available; however, for an accurate representation of energy input into building components suitable for use as a companion to a cost estimating manual, more investigation is necessary.

There are several methods of approach to this investigation:

1. Use the Census Bureau's detailed information regarding direct energy input to all of the CM industries. The CM report, which documents industry output at 7-digit detail, reports input to industry at 4-digit detail only. According to BEA, all further information is broken down into separate establishment reports, and is stored on confidential tapes within the Census Bureau. Access to this information, which we believe to be highly accurate, is not available.

2. Ascertain direct energy data for specific products from published sources. Substitute this figure for the average direct energy transactions figure shown in the CAC data for the appropriate 399-level sector, and recalculate the energy intensity (Btu/$) specific to the product under investigation. A number of such independent studies exist. They do not cover all relevant industries, nor do different studies of the same industry correspond with each other. The lack of correspondence is based on differences in approach, difference in parameters of study, and difference in data base. This approach is similar to the hybrid analysis outlined below. It differs in that none of the independent studies includes a factor for "administrative" energy, that is, electricity to light the plant and the administrative offices, or to run office machines; fuel to heat and air condition these spaces, etc. It is not possible to separate this energy increment from other direct energy transactions within either CAC or Census Bureau data.

3. Perform a hybrid analysis. That is, isolate the components of the material or product to be analyzed, apply CAC total energy intensities to the individual components, and combine the results, adding a factor for direct energy used in the final assembly or manufacturing process and another for transfer of the product to the next stage of manufacture or to the jobsite. It is possible to take this type of analysis back as many steps as is deemed necessary. Depending on how far back one goes, this process becomes increasingly complex. Furthermore, one is still applying average energy intensity figures to each of the components.

4. Use weighted factors to establish energy differences. If detailed sales information (in producer's dollars) were available for all products within a given sector, a more accurate $/unit figure could be obtained than is possible from the Census of Manufactures. These figures would then be applied to the CAC Btu/$ figure to obtain Btu/unit. This method would be most accurate for products such as bricks, where fluctuations in price can be assumed to be largely or entirely a function of energy use, but it is dependent on classified information which is generally not available to people outside of the specific industry.

However, because of the confidentiality of the Census Bureau and industrial data on the one hand and the potential lack of correlation between other published data and the data in this study, we feel that the greatest degree

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — WOOD PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	CENSUS OF MANUFACTURES DATA: Total $ (Millions)	CENSUS OF MANUFACTURES DATA: Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	BEFORE DELIVERY TO JOBSITE: Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	DELIVERY & TRADE ENERGY INPUT: Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
135	2421	SAWMILL + PLANING MILL PRODUCTS [1]		-	-	-	65,285	-	29,743	-	-
	24211	ROUGH LUMBER:									
	24211 61 63 65	SOFTWD BOARDS < 2" THICK " " = 2" THICK " " > 2" THICK	BD FT	4,545.1	364.1	.0801	"	5,229	"	2,382	7,611
	242212	DRESSED LUMBER									
	242212 21 23 25	SOFTWD BOARDS < 2" THICK " " = 2" THICK " " > 2" THICK	BD FT	19,819.6	1,640.0	.0827	"	5,399	"	2,460	7,859

PRODUCT EXAMPLE - ROUGH SOFTWOOD

SIZE	BD FT/LF	TOTAL BTU/LF
2 x 4	2/3 BD FT	5,074
2 x 8	1 1/3 BD FT	10,145
3 x 4	1 BD FT	7,611
6 x 6	3 BD FT	22,833

CAC NO.	SIC NO.	SIC TITLE	UNIT	No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
135	2421	SAWMILL + PLANING [1] MILL PRODUCTS	-	-	-	-	65,285	-	29,743	-	-
	24211	ROUGH LUMBER									
	24211 67	HARDWOOD	BD FT	2,287.9	236.3	.1033	"	6,744	"	3,072	9,816
	24212	DRESSED LUMBER									
	24212 27	HARDWOOD	BD FT	732.4	74.4	.1016	"	6,633	"	3,022	9,655

PRODUCT EXAMPLE - ROUGH HARDWOOD

SIZE	BD FT/LF	TOTAL BTU/LF
1" x 3"	1/4 BD FT	2,454
1" x 4"	1/3 BD FT	3,272
1 1/2" x 5"	5/8 BD FT	6,135
1 1/2" x 6"	3/4 BD FT	7,362
2" x 8"	1 1/3 BD FT	13,055

CAC NO.	SIC NO.	SIC TITLE	UNIT	No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
135	2421	SAWMILL + PLANING MILL PRODUCTS	-	-	-	-	65,285	-	29,743	-	-
	24218	SOFTWD FLOORING + OTHER MILL PRODUCTS									
	24218 11	SOFTWOOD FLOORING	BD FT	120.5	13.0	.1079	"	7,043	"	3,209	10,252

NOTE: 1. NEGLIGIBLE DIFFERENCES IN ENERGY EMBODIMENT OF ROUGH VERSUS DRESSED LUMBER ARE ASSUMED TO BE A FUNCTION OF MARKET CONDITIONS RATHER THAN DIFFERENCE IN INDUSTRIAL PROCESS. THE AVERAGE HAS BEEN ASSUMED TO BE ACCURATE.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — WOOD PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA			BEFORE DELIVERY TO JOBSITE		DELIVERY & TRADE ENERGY INPUT		TOTAL AT JOBSITE
				No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
136	2426	HARDWOOD DIMENSION[1] AND FLDDRING	-	-	-	-	55,516	-	30,459	-	-
	24261	HARDWODO FLDORING									
	24261 11 19 31 98	OAK STRIP FLDDRING DAK SPECIALTY FLOORING MAPLE FLDDRING DTHER HARDWDDDS	BD FT	763.8	126.9	.1661	"	9,224	"	5,059	14,283
137	2429	SPECIAL PRODUCT SAWMILL GODDS	-	-	-	-	39,319	-	22,107	-	-
	24290	SHINGLES, CODPERAGE STOCK + EXCELSIOR: REO CEOAR									
	24290 03 05 07	SHINGLES REMANUFACTURED HANDSPLIT SHAKES	SQ FT[2]	325.86	38.8	.1191	"	4,682	"	2,633	7,315

NOTE: 1. THE PRODUCTION OF HAROWOOO FLOORING FDLLOWS THE SAME PROCESS REGAROLESS OF THE VARIETY OF WOOO USEO. THE PRICE OIFFERENTIAL IS BASEO ON THE VARIETY OF MATERIAL ANO MARKET CONOITIONS, NOT ENERGY EXPENDED. THEREFORE, THE INDIVIOUAL 7-OIGIT CATEGORIES HAVE BEEN COMBINED IN THIS CASE TO ARRIVE AT AN AVERAGE FIGURE FOR BTU/UNIT.

2. SQUARE FOOT REFERS TO THE AMOUNT OF WOOO SHINGLE NECESSARY TO COVER ONE SQUARE FOOT OF ROOF, TAKING INTO ACCOUNT NORMAL SHINGLE DVERLAP. A SQUARE (100 SQ FT) OF SHINGLES, SOLD AS A BUNDLE, WILL COVER 100 SQUARE FEET DF RDDF.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — WOOD PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA			BEFORE DELIVERY TO JOBSITE		DELIVERY & TRADE ENERGY INPUT		TOTAL AT JOBSITE
				No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
138	2431	MILLWORK[1]					47,350	-	15,765		
	24311	WINDOW UNITS, WOOD[2]									
	24311 33	CONVENTIONAL DOUBLE HUNG	1 EA	3.478	62.1	17.86	"	845,671	"	281,563	1,127,234
	36	AWNINGS + CASEMENT	1 EA	3.271	61.7	18.86	"	893,021	"	297,328	1,190,349
	39	ALL OTHER WOOD WINDOWS	1 EA	.638	18.5	29.00	"	1,373,150	"	457,185	1,830,335
	24312	WOOD WINDOW SASH									
	24312 11	KNOCK DOWN	1 EA	3.242	8.6	2.65	"	125,478	"	41,777	167,255
	13	OPEN	1 EA	2.508	6.7	2.67	"	126,425	"	42,092	168,517
	15	GLAZED	1 EA	3.691	17.0	4.61	"	218,283	"	72,677	290,960
	65	STORM SASH	1 EA	.636	4.3	6.76	"	320,086	"	106,571	426,657
	24314	DOORS, WOOD, INTERIOR[2] + EXTERIOR: PANEL TYPE									
	24314 11 / 13 / 19	DOUGLAS FIR / WESTERN PINE / OTHER SPECIES[3]	1 EA	5.089	7.04	13.83	"	654,851	"	218,030	872,881
		FLUSH TYPE, HOLLOW CORE									
	24314 31 / 33 / 39	SOFTWOOD FACES / HARDWOOD / OTHER FACES[3]	1 EA	22.936	126.0	5.49	"	259,952	"	86,550	346,502
		FLUSH TYPE, SOLID CORE									
	24314 43 / 49	HARDWOOD FACES / SOFTWOOD + OTHER[3]	1 EA	3.571	67.4	18.87	"	893,696	"	297,485	1,191,182
	24315	OTHER WOOD DOORS[2]									
	24315 51	COMBINATION STORM + SCREEN	1 EA	.804	10.2	12.69	"	600,872	"	200,057	800,929
	61	GARAGE DOORS	1 EA	1.087	57.2	52.62	"	2,491,557	"	829,554	3,321,111
	71	SCREEN DOORS	1 EA	1.562	8.9	5.70	"	269,895	"	89,861	359,756
	81	LOUVRE DOORS	1 EA	2.044	15.4	7.53	"	356,546	"	118,710	475,256
	24316	FINISHED WOOD MOULDINGS									
	24316 11 / 51	SOFTWOOD / HARDWOOD	BD FT	668.0	189.1	.2831	"	13,404	"	4,463	17,867

NOTE: 1. DUE TO THE GREAT VARIETY AMONG UNITS, ANY AVERAGE FIGURE DERIVED FROM DIVIDING TOTAL TRANSACTIONS BY QUANTITY OF UNITS CANNOT BE ASSUMED TO BE ACCURATE FOR ALL UNITS.

2. A GENERAL INVESTIGATION OF THE PRODUCTS IN THIS SECTOR INDICATES THAT AN AVERAGE WINDOW IS APPROXIMATELY 3'-0" WIDE BY 4'-0" HIGH, AND AN AVERAGE DOOR IS 3'-0" WIDE BY 6'-8" HIGH. AN AVERAGE GARAGE DOOR IS 8'-0" WIDE BY 7'-0" HIGH. SEE DESCRIPTION OF HYBRID ANALYSIS IN TEXT, SECTION B.1.

3. SINCE ENERGY IN DOOR MANUFACTURE IS APPROXIMATELY THE SAME REGARDLESS OF FACE VENEER, AND PRICE DIFFERENTIAL REFLECTS MATERIAL SCARCITY AND THE MARKET RATHER THAN PROCESS, THE INDIVIDUAL 7-DIGIT CATEGORIES HAVE BEEN COMBINED TO ARRIVE AT AN AVERAGE FIGURE FOR BTU/UNIT.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — WOOD PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA			BEFORE DELIVERY TO JOBSITE		DELIVERY & TRADE ENERGY INPUT		TOTAL AT JOBSITE
				No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
139	2432	VENEER + PLYWOOD[1, 3]	-	-	-	-	67,686	-	21,353	-	-
	24321 00	HARDWOOD PLYWOOD	SQ FT SM	1,741.30	333.0	.1912	"	12,942	"	4,083	17,025
	24322 00	SOFTWOOD PLYWOOD (INTERIOR TYPE)	SQ FT 3/8"	6,919.10	387.4	.0560	"	3,790	"	1,196	4,986
	24323 00	SOFTWOOD PLYWOOD (EXTERIOR TYPE)	SQ FT 3/8"	6,183.80	401.10	.0649	"	4,393	"	1,386	5,779
	24324 00	PREFINISHED HARDWOOD PLYWOOD	SQ FT SM	922.80	105.10	.1139	"	7,709	"	2,432	10,141
	21, 23	PREFINISHED HDWD BASES, PREFINISHED SFTWD BASES	SQ FT SM	576.6	57.2	.0992	"	6,714	"	2,118	8,832
	24325	HARDWOOD VENEER									
	24325 11	SPECIAL + TYPE FACE	SQ FT SM	2,387.5	91.7	.0384	"	2,599	"	820	3,419
	31	COMMERCIAL + UTILITY TYPE	SQ FT SM	985.6	24.7	.0251	"	1,699	"	536	2,235
	51, 71	CONTAINER TYPE, FLAT TYPE	SQ FT SM	377.4	6.5	.0172	"	1,164	"	367	1,531
	24326	SOFTWOOD VENEER									
	24326 11	PLYWOOD VENEER	SQ FT 1"	1,419.1	131.7	.0928	"	6,282	"	1,982	8,264
	31	CONTAINER VENEER	SQ FT 1"	33.5	3.6	.1075	"	7,276	"	2,295	9,571
140	2433	PREFABRICATED WOOD STRUCTURES	-	-	-	-	55,182	-	7,746	-	-
	24331	FABRICATED STRUCTURAL WOOD MEMBERS									
	24331 31	GLUED LAMINATED LUMBER	BD FT	147.80	39.30	.2659	"	14,673	"	2,060	16,733
	33	SAWN LUMBER	BD FT	57.90	5.90	.1019	"	5,623	"	789	6,412
	35	COMBINATION GLUED + SAWN LUMBER	BD FT	68.10	17.80	.2614	"	14,426	"	2,025	16,451
	24332	READY-CUT + PREFAB WOOD BUILDINGS[2, 3]									
	24332 31	DWELLINGS	1 EA	.0572	264.40	4582.32	"		"		
	41	FARM BUILDINGS	1 EA	.0133	26.80	2015.04	"		"		
	51	ROOF TRUSSES MADE OF SAWN LUMBER - LIGHT CONSTRUCTION	1 EA	2.957	41.60	14.07	"		"		

NOTES:

1. THE PRICE DIFFERENTIAL EVIDENT AMONG THE VARIOUS PLYWOOD CATEGORIES IS NOT NECESSARILY A RESULT OF ENERGY EXPENDITURE, BUT RATHER OF QUALITY OF VENEER (SOUNDNESS, PRESENCE OF KNOTS AND FLAWS, ETC.), LABOR INTENSIVITY AND/OR MARKET CONDITIONS.
2. DUE TO THE GREAT VARIETY AMONG UNITS, ANY AVERAGE FIGURE DERIVED FROM DIVIDING TOTAL TRANSACTIONS BY QUANTITY OF UNITS CANNOT BE ASSUMED TO BE ACCURATE FOR ALL UNITS.
3. FOR GREATER ACCURACY A HYBRID ANALYSIS MUST BE PERFORMED ON THE PRODUCTS OF THESE SECTORS. (SEE DESCRIPTION OF HYBRID ANALYSIS IN TEXT SECTION B.1.)

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — PAPER PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	CENSUS OF MANUFACTURES DATA: Total $ (Millions)	CENSUS OF MANUFACTURES DATA: Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	BEFORE DELIVERY TO JOBSITE: Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	DELIVERY & TRADE ENERGY INPUT: Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
160	2661	BUILDING PAPER + BOAROS	-	-	-	-	189,900	-	35,151	-	-
	26612	CONSTRUCTION PAPER									
	26612 00	CONSTRUCTION PAPER[1] (DRY BASIS BEFORE SATURATING)	LB	2,910.6	135.5	.0466	"	8,841	"	1,638	10,479

PRODUCT EXAMPLE - BLOG PAPER

SIZE	LB/SQ FT	TOTAL BTU/SQ FT
1 PLY	.05 LB	524
2 PLY	.10 LB	1,048

NOTE: 1. CONSTRUCTION PAPER IS SOLO IN ROLLS BY THE SQUARE (100 SQ FT).

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — PAINT PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
182	2851	PAINTS + ALLIED PRODUCTS[1]	-	-	-	-	122,390	-	22,359	-	-
	28511	EXTERIOR OIL-TYPE TRADE SALES PAINT PRODUCTS									
	28511 11	SEMI-PASTE OIL + ALKYD PAINTS									
		READY-MIX OIL, ENAMEL + VARNISHES:									
	21 22 24 25 27 28 31 32 35 37 39	HOUSE PAINTS SASH + TRIM ENAMELS PORCH + DECK ENAMELS UNDERCOATS + PRIMERS BARN + ROOF PAINTS MARINE PAINTS METALLIC PAINTS TRAFFIC PAINTS VARNISH STAINS OTHER EXTERIOR OIL PAINTS	GAL	88.0	297.0	3.3750	"	413,066	"	75,462	488,528
	28512	EXTERIOR WATER-TYPE TRADE SALES PAINT PRODUCTS									
	28512 11 16 19	ALL PURPOSE PAINTS MASONRY PAINTS OTHER WATER BASE PAINTS	GAL	36.7	124.0	3.3787	"	413,519	"	75,544	489,063
	28513	INTERIOR OIL-TYPE TRADE SALES PAINT PRODUCTS									
		READY-MIX OILS + ENAMELS									
	28513 52 53 54 56 59	FLAT WALL PAINT GLASS ENAMELS SEMIGLOSS PAINTS UNDERCOATS + PRIMERS OTHER OIL PAINTS	GAL	54.6	191.8	3.5128	"	429,932	"	78,543	508,475
		VARNISHES + STAINS									
	65 67 71	VARNISHES SHELLAC STAINS	GAL	9.8	34.1	3.4796	"	425,868	"	77,800	503,668
	28514	INTERIOR WATER-TYPE TRADE SALES PAINT PRODUCTS									
	28514 11 21 31 98	FLAT PAINT SEMIGLOSS PAINT ALL PURPOSE OTHER INTERIOR PAINT	GAL	93.8	283.2	3.0192	"	369,519	"	67,506	437,025

NOTE: 1. ON AN AVERAGE, 1 GALLON OF PAINT WILL SUPPLY 1 COAT OF PAINT FOR 300-350 SQUARE FEET OF EXTERIOR WOOD OR MASONRY WALL: 475 SQUARE FEET OF INTERIOR WOOD OR MASONRY WALL; 475 SQUARE FEET OF INTERIOR WALL OR TRIM; AND 525 SQUARE FEET OF EXTERIOR TRIM.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — ASPHALT PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA			BEFORE DELIVERY TO JOBSITE		DELIVERY & TRADE ENERGY INPUT		TOTAL AT JOBSITE
				No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
184	2952	ASPHALT FELTS & COATINGS	-	-	-	-	478,610	-	15,222	-	-
	29522	ROOFING ASPHALTS + PITCHES									
	29522 12	ROOFING ASPHALT	LB	3,070.00	43.10	.0140	"	6,701	"	213	6,914
	29523	ASPHALT + TAR ROOFING + SIDING PRODUCTS									
	29523 11	ASPHALT ROOFING: SMOOTH SURFACED ROLLED ROOFING & CAP SHEET, INCLUDING SANDED, TALC, MICA, & OTHER FINE MATERIAL SURFACING	SQ FT	1,690.00	26.50	.0157	"	7,514	"	239	7,753
	13	MINERAL SURFACED ROLL ROOFING & CAP SHEET	SQ FT	1,370.00	30.50	.0223	"	10,673	"	339	11,012
	14	STRIP SHINGLES-SELF SEALING	SQ FT	1,910.00	114.90	.0602	"	28,812	"	916	29,728
	16	STANDARD OR REGULAR STRIP SHINGLES	SQ FT	2,330.00	119.50	.0513	"	24,553	"	781	25,334
	17	INDIV. SHINGLES-ALL STYLES	SQ FT	400.00	20.7	.0518	"	24,792	"	789	25,581
	31	ASPHALT BLDG SIDINGS: ROLL FORM & SHINGLE FORM ALL PATTERNS	SQ FT	40.00	1.10	.0275	"	13,162	"	419	13,581
	35	MINERAL-SURFACED INSULATING BOARD BASE SIDING (ALL TYPES AND FINISHES)	SQ FT	30.00	4.10	.1367	"	65,426	"	2,080	67,506
	51	SATURATED FELTS: ASPHALT SATURATED FELTS FOR ROOFING AND SIDINGS	LB	1,729.20	47.70	.0276	"	13,210	"	420	13,630
	55	SATURATED FELTS: TAR SATURATED FELTS FOR ROOFING AND SIDINGS	LB	93.20	3.20	.0343	"	16,416	"	522	16,938

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — GLASS PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA			BEFORE DELIVERY TO JOBSITE		DELIVERY & TRADE ENERGY INPUT		TOTAL AT JOBSITE
				No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
193	3211	FLAT GLASS[1]	-	-	-	-	102,810	-	15,248	-	-
	32111	SHEET GLASS (WINDDWS)									
	32111 22	SINGLE STRENGTH	SQ FT	490.0	56.7	.1157	"	11,895	"	1,764	13,659
	23	DDUBLE STRENGTH	SQ FT	205.0	26.8	.1307	"	13,437	"	1,993	15,430
	24	HEAVY SHEET	SQ FT	300.0	37.0	.1233	"	12,676	"	1,880	14,556
	26	THIN, INCLUDING PICTURE GLASS + TINTED (ALL THICKNESSES	SQ FT	65.0	11.0	.1692	"	17,395	"	2,580	19,975
	33114	OTHER FLAT GLASS									
	33114 23	TEMPERED GLASS FOR ARCHITECTURAL CONSTRUCTION PURPOSES	SQ FT	166.9	102.6	.6147	"	63,197	"	9,373	72,570
	98	DTHER FLAT GLASS (SUCH AS PLATE GLASS BLANKS, BENT OR ENAMELED SHEET, PLATE FLOAT AND ROLLED GLASS, MULTIPLE GLAZED AND SEALED INSULATION UNITS	SQ FT	19.1	5.6	.2932	"	30,143	"	4,471	34,614
	33112	PLATE + FLOAT GLASS									
	33112 13	PLATE + FLOAT GLASS LESS THAN 1/8" THICK	SQ FT	282.5	89.8	.3179	"	32,683	"	4,847	37,530
	15	PLATE + FLOAT GLASS' BETWEEN 1/8" + 1/4" THICK	SQ FT	210.4	85.6	.4068	"	41,828	"	6,203	48,031
	33112 17 33114 11	PLATE + FLOAT GLASS OVER 1/4" THICK + ROLLED WIRE GLASS	SQ FT	54.2	25.1	.4631	"	47,611	"	7,061	54,672
	32113	LAMINATED GLASS									
	32113 11 32313 11 32113 31 32313 31	LAMINATED PLATE 1/4" AND UNDER LAMINATED PLATE 1/4" AND OVER	SQ FT	190.0	342.0	1.8000	"	185,058	"	27,446	212,504
	32113 51 32313 51 32113 71 32313 98	LAMINATED SHEET (WINDOW) GLASS OTHER LAMINATED GLASS	SQ FT	20.50	19.7	.9610	"	98,820	"	14,653	113,453

NOTE: 1. AGGREGATIONS SHOWN IN THIS SECTOR CORRESPOND TO CENSUS OF MANUFACTURES AGGREGATIONS.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — STONE & CLAY PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	CENSUS OF MANUFACTURES DATA: Total $ (Millions)	CENSUS OF MANUFACTURES DATA: Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	BEFORE DELIVERY TO JOBSITE: Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	DELIVERY & TRADE ENERGY INPUT: Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
195[1]	3241	CEMENT, HYDRAULIC	-	-	-	-	479,590	-	17,477	-	-
	32410 11	PORTLAND CEMENT	1 bbl @ 376 lbs	361.90	1,151.90	3.1829	"	1,526,498	"	55,628	1,582,126
	32410 31	PREPARED OR MIXED HYDRAULIC & MASONRY CEMENTS OTHER THAN SPECIAL PORTLANDS	1 bbl @ 280 lbs	20.80	66.40	3.1923	"	1,530,995	"	55,792	1,586,787
196[2]	3251	BRICK & STRUCTURAL CLAY TILE	-	-	-	-	340,290	-	17,865	-	-
	32511	BRICK, EXCEPT CERAMIC GLAZED + REFRACTORY									
	32511 11	BLDG OR COMMON BRICK & FACE (2 1/4" x 3 5/8" x 7 5/8")	1 BRK	7,394.90	294.90	.0399	"	13,570	"	713	14,283
	32511 19	OTHER BRICK (PAVING, FLOOR & SEWER) (2 1/4" x 3 5/8" x 7 5/8")	1 BRK	21.00	1.50	.0714	"	24,306	"	1,276	25,582
	32512	GLAZED BRICK + STRUCTURAL HOLLOW TILE									
	32512 11	STRUCTURAL CLAY TILE EXCEPT FACING INCLUDING LOAD BEARING & NON-LOAD BEARING TILE	1 TILE	80.20	6.20	.0773	"	26,304	"	1,381	27,685
	32512 31	FACING TILE (STRUCTURAL)[3] & CERAMIC GLAZED BRICK (2 1/4" x 3 5/8" x 7 5/8")	1 BRK	231.50	21.60	.0933	"	31,749	"	1,667	33,416
	32412 51	UNGLAZED & SALT GLAZED FACING TILE (8" x 5" x 12")	1 TILE	4.20	.80	.1905	"	64,817	"	3,403	68,220
197	3253	CERAMIC WALL & FLOOR TILE	-	-	-	-	110,610	-	10,547	-	-
	32530 71	QUARRY TILE & PROMENADE TILE	SQ FT	34.90	14.70	.4212	"	46,589	"	4,442	51,031
	32530 13	CERAMIC MOSAIC TILE & ACCESSORIES - GLAZED	SQ FT	6.00	3.40	.5667	"	62,682	"	5,977	68,660
	32530 53	CERAMIC MOSAIC TILE & ACCESSORIES - UNGLAZED	SQ FT	29.90	15.70	.5251	"	58,081	"	5,538	63,619

NOTE: 1. DIFFERENT WEIGHTS/BBL CORRESPOND TO CENSUS OF MANUFACTURES DESIGNATION.

2. CENSUS OF MANUFACTURES LISTED QUANTITIES BY WEIGHT ONLY FOR THIS CATEGORY. THE UNIT QUANTITY WAS DETERMINED BY ASSUMING AN AVERAGE STRUCTURAL CLAY TILE WEIGHS APPROXIMATELY 6 POUNDS.

3. DESIGNATION PER CENSUS OF MANUFACTURERS.

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE Embodied Energy (Btu/Unit)
204	3217	CONCRETE BLOCKS[1]	-	-	-	-	141,630	-	13,683	-	-
	32710 16 18	STRUCTURAL BLOCK - HEAVY WEIGHT AGGREGATE 8" x 8" x 16" STRUCTURAL BLOCK - OECORATIVE	1 BLK	630.6	129.2	.2049	"	29,018	"	2,803	31,821
	32710 51	BRICK (2 1/4 x 3 5/8 x 7 5/8")	1 BRK	479.70	15.50	.0321	"	4,546	"	439	4,985
206	3273	READY MIX CONCRETE	CU YD	162.40	2,330.50	14.3509	180,130	2,584,938	655	9,400	2,594,338
207	3274	LIME	-	-	-	-	507,010	-	37,482	-	-
	32740 11	QUICKLIME	1 T	7.548	95.20	12.6126	"	6,394,720	"	472,745	6,867,465
	32740 51	HYORATED LIME	1 T	2.123	36.90	17,3811	"	8,812,374	"	651,478	9,463,852
	32740 71	OEAO BURNED OOLOMITE	1 T	1.307	23.40	17,9036	"	9,077,302	"	671,063	9,748,365
208	3275	GYPSUM PRODUCTS		-	-	-	158,540	-	19,998	-	-
	32751 11	CALCINEO GYPSUM BLOG MATERIALS, BLOG PLASTERS & PREFAB BLOG MATERIALS	1 T	8.686	339.10	39.0398	"	6,189,370	"	780,718	6,970,088
	3275!	OTHER CALCINED GYPSUM	1 T	.785	19.40	24.7134	"	3,918,062	"	444,219	4,362,281

PROOUCT EXAMPLE - GYP BOARO

SIZE	LB/SF	TOTAL BTU/SF
3/8"	1.52	5,297
1/2"	2.00	6,970

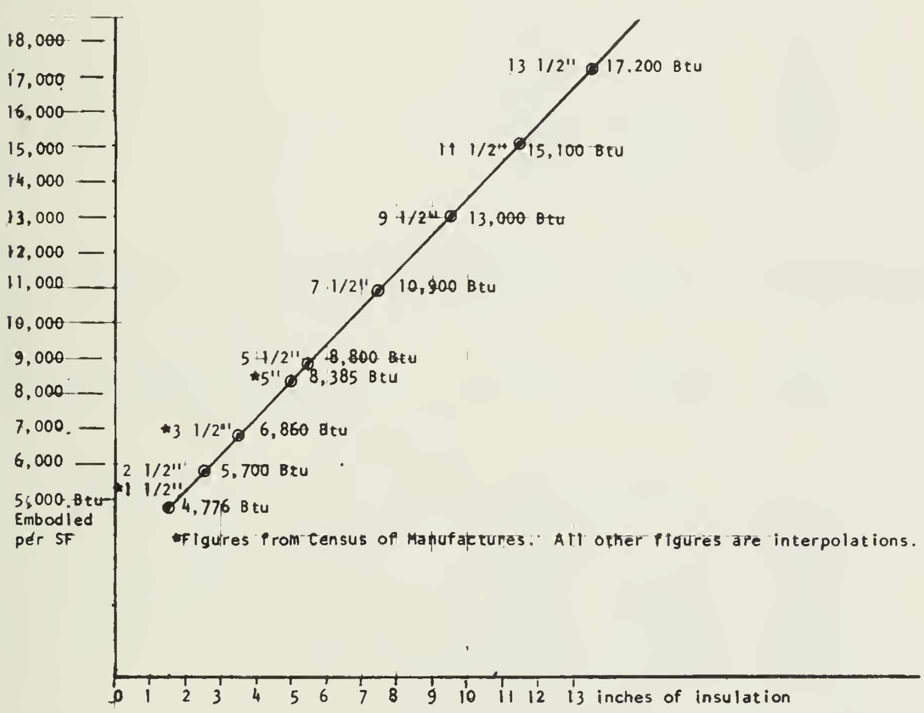
NOTE: 1. THE PRICE OIFFERENTIAL BETWEEN STRUCTURAL BLOCK - HEAVY WEIGHT AND STRUCTURAL BLOCK - OECORATIVE IS BASEO ON LABOR AND MARKET CONOITIONS, NOT ENERGY EXPENOEO. THEREFORE, THE INOIVIDUAL 7-OIGIT CATEGORIES HAVE BEEN COMBINEO IN THIS CASE TO ARRIVE AT AN AVERAGE BTU/UNIT FIGURE.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — STONE & CLAY PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
214	3296	MINERAL WOOL	-	-	-	-	155,870	-	19,088	-	-
	32961	MINERAL WOOL FOR STRUCTURAL INSULATION									
	32961 11	LOOSE FIBER (BLOWING + POURING + GRANULATED FIBER)	SH T	.2619	19.2	73.31	"	11,426,830	"	1,399,341	12,826,171
	23	4.5 INCHES OR MORE THICK (BLDG BATTS, BLANKETS + ROLLS)	SQ FT	274.9	13.1	.0477	"	7,435	"	910	8,345
	27 33	2.0 TO 4.4 INCHES THICK[1]	SQ FT	1,576.1	61.8	.0392	"	6,112	"	748	6,860
	37	LESS THAN 2.0 INCHES THICK	SQ FT	417.2	11.4	.0273	"	4,255	"	521	4,776

NOTE: 1. PRICE DIFFERENTIAL NOT BASEO ON ENERGY.

2. CHART SHOWS INTERPOLATED BTU VALUES FOR DIFFERENT THICKNESSES OF INSULATION BASEO ON SPECIFIC VALUES DERIVEO THROUGH BEA OATA. IT IS ASSUMEO THAT THE ENERGY EMBODIMENT OF THIS MATERIAL IS A OIRECT FUNCTION OF QUANTITY OF MATERIAL.



CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA			BEFORE DELIVERY TO JOBSITE		DELIVERY & TRADE ENERGY INPUT		TOTAL AT JOBSITE
				No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
217	331	STEEL PRODUCTS[1, 2]	-	-	-	-	266,980	-	13,910	-	-
	33121	COKE OVEN + BLAST FURNACE PRODUCTS									
	33121 91	PIG IRON	LB	24,950.8	660.2	.0265	"	7,075	"	369	7,444
217	331	STEEL PRODUCTS	-	-	-	-	266,980	-	13,910	-	-
	33123	TIN MILL PRODUCTS									
	33123 11 / 15	CARBON STEEL SHEETS: HOT ROLLED + ENAMELED	LB	28,152.514	1,684.234	.0598	"	15,965	"	838	16,803
217	331	STEEL PRODUCTS	-	-	-	-	266,980	-	13,910	-	-
	33123	TIN MILL PRODUCTS									
	33123 13	CARBON STEEL SHEETS: GALVANIZED	LB	8,013.538	794.463	.0991	"	26,458	"	1,378	27,836

PRODUCT EXAMPLE - STEEL STEETS

THICKNESS	LB/SF	TOTAL BTU/SF
22 GA	1.75 LB	29,405
20 GA	2.14 LB	35,286
18 GA	2.83 LB	47,048
16 GA	3.54 LB	58,811

PRODUCT EXAMPLE - GALV SHEETS

THICKNESS	LB/SF	TOTAL BTU/SF
22 GA	1.79 LB	49,826
20 GA	2.14 LB	59,526
18 GA	2.83 LB	78,776
16 GA	3.54 LB	98,539

NOTE: 1. AGGREGATIONS SHOWN IN THESE SECTORS CORRESPOND WITH CENSUS OF MANUFACTURES AGGREGATIONS.

2. ENERGY IN STEEL PRODUCTS IS AVERAGE NATIONWIDE AND INCLUDES SUCH VARIABLES AS RANGE OF ORE QUALITY, DIFFERENT BLAST FURNACE OR OTHER FURNACE METHODS, OR DIFFERENCES IN LOCATION OF FACILITIES PREVAILING IN 1967.

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
217	331	STEEL PRODUCTS	-	-	-		266,980	-	13,910	-	-
	33124	HOT ROLLED BARS + SHAPES [1]									
	33124 15, 17, 19	CARBON STEEL: STRUCTURAL SHAPES, SHEET PILINGS, BEARING PILES	LB	11,749.972	782.989	.0667	"	17,808	"	928	18,736

PRODUCT EXAMPLE - STEEL SHAPES

SIZE	LB/LF	TOTAL BTU/LF
W12 x 65	65 LB	1,217,840
W16 x 36	36 LB	655,760
C x 2 x 30	30 LB	562,080
L x 8 x 4 x 1	37.4 LB	700,726
WT6 x 27	29 LB	543,344

CAC NO.	SIC NO.	SIC TITLE	UNIT	No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Total Embodied Energy (Btu/Unit)
217	331	STEEL PRODUCTS	-	-	-	-	266,980	-	13,910	-	-
	33124	HOT ROLLED BARS + SHAPES [2]									
	33124 25, 27	CARBON STEEL CONC REINF BARS ROLLED FROM NEW BILLET; ROLLED FROM OLD MATERIAL	LB	7,784.59	434.118	.0558	"	14,888	"	776	15,664

PRODUCT EXAMPLE - REINF BARS

BAR SIZE	LB/LF	TOTAL BTU/LF
#2	.167 LB	2,569
#3	.376 LB	5,890
#4	.668 LB	10,464
#5	1.043 LB	16,338
#6	1.502 LB	23,527
#7	2.044 LB	32,017
#8	2.670 LB	41,823

CAC NO.	SIC NO.	SIC TITLE	UNIT	No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Total Embodied Energy (Btu/Unit)
217	331	STEEL PRODUCTS	-	-	-	-	266,980	-	13,910	-	-
	33124	HOT ROLLED BARS AND SHAPES									
	33124 31, 35	ALLOY STEEL: PLATES + STRUCTURAL SHAPES	LB	4,121.584	394.947	.0958	"	25,577	"	1,333	26,910

PRODUCT EXAMPLE - STEEL SHAPES

SIZE	LB/LF	TOTAL BTU/LF
W12 x 65	65 LB	1,749,150
W16 x 36	36 LB	968,760
C x 2 x 30	30 LB	807,300
L x 8 x 4 x 1	37.4 LB	1,006,434
WT6 x 27	29 LB	780,390

NOTE: 1. AGGREGATIONS SHOWN IN THESE SECTORS CORRESPOND WITH CENSUS OF MANUFACTURES AGGREGATIONS.

2. REINFORCING BARS, WHICH MUST CONFORM TO ASTM STANDARDS, HAVE BEEN AGGREGATED BECAUSE NO DIFFERENTIATION IS MADE WITH REGARD TO THEIR METHOD OF MANUFACTURE AT POINT OF SALE TO CONTRACTOR.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — PRIMARY IRON & STEEL

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
217	331	STEEL PRODUCTS [1]	-	-	-	-	266,980	-	13,910	-	-
	33151	NONINSULATED FERROUS WIRE									
	33151 35 34811 35	WIRE STRAND FOR PRESTRESSED CONCRETE	LB	119.6	19.0	.1589	"	42,423	"	2,210	44,633
217	331	STEEL PRODUCTS	-	-	-	-	266,980	-	13,910	-	-
	33152	STEEL NAILS + SPIKES									
	33152 21	CARBON STEEL WIRE PRODUCTS: NAILS + STAPLES	LB	741.972	89.865	.1211	"	32,331	"	1,685	34,016
217	331	STEEL PRODUCTS	-	-	-	-	266,980	-	13,910	-	-
	33155	STEEL WIRE									
	33155 11	PLAIN WIRE	LB	3,532.388	391.979	.1110	"	29,635	"	1,544	31,179
	15	GALVANIZED WIRE	LB	523.852	64.128	.1224	"	32,683	"	1,702	34,385

PRODUCT EXAMPLE - 7 WIRE STRAND

DIA	LB/LF	TOTAL BTU/LF
1/4"	.122 LB	5,445
1/2"	.198 LB	8,837
3/8"	.274 LB	12,229
7/16"	.373 LB	16,648

PRODUCT EXAMPLE - COMMON NAILS

SIZE	LB/NAIL	TOTAL BTU/NAIL
2 PENNY	.0012 LB	41
3 PENNY	.0018 LB	61
4 PENNY	.0033 LB	112
5 PENNY	.0039 LB	133
10 PENNY	.015 LB	510

NOTE: 1. AGGREGATIONS SHOWN IN THESE SECTORS CORRESPOND WITH CENSUS OF MANUFACTURES AGGREGATIONS.

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA			BEFORE DELIVERY TO JOBSITE		DELIVERY & TRADE ENERGY INPUT		TOTAL AT JOBSITE
				No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
217	331	STEEL PRODUCTS[1]	-	-	-	-	266,980	-	13,910	-	-
	33159	OTHER FABRICATED WIRE PRODUCTS									
	33159 61 34819 61	CONC REINFORCING MESH (WELDED WIRE)	LB	1,357.6	116.9	.0861	"	22,989	"	1,198	24,187

PRODUCT EXAMPLE - WIRE MESH

SIZE	LB/SF	TOTAL BTU/SF
2 x 4 14/14	.16 LB	3,870
2 x 12 8/8	1.05 LB	25,396
2 x 16 8/12	.46 LB	11,126
2 x 16 6/10	.65 LB	15,722

CAC NO.	SIC NO.	SIC TITLE	UNIT	No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
217	331	STEEL PRODUCTS[1]	-	-	-	-	266,980	-	13,910	-	-
	33176	STEEL PIPES AND TUBES									
	33176 11	CARBON STEEL FINISHED SHAPES + FORMS: STANDARD PIPE	LB	5,673.528	521.384	.0919	"	24,535	"	1,278	25,813

PRODUCT EXAMPLE - STANDARD PIPE

NOM DIA	LB/LF	TOTAL BTU/LF
1/2"	.85 LB	21,941
3/4"	1.13 LB	29,169
1"	1.68 LB	43,366
2"	3.65 LB	94,217
6"	18.97 LB	489,673

NOTE: 1. AGGREGATIONS SHOWN IN THESE SECTORS CORRESPOND WITH CENSUS OF MANUFACTURES AGGREGATIONS.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — PRIMARY IRON & STEEL

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
217	331	STEEL PROOUCTS	-	-	-	-	266,980	-	13,910	-	-
		STAINLESS STEEL - FINISHED SHAPES + FORMS:[1]									
	33167 51	SHEETS - COLD ROLLED	LB	373.48	183.885	.4924	"	131,449	"	6,849	138,298
	33123 51	SHEETS - HOT ROLLEO	LB	547.07	157.4	.2877	"	76,814	"	4,002	80,816
	33123 59 33167 55	STRIP - HOT + CDLD ROLLED	LB	708.25	304.653	.4302	"	114,842	"	5,983	120,825
	33124 51	PLATES	LB	154.004	87.365	.5673	"	151,455	"	7,891	159,346
	33124 61	BARS - HOT ROLLEO	LB	152,668	85,463	.5598	"	149,454	"	7,787	157,241
	33168 51	BARS - CDLD FINISHED	LB	205.898	141.578	.6876	"	183,579	"	9,565	193,144
	33155 51	WIRE	LB	98.326	83.987	.8542	"	228,046	"	11,881	239,927

NOTE: 1. AGGREGATIONS SHOWN IN THIS SECTDR CORRESPOND TO CENSUS OF MANUFACTURES AGGREGATIONS.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — PRIMARY NONFERROUS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	CENSUS OF MANUFACTURES DATA: Total $ (Millions)	CENSUS OF MANUFACTURES DATA: Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	BEFORE DELIVERY TO JOBSITE: Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	DELIVERY & TRADE ENERGY INPUT: Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
228	3352	ALUMINUM ROLLING[2]	-	-	-	-	244,200	-	3,479	-	-
	33522	ALUMINUM PLATE + SHEET									
	33522 15	PLATE: NON-HEAT TREATABLE	LB	152.6	71.2	.4666	"	113,949	"	1,623	115,567
				PROOUCT EXAMPLE - ALUM PLATE							
				THICKNESS	LB/SF	TOTAL BTU/SF					
				1/4"	3.64 LB	420,663					
				1/2"	7.27 LB	840,172					
				3/4"	10.91 LB	1,260,836					
				1"	14.54 LB	1,680,344					
228	3352	ALUMINUM ROLLING[2]	-	-	-	-	244,200	-	3,479	-	-
	33522	ALUMINUM PLATE + SHEET									
	33522 24	SHEET: NON-HEAT TREATABLE	LB	388.0	150.3	.3873	"	94,596	"	1,347	95,943
				PRODUCT EXAMPLE - ALUM SHEET							
				THICKNESS	LB/SF	TOTAL BTU/SF					
				1/8"	1.82 LB	174,816					
				3/16"	2.73 LB	261,924					
228	3352	ALUMINUM ROLLING[1, 2]	-	-	-	-	244,200	-	3,479	-	-
	33524	ROLLEO ALUMINUM ROO, BAR + STRUCTURAL SHAPE									
	33524 21, 25, 26	ROLLEO BAR + ROD; CONTINUOUS CAST; ROLLEO STRUCTURAL SHAPE	LB	692.4	257.6	.3720	"	90,852	"	1,294	92,146
				PROOUCT EXAMPLE - STANOARO SHAPES							
				SIZE	LB/LF	TOTAL BTU/LF					
				818.81	8.81 LB	811,806					
				716.05	6.05 LB	557,483					
				615.10	5.10 LB	469,945					

NOTE: 1. AGGREGATIONS IN THESE SECTORS CORRESPONO WITH CENSUS OF MANUFACTURES AGGREGATIONS.

2. THESE ARE AVERAGE ENERGY VALUES WHICH INCLUDE VARIABLES SUCH AS ORE QUALITY ANO THE AMOUNT OF RECYCLED METAL USED IN 1967.

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — FABRICATED METAL PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
240	3441	FABRICATEO STRUCTURAL STEEL[1, 2]		-	-	-	124,320	-	5,704	-	-
	34411	FABRICATEO STRUCTURAL METAL FOR BUILOINGS									
	34411 61	INOUSTRIAL	LB	2,332.2	407.3	.1746	"	21,711	"	996	22,707
	65	COMMERCIAL, RESIOENTIAL + INSTITUTIONAL									
	67	PUBLIC UTILITIES									

PROOUCT EXAMPLE - STEEL SHAPES

SIZE	LB/LF	TOTAL BTU/LF
W12 x 65	65 LB	1,475,370
W16 x 36	36 LB	817,128
C x 2 x 30	30 LB	680,940
L x 8 x 4 x 1	37.4 LB	848,905

NOTE: 1. AGGREGATIONS SHOWN IN THIS SECTOR CORRESPONO WITH CENSUS OF MANUFACTURES AGGREGATIONS.

2. MOST STEEL IN BUILOINGS COMES FROM THIS SECTOR, WHICH HAS BEEN OIFFERENTIATEO BY THE CENSUS OF MANUFACTURES IN ACCOROANCE WITH THE TYPE OF BUILOING IN WHICH IT WAS USEO. THEREFORE, USING CM OATA ALONE, IT IS POSSIBLE TO ARRIVE ONLY AT AN AVERAGE FIGURE OF BTU/LB FOR ALL STEEL SECTIONS. A HYBRIO ANALYSIS OF THIS SECTOR WOULO PERMIT FURTHER REFINEMENT BY TAKING THE BTU/LB FOR SPECIFIC SECTIONS ANO AOOING AN AVERAGE BTU/LB FOR THE ENERGY USEO IN TRANSPORTING THE SECTION FROM THE STEEL MILL TO THE FABRICATING PLANT ANO THE ENERGY USEO AT THE FABRICATING PLANT ITSELF. (SEE TEXT, SECTION B.I FOR OESCRIPTION OF HYBRIO ANALYSIS.)

1967 ENERGY EMBODIMENT PER UNIT OF MATERIAL — SCREW MACHINE PRODUCTS

CAC NO.	SIC NO.	SIC TITLE	UNIT	CENSUS OF MANUFACTURES DATA: No. of Units (Millions)	Total $ (Millions)	Average $/Unit	BEFORE DELIVERY TO JOBSITE: CAC Btu/$	Embodied Energy (Btu/Unit)	DELIVERY & TRADE ENERGY INPUT: CAC Btu/$	Embodied Energy (Btu/Unit)	TOTAL AT JOBSITE: Embodied Energy (Btu/Unit)
246	3452	SCREW MACHINE PRODUCTS	-	-	-	-	85,812	-	15,851	-	-
	34521	NUTS, BOLTS AND OTHER STANDARD FASTENERS									
	34521 03 04 05 07	STANDARD HEX STANDARD ROUND LAG SCREWS + BOLTS STUDS + THREADED RODS	LB	672.1	176.0	.2619	"	22,474	"	4,151	26,625

PRODUCT EXAMPLE - BOLTS

SIZE	LB/BOLT	TOTAL BTU/BOLT
1" x 1/4"	.02 LB	533
2" x 1/2"	.18 LB	4,793
3" x 1/2"	.23 LB	6,124
4" x 1/2"	.29 LB	7,721
5" x 3/8"	.18 LB	4,793

CAC NO.	SIC NO.	SIC TITLE	UNIT	No. of Units (Millions)	Total $ (Millions)	Average $/Unit	CAC Btu/$	Embodied Energy (Btu/Unit)	CAC Btu/$	Embodied Energy (Btu/Unit)	Embodied Energy (Btu/Unit)
246	3452	SCREW MACHINE PRODUCTS	-	-	-	-	85,812	-	15,851	-	-
	34521	NUTS, BOLTS + OTHER STANDARD FASTENERS									
	34521 57	RIVETS 1/2" AND OVER	LB	29.9	5.1	.1706	"	14,640	"	2,704	17,344

PRODUCT EXAMPLE - RIVETS

SIZE	LB/RIVET	TOTAL BTU/RIVET
1 1/4" x 1/2"	.11	1,908
1 1/2" x 1/2"	.12	2,081
2" x 1/2"	.15	2,602
3" x 3/4"	.70	12,141
4" x 1"	1.16	20,119

of accuracy possible in a detailed study within a given sector is through the hybrid analysis described in 3 above.

Hybrid Analysis

As an example of a hybrid analysis, we have chosen to examine some typical wood windows.

The Census of Manufacturers divides stock wood windows into three categories: Double hung, Casement, and Other[2]. The double-hung category would include single-hung, since the framing is identical and the hardware is similar. The casement category includes awnings and hoppers for the same reasons. The third category, Other, which accounts for only 13 percent of the dollar transactions for stock wood windows reported to the Census Bureau, includes fixed windows, bow windows, sliding windows and prefabricated combination units.

In all of these categories, the units may be sold glazed or unglazed. If glazed, they may have single or double glass. The glass may be a single pane or it may be divided into 2, 4, 6 or more "lights" by muntin bars. The size of the window will also vary.

We have chosen as a base unit a casement window 3 feet wide by 4 feet high, composed of two side-hinged leaves meeting in the center. Each leaf is glazed with one light of glass without muntin bars, either single- or double-glazed. In our experience, this is an average unit, and its embodied energy should be close to the average figure shown on Table B-3. The average cost of a wood casement window, taken from the same table, is $18.86 per unit.

A hybrid analysis consists of several steps. (See Appendix C for supporting calculations not shown in text.) Using the 3' x 4' wood casement window for all examples they are:

A. Breakdown the unit to be studied into components and ascertain the energy embodied in each component.

EXAMPLE: 1. Wood Frame & Sash: Finished Wood Moulding @ 13,258 Btu/Bd Ft (From Table B-3, Sector 138: Millwork)

	Component	Stock	Length	Bd Ft/LF	Bd Ft
a)	Window Frame	2 x 6	14 ft	1	14.00
b)	Window Sash	1½ x 2	22 ft	1/4	5.50
c)	Interior Trim	1 x 1½	22 ft	1/8	2.75
d)	Center Post	2 x 4	4 ft	2/3	2.67
			Total Bd Ft:		24.92 Bd Ft.

24.92 Bd Ft x 13,258 Btu/Bd Ft = 330,389 Btu

2. Glass: Double Strength Window Glass @ 13,440 Btu/SF (From Table B-8, Sector 193: Flat Glass)

a) Single-glazed = 12 SF x 13,440 = 161,280 Btu

b) Double-glazed = 24 SF x 13,440 = 322,560 Btu

B. Ascertain margin, if any, between supplier of component and manufacturer of unit.

EXAMPLE: 1. Wood Frame & Sash: Finished Wood Mouldings and Wood Windows are both in the same 399-level sector (138: Millwork) and are often manufactured and supplied by the same establishment. Thus, there is no margin factor to transfer the frame components to the window manufacturer.

2. Glass: Glass (Sector 193) embodied energy in margin to Millwork (Sector 138) of 7001 Btu/$ of Glass Product. Double-strength window glass costs $0.13/SF. 7001 Btu/$ x $0.13/SF = 910 Btu/SF.

   a) Single-glazed margin: 12 SF x 910 Btu/SF = 10,920 Btu
   b) Double-glazed margin: 24 SF x 910 Btu/SF = 21,840 Btu

C. Ascertain energy for assembly of unit.

EXAMPLE: The total energy embodied in direct fuel purchases by Sector 138: Millwork, amounted to 8,487 Btu/$ of Millwork products.

The average wood casement window cost $18.86/unit. 8487 Btu/$ x $18.86 = 160,065 Btu/unit for assembly.

Note: Since the process of assembly is roughly the same regardless of the size of the unit, this energy increment would be the same for all wood casement windows.

D. Ascertain overhead energy at the establishment which manufactures the unit.

EXAMPLE: Of the 75 sectors providing input to Sector 138, 33 concern direct energy and materials to be incorporated in the products of the sector. Seven concern margin activity, i.e., transportation and trade between the input sectors and Sector 138. The 35 remaining input sectors concern the operation of the manufacturing establishments themselves, e.g. Sector 275: Woodworking Machinery or Sector 385: Advertising. The energy embodied in these 35 sectors is considered overhead, and it must be prorated to Sector 138's products. In addition, there were margins on 12 of the 35 overhead sectors, and this increment must also be prorated to the products of the sector and included in the hybrid analysis.

Thus: Total Energy Intensity of Overhead Sectors	=	5,528 Btu/$
Margin Energy Intensity due to Overhead Sectors	=	340 Btu/$
Total Energy Intensity Attributable to Overhead for Sector 138:		5,868 Btu/$

5,868 Btu/$ x $18.86 per unit = 110,670 Btu/unit.

E. Ascertain the energy embodied in the margin for transfer of the unit from the manufacturer/supplier to the end user (jobsite).

<u>EXAMPLE</u>: In Sector 138 energy embodied in margins to New Building Construction equal: 15,765 Btu/$ of 138 product.

15,765 x $18.86/unit = <u>297,328 Btu/unit</u>

Note: Presumably, the overhead factor and the segment of energy attributable to the wholesale and retail trade components of the margin factor are based on the dollar value of the unit and should vary with variation of the unit. Without detailed statistics regarding the quantities and varieties of units produced expressed in producer's dollars (and thus compatible with the CM data), these factors must remain fixed at the average for all units.

F. Add totals A through E.

<u>EXAMPLE</u>:

	Single-glazed	Double-glazed
A. Components	491,669	652,949
B. Components' margin	10,920	21,840
C. Assembly	160,065	160,065
D. Overhead	110,670	110,670
E. Margin to jobsite	297,328	297,328
Total Embodiment =	1,070,652 Btu	1,242,852 Btu

These totals exclude hardware, caulking, and plastic components, and so the actual figures should be slightly higher. According to Table B-3, the average energy embodiment for wood casement windows was 1,190,349 Btu, a figure generally in accord with the single-glazed unit.

Naturally, this total will vary with the size of the unit. If we extend our analysis to two other sizes of the same basic unit: 2' x 3' and 4' x 6', we find:

A. Components

1. Wood Frame and Sash	Bd Ft/LF	2' x 3' unit LF	2' x 3' unit Bd Ft	4' x 6' unit LF	4' x 6' unit Bd Ft
a) Window Frame	1	10	10	20	20
b) Window Sash	1/4	16	4	32	8
c) Interior Trim	1/8	16	2	32	4
d) Center Post	2/3	3	2	6	4
Total Board Feet:			18		36

Energy Embodiment: 13,258 x 18 = 238,644 Btu   13,258 x 36 = 477,288 Btu

2. Glass	2' x 3' unit	4' x 6' unit
a) Single-glazed:	6 SF x 13,440 = 80,640 Btu	24 SF x 18,440 = 322,560 Btu
b) Double-glazed:	12 SF x 13,440 = 161,280 Btu	48 SF x 18,440 = 645,120 Btu

B. Components Margin

1. Wood Frame and Sash - No margins

2. Glass	2' x 3' unit	4' x 6' unit
a) Single-glazed:	6 SF x 910 = 5,460	24 SF x 910 = 21,840
b) Double-glazed:	12 SF x 910 = 10,920	48 SF x 910 = 43,680

C. Assembly   160,065

D. Overhead   110,670

E. Margins in Transfer to Jobsite 297,328 Btu/unit

Factors C, D, and E remain fixed regardless of size of unit or type of glazing.

Their sum is: 568,063 Btu/unit

F. Total Energy Embodiment

		2' x 3' unit		4' x 6' unit	
A.	Components				
	a) Single-glazed	319,284		799,848	
	b) Double-glazed		399,924		1,122,498
B.	Components Margin				
	a) Single-glazed	5,460		21,840	
	b) Double-glazed		10,920		43,680
C - E.	Fixed Factors	568,063	568,063	568,063	568,063
	Totals	892,807	978,907	1,389,751	1,734,241

Note: These embodiments differ from the base 3' x 4' window embodiment up to 39.5 percent.

Upon examination of the above sample analyses, one discovers that the procedure can be simplified considerably and made applicable to any similar unit regardless of size or proportion. In terms of energy embodiment, the unit is divided into three parts:

1. Frame and Sash, the energy embodiment of which is a function of the number of board feet of lumber therein: a linear measure.

2. Glass, the embodiment of which is a function of the area of the unit. (The margin between Glass and Millwork is included with the material embodiment.)

3. Assembly, Overhead, and Margins (transport and trade), a fixed factor.

The sum of the parts may be expressed in a formula:

$$\text{Bd Ft of Frame} \times \frac{\text{Finished Moulding Btu}}{\text{Bd Ft}} + \text{SF of Glass} \times \frac{\text{Glass Btu}}{\text{SF}}$$

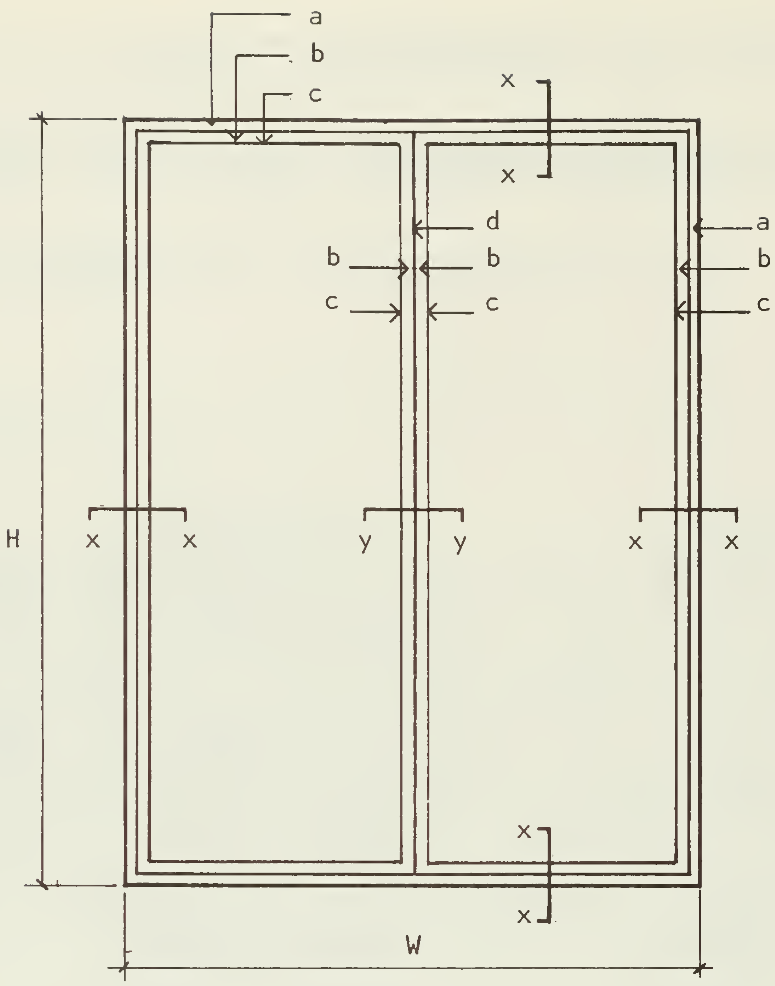
$$+ \text{Fixed Btu Factors} = \text{Btu embodied in Unit.}$$

The number of board feet in the frame is not a function of either the proportions or the perimeter of the unit. Table B-20 describes the method of deriving a formula to compute the number of board feet in the frame and sash. If a unit is composed of stock of other sizes, this formula will change accordingly. However, the sample chosen is a typical stock window, and variations will have a minimal effect on the total. If a greater degree of accuracy is desired, however, a formula for a different set of frame components can be easily derived using the same method.

The area of glass will be width times height for single glazed units and 2 times width times height for double glazed ones, with width and height being the nominal width and height of the unit in feet.

This same procedure would be followed for any material or component for which average figures were considered too gross.

A graph, based on the four window variations analyzed has been developed as an indication of an energy estimating format that will permit interpolation of energy values for windows of a different sizes than those actually computed. See Appendix C, Figure App C3.



	Lumber Dim	Bd Ft/LF
a = Window Frame	2" x 6"	1.000
b = Window Sash	1 1/2" x 2"	0.250
c = Interior Trim	1" x 1 1/2"	0.125
d = Center Post	2" x 4"	0.670

Section x-x = a + b + c = 1.375 Bd Ft/LF

Section y-y = 2b + 2c + d = 1.420 Bd Ft/LF

Entire Wood Frame = H[2(1.375) + 1.42] + W[2(1.375)]Bd Ft

= 4.17H + 2.75W Bd Ft

Energy Estimate for an Entire Building

Once a complete quantity and energy take-off has been made of all materials and components in a particular building, one must add the energy consumed to construct the building. Table C-2 shows the total energy embodied in direct fuel transactions per dollar of New Building Sector, prorated per square foot of building of that sector. By multiplying the Btu/SF for the appropriate building type by the gross square feet of the building under consideration, one can estimate not only the fuel needed for the actual construction process, but also that portion of the contractor or builder's office lighting and air conditioning which should rightfully be prorated to the construction project. It should be borne in mind that these figures are national averages and if applied to a specific project, will not reflect regional and local differences caused by weather patterns or the availability of different fuels.

This last increment of energy consumption must be added to the total embodiment of energy in materials and components at the jobsite to complete the analysis of energy embodied in a given building.

III B.2 Comparative Studies

B.2 COMPARATIVE STUDIES

There are several different methods employed to examine the energy used by industry to produce material goods.

1. An Industrial Process Survey. This is a detailed survey of each step in an industrial process. This study may be confined to only one portion in a chain of processes (e.g. iron smelting) or it may include the entire chain, e.g. steel making - from extraction of ore to the finished rolled sections. In general, this type of investigation is concerned with process energy only. It serves to pinpoint major points of energy use and is useful as a tool for energy conservation within the industrial process. Its data base is industry, and as far as it goes, this type of investigation is probably highly accurate; however, since it may not include all stages in a particular process chain from raw material in situ to finished product, and since it does not generally include transportation of materials at different stages of the chain or administrative energy, a significant amount of the energy ultimately attributable to a particular material is not counted.

2. Energy in/Product out. This type of analysis compares the energy purchased by a sector of industry to the material goods which it produced. Thus, it will include administrative energy and any transportation for which the fuel was purchased directly by the sector under study. It is more complete than a study of the process itself; however, if the sector itself produces a variety of products, the average values derived through this type of investigation may suffer distortion. The data source is generally the U.S. Department of Commerce, Bureau of the Census. These data will refer only to the specific sector under investigation, and will not include energy consumed during earlier stages of the process chain or in transportation between stages.

3. Energy Input/Output. This approach, which we have used in our study, uses as a base the economic input/output matrix developed by the Department of Commerce Bureau of Economic Analysis, and translated from dollar transactions into energy transactions by CAC. It includes all indirect purchases of fuel - process energy consumed by sectors contributing to the sector under investigation; transportation between stages of the process chain; administrative energy, etc. - and is the approach of choice for studying any large segment of the economy and/or any sector in terms of its relationship to the total economy. It is the only approach which includes all steps in the chain of industrial process and all inputs to a given sector from other sectors.

   As does the energy in/product out method, this approach uses average figures for groups of products which may be extremely diverse. In addition, since the basis for this approach is dollar value, there is the possibility of distortion of energy values due to price differences based on non-energy factors. However, when, in the investigation of specific products or materials, such distortion is found to occur, it is possible, within the I/O framework, to examine the product components individually through the hybrid analysis described in Section B.1, to arrive at an accurate energy value. This will redistribute the energy within a sector more accurately but will not destroy the completeness of the whole accounting.

As part of this study, we have investigated other studies of energy embodied in basic building materials and products. The following pages identify these studies, the basis approach used in each, and the different Btu/unit values arrived at. In general, none of the other studies was broken down to as specific a degree of detail as this one.

Although no single study included all of the materials and products investigated by CAC/RGSA, the aggregate 13 comparative studies include nearly all broad categories.

Considering the wide variation among all of the studies with reference to method of approach, data base, year of study, and depth of detail, it is not surprising that there is a variation of up to 2.5 times (in the case of aluminum) between the highest and lowest values found for comparable units across all of the studies considered. If the extremes are ignored, however, we find the degree of correlation confirms the validity of our results.

Tables B-21 to B-22 list the similar studies alphabetically, and identify the method used, reference year of data used, the factors included, and the national origin of the data in each study. Methods identified are: Industrial Process Survey (IPS), Energy in-Product Out (EI-PO) and Energy Input/Output (I/O.) "Transport" refers to the energy needed to transport the product and/or its components between stages in the process chain and from the termination of industrial process to the end user. "Administr. Energy" refers to the energy needed for administration of the industry: office lighting, space heating, and so forth. "Entire Process Chain" refers to the inclusion of all stages of process, from extraction of raw materials to production of the completed unit or material.

Tables B-23 to B-28 list the comparative energy values per unit of material cited in the different studies.

This Study	Method	Data Year	Study Includes: Transport Energy	Administr Energy	Entire Process Chain	Origin of Data
CAC/RGSA, "Energy Use For Building Construction" prepared for ERDA, 1976	I/O	1967	Yes	Yes	Yes	U.S.
Comparative Studies						
American Gas Assn., Inc. "A Study of Process Energy Requirements for U.S. Industries" Individual articles on: Cement, Lime, Gypsum Products, Brick, Steel, and Nonferrous Metals	IPS & EI-PO	Various (mid-1960's)	No	Some	Yes	U.S.
Berry & Fels, "The Production & Consumption of Automobiles" for Illinois Institute for Environmental Quality, July, 1972	EI-PO	1967	Yes	Yes	Yes	U.S.
Bravard, Flora, & Portal, "Production & Recycle of Metals," ORNL, Nov 1972	IPS	Various	No	No	Yes	U.S.
Chapman, P.F., "The Energy Costs of Materials," Energy Policy, Mar 1975	EI-PO	1971-72	No	Yes	Yes	U.K/ World
Conference Board, "Energy Consumption in Manufacturing," for NSF, 1974 Individual articles by different authors on: Brick, Structural Clay, Lime, Glass, Cement, Concrete, Steel, Aluminum	EI-PO & IPS	Various	No	Some	Yes	U.S.

Comparative Studies	Method	Data Year	Study Includes: Transport Energy	Administr Energy	Entire Process Chain	Origin of Data
Gartner & Smith, "Energy Costs of House Construction," Energy Policy, June, 1976	IPS & EI-PO	1968-75	No	Some	Yes	U.K.
Haseltine, B.A., "Comparison of Energy Requirements for Building Materials and Structures," The Structural Engineer, Sep 1975	EI-PO & I/O	Various 1963-74	Yes	Yes	Yes	U.K.
Hayes, Earl T., "Energy Implications of Materials Processing," Science Magazine	IPS & EI-PO	1973	No	Yes	Yes	U.S. & U.K.
Ilse, J., Univ. of Minnesota masters thesis, cited in Solar News & Views July, 1976, p. 4	IPS	Various		Not Known		U.S.
Kegel, R.A., "The Energy Intensity of Building Materials," Heating/Piping/Air Conditioning, Jun 1975	IPS	Not Known	Part	No	No	U.S.
Makhijani & Lichtenberg, "Energy and Well Being," Environment, June, 1972	IPS & EI-PO	Various 1963-68	Yes	Yes	Yes	U.S.
Portland Cement Assn, "Energy Conservation Potential in the Cement Industry," for FEA, June, 1975	IPS	1967	No	No	Yes	U.S.
Wright, D.J., "Energy Budgets: Goods & Services," Energy Policy, Dec 1974	I/O	1963	No	Yes	Yes	U.S. & U.K.

WOOD PRODUCTS		MBtu Embodied Before Delivery to Jobsite	MBtu Embodied After Delivery to Jobsite
Sawmill & Planing Mill Products per Bd Ft			
CAC/RGSA	Softwood	5.3	7.7
	Hardwood	6.7	9.7
Makhijani & Lichtenberg			5.2
Gartner & Smith		5.3	
Plywood per Sq Ft			
CAC/RGSA		3.8 - 12.9	5.0 - 17.0
Wright		4.8	

PAINTS & ALLIED PRODUCTS	MBtu Embodied Before Delivery to Jobsite	MBtu Embodied After Delivery to Jobsite
Paint per Gallon		
CAC/RGSA	369.5 - 429.9	437.0 - 489.1
Wright	681.4	

FLAT GLASS		MBtu Embodied Before Delivery to Jobsite	MBtu Embodied After Delivery to Jobsite
Glass per Sq Ft			
CAC/RGSA	Sheet	11.9 - 17.4	13.7 - 20.0
	Plate & Float	30.1 - 47.6	34.6 - 54.7
	Laminated	98.8 - 185.1	113.5 - 212.5
	Tempered	63.2	72.6
Ilse	Average	31.7	
Kegel	1/8" thick	19.5	
Flat Glass per Pound			
CAC/RGSA	Approx.	12.8	
Chapman		9.6	
Ilse	Approx.	13.9	
Kegel		12.6	
Makhijani		11.9	

STONE AND CLAY PRODUCTS		MBtu Embodied Before Delivery to Jobsite	MBtu Embodied After Delivery to Jobsite
Cement per Barrel			
CAC/RGSA	Average	1528.3	1584.4
Chapman		1280.6	
Haseltine		1263.1	1301.5
Gartner & Smith		1304.4	
Portland Cement Association		1243.1	
Conference Board - Gelb		1257.2	
American Gas Association		1136.6	
Makhijani & Lichtenberg			1475.3
Hayes		1428.8	
Brick per Brick			
CAC/RGSA	Common or Face (7 5/8" x 2 1/4" x 3 5/8")	13.6	14.3
Conference Board - Chiba		10.7	
Kegel		15.2	

NOTE: The values cited for brick in two British studies (Gartner & Smith and Chapman) have not been included in this tabulation because of the extreme discrepancy between their values and those cited in the three studies above, all of which use data referenced to U.S. industry. Whether this difference is a function of different materials, process, or method of accounting was not evident from the material available to us. According to representatives of the industry with whom we have spoken, neither process nor material differences account for the discrepancy.

STONE & CLAY PRODUCTS (Con't)		MBtu Embodied Before Delivery to Jobsite	MBtu Embodied After Delivery to Jobsite
Concrete Block per Block			
CAC/RGSA	Heavy aggregate	28.6	31.4
Conference Board - Chiba	Average	15.8 - 31.6	
Kegel		15.2	
Ready Mix Concrete per CY			
CAC/RGSA		2584.9	2594.3
Haseltine	Site mix	2733.6	3059.7
Gartner & Smith	Av. Light wt	1630	
	Av. Dense	2175	
Kegel		1672.7	
Berry & Fels			2541.9
Lime per T (2000 lbs)			
CAC/RGSA	Quicklime	6394.7	6967.5
	Hydrated Lime	8812.4	9463.9
	Dead-burned Dolomite	9077.3	9748.4
American Gas Association	Average	5935.7	
Conference Board - Chiba	Average	6217.7	
Hayes	Quicklime	8500	

PRIMARY IRON AND STEEL

Carbon Steel per Pound

		MBtu Embodied Before Delivery to Jobsite	MBtu Embodied After Delivery to Jobsite
CAC/RGSA	Reinf Bars	14.9	15.7
	Mesh	23.0	24.2
	Hot rolled struct'l shapes	17.8	18.7
	Pipe	24.5	25.8
Bravard	Raw steel	15.7	
	Fin steel	23.7	
Chapman	Raw steel	16.3	
	Fin steel	20.4	
Haseltine	Average	13.3	13.4
Ilse	Average	15.5	
Kegel	Average	13.8	
Conference Board - Rabitsch	Raw steel	12.7	
Makhijani & Lichtenberg	Rolled steel		21.5
Wright	Raw steel	11.8	
American Gas Association	Average	11.0	
Berry & Fels	Cold rolled pipe		26.4
	Wire		30.6
Hayes	Steel slab	12.0	

NONFERROUS METALS		MBtu Embodied Before Delivery to Jobsite	MBtu Embodied After Delivery to Jobsite
Aluminum per Pound			
CAC/RGSA	Plate	113.9	115.6
	Sheet	94.6	95.9
	Rolled shapes	90.9	92.1
American Gas Association	Ingot	74.5*	
Makhijani & Lichtenberg	Rolled shapes		114.6
Bravard		109.0	
Chapman		140.9	
Haseltine		111.3	111.8
Conference Board - Elliott-Jones		98.0	
Ilse		111.0	
Berry & Fels	Rolled shapes		125.3
Hayes	Ingot	122	
Kegel		126*	

*Figures cited in text have been adjusted here to account for source energy needed to produce electricity used in process.

III C

Energy Use per Square Foot in New Building

C. ENERGY USE PER SQUARE FOOT OF BUILDING TYPE

The base document for this sub-study is the Dodge Construction Statistics, United States Summary Bulletin for December, 1967, which tabulates both square footage and dollar cost of construction in that year according to the various building types. The building types categories used by Dodge are closely comparable to those used by BEA, which also uses the Dodge data as one of its sources, and the 23 building sectors isolated by Dodge are easily aggregated for comparison with 15 of the 18 New Building sectors isolated by BEA. Three of the BEA New Building sectors are not included: 27: Residential Alterations and Additions; 48: Farm Residential; and 49: Farm Service Facilities. Sector 27 is not quantifiable on a square foot basis, in that alterations add dollar cost and energy use to the total for the construction industry but do not add square footage to the building while additions add all three. It can be assumed that the Btu/SF figure applied to Sector 23: 1-Family Residential would apply to residential additions as well.

Data on square footage and dollar cost of New Farm Residential and New Farm Service Facilities are available for the two-year period, 1968 to 1970[3]. We have assumed that 1967 statistics, which are not available, are similar.

Table C1 shows Btu/SF used in 1967 by various new Building Construction Sectors. As has been mentioned earlier in this report, the data compiled by F.W. Dodge Company, noting dollars and square feet of construction for the various types of building construction must be used with a certain degree of care. The Dodge figures are based on information received from contractors for construction projects bid in 1967. This data base is comparable to that used by the Department of Commerce for its Census of Construction Industries (CCI)[4]. However, since Dodge does not cover the smaller establishments or smaller construction contracts, they report only about 75 percent of the dollar volume of construction reported in CCI.

Neither Dodge nor CCI reports that segment of construction performed by establishments or individuals not classified as "contractors" i.e., suppliers, materials manufacturers, and "do-it-yourself." According to BEA, which does include this activity in its data, this segment is substantial and accounts for nearly 1/3 of the dollar volume of all construction. In addition, mobile houses, which in 1967 represented over 22 percent of all new single family dwelling units, are not included.[5]

The Census of Agriculture (CA) represents yet another data base, and one of the sectors for which it provides information, namely, Sector 49; Farm Service Buildings, represents a class of construction which is distinctly different from all the other types of building construction. As a whole, the structures are much simpler than other types of buildings. The most complex: milking parlors and round grain storage facilities (silos), which approach warehouses in cost per square foot ($6.77 and $6.42, respectively), account for only 6 percent of the total square footage in this sector (but over 20 percent of the dollar cost). At the other end of the spectrum are hay storage sheds and a variety of livestock shelters which are often little more than lean-tos. Over 40 percent of the square footage (representing 24.9 percent of the dollar value) in this sector was built at costs ranging from $1.40 down to $0.78 per square foot. Also contributing to the extremely low overall average cost per square foot of construction in this sector is a significant amount of "do-it-yourself" activity and the reuse in new construction of materials taken from other buildings on the farms reporting to the Census Bureau.

The relatively high energy intensity of Sector 49 is a result of the fact that a high percentage of purchased materials were themselves energy intensive; e.g. metal cladding for silos, roofs, etc., which is a component of the miscellaneous metal sector (399 level) appearing in the bar chart on Table A-8. Sector 49 covers an unusually wide range of building types, and any further study of this sector should be broken down by building types. However, since the sector in its entirety represents only 1.7 percent of the total energy of final demand for New Building Construction, we have confined our study to the average figures.

Although the dollar figures shown by Dodge, CCI, CA and BEA cannot be used interchangeably, the average cost per square foot ($/SF) of the various building types derived from the Dodge or CA data alone is a valid average figure which can be applied to BEA/CAC figures. This application results in the derivation of not only a Btu/SF figure for each building type, but also a revised estimate of the total square footage of building in the year under study. This revision yields adjusted totals in square footage with little correlation to the Dodge totals. This is because the BEA/CAC data is derived from actual transactions in 1967 and therefore reflects actual construction during that year, while the Dodge data is derived from bidding occurring in 1967 and reflects construction transactions occurring over a period of years starting in 1967. Since the number of square feet of a particular building type built during one year is not constant, but varies widely from year to year, the lack of correlation with respect to total square feet is explainable. The important point is that the amounts bid for the square footage reported to Dodge remain an accurate estimate of building cost in 1967.

With regard to the two categories, 48 and 49, dealing with farm buildings, the Census of Agriculture is also referenced to a different year. In addition, however, reporting on farm structures is traditionally less precise than reporting in other categories and the entire segment is often left out of building statistics. There is no reason to assume that construction of farm residences actually dropped dramatically between 1967 and 1968 while construction of farm service facilities remained roughly the same; however, we are not aware of any other information in the subject. It should be noted that the Dodge and CA figures correspond to end use, (i.e., they include value added: rents, profits, wages, etc.) and are therefore compatible with the energy intensities produced by CAC.[1]

Table C-2 shows the amount of Btu/SF which may be attributed to the total energy embodied in direct fuel purchase for each of the 18 New Building Sectors. This represents the energy used in the construction process, including energy purchased by the Contractor to light and heat his home office; gasoline and diesel fuel purchased by the Contractor or builder to run his own vehicles and equipment, fuel and electricity required to heat, light and run on-site equipment during construction, and so forth. Once a take-off has been made of the energy embodied in the building materials at the job site (see Section B.1 of this report), the figures in Table C-2 may be multiplied by the total gross square footage of the building and added to the take-off to complete an estimate of the energy embodied in a given complete building.

Table C-3 presents in graphic form the revised estimate of total square footage allocated to each of the various building types and the total Btu and Equivalent Gallons of Oil which can be allocated to new construction for each type for the year 1967.

1967 ENERGY EMBODIMENT PER SQ FT OF BUILDING TYPE

CAC NO	1967 I/O 399 LEVEL NEW BUILDING CONSTRUCTION	1967 SQ FT + $ ESTIMATED VALUE REPORTED TO F.W. DODGE CO.[1] SQ FT	$	TOTAL $/SQ FT	BTU/$[2]	BTU/ SQ FT	TOTAL BTU PER SECTOR[2]	TOTAL SF BUILT (PER BEA) (BTU ÷ BTU/SF)
23	RESIDENTIAL - 1 FAMILY	1,050,517,000	13,285,874,000	12.65	55.511	702,047	780.98×10^{12}	1,112,432,899
24	RESIDENTIAL - 2-4 FAMILY	40,609,000	486,827,000	11.99	52,139	625,050	34.83	55,723,505
25	RESIDENTIAL - GARDEN APT	352,452,000	4,323,280,000	12.27	52,864	648,445	147.76	227,868,071
26	RESIDENTIAL - HIGH RISE				60,000	735,978	117.96	160,276,608
27	RESIDENTIAL - ALTER & ADDN	-	-	-	51,646	-	216.85	-
28	HOTEL/MOTEL	35,633,000	581,310,000	16.31	69,184	1,128,655	69.05	61,179,014
29	DORMITORIES	42,372,000	858,629,000	20.26	70,604	1,430,724	57.82	40,413,106
30	INDUSTRIAL BUILDINGS	269,650,000	3,700,726,000	13.72	70,864	972,551	463.38	476,458,548
31	OFFICE BUILDINGS	158,318,000	3,781,344,000	23.88	68,737	1,641,748	258.66	157,551,585
32	WAREHOUSES	95,390,000	686,843,000	7.20	77,556	558,432	57.78	103,467,569
33	GARAGES/SERVICE STATIONS	37,720,000	381,812,000	10.12	76,217	771,489	32.24	41,789,319
34	STORES/RESTAURANTS	170,146,000	2,188,587,000	12.86	73,183	941,353	197.01	209,283,984
35	RELIGIOUS BUILDINGS	41,379,000	793,407,000	19.17	65,597	1,257,766	68.61	54,549,077
36	EDUCATIONAL	204,258,000	4,168,058,000	20.41	67,924	1,386,046	437.36	315,544,880
37	HOSPITAL BUILDINGS	65,820,000	1,873,269,000	28.46	60,512	1,722,200	117.21	68,058,263
38	OTHER NON-FARM BUILDINGS	123,698,000	2,564,814,000	20.73	69,894	1,449,216	231.07	159,444,843
	a. AMUSEMENT, SOCIAL & REC[4]	42,249,000	834,047,000	19.74	69,894	1,379,793	-	-
	b. MISC NON-RESIDENTIAL BLDG[4]	43,299,000	682,678,000	15.77	69,894	1,101,991	-	-
	c. LABORATORIES[4]	20,387,000	604,970,000	29.67	69,894	2,074,056	-	-
	d. LIBRARIES, MUSEUMS, ETC.[4]	17,763,000	443,119,000	24.95	69,894	1,743,588	-	-
48	FARM RESIDENCES	29,463,000	303,930,000	10.32	53,773	554,703	30.22	54,479,560
49	FARM SERVICE	380,760,000	737,565,500	1.94	76,956	149,071	57.88	388,272,615
							TOTAL SQ FT:	3,686,793,446

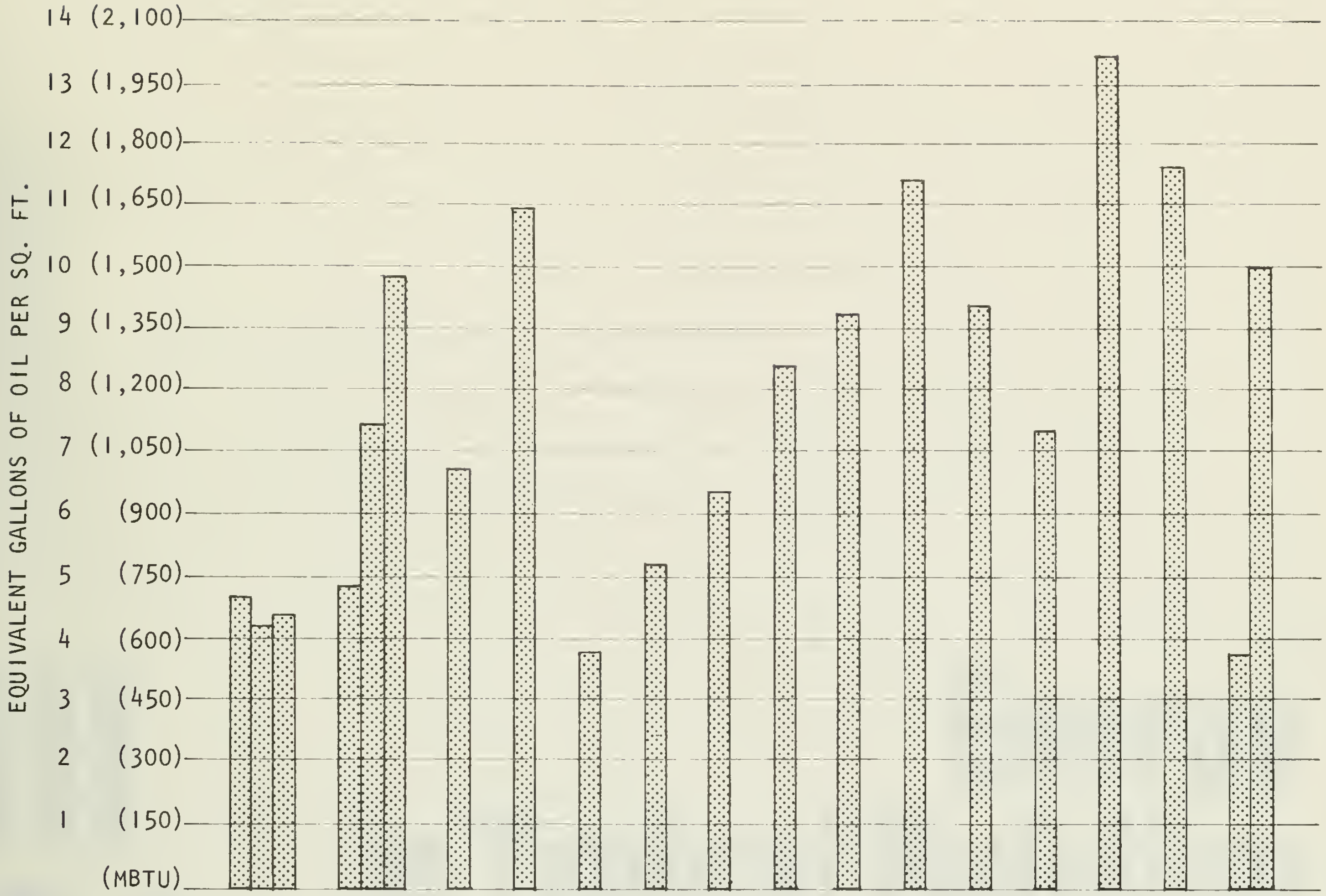
NOTES:

1. SOURCE: F.W. DODGE CO., DODGE CONSTRUCTION STATISTICS 1967 (BASED ON CONTRACTORS' BID PRICES)
2. SOURCE: FROM CENTER FOR ADVANCED COMPUTATION
3. SOURCE: 1969 CENSUS OF AGRICULTURE, VOL. V, SPECIAL REPORTS, FARM FINANCE
4. INCLUDED IN TOTAL FOR 38

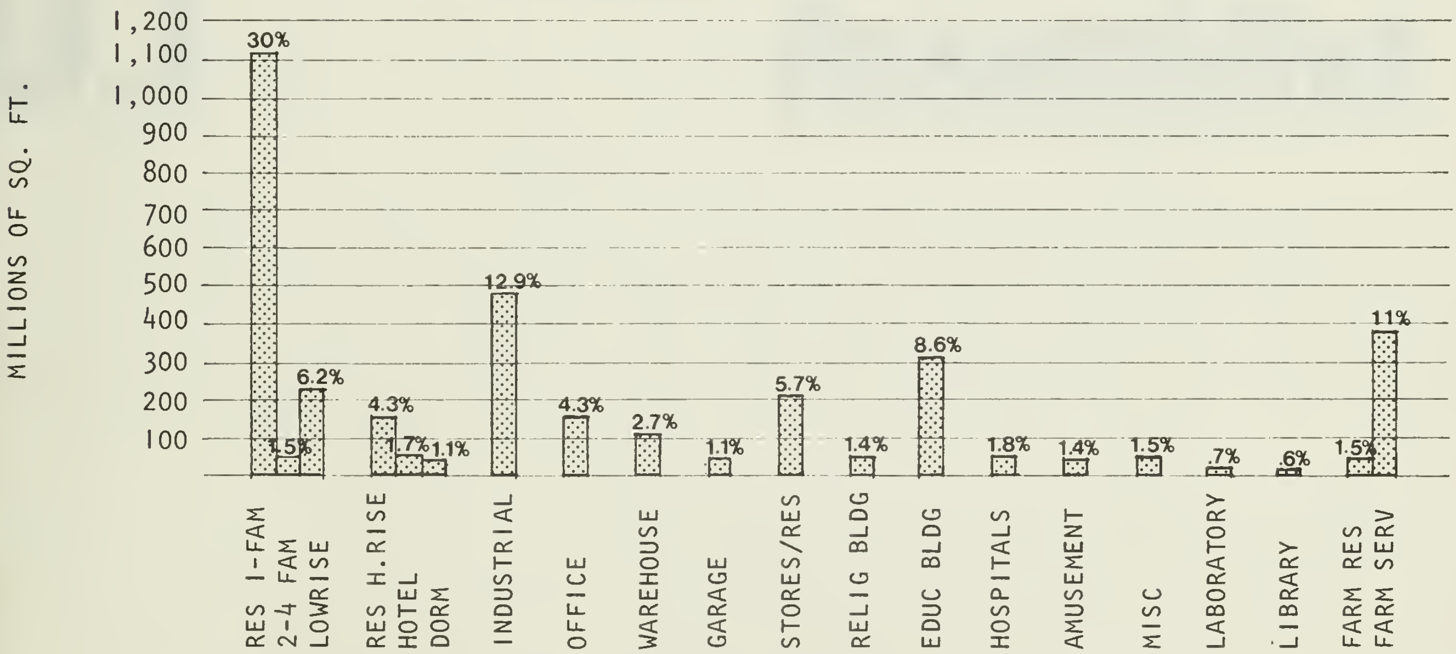
PARTIAL ENERGY EMBODIMENT

DIRECT FUEL PURCHASES PER SQ FT OF BUILDING TYPE

CAC NO	1967 I/O 399 LEVEL NEW BUILDING CONSTRUCTION	TOTAL $/SQ FT	ENERGY EMBODIED IN DIRECT FUEL PURCHASES BTU/$	BTU/SF
23	RESIDENTIAL - 1 FAMILY	12.65	6,892	87,184
24	RESIDENTIAL - 2-4 FAMILY	11.99	8,629	103,462
25	RESIDENTIAL - GARDEN APT	12.27	9,426	115,657
26	RESIDENTIAL - HIGHRISE		12,344	151,461
27	RESIDENTIAL - ALTER & ADDN	-	1,844	
28	HOTEL/MOTEL	16.31	15,093	246,167
29	DORMITORIES	20.26	16,186	327,928
30	INDUSTRIAL BUILDINGS	13.72	7,182	98,537
31	OFFICE BUILDINGS	23.88	15,150	361,782
32	WAREHOUSES	7.20	10,801	77,767
33	GARAGES/SERVICE STATIONS	10.12	15,073	152,539
34	STORES/RESTAURANTS	12.86	17,143	220,459
35	RELIGIOUS BUILDINGS	19.17	13,319	255,325
36	EDUCATIONAL BUILDINGS	20.41	13,025	265,840
37	HOSPITAL BUILDINGS	28.46	12,450	354,327
38	OTHER NON-FARM BUILDINGS	20.73	15,142	313,894
	a. AMUSEMENT, SOCIAL, RECREATION	19.74	15,142	298,903
	b. MISC NON-RESIDENTIAL BUILDINGS	15.77	15,142	238,789
	c. LABORATORIES	29,67	15,142	449,263
	d. LIBRARIES, MUSEUMS, ETC	24.96	15,142	377,944
48	FARM RESIDENCES	10.32	6,624	68,360
49	FARM SERVICE	1.94	5,612	10,887



TOTAL EMBODIED ENERGY PER SQUARE FOOT OF BUILDING PER BUILDING TYPE



TOTAL ANNUAL (1967) SQUARE FEET OF BUILDING PER BUILDING TYPE

CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791		date 30 Dec 76
and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	Subject Total Annual Area & Embodied Energy (Btu/SF) for Building Types	by **CAC** **RGS & A**	file **C3**

III
D.1

Energy in Typical Building Assemblies

D.1 ENERGY IN TYPICAL BUILDING ASSEMBLIES

Once the energy embodiment of various units of building materials is estimated, it is then possible to compare the energy needed to construct interchangeable assemblies which satisfy similar performance requirements (structural, fire resistance, acoustical, maintenance, etc.). It is also possible to reexamine energy efficiency of alternatives by comparing the energy cost of providing, say, extra insulation or double glazing with the operational energy saved thereby, and to arrive at an energy payback time. This comparison is exactly parallel with the calculation of capital payback which would be done as a matter of course. Then, by adding the operational energy demand implied by a particular assembly - an exterior wall section, one square foot in area, for example - to the energy embodied in its material components, together with the energy embodied in materials necessary to maintain it, such as paint, caulking, replacement of shingles, and so forth, it is also possible to estimate the life cycle energy cost of comparable assemblies and to extend such an analysis to an entire building. Tables D-1 to D-3 compute the energy embodied in a section of floor slab 30' by 30' square, typical of comtemporary high-rise office buildings. Three interchangeable structural systems have been shown: Steel, concrete, and composite. In spite of their names, all three use both steel and concrete in varying proportions. They all reflect the basic structural properties of these two materials, steel having strength in both compression and tension and concrete having strength in compression only.

In standard steel construction, the floor deck is typically concrete, designed to be strong enough to span between the beams on which it rests. Due to friction between the slab and the beams, the slab will contribute to the strength of the structure as a whole. The amount of the contribution is indeterminate, however, and building codes do not allow it to be considered in the design of the system. Thus, the slab is considered merely dead weight on the beams and girders. The slab itself is shown poured over a corrugated metal deck. The metal deck acts as both formwork and reinforcement for the concrete.

In composite construction metal shear connectors are welded through the deck to the beams below. This welding is generally done in the field. The shear connectors form a positive connection between the beams and the deck, creating, in effect, a compression flange on top of the steel beams. Because of the positive connection, the structural properties of the slab are permitted by building codes to be taken into consideration in the design of the steel beams below, and the weight of the beams and girders is reduced from that necessary for standard construction. In concrete construction a great deal of steel (in the form of reinforcing bars) is used to take care of tensile stress. Overall, however, there is less steel in a concrete structure (by weight) and the steel which is used is all reinforcing bars, which have a lower energy embodiment per pound than does fabricated structural steel (15,664 vs 22,698 Btu). Even so, 55.5 percent of the energy embodied in the concrete system is due to reinforcing steel.

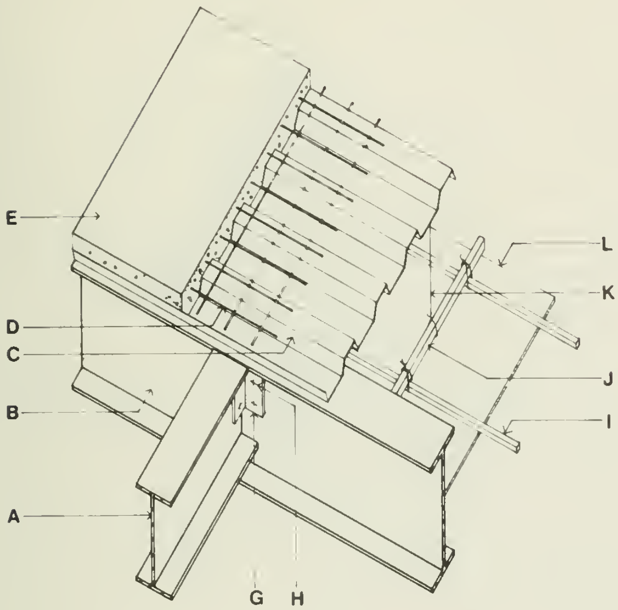
Factors which have not been included in these computations are formwork for the concrete structure and on-site energy use. The contribution of formwork and the temporary bracing to support it can be assumed to be insignificant. (3/4" plywood, assuming it will be reused 10 times, will add ±1,000 Btu/SF; metal pans and temporary braces may be reused dozens of times and thus their contribution is negligible.)

We can compute on-site energy use only as an average per square foot according to building type. The only on-site activity specific to these examples which might provide a significant increment beyond the average, is the field welding of shear connectors for the composite steel system. A closer investigation shows that this, too, will have a negligible effect overall:

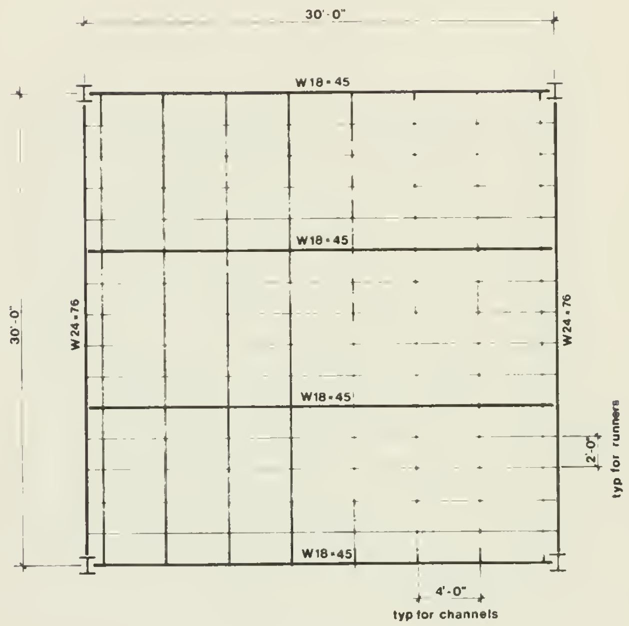
> A stud welder of the sort used in building construction draws 191.2 kw when it is actually in use. The rest of the time it idles, drawing 5.8 kw. The average machine will be used to weld 800 studs/day at 1 second of welding time/stud.[6] 800 seconds = 0.22 hours. Thus, during an 8 hour day, the machine will draw:
>
> 191.2 kw x 0.22 hours = 45.12 kwh
>
> \+ 5.8 kw x 7.78 hours = 9.27 kwh
>
> Total: 54.39 kwh/day or 6.8 kwh/hour

STANDARD STEEL SYSTEM
TYPICAL FLOOR BAY

TYPICAL CONSTRUCTION



FRAMING PLAN



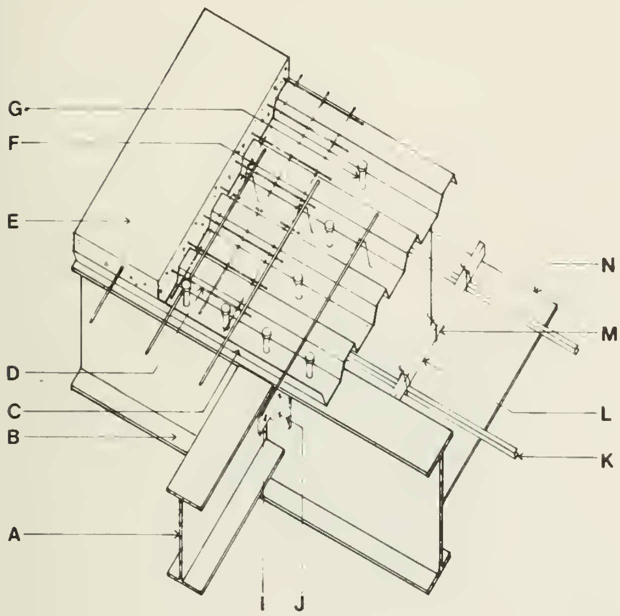
	Material	Size	Quantity	Weight/ Unit	Total Weight (30 x 30 Bay)	Embodied Energy (Btu/Unit)	Total Embodied Energy
A.	Filler Beams	W 18 x 45	90 ft	45 lb/ft	4,050 lb	22,707 Btu/lb	91,963,350 Btu
B.	Girder	W 24 x 76	30 ft	76 lb/ft	2,280 lb	22,707 Btu/lb	51,771,960 Btu
C.	Steel Deck	20 gauge	900 ft^2	2.15 lb/ft^2	1,935 lb	27,836 Btu/lb	53,[illegible],66[illegible] Btu
D.	Temp Reinf	6 x 6 #8/#8	900 ft^2	.30 lb/ft^2	270 lb	24,187 Btu/lb	6,530,490 Btu
E.	Conc Deck	4" thick	900 ft^2	.33 ft^3/ft^2	300 cu ft	96,087 Btu/cu ft	28,826,100 Btu
F.	Girder Angles	3½" x 5/16" x 10"	4	6.0 lb ea	24 lb	22,707 Btu/lb	544,968 Btu
G.	Filler Angles	3½" x 5/16" x 7"	12	4.2 lb ea	50.4 lb	22,707 Btu/lb	1,144,432 Btu
H.	Bolts	3/4" H.S. Bolts	36	.55 lb ea	19.8 lb	26,625 Btu/lb	527,175 Btu
I.	Channels	1½" x 3/4" x 1/8"	210 ft	1.20 lb/ft	252 lb	22,707 Btu/lb	5,722,164 Btu
J.	Runners	3/4" x 3/4" x 3/32"	480 ft	.72 lb/ft	346 lb	22,707 Btu/lb	7,856,622 Btu
K.	Wirehangers	¼" diam	98 ft	.17 lb/ft	16.6 lb	34,385 Btu/lb	570,791 Btu
L.	Gyp Board	½" thick	900 ft^2	2.0 lb/ft	1,800 lb	3,485 Btu/lb	6,273,000 Btu
							263,450,334 Btu

÷ 900 = 292,723 Btu/SF

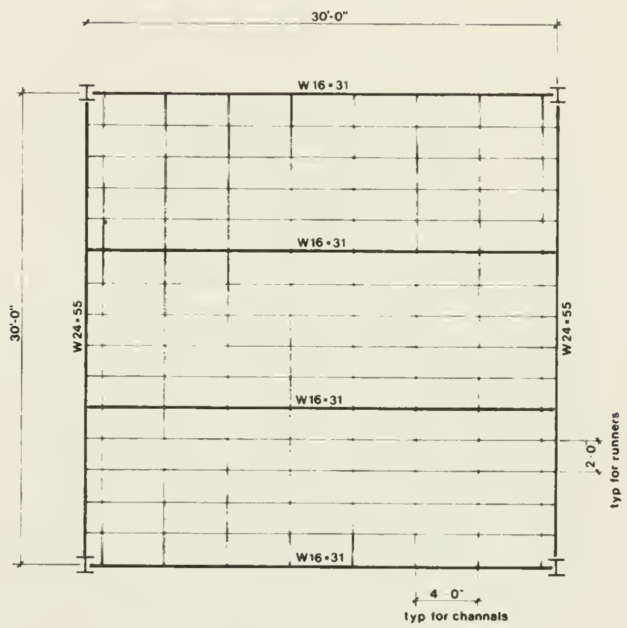
CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801 and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791	date 30 Dec 76
	Subject Embodied Energy in Typ. Building Assemblies by CAC / RGS & A	file **D1**

COMPOSITE STEEL SYSTEM TYPICAL FLOOR BAY

TYPICAL CONSTRUCTION



FRAMING PLAN



	Material	Size	Quantity	Weight/ Unit	Total Weight (30 x 30 Bay)	Embodied Energy (Btu/Unit)	Total Embodied Energy
A.	Filler Beam	W 16 x 31	90 ft	31 lb/ft	2,790 lb	22,707 Btu/lb	63,352,530 Btu
B.	Girder	W 24 x 55	30 ft	55 lb/ft	1,650 lb	22,707 Btu/lb	37,466,550 Btu
C.	Steel Deck	20 gauge	900 ft^2	2.15 lb/ft^2	1,935 lb	27,836 Btu/lb	53,862,660 Btu
D.	Temp Reinf	6 x 6 - #8/#8	900 ft^2	.30 lb/ft^2	270 lb	24,187 Btu/lb	6,530,490 Btu
E.	Conc Deck	4" thick	900 ft^2	.33 ft^3/ft^2	300 cu ft	96,087 Btu/cu ft	28,826,100 Btu
F.	Neg Reinf	#4 @ 12"	600 ft	.668 lb/ft	401 lb	15,664 Btu/lb	6,281,264 Btu
G.	Studs	3/4" x 3"	168	1.5 lb ea	252 lb	26,625 Btu/lb	6,709,500 Btu
H.	Girder Angles	3½" x 5/16" x 10"	4	6.0 lb ea	24 lb	22,707 Btu/lb	544,968 Btu
I.	Filler Angles	3½" x 5/16" x 7"	12	4.2 lb ea	50.4 lb	22,707 Btu/lb	1,144,432 Btu
J.	Bolts	3/4" H.S.	36	.55 lb ea	19.8 lb	26,625 Btu/lb	527,175 Btu
K.	Runners	3/4" x 3/4" x 3/32"	480 ft	.72 lb/ft	346 lb	22,707 Btu/lb	7,856,622 Btu
L.	Channels	1½" x 3/4" x 1/8"	210 ft	1.20 lb/ft	252 lb	22,707 Btu/lb	5,722,164 Btu
M.	Wirehangers	¼" diam	98 ft	.17 lb/ft	16.6 lb	34,385 Btu/lb	570,791 Btu
N.	Gyp Board	½" thick	900 ft^2	2.0 lb/ft^2	1,800 lb	3,485 Btu/lb	6,273,000 Btu
							[illegible]5,668,[illegible]46 Btu

÷ 900 = [illegible]50,095 Btu/SF

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University of Illinois Urbana IL 61801

and

RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS
588 Fifth Avenue New York NY 10036

ENERGY IN BUILDING CONSTRUCTION
ERDA Contract No. E (11-1)-2791

date: 30 Dec 76

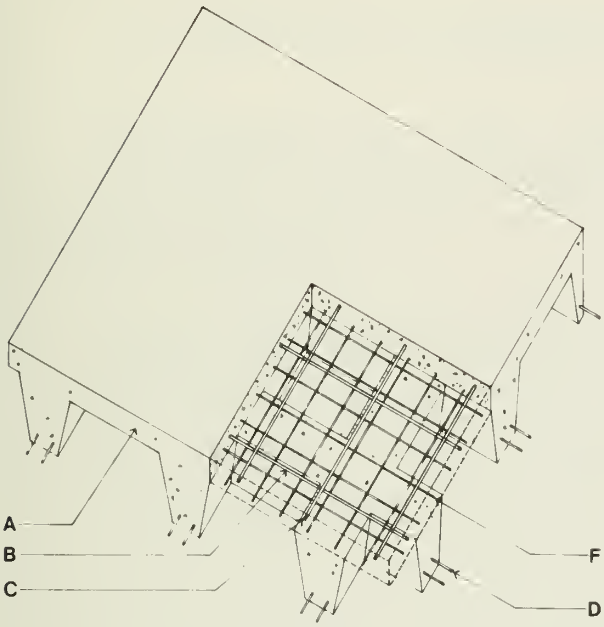
Subject: Embodied Energy in Typ. Building Assemblies

by: CAC / RGS & A

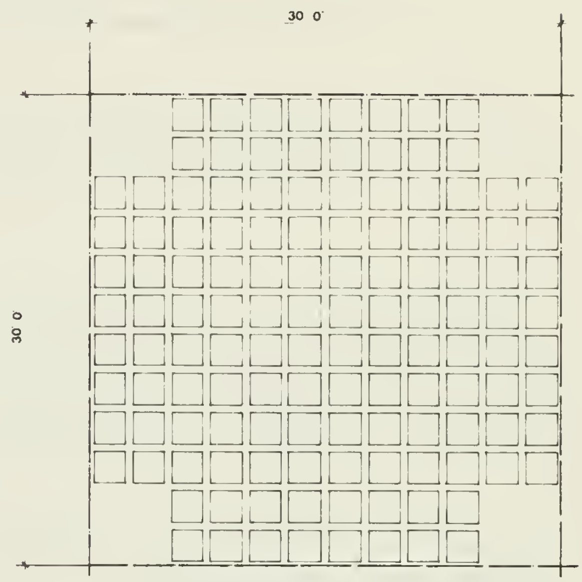
file: **D2**

REINFORCED CONCRETE SYSTEM TYPICAL FLOOR BAY

TYPICAL CONSTRUCTION



FRAMING PLAN



	Material	Size	Quantity	Weight/ Unit	Total Weight (30 x 30 bay)	Embodied Energy (Btu/Unit)	Total Embodied Energy
A.	Concrete	16" waffle	900 ft^2	.796 ft^3/ft^2	717 cu ft	96,087 Btu/cu ft	68,894,379 Btu
B.	Top col. strip Reinforcing	#6 bars	784	1.502 lb/ft	1,177 lb	15,664 Btu/lb	18,436,528 Btu
C.	Top mid strip Reinforcing	#4 bars	420 ft	.668 lb/ft	280.5 lb	15,664 Btu/lb	4,393,752 Btu
D.	Bottom rib col. strip reinf	#6 bars	960 ft	1.502 lb/ft	1,442 lb	15,664 Btu/lb	22,587,488 Btu
E.	Bottom rib mid strip reinf	#5 bars	1,440 ft	1.043 lb/ft	1,502 lb	15,664 Btu/lb	23,527,328 Btu
F.	Wire mesh Reinforcing	6" x 6" - 2/2	900 ft^2	.78 lb/ft^2	702 lb	24,187 Btu/lb	16,979,274 Btu
							154,818,749 Btu

÷ 900 = 172,021 Btu/SF

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University of Illinois Urbana IL 61801

and

RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS
588 Fifth Avenue New York NY 10036

ENERGY IN BUILDING CONSTRUCTION
ERDA Contract No. E (11-1)-2791

date 30 Dec 76

Subject: Embodied Energy in Typ. Building Assemblies

by **CAC** **RGS & A**

file **D 3**

At 800 studs/day, it will take 1.68 hours to install the 168 studs needed for the 900 square foot area shown in Figure D-2.

1.68 hours x 6.8 kwh/hour x 10,500 Btu/kwh = 119,952 Btu.

This represents less than 2 percent of the energy needed to produce the studs alone, and about 5/100 percent of the energy embodied in all of the materials shown.

As can be immediately observed from the three tables, a concrete waffle slab uses substantially less energy in its composition than either of the steel systems. Giving standard steel construction an index of 100, the three systems rank as follows:

System	Btu/SF	Energy Embodiment Index (for this comparison)
Standard Steel	293,187	100.0
Composite Steel	251,206	85.5
Concrete Waffle Slab	172,021	58.5

Although columns have not been considered in this analysis, a preliminary investigation indicates that the proportional difference in embodied energy between steel and concrete systems carries through the entire structure in spite of the fact that the concrete slab is approximately twice as heavy as the steel one. This is a conservative estimate, not taking into consideration lateral loads on tall buildings, which would penalize steel structures to a greater extent than concrete ones, or code-permitted reduction of live loads (people, furnishings, etc.) which would also be more advantageous to concrete.

These factors would both be taken into consideration in the actual design of a specific building. Local conditions could also affect the total embodiment of the two systems. These examples have been computed for codes and conditions pertaining to New York City, using high-strength steel with a 50 ksi (thousand pounds per square inch) yield point for the steel construction and 5 ksi concrete.

Interestingly, assuming a large project with many repetitive sections, the costs of the three systems are approximately the same. Cost differences fluctuate with market conditions (cost of steel versus cost of concrete at any given time) labor conditions and location. In general, the choice of system is made for other reasons.

1. If the depth of the structure is a problem, a concrete system will probably be chosen. If for other reasons a steel system is preferred, then a composite system will be chosen over standard construction. (In the example shown, the girder selected for the composite system is of the same depth but of a lighter weight than that selected for the standard system. A shallower, heavier girder could also be used.)

2. Although the timing of a project from start to finish of construction may be roughly the same for all three systems, the scheduling within that time will be different. In steel construction a great deal of time is needed at the start of a job to produce and check shop drawings and then to fabricate the steel. During this time no structural work is done on the job. This allows leeway in scheduling the work of other trades and in checking other trades' shop drawings.

   With concrete construction, on the other hand, the concrete work starts as soon as excavation is complete, in other words, close to the start of the construction period. There is less leeway in scheduling other trades, and there is a shorter period when changes arising from conflicts (discovered in checking other trades' shop drawings) may be easily made. Where scheduling is critical, a steel system might be preferred if steel is available.

   These conditions vary sufficiently from project to project, from locale to locale, and from one time to another to avoid generalizations. Recently, when the steel industry was operating at capacity, there were delays of a year and more before promised new rolled steel sections would be delivered, although bar steel for concrete construction was immediately available. That is no longer the case.

3. Many building designers - and many contractors - simply prefer working with one material over the other.

The differences in energy embodiment among the three systems are a function of the amount of steel necessary to each. Systems using less steel also use more on-site labor. At the moment the dollar cost of steel versus the dollar cost of labor appears to be an even trade off in this case.

If energy embodiment is the criterion, however, concrete will obviously be the system of choice. In 1967, we have estimated that there were 157.5 million square feet of new office building construction. If this area of construction had been built using a standard steel system exclusively, similar to the diagram shown in Table D-1, the energy embodiment for floor slabs alone would have been 46.18×10^{12} Btu. If only concrete waffle slab had been used, the total would have been 27.09×10^{12} Btu. The difference, 19.09×10^{12} Btu, is equivalent to over 127 million gallons or over 3 million barrels of No. 6 oil.

* * * *

Figures D-4 and D-5 compare two sections of wall typical of 1-Family Residential Construction: 2 x 4 wood framing with a wood shingle exterior and 2 x 4 wood framing with brick veneer. Whether the walls contain no insulation or 3½" of rock wool (as is common with this framing), the thermal performance of the all-wood alternative is similar to that of the brick veneered one.

Giving brick veneer on frame construction with no insulation an index of 100, the comparative sections rank as follows:

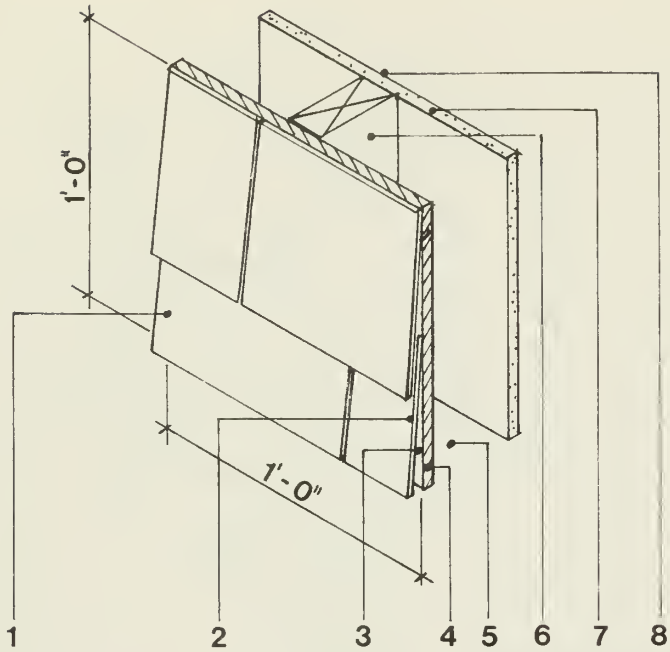
Section	Btu/SF	Energy Embodiment Index (For this comparison)
Brick Veneer on 2 x 4 Frame with no insulation	119,566	100.0
Wood Shingle on 2 x 4 Frame with no insulation	25,426	21.3
Brick Veneer on 2 x 4 with 3½" insulation	126,426	105.7
Wood Shingles on 2 x 4 Frame with 3½" insulation	32,286	27.0

The wide gap between the energy embodied in all wood construction as opposed to wood and brick is a function of the low energy intensity of wood and the high energy intensity of brick. In 1967, 1-Family Residential construction, in spite of a relatively low energy embodiment per square foot, accounted for more embodied energy than any other New Building Construction sector, mainly because of the large amount of square footage built in that year. Brick veneer is a common material in this building type, and in other low-rise constructions as well. Brick uses 4.4 percent of the energy allocated to 1-family residences. All told, 1-family residences accounted for 780.98 x 10^{12} Btu, of which brick accounted for 34.36 x 10^{12} Btu. At 85,698 Btu/SF,* this represents over 400 million square feet of brickwork. If the comparison between brick veneer and wood shingles shows a difference of 89,475 Btu/SF (119,566 -25,426), it accounts for a differential of a total of 37.66 x 10^{12} Btu for the entire square footage above. In terms of No. 6 oil, this amounts to 251.0 million gallons or 5.98 million barrels. A significant saving in energy consumption could be effected if brick and other energy intensive materials were limited to those uses where their inherent qualities made them most desirable.

In this study we have compared only two facing materials. A complete study, which would be necessary for a truly informed choice of materials to be made, would also include asbestos shingles, asphalt shingles, cement-asbestos board, and aluminum siding and other wood sidings. (The comparison of thermal performance is based on U-factors. For a description of U-factor, see Section D-2, page 98.)

*Six bricks/SF x 14.283 Btu/Brick = 85,698 Btu/SF

WOOD FRAME WALLS



	CONSTRUCTION	R VALUE		EMBODIED ENERGY (BTU/SQ FT) IN BLDG SECTION
1.	OUTSIDE SURFACE (15 MPH WIND)	.17		-
2.	WOOD SHINGLES (1/2" x 8" LAPPED)	.87		7,315
3.	BLDG PAPER (ASPHALT)	.15		-
4.	PLYWOOD (1/2")	.62		7,705
5.	4" AIRSPACE	.97		-
6.	2" x 4" @ 16" o.c.	-	4.35	3,486
7.	GYPSUM WALLBOARD (1/2")	.45		6,920
8.	INSIDE SURFACE (STILL AIR)	.68		-
		3.91	4.35	25,426

U = 1/R = .26   U = .23 @ FRAMING

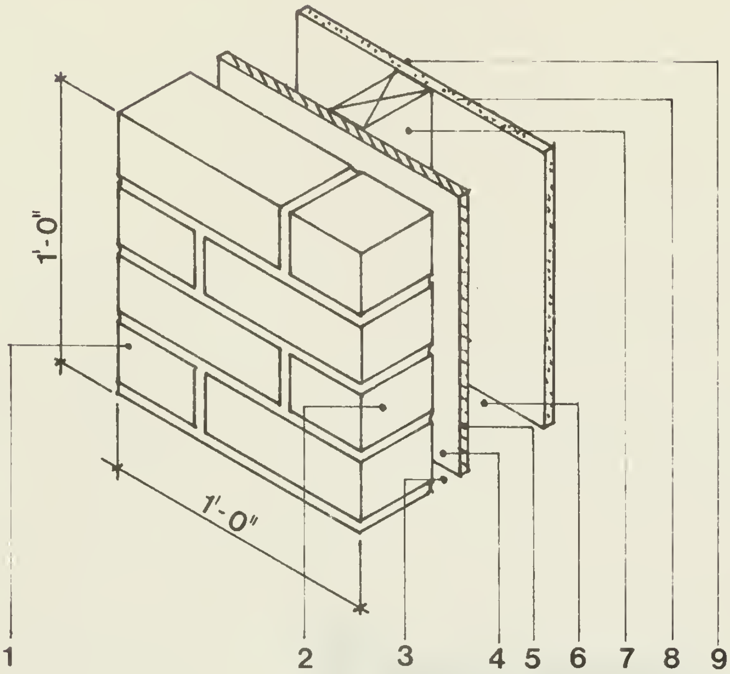
ADJUSTED U (TO ACCOUNT FOR FRAMING) = .25

ADDITION OF INSULATION	R VALUE	EMBODIED ENERGY (BTU/SQ FT) IN BLDG SECTION
ADD 3 1/2" BATT INSULATION	11.00	ADD 6,860
DEDUCT R VALUE OF AIR SPACE	.97	
	10.03	
ADD TO ABOVE R VALUE	3.91	
	13.79	32,286

U = 1/R = .07   U = .23 @ FRAMING

ADJUSTED U (TO ACCOUNT FOR FRAMING) = .085

BRICK ON WOOD FRAME WALLS



CONSTRUCTION	R VALUE		EMBODIED ENERGY (BTU/SQ FT) IN BLDG SECTION
1. OUTSIDE SURFACE (15 MPH WIND)	.17		-
2. BRICK & MASONRY (4")	.44		105,004
3. 1" AIRSPACE	.97		-
4. BUILDING PAPER (ASPHALT)	.15		-
5. PLYWOOD (3/8")	.47		5,779
6. 4" AIRSPACE	.97		-
7. 2" x 4" @ 16 o.c.	-	4.35	3,486
8. GYPSUM WALLBOARD (3/8")	.32		5,297
9. INSIDE SURFACE	.68		-
	3.98	4.35	119,566

U = 1/R = .25 U = .23 @ FRAMING

ADJUSTED U (TO ACCOUNT FOR FRAMING) = .24

ADDITION OF INSULATION	R VALUE	EMBODIED ENERGY ((BTU/SQ FT) IN BLDG SECTION
ADD 3 1/2" BATT INSULATION	11.00	ADD 6,860
DEDUCT R VALUE OF AIRSPACE	.97	
	10.03	
ADD TO ABOVE R VALUE	3.98	
	14.01	126,426

U = 1/R = .07 U = .23 @ FRAMING

ADJUSTED U (TO ACCOUNT FOR FRAMING) = .085

III D.2

Energy Cost Life-Cycle

D.2 ENERGY COST LIFE CYCLE

To understand the energy implications of building with various materials, one must look not only at the energy embodied in the construction and construction materials, but also at the energy demand which that construction imposes in terms of the operation of the completed building and the energy required to maintain or replace materials.

In some cases, such as alternate structural systems satisfying the same performance requirements, operational energy demand will not vary. In others, such as the amount of insulation in an exterior wall or double versus single glazing, the demand for operational energy may vary a great deal.

The demand for operational energy depends not only on the thermal qualities of the wall (or other assembly) but also on the location of the building. The thermal qualities of the wall are expressed by the "U-Factor," which is based on the thermal resistance of the various materials which make up the wall, and which indicates the number of Btu which will flow through one square foot of a material or assembly in one hour's time when there is a temperature difference of one degree Fahrenheit on opposite sides of the wall[7].

The average annual temperature variation, which will differ with the location of the building, is expressed by "degree days." The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) estimates that at 65° F. and below (outside temperature) one must start up a heating system in order to maintain 68° F. inside. The number of degrees below 65° F. of a given day's average temperature is equal to the number of heating degree days for that day. The U.S. Department of Commerce, National Oceanic and Atmospheric Administration has established annual heating and cooling degree day data for locations throughout the United States, based on a 30-year average. Since the degree day data refer to one average temperature for an entire day, one must multiply heating degree days by 24 to arrive at "degree hours" compatible with the U-factor (an hourly measure) in order to estimate the total number of Btu which would flow through a given wall or assembly in a year. This Btu flow (which must be counteracted by the building's heating system) is equal to the operational energy demand for heating posed by the given wall or assembly.

Operational energy demand for space heating per square foot of wall or other portion of the exterior envelope can thus be computed by the following formula:

Annual Heating Demand (Btu) = Heating Degree Days x 24 (hours/day) x U-Factor (Btu/hour)

Location	Heating Degree Days[8]	Annual Demand
Atlanta, GA (Atl)	3,095	x 24 = 74,280 x U = Btu/SF
New York City (NYC)	4,848	x 24 =116,352 x U = Btu/SF
Champaign-Urbana, IL (Ch-Urb):	5,641	x 24 =135,144 x U = Btu/SF

The U-values for the uninsulated walls shown in Figures D-4 and D-5 are .25 (wood shingle) and .24 (brick veneer). The U-values for walls with 3½" of insulation are .085 for both. The following table shows the annual Btu demand per square foot of these four wall types for the three locations cited above:

	Wall Type	U-Value	Atl	NYC	Ch-Urb
A.	No insulation, wood shingles	.25	18,600	29,100	33,800
B.	No insulation, brick veneer	.24	17,800	27,900	32,400
C.	3½" insulation, wood or brick	.085	6,300	9,900	11,500

The addition of insulation to a typical 2 x 4 frame wall is now generally acknowledged to be cost effective. It is also highly energy effective. In New York City, addition of insulation will save an average 18,600 Btu/SF of wall annually at an additional embodiment (from Figure D-4) of 6,860 Btu. Energy payback (Btu saved versus extra Btu embodied) will be in approximately 1/3 heating season.

Figure D-6 plots the total energy embodied in and demanded by one square foot of a series of frame walls located in New York City over a period of 20 years. The walls are similar to those shown in Figures D-4 and D-5; however, five more alternative shingle walls with depth of wall and insulation increasing in 2" increments have been added. Table D-7 outlines the characteristics of the walls selected for investigation.

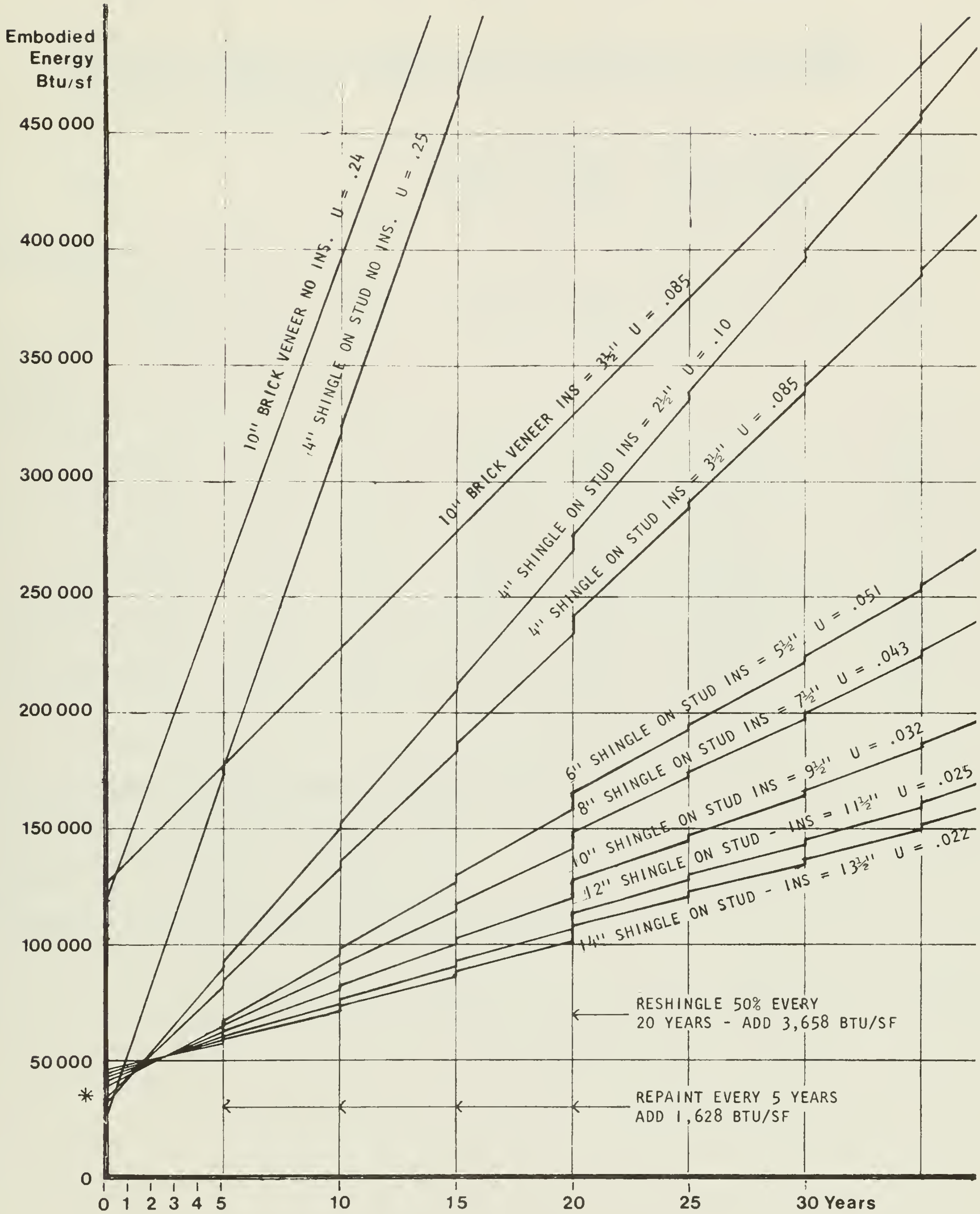
Several conclusions may be drawn from observation of the diagram. First of all, compared with no insulation at all, the energy embodied in insulation of any thickness will be paid back in terms of operational energy saved within one heating season. Second, 5½" of insulation will have an energy payback relative to 3½" of insulation within 1 heating season. And third, all thicknesses of insulation greater than 3½" will have demanded the same total number of Btus in a period of 3½ heating seasons. After this time, walls with more insulation will demand correspondingly less energy. (See Table D-7).

Three and one half inches of insulation is now used routinely in 2" x 4" exterior walls in residential construction and 5½" in a 2" x 6" stud wall is becoming more and more common. Thicknesses greater than that provide ever smaller increments of operational savings.

Only a portion of the wall will be solid (without openings), however. Glass areas will also have different properties regarding thermal transfer depending on whether they are single or double glazed. Table D-8 outlines these.

(This comparison deals only with the inducted thermal transfer characteristics of walls. In addition, heat is transferred, beneficially or detrimentally, as a result of infiltration and opening of windows, doors and louvers. Furthermore, by admitting light, which makes energy-supplied artificial light unnecessary and by admitting air for natural, non-mechanical ventilation, the wall serves to influence the energy requirements of the space other than thermally.)

ENERGY DEMAND — WOOD STUD WALLS



* FOR INITIAL EMBODIMENT, SEE TABLE D-7

NOTE: INS = INSULATION

CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801 and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791 Subject Energy Cost Life-Cycle Mineral Wool Insulation in Wood Stud Walls	by **CAC** **RGS & A**	date 30 Dec 76 file **D6**

COMPARISON OF ENERGY EMBODIMENT AND ANNUAL OPERATIONAL ENERGY DEMAND FOR HEATING IMPOSED BY 1 SQUARE FOOT OF WOOD FRAME WALL WITH VARYING THICKNESS OF INSULATION

Nominal Wall Thickness	Type of Framing	Insul.	U-Factor	Embodied Energy (Btu)	Annual Demand (Btu)	Total Energy Consumed Over 20 Years (Btu)	No. 6 Fuel Oil Equivalent (Gal)
Brick Veneer Walls							
10"	2 x 4 @ 16"	0	.24	119,566	27,924	678,046	4.52
10"	2 x 4 @ 16"	3½"	.085	126,426	9,889	324,206	2.16
Shingled Walls							
4"	2 x 4 @ 16"	0	.25	25,426	29,088	617,356	4.12
4"	2 x 4 @ 16"	2½"	.10	31,126	11,635	273,996	1.83
4"	2 x 4 @ 16"	3½"	.085	32,286	9,889	240,236	1.60
6"	2 x 6 @ 24"	5½"	.051	34,670	5,934	163,520	1.09
8"	2 x 8 @ 24"	7½"	.043	38,074	4,889	146,024	0.97
10"	(2) 2 x 4 @ 24"	9½"	.032	40,174	3,770	125,744	0.84
12"	(2) 2 x 4 @ 24"	11½"	.025	42,274	2,932	111,084	0.74
14"	(2) 2 x 4 @ 24"	13½"	.022	44,374	2,560	105,744	0.70

Additional Embodiment for Maintenance (Shingled Walls)

Paint - one coat every 5 years: 1,628 Btu/SF

Reshingle 50% every 20 years: 3,658 Btu/SF

(Brick veneer walls are assumed to be maintenance free.)

COMPARISON OF ENERGY EMBODIMENT AND OPERATIONAL ENERGY DEMAND FOR HEATING IMPOSED BY 1 SQUARE FOOT OF SINGLE OR DOUBLE GLAZING

		1 SF Embodied Btu	U-Factor	Annual Demand/SF NYC (4,848 deg day)
Glass:	a) Single glass	15,430	1.13	131,477 Btu
	b) Double with +¼" sp	30,860	.65	75,628 Btu
	c) Double with +½" sp	30,860	.58	67,484 Btu

Compared with a) single glazing:

b) Double with ¼" sp — uses 15,430 Btu more to produce;
demands 55,849 less annually;
pays back in ¼+ heating season

c) Double with ½" sp — uses 15,430 Btu more to produce;
demands 63,993 less annually;
pays back under ¼ heating season.

Compared with b) double glazing with ¼" space:

c) Double with +½" sp — uses the same Btu to produce;
demands 8,144 less annually.

Over a 20-year period, 1 Square Foot of glass will require (Embodiment & Demand)

		No. 6 Fuel Oil Equivalent (gal)
a) Single glass:	2.64 million Btu	17.6
b) Double with ¼" sp	1.54 million	10.3
c) Double with ½" sp	1.38 million	9.2

Maintenance factors with regard to glazing will be periodic recaulking and replacement of glass. The energy embodied in caulking compound, along with the energy embodied in other plastics and synthetics, has not been studied in this report. We assume that in the small quantities necessary for re-caulking, this additional increment will be negligible. Glass replacement, required by breakage, varies in accordance with building type and location. In 1-family residences, glass replacement is inconsequential; in high-rise buildings, wind loads may make glass replacement a regular maintenance item; in school buildings in some areas vandalism is so severe that maintenance budgets are strained by this one item alone, and local school boards have considered replacing all glass with unbreakable polycarbonate plastic. Thus, a factor for glass replacement has not been included in Table D-9, but should be considered separately specific to a particular building.

We have not dealt with roofs in any detail in this report. However, a brief comparison of the operational energy required by two typical alternatives indicates similar choices and opportunities in this area as well.

Using the same method shown for exterior walls in Table D-4 and D-5, we can calculate the thermal characteristics for a typical flat roof with either 3½" or 5½" of mineral wool insulation. Assuming in both cases 2 x 12 wood rafters at 16" o.c. with built-up roofing on a plywood deck over the rafters and a ½" gypsum board ceiling below, we arrive at the following figures:

Per Square Foot of Roof Roof Insulation	U-Factor	Annual Energy Demand/SF-NYC (Btu)	Demand Over 20 Years (Btu)	Embodied Energy (Btu)
a) 3½" thick	.075	8,726	174,528	68,063
b) 5½" thick	.036	4,189	83,773	70,003

Adding 2" of insulation between the rafters would save 4,537 Btu annually per square foot of roof at an additional embodiment of 1,940 Btu. Energy payback would be in less than ½ heating season.

To put these figures into perspective, let us assume a simple rectangular one-story wood frame residence 30' wide by 50' long with walls 10' high and a flat roof. Eighty percent of the wall is solid with a wood shingled exterior.

Twenty percent of the wall is window or door. The roof is covered with built-up roofing as in the example above.

The general characteristics of the building are then:
Roof (or floor) area: 1,500 SF
Wall perimeter: 160 LF

Wall Area: 1,600 SF of which 1,284 SF are solid and 316 SF are doors and windows. 316 SF = 2 doors @ 3' x 6'-8" and 23 windows @ 3' x 4' (casements - See Section B.1). Assume all openings - windows or doors - have a similar U-factor.

We can now make a rough estimate of the energy embodied in the walls and roof of the building and of the energy this building will demand in terms of heating due to thermal transfer characteristics. Although numerous comparisons can be made with the data at hand, we will limit the study to a comparison of the exterior walls and roof only, under two different insulation conditions.

(Note that this energy accounting includes only the outer shell of the building. It does not include foundations, floors, interior partitions, paint and other finishes, plumbing and electrical systems, and other components which do not affect thermal transfer.)

a) Single-Glazed, 3½" Insulation in Walls, 3½" Insulation in Roof

Embodiment

Solid Walls:	1,284	x	32,286 Btu/SF	=	41,455,224 Btu
Openings:	2 doors	x	346,502 Btu	=	693,004 Btu
	23 windows	x	1,070,652 Btu	=	24,624,996 Btu
Roof:	1,500	x	68,063 Btu/SF	=	102,094,500 Btu
			Total	=	168,867,724 Btu

Operational Demand per year (Exclusive of Maintenance Factors)

Solid Walls:	1,284 SF	x	9,889 Btu/SF	=	12,697,476 Btu
Openings:	316 SF	x	131,477 Btu/SF	=	41,546,732 Btu
Roof:	1,500	x	8,726 Btu/SF	=	13,089,000 Btu
			Total	=	67,333,208 Btu

Operational Demand Over 20 Years: 1,346,664,160 Btu

b) Double-Glazed, 5½" Insulation in Walls, 5½" Insulation in Roof

Embodiment

Solid Walls:	1,284 SF	x	34,670 Btu/SF	=	44,516,280 Btu
Openings:	2 doors	x	346,502 Btu	=	693,004 Btu
	23 windows	x	1,242,852 Btu	=	28,585,596 Btu
Roof	1,500	x	70,003 Btu/SF	=	105,004,500 Btu
			Total	=	178,799,380

Operational Demand per Year (Exclusive of Maintenance Factors)

Solid Walls:	1,284 SF	x	5,934 Btu/SF	=	7,619,256 Btu
Openings:	316 SF	x	67,484 Btu	=	21,324,944 Btu
Roof:	1,500	x	4,189 Btu/SF	=	6,283,500 Btu
			Total	=	35,227,700 Btu

Operational Demand Over 20 Years: 704,554,000 Btu

To recapitulate: (numbers in parentheses represent equivalent gallons of No. 6 Oil.)

Building	Embodiment in Outer Shell - Btu	Annual Demand Btu	20-Year Demand + Embodiment - Btu
a)	168,867,724 (1126)	67,333,208 (449)	1,516 million (10,107)
b)	178,799,380 (1192)	35,227,700 (235)	884 million (5,893)

It will be seen that by increasing the energy embodiment in the walls and roof 6 percent, the annual energy demand through conducted heat loss is reduced 48 percent. The additional energy embodied, 10 million Btu is repaid in about 1/3 of a heating season.

Infiltration, a function of air flowing through the cracks around each opening and through gaps in the construction will also have an effect on heating demand, adding an additional 41,785,544 Btu/year*

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*Consider only doors and windows. The crack around each door will be 19'-4" long. The crack at each window will be 18' long (perimeter plus 4' length where the window sections meet). Therefore, doors will account for 38.66 LF and windows will account for 414 LF of crack.[9] (There is also infiltration resulting from incomplete caulking, porosity of brick and block, joints in siding, etc.)

At a wind velocity of 15 mph, approximately 25 cu ft of air per hour will enter between sash and frame of a weather-stripped wood casement window per linear foot of crack. 25 x 414 = 10,350 cu ft of air per hour.

At the same wind velocity, approximately 35 cu ft of air per hour will enter between door and frame of a weather-stripped wood door per foot of crack. 35 x 38.66 = 1,353 cu ft of air per hour.

Total hourly air flow will be 11,703 cu ft of air per hour.

The heat required to raise 1 pound of air 1° F. is .24 Btu. The density of air averages .075 lbs/cu ft. Thus, 11,703 cu ft x .075 lbs/cu ft x 24 Btu/lb = 210.7 Btu.

210.7 Btu x 4,848 NYC degree days x 24 hours = 24.5 million Btu/year. (Equivalent to 163.4 gallons of No. 6 fuel oil.)

Further, if, in toto, the doors are opened 30 times per day and are left open for 10 seconds average, this represents a total of 300 seconds, or 5 minutes or 1/12 of an hour per day. The volume of air in cubic feet introduced at 15 miles per hour is:

$$\frac{3' \times 6.67' \times 5,280' \times 15}{12} = 132,066 \text{ cu ft/day}$$

Energy required to heat this per degree per day is:
132,066 cu ft/day x .075 lbs/cu ft x .24 Btu/lb = 2,377 Btu/degree day.

Total Btu required per year for doors is:
2,377 x 4,848 degree days = 11,523,696 Btu/year.

Assume window air passage from open windows would be half the air loss through doors = an additional 5,761,848 Btu/year. Total heat loss from infiltration and air passage through doors and windows =
24,500,000 + 11,523,696 + 5,761,848 = 41,785,544 Btu/year.

Therefore, the total heating requirement to counteract conducted heat loss and infiltration = Building a) 67,333,208 + 41,785,544 = 109,118,752 Btu/year.
Building b) 35,227,700 + 41,785,544 = 77,013,244 Btu/year.*

Stated in other terms, of the 1.053×10^9 Btu embodied in the entire building (from Table C-1: 702,047 Btu/SF average for 1-Family Residences x 1,500 SF), approximately 168.86×10^6 Btu (or 16%) in Building a) and 178.80×10^6 Btu in Building b) are in the shell of the building where thermal exchanges take place.

Of the 109.12×10^6 annual Btu heating requirement for Building a): 67.33×10^6 Btu, 62% is as a result of the conducted heat loss through the building skin. Adding the insulation and double glazing for Building b) (at an energy cost of 10×10^6 Btu), results in an annual fuel saving of 32.11×10^6 Btu and changes the pattern of energy use to one in which the infiltration is the predominant factor in heat loss, since now, of 77.013×10^6 Btu, only 35.227×10^6 Btu (or 46%) is due to conducted heat loss.

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*This is a highly simplified calculation of the heating demand imposed by the structural characteristics of a typical 1,500 SF, 1-story residence in NYC. It does not include factors for window frames (e.g., wood vs aluminum); window orientation; heat loss at edge of wall; or other similar refinements. A more detailed investigation by Hittman Associates (Residential Energy Consumption - Single Family Housing, 1973, for HUD) estimated structural heating energy demand for a 1,700 SF 2-story house in the Baltimore/Washington area to be 84.5 million Btu/year. With the addition of storm windows and better insulation, the same house would demand 66.2 million Btu/year for heating. In NYC these values would be 89 million and 69.8 million respectively.

III

E

Energy Flow Model

E. ENERGY FLOW MODEL

A technique has been developed which permits the tracing of the energy actually embodied in the product of New Building Construction from its initial appearance in the economy as Primary Energy resource through its various stages of refinement until it becomes the ultimate energy product (refined petroleum, natural gas, electricity, etc.) which is then sold to a non-energy industry, and from there, is carried through the various non-energy industries in the form of embodied energy in goods and services to the industries which sell directly to New Building Construction. It is finally incorporated into New Building Construction itself. The base data for this analysis comes from the 399 level input/output model of energy flow through the United States economy developed by the Center for Advanced Computation in the University of Illinois.[1]

Uses for a Flow Model

The development of these data and their organization into a flow diagram make the following energy information relating to new building construction immediately apparent.

A. The total amounts of each primary energy resource (coal, crude petroleum, non-fossil electricity, and imports) required due to the direct or indirect demand from New Building Construction.

B. The transactions between primary energy resources and those sectors which consume primary energy resources directly. These will include the five energy industries, the non-energy industries which purchase energy resources directly, such as the steel industry's purchase of coal, and the industries which purchase imports.

C. Transactions between the energy industries which use energy resources directly, to the energy industries which finally sell the energy product to some non-energy industry.

For example, a portion of the crude petroleum resource will be transferred to refined petroleum and then to electric utilities before it is sold to a non-energy sector such as steel. Other crude petroleum will be transferred to refined petroleum and sold directly to the steel industry.

D. The flow through some yet-to-be determined number of transactions between the stage described in C above and the stage containing the industries which sell directly to new building construction.

The purpose for establishing this network is to permit the identification of nodes in the flow which may become control or limiting points for alternative material strategies. For example, it may be found that the products from 50 small industries which purchase energy directly are sold to some industry, X, which, in turn, sells its products to 50 other industries, each of which makes a small contribution to New Building Construction. Industry X will not show up in either the direct primary energy contributions to the economy resulting from New Building Construction, or in the direct contributions to New Building Construction of primary and embodied energy. The knowledge of this intermediate industry is important since a restriction at this point will affect a substantial number of small paths which eventually lead to New Building Construction. It may, for example, turn out that if five of these small products are proposed as substitutes for some other product in order to reduce resource energy requirements, Sector X may have to be tripled in size since these five paths all flow through Sector X. A brief look at Sector X may indicate that a tripling in size is impossible and therefore, it will be necessary to either abandon this strategy or find alternate means for developing five substitute materials.

E. The identity and quantity of the primary and embodied energy contained in transactions directly with New Building Construction. This will include the transactions between New Building Construction and the five energy sectors and between New Building Construction and the non-energy sectors. The energy sector transactions will represent the total energy embodied in the products transferred from the energy sectors to New Building Construction. For example, in the case of gasoline consumed by building machinery, the quantity of energy indicated in the transaction will include the total amount of energy resource which was required eventually to deliver that gasoline to new building construction in addition to the actual useful energy contained in that gasoline. For the non-energy industry transactions, the magnitude of the transaction will simply represent the total energy resource required at the beginning of the flow to achieve this transaction at the end. In the case of a plastic product for example, this will include the energy content of the petroleum feedstock for the material, the energy required to extract that feedstock, and the energy required for all of the transformations and the other processes which occur prior to the entry of that plastic material into the New Building Construction sector.

The energy flow diagram is to be developed as a dynamic model. In this way, changes at any point in the eventual delivery of goods and services to New Building Construction can be evaluated with respect to the impact which they will have at any other critical point. For example, as cited earlier, a substitution of one material for another at the output end of the flow pattern may produce a reduction in the demand for primary energy resource but may also produce an unacceptable expansion of some node in the flow of raw material to the finished product. Similarly, if it is found that some node industry has an unacceptable environmental impact and that therefore this industry must be reduced by 50 percent, it can rapidly be determined what effect this constriction at a node will have on the materials available for New Building Construction. By working backwards, it will be possible to identify substitute materials which can then be used which will not, in turn, create unacceptable nodal conditions or excessive demands for primary energy resources.

It will be possible to determine shifts, not only in the total quantity of raw energy resource as a result of material substitution, but also shifts in the type of energy resource. It may be desirable, for example, to identify a material substitution which will produce a shift in demand from crude petroleum to coal. Because the entire flow is followed from start to finish, it will be possible to identify points within the flow patterns, if they exist, where decisions can be made to shift the demand from petroleum to other energy resources without changing the end product.

It will also be possible to analyze the effect on building materials of changes which occur in the availability of energy resources. For example, it will be possible to determine what would happen based on today's practices if there were a 40 percent reduction in the availability of petroleum and a 60 percent increase in the availability of coal. From this initial transformation, it would then be possible to determine the change required in industries within the flow in order to provide the materials necessary to continue new building construction.

A schematic graphic model and discussion of methodology may be found in Appendix D.

IV CONCLUSION

CONCLUSIONS

This report has been the result of a successful collaboration between Richard G. Stein and Associates, a private architectural firm, and the Energy Research Group at the Center for Advanced Computation, University of Illinois, a multi-disciplinary research center in a major university. To the energy input-output matrix already developed at the Center for Advanced Computation, Richard G. Stein and Associates were able to add the detail and specific professional information required for the production of data useful to the construction field and governmental bodies consistent with the integrity of the rest of the matrix. The methodology combined the extraction of information from government sources (Bureau of Economic Analysis, Bureau of the Census, and others) construction industry statistical information sources (Dodge Reports, McGraw Hill Information Service, Means Co., Inc., etc.) and from private sources (RGS&A files, CAC library, consulting engineers, construction management consultants, materials producers, trade associations, etc.). The data in this report are from 1967, the most recent year with complete economic and energy use reporting. Conclusions are broadly applicable to other years and serve as a base to observe changes.

Until now, the entire emphasis in energy conservation in buildings has been on their operation. This has been because building operation has been a visible large target, susceptible to rapid modification as a result of straightforward changes in operation methods as well as physical modification of the buildings themselves.

On the basis of this report, the energy used in constructing buildings can be more clearly understood - in broad terms and in detail.

By using the large computer model at the Center for Advanced Computation, Richard G. Stein and Associates and the Center for Advanced Computation together were able to extract base information on:

1. The total energy embodied in new construction in 1967, divided into 49 separate sectors according to construction type.

2. The division between energy used in new building construction (18 sectors), building maintenance and repair construction (4 sectors), new non-building construction (14 sectors), and non-building maintenance and repair construction (13 sectors).

3. The energy embodied in direct energy purchased and used at the jobsite for each category and the energy embodied indirectly in the materials and assemblies brought to the jobsite.

4. The division by percentage within each construction category of materials required from all other sectors of the economy supplying products to the construction industry, both building and non-building.

5. The energy embodiment per unit of the major building materials, including all energy for the entire process up to incorporation in the building.

6. Application of the unit energy embodiment values to specific characteristic assemblies, demonstrating not only the energy embodied in initial construction, but also lifetime energy cost comparisons based on operation and maintenance energy in addition to the original cost.

7. The amount of energy embodied in each new building sector prorated per square foot of building constructed for that sector in 1967.

8. The flow of energy through the economy starting with energy sources in their natural state and following their entire conversion to embodied energy through the energy industries into the production of materials and on into incorporation in buildings. Diagrams have been developed but not completed with all detail.

Extracting significant detail from the report, the following factual details and conclusions can be noted:

1. The entire construction industry required 7,235.6 trillion Btu (10.82 percent of total U.S. energy consumption) in 1967. Of this, New Building Construction required 3,421.6 trillion Btu (over 47 percent of the industry total and over 5 percent of the U.S. total) and Building Maintenance and Repair accounted for an additional 733.5 trillion Btu (over 10 percent of the industry and 1 percent of U.S.). The Non-building sectors required 2,499.9 trillion Btu for new construction (34.5 percent of the industry total and nearly 4 percent of U.S.) while Non-building Maintenance and Repair required 580.6 trillion Btu (8 percent of the industry and under 1 percent of U.S.).

2. Within the new building construction sectors the largest single category was 1-family residences, accounting for over 1.17 percent of the U.S. total, followed by industrial buildings (0.7 percent) and educational buildings (0.66 percent) and residential alterations or additions and office buildings (0.39 percent each). The remaining 13 categories vary from 0.35 percent to 0.05 percent.

3. Within the non-building construction categories, highways was by far the greatest energy user, accounting for 1.55 percent of the entire U.S. energy use. Just as some of the building sectors may include substantial increments of energy for non-building activity (e.g. parking lots for shopping centers or bunker silos for farm service construction), so some of the non-building sectors may include a significant increment of building. Non-building sectors such as electric utilities, for example, include the housing for generating and transmission equipment, which fall into the building construction category. However, they also include large increments for specialized materials and machinery. New Construction, Military, is listed in non-building sectors, although a major part of the construction it represents (judging by the relatively large percentage of embodied energy attributable to metal doors) may be in buildings; however, it is not possible to break down the data within a given sector into building and non-building projects.

4. One fifth as much energy is used in construction of new buildings as in operating the entire stock of existing buildings. With reduced energy requirements for building operation, some building types will use as much energy in the building process as in ten years of operation.

These percentages reflect the 1967 economy. It would be possible to approximate any other year, based on the divisions reported either by dollar or square foot, and then, without accounting for changes in construction methods in the years after 1967, to revise the model for the construction industry. It is also possible (inherent in the I/O method) to develop with a high degree of accuracy the resulting shifts across the economy caused by shifts in construction commitments. One such shift could be from 1-family residences to garden apartments and high-rise residential. Another could be from highway construction to mass transit. A third could be a major commitment to solar technology rather than electricity for space and water heating across the country.

There is a wide variation in energy embodiment per square foot of building among the different building categories. The highest energy-using category is Laboratories, requiring 2,074,056 Btu per square foot, and the lowest is Farm Service, requiring 149,071 Btu per square foot, a 14 to 1 ratio. Among the largest energy-using categories, there are also important differences in quantities. Single-family residences require 702,047 Btu. In examining the profile of distribution, it becomes apparent that the importance of wood, a material with low energy embodiment is the major reason. Hospital buildings, which require 1,722,200 Btu - only slightly less than laboratories - have over 30 percent of their energy in specialty items and systems that do not appear as significant contributors to less specialized buildings. These would include the transportation and conveyor systems, the sterilizing equipment, the extensive use of stainless steel and aluminum for equipment, the use of plastic piping systems, etc. The average for all the categories listed is 935,440 Btu per square foot.

It is essential to bear in mind that all the figures given are average figures. They do not reflect regional differences that require different detailing, such as the deeper footings that are required for buildings in Minnesota where there is a deep frost line in comparison with Southern California where there is no frost problem, or the difference required to satisfy special programmatic requirements, as the equipment in a complicated research hospital as opposed to a facility that is primarily a long-term residential center for the chronically ill. Moreover, as other studies in the report demonstrate, there are means available in building to satisfy similar performance requirements in assemblies with markedly different energy embodiments.

An informed choice in materials selection can reduce building energy use appreciably. A sample analysis of three interchangeable floor systems typical of high-rise office construction demonstrated that the production of a reinforced concrete structure will use less than 60 percent of the energy needed to produce a comparable standard steel structure. For the floor alone, not including columns, concrete would require 172 MBtu/SF compared to 293 MBtu/SF for steel. Although, in general, dollar cost has not been a consideration in this report, it should be noted that concrete and steel systems are generally similar in overall cost for large, repetitive systems, and cost is not typically the major consideration in choosing one over the other. Applied to the total area of office buildings in a given year (157.6 million SF in 1967) the difference in embodied energy is significant. (19 trillion Btu, equivalent to 3 million barrels of No. 6 oil.).

Another analysis of walls typical of 1-family residential construction and with equivalent thermal resistance capabilities has been made. Both are wood frame construction; however, one has a brick veneer exterior and the other is shingled. The brick veneered wall is 4 to 5 times as energy intensive per square foot as the shingled one - a function of the high energy intensity of brick compared to the low energy intensity of wood. This analysis has been carried further, adding more insulation in 2-inch increments to deeper stud walls and comparing not only the energy embodied in construction of the assemblies, but also the energy demanded by the thermal characteristics of the walls for heating the spaces which these walls (which range from 4" deep with 0" insulation to 14" deep with 13½" insulation) would enclose. Extension of this analysis to a similar consideration of single versus double glazing, and flat roofs with 3½" of mineral wool insulation versus 5½", has allowed us to make a general comparison between the outer shells of two typical 1,500 square foot, 1-family residences, either of them in accordance with construction practices today. The first, which has 3½" of insulation in the walls, 3½" insulation in the roof, and single glazing, would have an embodied energy value of 168,867,724 Btu. Operational energy demand would be 67,333,208 Btu per year for heat lost through thermal transmission. The second, which has 5½" of insulation in both roof and walls and double glazing would have an embodied energy value of 178,799,380 Btu (5.9 percent more than the first example) and an operational energy demand due to thermal transmission losses of 35,227,200 Btu/year (48 percent lower than the first example). In addition, both buildings would require a further input of operational energy of 41.8 million Btu/year to counteract heat lost through infiltration, opening of doors and windows, etc. Thus, the total energy which these buildings would cause to be consumed, either in their construction or in their operation over a period of 20 years, would be 168.9 + 20 (67.3 + 41.8) million Btu = 168.9 + 2,182 million Btu = 2,350.9 million Btu for the first building and 178.8 + 20 (35.2 + 41.8) million Btu = 178.8 + 1,540 million Btu = 1,718.8 million Btu for the second - a reduction of 27 percent. It is evident that, although in both these cases, the energy embodied is a small percentage of the energy which will be demanded over a period of time, the choice of materials of construction will have a significant effect nonetheless. This is particularly true in the case of materials and assemblies inherent in 1-family construction, which in 1967, out of 49 construction sectors, accounted for a total amount of energy second only to highway construction, amounting by itself to 1.17 percent of all energy consumed in the United States in that year.

To use this information most effectively, one must understand the way in which energy, starting as petroleum in the ground or unmined coal, is processed and used in the various steps that culminate in the completed building. Enough of this information is immediately retrievable from the CAC I/O matrix to establish the entire extent of source energy that was necessary to enable the production of the New Building industries product in 1967, divided among prime energy sources, and the distribution of this energy among all the suppliers who sell their products directly to the building industry for assembly at the jobsite.

A graphic representation of this process has been developed, using actual recorded quantities at both ends of the diagram - energy in the ground at one end, and energy by final sales sectors plus direct energy used at the jobsite at the other. The diagram shows a simulated pathway network joining the two ends, accounting for the energy cost of energy as well as the work content of the energy. The first part of the diagram details the rearrangements of raw energy into the forms it takes for sale to the various non-energy industries whose products make up our buildings. The diagram describes the process by which this simulated information can actually be determined, starting at the final products and going back in each case, transaction by transaction, until the earliest processes requiring energy have been identified.

Since this would be a dynamic model, it would permit an immediate evaluation of alternative materials, would assess the impact of any local shortages, and would predetermine the consequence of any change in building types, building unit quantities, and shifting national priorities.

FUTURE WORK

The report has provided the base for a number of useful studies which can contribute to significant energy reductions in the building of buildings.

1. A methodology has been developed for the comparison of different assemblies responding to the same programmatic requirements, fireproof slabs in high-rise buildings and frame structures with different facing materials. The method can now be used in comparing larger assemblies, buildings. By taking as constants two factors - one, the capability of answering a certain use requirement (program); and two, the ability to do this with a fixed amount of energy for operational purposes, two or more buildings can be analyzed to ascertain what the construction of each will require in Btu.

The examples proposed for such a study would, in themselves, produce answers to questions that are now being asked. One example is the comparison between building a new office structure and renovating (recycling) an existing building to a similar performance level. Another comparison would be the energy to build a new frame house versus renovating an existing one versus constructing a mobile home. If performance standards were not comparable because of an inherent characteristic of the building type in question, an energy life cycle estimate would be made.

2. There are now possibilities for the examination of important strategies, such as the true energy cost of solar collectors. Using the figures on energy embodiment for the various component materials - aluminum, glass, sealants, insulation, paint, etc., the embodied energy in a solar collector can be established. This can be compared with the energy required to build a similar unit with copper, or to glaze it with fiberglas or plastic. A multiplication of the single unit by the amount anticipated for an effective national program can be compared against the productive capacity both of the industry and the energy products necessary to sustain that industry. It will be possible to develop an energy cost/benefit chart noting the payback time to recoup the capital energy, and the maintenance and replacement energy necessary to keep the unit in operation.

3. Knowing the energy content of the components of structural systems, we can now determine the energy benefits in adopting more responsive engineering methods (which may require more labor intensive methods in the building process) and estimate their impact on total building energy requirements.

4. The data developed on energy per unit of building material or component can be placed in an energy-estimating computer program. Such a program would have to be considerably expanded to include the major divisions and subdivisions used in building estimating. The mechanism of hybrid analyses has been developed and can be employed in the expansion of the data base.

Such a program could be used to ascertain the energy embodiment of particular buildings as part of the estimating process. There is interest at the State energy code level to require such information in the filing of buildings for energy approvals. We have been requested to provide the data that would permit such a requirement for building approval conforming with energy conservation standards. Expanded energy per unit data will thus lead ultimately to the establishment of energy budgets, not merely for the operational requirements of buildings, but also for their construction.

As a document that will have applicability over a number of years and will be subject to continual updating and expansion, such a study has complex organizational aspects that must be investigated carefully. Having the technical and informational means to achieve this, the study would have to begin with a careful analysis of the proper sponsorship and curatorship.

5. The data related to the plastics industry in the 1967 statistics are not sufficiently detailed or described to permit a full evaluation of their impact on the whole building field. Most of the plastics are petroleum based. In addition, their conversion to their ultimate form is the result of further commitments of energy. In many cases they replace a natural material, either a plant fiber (cotton, wool, linen), a direct cellulose product (wood), a plant fluid or sap (rubber, turpentine, oils), or a geological product (rock, gypsum, stone aggregates). An understanding of the energy embodiment in the materials in question and the materials they replace is in order. Part of the study will include the description of the unique properties of the plastics that makes them important or desirable, coupled with an estimation of the amount of that material required to satisfy the unique demands. On this basis, the net reduction in source energy can be determined.

6. A procedure has been described and graphically represented illustrating the energy flow patterns in the New-building construction industry. Developing this dynamic model of the entire energy flow through the construction industry will have enormous value in determining the effects of alternate strategies. As a planning tool available to the highest level of governmental economic planners, it will permit the determination of which programs and strategies to support, and what the industrial preconditions must be for the success of new policies.

7. The inspection of similar building components serving similar functions provides important information, as can be seen by the comparisons of fireproof floor systems and of alternative wood wall systems. These studies can be enlarged but by no means exhausted by inspecting other components and typical building sections. For example, the curtain wall for fireproof frame construction is available in many forms: insulated sandwich with aluminum facing, with glass facing, precast concrete panels, prefabricated brick panels and others. Floor systems used in high-rise residential developments include 1-way concrete slab and beam, 2-way flat flab, light weight steel joists, and standard steel construction. Definitive information in any of these categories would probably point to methods for achieving large scale energy savings in construction.

8. There has been a large body of literature developed within the past several years outlining methods for the reduction of energy waste in the industrial process. Heat reclamation, process improvement and greater operational and maintenance skill can produce large savings. Recently published comparisons between Sweden and the United States document major industries in Sweden that produce their end products with only 60 percent of the energy that the same product would require in American factories. Steel and paper are among the materials in this category. In some cases, obsolete production facilities are responsible for the difference. The method of achieving these savings is not within the competence of the team preparing this report. The results of such process improvements, however, is. The information bank permits the identification of the savings and the particular products that would be favorably affected by them.

9. Since the study deals with average figures, the identification of the range of some of the items within those averages also suggests opportunities for energy reductions. One of these items is transportation, a margin that is uniformly prorated to every unit of the product in the category being examined. In some products, lumber, for instance, the transportation energy between the sawmill and the ultimate user, appears to be large enough to warrant examination. If it is, the result of averaging very large transportation margins for cross-continent shipments with very small margins for local shipments, regionalism in distribution and use patterns for local materials may provide the basis for significant savings. (In the case of rough dimensioned lumber, the margins to the jobsite are about 50 percent as great as the entire previous energy embodiment.) There are enormous consequences both in the resulting architectural practices that would ensue from this new regionalism, and in the appearance of buildings in different parts of the country.

10. Having the 1967 data base with its detail in the construction industry permits an evaluation of the changes that have taken place in the years that followed. The information is now almost complete for a 1972 update. Carried into the construction field, it would reveal shifts in proportioning between building types and building materials. For example, there is a large growth in the mobile home industry. There is probably also a marked increase in the use of plastics. The results of changes and the new figures on energy use by building type and building material are important in verifying theoretical assumptions.

11. Although transportation is documented as one of the margins in the CAC program, workers' transportation to the jobsite is considered personal, optional energy use. In reality, it is a job-related energy use whose extent is not reflected in the energy necessary to produce our buildings. It will be worth while to study this pattern, determine its size and see whether alternatives exist for its reduction. The implications can affect the relationship between onsite work and factory assembly. On the other hand, the more labor intensive a building operation becomes, the greater the impact of private auto use will be.

These are among the options that can now be examined, based on the data contained in this report.

V APPENDICES

APPENDIX A

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APPENDIX A

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V

B

Documentation for Expanded Energy I/O Model

APPENDIX B

DOCUMENTATION FOR EXPANDED ENERGY INPUT/OUTPUT MODEL

This section describes in detail the development of the Expanded Energy Input/Output Model (see Section II) and provides full tabular results for the building construction industry. The description which follows consists of two parts:

- General description of the expanded I/O Model with tabular results.
- Detailed documentation of 1967 direct energy use data for construction industry.

(Tables referred to in these sub-sections are located directly after the corresponding texts.)

B1. General Description & Tabular Results.

As mentioned in Section II, the Expanded I/O Model was formed by inserting 49 construction sectors from a detailed BEA breakdown into the 1967 CAC Energy I/O Model.[1] The latter usually consists of 357 sectors, including 7 construction sectors. Thus, insertion of the 49 disaggregated construction sectors expanded the CAC model to 399 sectors, shown in Table B1-1. Construction sectors wind up in positions 23 through 71, inclusive.

A crucial step in implementing the Expanded I/O Model was collection of 1967 direct energy use data for the construction sectors, i.e., their purchases from the Coal, Crude Petroleum, Refined Petroleum, Electricity, and Natural Gas Sectors. These transactions (see Table B.1-2) were computed using data collected by RGSA on energy prices paid by the construction industry in 1967. (This data collection is fully described in part B.2 of this appendix.) Given the price per Btu of a given energy type paid by a given construction sector and the corresponding dollar transaction from BEA, computation of the implied energy flow (Btu) is straightforward. (Where prices supplied by RGSA were in purchaser dollars, BEA margin figures were used along with inter-industry transactions.)

Once the direct energy figures were embedded in CAC's Energy I/O tables, energy intensities were computed. The intensity figures for building construction sectors (Btu/$) are shown in Table B1-3. Total primary intensity is the sum of the Coal, Crude Petroleum, and the hydro and nuclear portion of Electricity figures. The total primary intensities of construction are shown ranked in Table B1-4.

To obtain a broad picture of the building construction industry, various average energy intensities were computed by weighting the figures for the construction sectors by the corresponding gross domestic outputs for those sectors. The gross domestic outputs of the construction sectors in 1967 are shown in Table B1-5. Average energy intensities are shown in Table B1-6.

Using the energy intensities of construction sectors along with the total final demand dollar figures for these sectors (from BEA), the total energy of final demand required by the construction sectors was determined. These total energy figures (see Table B1-7) include direct and indirect energy use. Table B1-7 also shows the percentage of each construction sector's total energy use which was direct, and the percentage of total energy each sector required with respect to the total construction industry and the total U.S. economy. Table B1-8 shows the ranked total final demand energy use figures for building construction. (The zeros which appear for certain maintenance and repair construction sectors occur because these sectors have no dollar (or energy) transactions to final demand.)

To set the groundwork for further analysis of the energy used in the construction industry, the total primary energy (direct and indirect) required in 1967 by each construction sector for production of its total output was computed, along with corresponding input fractions. The resulting tables are huge and do not appear here. Table B1-9 summarizes these results, however, showing the total energy requirements of each sector. Note that the total energy requirements figure shown in Table B1-9 is larger than the total final demand energy requirements figure of Table B1-7. This is because certain Maintenance Construction sectors do not sell to final demand, but do interact with other sectors.

Finally, to allow focusing of research effort on the energy needs of new buildings, an aggregate New Building Construction sector was formed by combining sectors 23 through 38, 48 and 49. Total primary energy requirements of this aggregate sector for 1967 are shown ranked in Table B1-10. Energy requirements are allocated among New Building Construction's direct purchases from other sectors and corresponding input and cumulative fractions are also shown.

TABLE B1-1. 399-ORDER SECTORS

399-ORDER INDEX	90-ORDER INDEX	I/O CODE	NAME
1	1	700	COAL MINING
2	2	800	CRUDE PETRO, GAS
3	3	3101	PETRO REFIN PROD
4	4	6801	ELECTRIC UTIL
5	5	6802	GAS UTILITIES
6	6	101	DAIRY
7	6	102	POULTRY, EGGS
8	6	103	MEAT,ANIMAL PROD
9	7	201	COTTON
10	7	202	FEED GRAINS
11	7	203	TOBACCO
12	7	204	FRUITS
13	7	205	VEGT,MISC CROPS
14	7	206	OIL BEARING CROP
15	7	207	FOR,GRHOUSE,NURS
16	8	300	FOREST FISH PROD
17	9	400	AG FOR,FISH SER
18	10	500	IRON ORE MINING
19	11	601	COPPER MINING
20	11	602	NONFERR MINING
21	12	900	STONE CLAY MIN
22	13	1000	CHEM MINERAL MIN
23	14	110101	NEW CONST RES--1 FAM.
24	14	110102	NEW CONST RES--2-4 FAM.
25	14	110103	NEW CONST RES--GRDN APT.
26	14	110104	NEW CONST HIGH-RISE APT.
27	14	110105	NEW CONST RES--ALT.,ADD.
28	14	110106	NEW CONST HOTELS,MOTELS
29	14	110107	NEW CONST DORMITORIES
30	14	110201	NEW CONST INDUST. BLDG.
31	14	110202	NEW CONST OFFICE BLDG.
32	14	110203	NEW CONST WAREHOUSES
33	14	110204	NEW CONST GAR.,SRV. STA.
34	14	110205	NEW CONST STORES,RSTRNTS
35	14	110206	NEW CONST RELIG. BLDG.
36	14	110207	NEW CONST EDUC. BLDG.
37	14	110208	NEW CONST HOSPITAL BLDG.
38	14	110209	NEW CONST OTH. NON-FARM
39	14	110301	NEW CONST TELEPH.,TELEG.
40	14	110302	NEW CONST RAILROADS
41	14	110303	NEW CONST ELECT. UTIL.
42	14	110304	NEW CONST GAS UTIL.
43	14	110305	NEW CONST PETROL. PIPE.
44	14	110306	NEW CONST WATER SUPPLY
45	14	110307	NEW CONST SEWER
46	14	110308	NEW CONST LOC. TRANSIT
47	14	110400	NEW CONST HIGHWAYS
48	14	110501	NEW CONST FARM RESID.
49	14	110502	NEW CONST FARM SERVICE
50	14	110503	NEW CONST OIL/GAS WELLS
51	14	110504	NEW CONST OIL/GAS EXPL.
52	14	110505	NEW CONST MILITARY
53	14	110506	NEW CONST CONS.,DEV.
54	14	110507	NEW CONST OTH. NON-BLDG.
55	15	120100	MAINT CONST RESID.
56	15	120201	MAINT CONST OTH. NON-FRM
57	15	120202	MAINT CONST FARM RESID.
58	15	120203	MAINT CONST FARM SERVICE
59	15	120204	MAINT CONST TEL.,TEL.
60	15	120205	MAINT CONST RAILROADS
61	15	120206	MAINT CONST ELECT. UTIL.
62	15	120207	MAINT CONST GAS UTIL.
63	15	120208	MAINT CONST PETR. PIPE.
64	15	120209	MAINT CONST WATER SUPPLY
65	15	120210	MAINT CONST SEWER
66	15	120211	MAINT CONST LOC. TRANSIT
67	15	120212	MAINT CONST MILITARY
68	15	120213	MAINT CONST CONSER.,DEV.
69	15	120214	MAINT CONST HIGHWAYS
70	15	120215	MAINT CONST OIL/GS WELLS
71	15	120216	MAINT CONST OTH. N-BLDG.
72	16	1301	GUIDED MISSILES
73	16	1302	AMMUNITION
74	16	1303	TANKS
75	16	1304	FIRE CONTROL EQ
76	16	1305	SMALL ARMS
77	16	1306	SMALL ARMS AMMUN
78	16	1307	OTHER ORDNANCE
79	17	1401	MEAT PRODUCTS
80	17	1402	BUTTER
81	17	1403	CHEESE
82	17	1404	CONDENSED MILK
83	17	1405	ICE CREAM
84	17	1406	FLUID MILK
85	17	1407	CANNED SEA FOODS
86	17	1408	CANNED SPECIALTY
87	17	1409	CANNED FRUIT,VEG
88	17	1410	DEHYDRATED PROD
89	17	1411	PICKLES,DRESSING
90	17	1412	FISH
91	17	1413	FROZEN FRUIT,VEG
92	17	1414	FLOUR,CEREALS
93	17	1415	PREP ANIMAL FEED
94	17	1416	RICE MILLING
95	17	1417	WET CORN MILLING
96	17	1418	BAKERY PRODUCTS
97	17	1419	SUGAR
98	17	1420	CONFECTIONERY
99	17	1421	ALCOHOLIC BEV
100	17	1422	SOFT DRINKS
101	17	1423	FLAVORINGS
102	17	1424	COTTONSEED MILLS
103	17	1425	SOYBEAN MILLS
104	17	1426	VEG OIL MILLS
105	17	1427	ANIMAL FATS
106	17	1428	COFFEE
107	17	1429	COOKING OILS
108	17	1430	MANUFACTURED ICE
109	17	1431	MACARONI
110	17	1432	FOOD PREPARATION
111	18	1501	CIGARETTES
112	18	1502	TOBACCO STEMMING
113	19	1601	BROAD FAB MILLS
114	19	1602	NAR FABRIC MILLS
115	19	1603	YARN MILLS
116	19	1604	THREAD MILLS
117	20	1701	FLOOR COVERINGS
118	20	1702	FELT GOODS
119	20	1703	LACE GOODS
120	20	1704	UPHOLSTERY FILL
121	20	1705	PROC TEX WASTE
122	20	1706	COATED FABRICS
123	20	1707	TIRE CORD
124	20	1708	SCOURING PLANTS
125	20	1709	CORDAGE, TWINE
126	20	1710	TEXTILE GOODS
127	21	1801	HOSIERY
128	21	1802	KNIT APPRL MILLS

TABLE B1-1. 399-ORDER SECTORS (continued)

399-ORDER INDEX	90-ORDER INDEX	I/O CODE	NAME
129	21	1803	KNIT FAB MILLS
130	21	1804	APPAREL,PURCH MAT
131	22	1901	CURTAINS
132	22	1902	HOUSEFURNISHINGS
133	22	1903	FAB TEXTILE PROD
134	23	2001	LOGGING
135	23	2002	SAWMILLS
136	23	2003	HARDWD FLOORING
137	23	2004	SPEC PROD SAWMIL
138	23	2005	MILLWORK
139	23	2006	VENEER,PLYWOOD
140	23	2007	PREFAB WD STRUC
141	23	2008	WOOD PRESERVING
142	23	2009	WOOD PRODUCTS
143	24	2100	WOOD CONTAINERS
144	25	2201	WOOD H'HOLD FURN
145	25	2202	UPH H'HOLD FURN
146	25	2203	MET H'HOLD FURN
147	25	2204	MATTRESSES
148	26	2301	WOOD OFC FURN
149	26	2302	METAL OFC FURN
150	26	2303	PUBLIC BLDG FURN
151	26	2304	WOOD FIXTURES
152	26	2305	MET FIXTURES
153	26	2306	BLINDS, SHADES
154	26	2307	FURN, FIXTURES
155	27	2401	PULP MILLS
156	27	2402	PAPER MILLS
157	27	2403	PAPERBOARD MILLS
158	27	2404	ENVELOPES
159	27	2405	SANIT PAPER PROD
160	27	2406	BUILDING PAPER
161	27	2407	CONV PAPER PROD
162	28	2500	PAPERBOARD CONT
163	29	2601	NEWSPAPERS
164	29	2602	PERIODICALS
165	29	2603	BOOK PUBLISHING
166	29	2604	MISC PUBLISHING
167	29	2605	COMM PRINTING
168	29	2606	BUSINESS FORMS
169	29	2607	GREETING CARDS
170	29	2608	MISC PRINTING
171	30	2701	INORG-ORG CHEM
172	30	2702	FERTILIZERS
173	30	2703	AG CHEMICALS
174	30	2704	MISC CHEM PROD
175	31	2801	PLASTICS
176	31	2802	SYN RUBBER
177	31	2803	MAN-MADE FIBERS
178	31	2804	ORGANIC FIBERS
179	32	2901	DRUGS
180	32	2902	CLEANING PREP
181	32	2903	TOILET PREP
182	33	3000	PAINT PRODUCTS
183	34	3102	PAVING
184	35	3103	ASPHALT
185	36	3201	TIRES
186	36	3202	RUBBER FOOTWARE
187	36	3203	MISC RUBBER PROD
188	36	3204	MISC PLASTICS
189	37	3300	INDUST LEATHER
190	38	3401	FOOTWARE CUT STK
191	38	3402	FOOTWARE EXC RUB
192	38	3403	MISC LEATHER
193	39	3501	GLASS PRODUCTS
194	39	3502	GLASS CONTAINERS
195	40	3601	CEMENT
196	40	3602	BRICKS
197	40	3603	CERAMIC TILE
198	40	3604	CLAY REFRACT
199	40	3605	CLAY PRODUCTS
200	40	3606	PLUMBING FIXTURE
201	40	3607	FOOD UTENSILS
202	40	3608	PORCEL ELEC SUPP
203	40	3609	POTTERY PRODUCTS
204	40	3610	CONCRETE BLOCKS
205	40	3611	CONCRETE PRODUCT
206	40	3612	READY-MIX CONCR
207	40	3613	LIME
208	40	3614	GYPSUM PRODUCTS
209	40	3615	STONE PRODUCTS
210	40	3616	ABRASIVE PRODUCT
211	40	3617	ASBESTOS PRODUCT
212	40	3618	GASKETS
213	40	3619	TREATED MINERALS
214	40	3620	MINERAL WOOL
215	40	3621	NONCLAY REFRACT
216	40	3622	NONMET MIN PROD
217	41	3701	STEEL PROD
218	41	3702	IR,STL FOUNDRIES
219	41	3703	IR,STL FORGING
220	41	3704	PRIMARY MET PROD
221	42	3801	PRIMARY COPPER
222	42	3802	PRIMARY LEAD
223	42	3803	PRIMARY ZINC
224	42	3804	PRIM ALUMINUM
225	42	3805	PRIM NONFER MET
226	42	3806	SEC NONFERR MET
227	42	3807	COPPER ROLLING
228	42	3808	ALUM ROLLING
229	42	3809	NONFER ROLLING
230	42	3810	NONFER WIRE
231	42	3811	ALUM CASTINGS
232	42	3812	BRASS,OTHR CAST
233	42	3813	NONFER CASTING
234	42	3814	NONFER FORGING
235	43	3901	METAL CANS
236	43	3902	METAL BARRELS
237	44	4001	METAL SANIT WARE
238	44	4002	PLUMB FITTINGS
239	44	4003	HEATING EQUIP
240	44	4004	FAB STRUC STEEL
241	44	4005	METAL DOORS
242	44	4006	FAB PLATE WORK
243	44	4007	SHEET METAL WORK
244	44	4008	ARCH METAL WORK
245	44	4009	MISC METAL WORK
246	45	4101	SCREW MACH PROD
247	45	4102	METAL STAMPINGS
248	46	4201	CUTLERY
249	46	4202	HANDTOOLS
250	46	4203	HARDWARE
251	46	4204	COAT, ENGRAV SER
252	46	4205	FAB WIRE PRODUCT
253	46	4206	SAFES, VAULTS
254	46	4207	STEEL SPRINGS
255	46	4208	PIPE
256	46	4209	COLLAPSIBLE TUBE
257	46	4210	METAL FOIL, LEAF
258	46	4211	FAB METAL PROD
259	47	4301	STEAM ENGINES
260	47	4302	INT COMBUST ENG
261	48	4400	FARM MACHINERY
262	49	4501	CONST MACHINERY
263	49	4502	MINING MACHINERY
264	49	4503	OIL FIELD MACH

TABLE B1-1. 399-ORDER SECTORS (continued)

399-ORDER INDEX	90-ORDER INDEX	I/O CODE	NAME
265	50	4601	ELEVATORS
266	50	4602	CONVEYORS
267	50	4603	HOISTS, CRANES
268	50	4604	INDUSTRIAL TRUCK
269	51	4701	MET CUTTING TOOL
270	51	4702	MET FORMING TOOL
271	51	4703	SPECIAL DIE TOOL
272	51	4704	MET'WORKING MACH
273	52	4801	FOOD PROD MACH
274	52	4802	TEXTILE MACH
275	52	4803	WOODWORKING MACH
276	52	4804	PAPER IND MACH
277	52	4805	PRINTING MACH
278	52	4806	SPECIAL IND MACH
279	53	4901	PUMPS,COMPRESORS
280	53	4902	BEARINGS
281	53	4903	BLOWERS
282	53	4904	INDUST PATTERNS
283	53	4905	POWER TRANS EQ
284	53	4906	INDUS FURNACES
285	53	4907	GENERAL IND MACH
286	54	5000	MACH SHOP PROD
287	55	5101	COMPUTING MACH
288	55	5102	TYPEWRITERS
289	55	5103	SCALES
290	55	5104	OFC MACHINES
291	56	5201	MERCH'DISE MACH
292	56	5202	LAUNDRY EQUIP
293	56	5203	REFRIG MACH
294	56	5204	MEASURING PUMPS
295	56	5205	SERVICE IND MACH
296	57	5301	ELEC MEAS INSTR
297	57	5302	TRANSFORMERS
298	57	5303	SWITCHGEAR
299	57	5304	MOTORS,GENERATOR
300	57	5305	IND CONTROLS
301	57	5306	WELDING APPARAT
302	57	5307	CARBON PRODUCTS
303	57	5308	ELEC IND APPARAT
304	58	5401	H'HOLD COOK EQ
305	58	5402	H'HOLD REFRIG EQ
306	58	5403	H'HOLD LAUNDRY
307	58	5404	ELECTRIC H'WARES
308	58	5405	H'HOLD VACUUMS
309	58	5406	SEWING MACHINES
310	58	5407	H'HOLD APPLIANCE
311	59	5501	ELECTRIC LAMPS
312	59	5502	LIGHT FIXTURES
313	59	5503	WIRING DEVICES
314	60	5601	RADIO,TV SETS
315	60	5602	PHONO RECORDS
316	60	5603	PHONE,TELEGR EQ
317	60	5604	R-TV COMMUN EQ
318	61	5701	ELECTRON TUBES
319	61	5702	SEMICONDUCTORS
320	61	5703	ELECTRONIC COMP
321	62	5801	STORAGE BATTERY
322	62	5802	PRIMARY BATTERY
323	62	5803	X-RAY EQUIPMENT
324	62	5804	ENGINE ELEC EQ
325	62	5805	ELECTRICAL EQUIP
326	63	5901	TRUCK,BUS BODIES
327	63	5902	TRUCK TRAILERS
328	63	5903	MOTOR VEH & PART
329	64	6001	AIRCRAFT
330	64	6002	AIRCRAFT ENGINES
331	64	6003	AIRCRAFT PROPELL
332	64	6004	AIRCRAFT EQUIP

399-ORDER INDEX	90-ORDER INDEX	I/O CODE	NAME
333	65	6101	SHIPBUILDING
334	65	6102	BOATBUILDING
335	65	6103	LOCOMOTIVES
336	65	6104	RR, STREET CARS
337	65	6105	MOTOR, BICYCLES
338	65	6106	TRAILER COACHES
339	65	6107	TRANSPORT EQUIP
340	66	6201	SCIEN INSTR
341	66	6202	MECH MEAS DEVICE
342	66	6203	TEMP CONTROLS
343	66	6204	MEDICAL INSTR
344	66	6205	SURGICAL SUPPLY
345	66	6206	DENTAL EQUIPMENT
346	66	6207	WATCHES, CLOCKS
347	67	6301	OPTICAL INSTR
348	67	6302	OPHTHALMIC GOODS
349	67	6303	PHOTOGRAPHIC EQ
350	68	6401	JEWELRY
351	68	6402	MUSICAL INSTR
352	68	6403	GAMES
353	68	6404	ATHLETIC EQUIP
354	68	6405	PENS AND PENCILS
355	68	6406	ARTIFICAL FLOWER
356	68	6407	CLOTH FASTENERS
357	68	6408	BRUSHES
358	68	6409	HARD FLOOR COV
359	68	6410	MORTICIAN GOODS
360	68	6411	SIGNS, ADS
361	68	6412	MISC MFG
362	69	6501	RAILROAD
363	70	6502	LOCAL TRANSPORT
364	71	6503	MOTOR FGT TRANSP
365	72	6504	WATER TRANSPORT
366	73	6505	AIR TRANSPORT
367	74	6506	PIPE LINE TRANSP
368	75	6507	TRANSP SERVICES
369	76	6600	COMMUNICATIONS
370	77	6700	R-TV BROADCAST
371	78	6803	WATER,SANIT SER
372	79	6901	WHOLSALE TRADE
373	79	6902	RETAIL TRADE
374	80	7001	BANKING
375	80	7002	CREDIT AGENCIES
376	80	7003	SEC, COMMOD BROK
377	80	7004	INSUR CARRIERS
378	80	7005	INSURANCE AGENTS
379	81	7101	OWNER-OCC DWLNG
380	81	7102	REAL ESTATE
381	82	7201	HOTELS
382	82	7202	PERSONAL SERVICE
383	82	7203	BARB,BEAUT SHOPS
384	83	7301	MISC BUS SERVICE
385	83	7302	ADVERTISING
386	83	7303	MISC PROF SER
387	84	7500	AUTO REPAIR
388	85	7601	MOTION PICTURE
389	85	7602	AMUSMNT,REC SER
390	86	7701	DOCTORS,DENTISTS
391	86	7702	HOSPITALS
392	86	7703	MED, HEALTH SER
393	86	7704	EDUCATIONAL SER
394	86	7705	NONPROFIT ORG
395	87	7801	POST OFFICE
396	87	7804	FED GOVT ENTERP
397	88	7903	ST,LOC GOVT ENTR
398	89	8100	BUSINESS TRAVEL
399	90	8200	OFFICE SUPPLIES

TABLE B1-2. DIRECT ENERGY TRANSFERS TO CONSTRUCTION SECTORS -- 1967
(TRILLION BTUS)

NUMBER	399-ORDER INDEX	NAME	COAL	CRUDE PETROLEUM	REFINED PETROLEUM	ELECTRICITY	NATURAL GAS	TOTAL
1	23	NEW CONST RES--1 FAM.	0.0	0.0	74.01	1.02	2.63	77.66
2	24	NEW CONST RES--2-4 FAM.	0.0	0.0	4.45	0.05	0.18	4.68
3	25	NEW CONST RES--GRDN APT.	0.0	0.0	20.89	0.16	0.35	21.40
4	26	NEW CONST HIGH-RISE APT.	0.0	0.0	18.89	0.20	0.53	19.61
5	27	NEW CONST RES--ALT.,ADD.	0.0	0.0	7.26	0.08	0.18	7.51
6	28	NEW CONST HOTELS,MOTELS	0.0	0.0	11.67	0.13	0.35	12.15
7	29	NEW CONST DORMITORIES	0.0	0.0	10.45	0.10	0.18	10.72
8	30	NEW CONST INDUST. BLDG.	0.0	0.0	37.41	0.21	0.53	38.15
9	31	NEW CONST OFFICE BLDG.	0.0	0.0	44.55	0.44	1.05	46.04
10	32	NEW CONST WAREHOUSES	0.0	0.0	6.33	0.05	0.18	6.56
11	33	NEW CONST GAR.,SRV. STA.	0.0	0.0	4.96	0.05	0.18	5.19
12	34	NEW CONST STORES,RSTRNTS	0.0	0.0	36.09	0.34	0.88	37.31
13	35	NEW CONST RELIG. BLDG.	0.0	0.0	10.95	0.11	0.18	11.24
14	36	NEW CONST EDUC. BLDG.	0.0	0.0	65.41	0.70	1.58	67.69
15	37	NEW CONST HOSPITAL BLDG.	0.0	0.0	18.70	0.21	0.53	19.44
16	38	NEW CONST OTH. NON-FARM	0.0	0.0	39.17	0.39	0.88	40.44
17	39	NEW CONST TELEPH.,TELEG.	0.0	0.0	12.08	0.08	0.18	12.34
18	40	NEW CONST RAILROADS	0.0	0.0	2.78	0.02	0.0	2.79
19	41	NEW CONST ELECT. UTIL.	0.0	0.0	37.36	0.34	0.38	38.08
20	42	NEW CONST GAS UTIL.	0.0	0.0	61.53	0.16	0.35	62.04
21	43	NEW CONST PETROL. PIPE.	0.0	0.0	15.69	0.02	0.0	15.71
22	44	NEW CONST WATER SUPPLY	0.0	0.0	15.69	0.11	0.18	15.98
23	45	NEW CONST SEWER	0.0	0.0	15.42	0.13	0.35	15.90
24	46	NEW CONST LOC. TRANSIT	0.0	0.0	2.22	0.02	0.0	2.24
25	47	NEW CONST HIGHWAYS	0.0	0.0	407.50	0.78	1.93	410.21
26	48	NEW CONST FARM RESID.	0.0	0.0	1.32	0.02	0.0	1.34
27	49	NEW CONST FARM SERVICE	0.0	0.0	2.64	0.02	0.0	2.65
28	50	NEW CONST OIL/GAS WELLS	0.0	0.0	71.53	0.11	0.35	71.99
29	51	NEW CONST OIL/GAS EXPL.	0.0	0.0	15.83	0.03	0.0	15.87
30	52	NEW CONST MILITARY	0.0	0.0	10.14	0.07	0.18	10.38
31	53	NEW CONST CONS.,DEV.	0.0	0.0	90.55	0.20	0.53	91.28
32	54	NEW CONST OTH. NON-BLDG.	0.0	0.0	26.94	0.11	0.35	27.41
33	55	MAINT CONST RESID.	0.0	0.0	21.64	0.31	0.88	22.82
34	56	MAINT CONST OTH. NON-FRM	0.0	0.0	36.51	0.29	0.70	37.51
35	57	MAINT CONST FARM RESID.	0.0	0.0	1.85	0.03	0.0	1.88
36	58	MAINT CONST FARM SERVICE	0.0	0.0	1.85	0.0	0.0	1.85
37	59	MAINT CONST TEL.,TEL.	0.0	0.0	2.92	0.03	0.0	2.95
38	60	MAINT CONST RAILROADS	0.0	0.0	5.83	0.03	0.0	5.87
39	61	MAINT CONST ELECT. UTIL.	0.0	0.0	2.36	0.03	0.0	2.39
40	62	MAINT CONST GAS UTIL.	0.0	0.0	5.83	0.0	0.0	5.83
41	63	MAINT CONST PETR. PIPE.	0.0	0.0	2.78	0.0	0.0	2.78
42	64	MAINT CONST WATER SUPPLY	0.0	0.0	14.31	0.07	0.0	14.37
43	65	MAINT CONST SEWER	0.0	0.0	4.03	0.03	0.0	4.06
44	66	MAINT CONST LOC. TRANSIT	0.0	0.0	0.42	0.0	0.0	0.42
45	67	MAINT CONST MILITARY	0.0	0.0	14.58	0.10	0.18	14.86
46	68	MAINT CONST CONSER.,DEV.	0.0	0.0	13.19	0.0	0.0	13.19
47	69	MAINT CONST HIGHWAYS	0.0	0.0	98.75	0.08	0.18	99.01
48	70	MAINT CONST OIL/GS WELLS	0.0	0.0	11.81	0.03	0.0	11.84
49	71	MAINT CONST OTH. N-BLDG.	0.0	0.0	20.28	0.14	0.18	20.59
		TOTAL	0.0	0.0	1459.36	7.64	17.71	1484.71

TABLE B1-3. ENERGY INTENSITIES FOR 399-ORDER CONSTRUCTION SECTORS -- 1967
(BTUS/$)

NUMBER	399 ORDER INDEX	I/O CODE	NAME	COAL	CRUDE PETROLEUM	REFINED PETROLEUM	ELECTRICITY	NATURAL GAS	TOTAL PRIMARY
1	23	110101	NEW CONST RES--1 FAM.	14003.	39413.	19978.	3397.	18462.	55511.
2	24	110102	NEW CONST RES--2-4 FAM.	13355.	36375.	19221.	3096.	16763.	52139.
3	25	110103	NEW CONST RES--GRDN APT.	13605.	37351.	20061.	3095.	16408.	52864.
4	26	110104	NEW CONST HIGH-RISE APT.	16495.	41452.	21938.	3329.	13536.	60000.
5	27	110105	NEW CONST RES--ALT.,ADD.	15047.	34245.	14833.	3820.	18514.	51646.
6	28	110106	NEW CONST HOTELS.MOTELS	18493.	48311.	26089.	3862.	21071.	69184.
7	29	110107	NEW CONST DORMITORIES	18828.	49390.	26507.	3869.	21711.	70604.
8	30	110201	NEW CONST INDUST. BLDG.	22820.	45543.	21141.	4055.	23311.	70864.
9	31	110202	NEW CONST OFFICE BLDG.	19360.	46984.	25301.	3882.	20564.	68737.
10	32	110203	NEW CONST WAREHOUSES	24198.	50752.	26327.	4227.	23224.	77555.
11	33	110204	NEW CONST GAR.,SRV. STA.	22108.	51517.	28071.	4203.	22250.	76217.
12	34	110205	NEW CONST STORES,RSTRNTS	19519.	51308.	29090.	3821.	21039.	73183.
13	35	110206	NEW CONST RELIG. BLDG.	17318.	46060.	24464.	3598.	20481.	65597.
14	36	110207	NEW CONST EDUC. BLDG.	18677.	46869.	24693.	3857.	20996.	67924.
15	37	110208	NEW CONST HOSPITAL BLDG.	16746.	41563.	21726.	3670.	18809.	60572.
16	38	110209	NEW CONST OTH. NON-FARM	19887.	47587.	25532.	3925.	20939.	69894.
17	39	110301	NEW CONST TELEPH.-TELEG.	17424.	45895.	22999.	5381.	21608.	66636.
18	40	110302	NEW CONST RAILROADS	28458.	46451.	23903.	4339.	21433.	77585.
19	41	110303	NEW CONST ELECT. UTIL.	20993.	43175.	21598.	4008.	20545.	66639.
20	42	110304	NEW CONST GAS UTIL.	45636.	91094.	59589.	5366.	29562.	140038.
21	43	110305	NEW CONST PETROL. PIPE.	42247.	101722.	70642.	5235.	28955.	147197.
22	44	110306	NEW CONST WATER SUPPLY	23406.	47726.	25645.	4227.	20957.	73738.
23	45	110307	NEW CONST SEWER	18434.	56272.	28993.	3442.	25944.	76328.
24	46	110308	NEW CONST LOC. TRANSIT	20327.	40174.	21904.	3157.	17338.	62447.
25	47	110400	NEW CONST HIGHWAYS	20241.	101369.	75998.	3464.	23254.	123745.
26	48	110501	NEW CONST FARM RESID.	15569.	35935.	15948.	3681.	19060.	53773.
27	49	110502	NEW CONST FARM SERVICE	26409.	46623.	21702.	4744.	23754.	75956.
28	50	110503	NEW CONST OIL/GAS WELLS	37407.	76881.	49357.	4229.	25530.	116895.
29	51	110504	NEW CONST OIL/GAS EXPL.	5356.	86708.	74494.	1422.	10144.	92941.
30	52	110505	NEW CONST MILITARY	20415.	55006.	31182.	3884.	22537.	77815.
31	53	110506	NEW CONST CONS.,DEV.	12722.	70539.	54079.	2476.	14970.	84788.
32	54	110507	NEW CONST OTH. NON-BLDG.	18129.	69414.	48460.	3120.	19467.	89465.
33	55	120100	MAINT CONST RESID.	11488.	36812.	20899.	2875.	15033.	50072.
34	56	120201	MAINT CONST OTH. NON-FRM	12150.	35776.	18784.	2910.	16154.	49720.
35	57	120202	MAINT CONST FARM RESID.	20102.	48673.	26137.	4083.	21373.	71292.
36	58	120203	MAINT CONST FARM SERVICE	26852.	66421.	38132.	4890.	26744.	96288.
37	59	120204	MAINT CONST TEL.,TEL.	8819.	25240.	14395.	2385.	10267.	35530.
38	60	120205	MAINT CONST RAILROADS	15268.	26129.	13882.	2270.	11617.	42796.
39	61	120206	MAINT CONST ELECT. UTIL.	8253.	17092.	8891.	1741.	7802.	25418.
40	62	120207	MAINT CONST GAS UTIL.	22534.	58705.	40899.	2821.	16578.	83078.
41	63	120208	MAINT CONST PETR. PIPE.	32697.	82023.	57954.	3956.	22337.	117158.
42	64	120209	MAINT CONST WATER SUPPLY	11793.	48781.	34501.	2193.	13261.	61927.
43	65	120210	MAINT CONST SEWER	10341.	33544.	20229.	1880.	12580.	45044.
44	66	120211	MAINT CONST LOC. TRANSIT	11190.	35902.	23320.	2353.	11786.	48542.
45	67	120212	MAINT CONST MILITARY	11130.	49546.	34243.	2718.	14238.	62352.
46	68	120213	MAINT CONST CONSER.,DEV.	4484.	87809.	76723.	1088.	9348.	92963.
47	69	120214	MAINT CONST HIGHWAYS	7345.	67689.	55122.	1638.	11228.	76044.
48	70	120215	MAINT CONST OIL/GS WELLS	39382.	67146.	39866.	4177.	25703.	109103.
49	71	120216	MAINT CONST OTH. N-BLDG.	7104.	53819.	42237.	1819.	10464.	62045.

TABLE B1-4. RANKED TOTAL PRIMARY ENERGY INTENSITIES FOR 399-ORDER CONSTRUCTION SECTORS -- 1967 (BTUS/$)

RANK	399-ORDER INDEX	I/O CODE	NAME	TOTAL PRIMARY INTENSITY
1	43	110305	NEW CONST PETROL. PIPE.	147197.
2	42	110304	NEW CONST GAS UTIL.	140038.
3	47	110400	NEW CONST HIGHWAYS	123745.
4	63	120208	MAINT CONST PETR. PIPE.	117159.
5	50	110503	NEW CONST OIL/GAS WELLS	116895.
6	70	120215	MAINT CONST OIL/GS WELLS	109103.
7	58	120203	MAINT CONST FARM SERVICE	96288.
8	68	120213	MAINT CONST CONSER.,DEV.	92963.
9	51	110504	NEW CONST OIL/GAS EXPL.	92941.
10	54	110507	NEW CONST OTH. NON-BLDG.	89465.
11	53	110506	NEW CONST CONS.,DEV.	84788.
12	62	120207	MAINT CONST GAS UTIL.	83078.
13	52	110505	NEW CONST MILITARY	77815.
14	40	110302	NEW CONST RAILROADS	77585.
15	32	110203	NEW CONST WAREHOUSES	77555.
16	45	110307	NEW CONST SEWER	76628.
17	33	110204	NEW CONST GAR.,SRV. STA.	76217.
18	69	120214	MAINT CONST HIGHWAYS	76044.
19	49	110502	NEW CONST FARM SERVICE	75956.
20	44	110306	NEW CONST WATER SUPPLY	73738.
21	34	110205	NEW CONST STORES,RSTRNTS	73183.
22	57	120202	MAINT CONST FARM RESID.	71292.
23	30	110201	NEW CONST INDUST. BLDG.	70864.
24	29	110107	NEW CONST DORMITORIES	70604.
25	38	110209	NEW CONST OTH. NON-FARM	69894.
26	28	110106	NEW CONST HOTELS,MOTELS	69184.
27	31	110202	NEW CONST OFFICE BLDG.	68737.
28	36	110207	NEW CONST EDUC. BLDG.	67924.
29	41	110303	NEW CONST ELECT. UTIL.	66639.
30	39	110301	NEW CONST TELEPH.,TELEG.	66636.
31	35	110206	NEW CONST RELIG. BLDG.	65597.
32	46	110308	NEW CONST LOC. TRANSIT	62447.
33	67	120212	MAINT CONST MILITARY	62352.
34	71	120216	MAINT CONST OTH. N-BLDG.	62045.
35	64	120209	MAINT CONST WATER SUPPLY	61927.
36	37	110208	NEW CONST HOSPITAL BLDG.	60572.
37	26	110104	NEW CONST HIGH-RISE APT.	60000.
38	23	110101	NEW CONST RES--1 FAM.	55511.
39	48	110501	NEW CONST FARM RESID.	53773.
40	25	110103	NEW CONST RES--GRDN APT.	52864.
41	24	110102	NEW CONST RES--2-4 FAM.	52139.
42	27	110105	NEW CONST RES--ALT.,ADD.	51646.
43	55	120100	MAINT CONST RESID.	50072.
44	56	120201	MAINT CONST OTH. NON-FRM	49720.
45	66	120211	MAINT CONST LOC. TRANSIT	48542.
46	65	120210	MAINT CONST SEWER	45044.
47	60	120205	MAINT CONST RAILROADS	42796.
48	59	120204	MAINT CONST TEL.,TEL.	35530.
49	61	120206	MAINT CONST ELECT. UTIL.	26418.

TABLE B1-5. GROSS DOMESTIC OUTPUT FOR CONSTRUCTION SECTORS -- 1967
(MILLIONS OF DOLLARS)

399-ORDER INDEX	NAME	GDO
23	NEW CONST RES--1 FAM.	14069.0
24	NEW CONST RES--2-4 FAM.	668.0
25	NEW CONST RES--GRDN APT.	2795.0
26	NEW CONST HIGH-RISE APT.	1966.0
27	NEW CONST RES--ALT.,ADD.	5070.0
28	NEW CONST HOTELS,MOTELS	998.0
29	NEW CONST DORMITORIES	819.0
30	NEW CONST INDUST. BLDG.	6539.0
31	NEW CONST OFFICE BLDG.	3763.0
32	NEW CONST WAREHOUSES	745.0
33	NEW CONST GAR.,SRV. STA.	423.0
34	NEW CONST STORES,RSTRNTS	2692.0
35	NEW CONST RELIG. BLDG.	1046.0
36	NEW CONST EDUC. BLDG.	6439.0
37	NEW CONST HOSPITAL BLDG.	1935.0
38	NEW CONST OTH. NON-FARM	3306.0
39	NEW CONST TELEPH.,TELEG.	1638.0
40	NEW CONST RAILROADS	327.0
41	NEW CONST ELECT. UTIL.	4561.0
42	NEW CONST GAS UTIL.	1549.0
43	NEW CONST PETROL. PIPE.	312.0
44	NEW CONST WATER SUPPLY	1270.0
45	NEW CONST SEWER	1058.0
46	NEW CONST LOC. TRANSIT	204.0
47	NEW CONST HIGHWAYS	8371.0
48	NEW CONST FARM RESID.	562.0
49	NEW CONST FARM SERVICE	762.0
50	NEW CONST OIL/GAS WELLS	2015.0
51	NEW CONST OIL/GAS EXPL.	243.0
52	NEW CONST MILITARY	695.0
53	NEW CONST CONS.,DEV.	2124.0
54	NEW CONST OTH. NON-BLDG.	925.0
55	MAINT CONST RESID.	6265.0
56	MAINT CONST OTH. NON-FRM	7166.9
57	MAINT CONST FARM RESID.	354.2
58	MAINT CONST FARM SERVICE	396.8
59	MAINT CONST TEL.,TEL.	517.0
60	MAINT CONST RAILROADS	1094.0
61	MAINT CONST ELECT. UTIL.	717.0
62	MAINT CONST GAS UTIL.	259.0
63	MAINT CONST PETR. PIPE.	65.0
64	MAINT CONST WATER SUPPLY	993.0
65	MAINT CONST SEWER	401.0
66	MAINT CONST LOC. TRANSIT	43.0
67	MAINT CONST MILITARY	849.0
68	MAINT CONST CONSER.,DEV.	194.0
69	MAINT CONST HIGHWAYS	2988.0
70	MAINT CONST OIL/GS WELLS	426.0
71	MAINT CONST OTH. N-BLDG.	662.0
	TOTAL	103278.3

TABLE B1-6. AVERAGE ENERGY INTENSITIES FOR CONSTRUCTION -- 1967
(BTUS/$)

	NEW CONSTRUCTION	MAINTENANCE AND REPAIR CONSTRUCTION	ALL CONSTRUCTION
COAL	19138.	12059.	17535.
CRUDE PETROLEUM	52678.	42498.	50372.
REFINED PETROLEUM	30755.	26946.	29893.
ELECTRICITY	3742.	2635.	3492.
NATURAL GAS	20695.	14601.	19315.
TOTAL PRIMARY	74122.	56182.	70059.

TABLE B1-7. TOTAL ENERGY OF FINAL DEMAND FOR CONSTRUCTION SECTORS -- 1967 (TRILLIONS OF BTUS)

NUMBER	399-ORDER INDEX	I/O CODE	NAME	TOTAL ENERGY (DIRECT AND INDIRECT)	PERCENT DIRECT	PERCENT OF TOTAL CONSTRUCTION (DIRECT AND INDIRECT)	PERCENT OF TOTAL UNITED STATES (DIRECT AND INDIRECT)
1	23	110101	NEW CONST RES--1 FAM.	780.98	9.94	12.39	1.17
2	24	110102	NEW CONST RES--2-4 FAM.	34.83	13.43	0.55	0.05
3	25	110103	NEW CONST RES--GRDN APT.	147.76	14.49	2.34	0.22
4	26	110104	NEW CONST HIGH-RISE APT.	117.96	16.63	1.87	0.18
5	27	110105	NEW CONST RES--ALT.,ADD.	261.65	2.87	4.16	0.39
6	28	110106	NEW CONST HOTELS,MOTELS	69.05	17.60	1.10	0.10
7	29	110107	NEW CONST DORMITORIES	57.82	18.54	0.92	0.09
8	30	110201	NEW CONST INDUST. BLDG.	463.38	8.23	7.35	0.69
9	31	110202	NEW CONST OFFICE BLDG.	258.66	17.80	4.10	0.39
10	32	110203	NEW CONST WAREHOUSES	57.78	11.35	0.92	0.09
11	33	110204	NEW CONST GAR.,SRV. STA.	32.24	16.09	0.51	0.05
12	34	110205	NEW CONST STORES,RSTRNTS	197.01	18.94	3.13	0.29
13	35	110206	NEW CONST RELIG. BLDG.	68.61	16.39	1.09	0.10
14	36	110207	NEW CONST EDUC. BLDG.	437.36	15.48	6.94	0.65
15	37	110208	NEW CONST HOSPITAL BLDG.	117.21	16.58	1.86	0.18
16	38	110209	NEW CONST OTH. NON-FARM	231.07	17.50	3.67	0.35
17	39	110301	NEW CONST TELEPH.,TELEG.	109.15	11.31	1.73	0.16
18	40	110302	NEW CONST RAILROADS	25.37	11.01	0.40	0.04
19	41	110303	NEW CONST ELECT. UTIL.	303.94	12.69	4.82	0.45
20	42	110304	NEW CONST GAS UTIL.	216.92	28.60	3.44	0.32
21	43	110305	NEW CONST PETROL. PIPE.	45.93	34.21	0.73	0.07
22	44	110306	NEW CONST WATER SUPPLY	93.65	17.07	1.49	0.14
23	45	110307	NEW CONST SEWER	81.28	19.56	1.29	0.12
24	46	110308	NEW CONST LOC. TRANSIT	12.74	17.57	0.20	0.02
25	47	110400	NEW CONST HIGHWAYS	1035.87	39.60	16.44	1.55
26	48	110501	NEW CONST FARM RESID.	30.22	4.42	0.48	0.05
27	49	110502	NEW CONST FARM SERVICE	57.88	4.59	0.92	0.09
28	50	110503	NEW CONST OIL/GAS WELLS	235.54	30.56	3.74	0.35
29	51	110504	NEW CONST OIL/GAS EXPL.	22.58	70.25	0.36	0.03
30	52	110505	NEW CONST MILITARY	54.08	19.19	0.86	0.08
31	53	110506	NEW CONST CONS.,DEV.	180.09	50.68	2.86	0.27
32	54	110507	NEW CONST OTH. NON-BLDG.	82.76	33.12	1.31	0.12
33	55	120100	MAINT CONST RESID.	8.81	7.28	0.14	0.01
34	56	120201	MAINT CONST OTH. NON-FRM	70.79	10.53	1.12	0.11
35	57	120202	MAINT CONST FARM RESID.	0.0	0.0	0.0	0.0
36	58	120203	MAINT CONST FARM SERVICE	0.0	0.0	0.0	0.0
37	59	120204	MAINT CONST TEL.,TEL.	0.0	0.0	0.0	0.0
38	60	120205	MAINT CONST RAILROADS	0.0	0.0	0.0	0.0
39	61	120206	MAINT CONST ELECT. UTIL.	0.0	0.0	0.0	0.0
40	62	120207	MAINT CONST GAS UTIL.	0.0	0.0	0.0	0.0
41	63	120208	MAINT CONST PETR. PIPE.	0.0	0.0	0.0	0.0
42	64	120209	MAINT CONST WATER SUPPLY	0.0	0.0	0.0	0.0
43	65	120210	MAINT CONST SEWER	0.0	0.0	0.0	0.0
44	66	120211	MAINT CONST LOC. TRANSIT	0.0	0.0	0.0	0.0
45	67	120212	MAINT CONST MILITARY	52.94	28.07	0.84	0.08
46	68	120213	MAINT CONST CONSER.,DEV.	18.03	73.16	0.29	0.03
47	69	120214	MAINT CONST HIGHWAYS	220.00	43.57	3.49	0.33
48	70	120215	MAINT CONST OIL/GS WELLS	0.0	0.0	0.0	0.0
49	71	120216	MAINT CONST OTH. N-BLDG.	9.85	50.13	0.16	0.01
			TOTAL	6301.94	19.52	100.00	9.42

TABLE B1-8. RANKED TOTAL ENERGY OF FINAL DEMAND FOR CONSTRUCTION SECTORS -- 1967 (TRILLION BTUS)

RANK	399-ORDER INDEX	NAME	TOTAL ENERGY (DIRECT AND INDIRECT)	PERCENT DIRECT
1	47	NEW CONST HIGHWAYS	1035.87	39.60
2	23	NEW CONST RES--1 FAM.	780.98	9.94
3	30	NEW CONST INDUST. BLDG.	463.38	8.23
4	36	NEW CONST EDUC. BLDG.	437.36	15.48
5	41	NEW CONST ELECT. UTIL.	303.94	12.69
6	27	NEW CONST RES--ALT.,ADD.	261.85	2.87
7	31	NEW CONST OFFICE BLDG.	258.66	17.80
8	50	NEW CONST OIL/GAS WELLS	235.54	30.56
9	38	NEW CONST OTH. NON-FARM	231.07	17.50
10	69	MAINT CONST HIGHWAYS	220.00	43.57
11	42	NEW CONST GAS UTIL.	216.92	28.60
12	34	NEW CONST STORES,RSTRNTS	197.01	18.94
13	53	NEW CONST CONS.,DEV.	180.09	50.68
14	25	NEW CONST RES--GRDN APT.	147.76	14.49
15	26	NEW CONST HIGH-RISE APT.	117.96	16.63
16	37	NEW CONST HOSPITAL BLDG.	117.21	16.58
17	39	NEW CONST TELEPH.,TELEG.	109.15	11.31
18	44	NEW CONST WATER SUPPLY	93.65	17.07
19	54	NEW CONST OTH. NON-BLDG.	82.76	33.12
20	45	NEW CONST SEWER	81.28	19.56
21	56	MAINT CONST OTH. NON-FRM	70.79	10.53
22	28	NEW CONST HOTELS,MOTELS	69.05	17.60
23	35	NEW CONST RELIG. BLDG.	68.61	16.39
24	49	NEW CONST FARM SERVICE	57.88	4.59
25	29	NEW CONST DORMITORIES	57.82	18.54
26	32	NEW CONST WAREHOUSES	57.78	11.35
27	52	NEW CONST MILITARY	54.08	19.19
28	67	MAINT CONST MILITARY	52.94	23.07
29	43	NEW CONST PETROL. PIPE.	45.93	34.21
30	24	NEW CONST RES--2-4 FAM.	34.83	13.43
31	33	NEW CONST GAR.,SRV. STA.	32.24	15.09
32	48	NEW CONST FARM RESID.	30.22	4.42
33	40	NEW CONST RAILROADS	25.37	11.01
34	51	NEW CONST OIL/GAS EXPL.	22.58	70.25
35	68	MAINT CONST CONSER.,DEV.	18.03	73.16
36	46	NEW CONST LOC. TRANSIT	12.74	17.57
37	71	MAINT CONST OTH. N-BLDG.	9.85	50.13
38	55	MAINT CONST RESID.	8.81	7.23
39	57	MAINT CONST FARM RESID.	0.0	0.0
40	58	MAINT CONST FARM SERVICE	0.0	0.0
41	59	MAINT CONST TEL.,TEL.	0.0	0.0
42	60	MAINT CONST RAILROADS	0.0	0.0
43	61	MAINT CONST ELECT. UTIL.	0.0	0.0
44	62	MAINT CONST GAS UTIL.	0.0	0.0
45	63	MAINT CONST PETR. PIPE.	0.0	0.0
46	64	MAINT CONST WATER SUPPLY	0.0	0.0
47	65	MAINT CONST SEWER	0.0	0.0
48	66	MAINT CONST LOC. TRANSIT	0.0	0.0
49	70	MAINT CONST OIL/GS WELLS	0.0	0.0

TABLE B1-9. TOTAL ENERGY REQUIREMENT BY CONSTRUCTION SECTOR -- 1967 (TRILLION BTU)

NUMBER	399-ORDER INDEX	NAME	TOTAL REQUIREMENT	PERCENT OF GRAND TOTAL
1	23	NEW CONST RES--1 FAM.	780.96	10.79
2	24	NEW CONST RES--2-4 FAM.	34.83	0.48
3	25	NEW CONST RES--GRDN APT.	147.75	2.04
4	26	NEW CONST HIGH-RISE APT.	117.96	1.63
5	27	NEW CONST RES--ALT.,ADD.	261.85	3.62
6	28	NEW CONST HOTELS,MOTELS	69.05	0.95
7	29	NEW CONST DORMITORIES	57.82	0.80
8	30	NEW CONST INDUST. BLDG.	463.37	6.40
9	31	NEW CONST OFFICE BLDG.	258.66	3.57
10	32	NEW CONST WAREHOUSES	57.78	0.80
11	33	NEW CONST GAR.,SRV. STA.	32.24	0.45
12	34	NEW CONST STORES,RSTRNTS	197.01	2.72
13	35	NEW CONST RELIG. BLDG.	68.61	0.95
14	36	NEW CONST EDUC. BLDG.	437.35	6.04
15	37	NEW CONST HOSPITAL BLDG.	117.21	1.62
16	38	NEW CONST OTH. NON-FARM	231.07	3.19
17	39	NEW CONST TELEPH.,TELEG.	109.15	1.51
18	40	NEW CONST RAILROADS	25.37	0.35
19	41	NEW CONST ELECT. UTIL.	303.94	4.20
20	42	NEW CONST GAS UTIL.	216.92	3.00
21	43	NEW CONST PETROL. PIPE.	45.92	0.63
22	44	NEW CONST WATER SUPPLY	93.65	1.29
23	45	NEW CONST SEWER	81.28	1.12
24	46	NEW CONST LOC. TRANSIT	12.74	0.18
25	47	NEW CONST HIGHWAYS	1035.86	14.32
26	48	NEW CONST FARM RESID.	30.22	0.42
27	49	NEW CONST FARM SERVICE	57.88	0.80
28	50	NEW CONST OIL/GAS WELLS	235.54	3.26
29	51	NEW CONST OIL/GAS EXPL.	22.58	0.31
30	52	NEW CONST MILITARY	54.08	0.75
31	53	NEW CONST CONS.,DEV.	180.09	2.49
32	54	NEW CONST OTH. NON-BLDG.	82.76	1.14
33	55	MAINT CONST RESID.	313.70	4.34
34	56	MAINT CONST OTH. NON-FRM	356.33	4.92
35	57	MAINT CONST FARM RESID.	25.25	0.35
36	58	MAINT CONST FARM SERVICE	38.21	0.53
37	59	MAINT CONST TEL.,TEL.	18.37	0.25
38	60	MAINT CONST RAILROADS	46.82	0.65
39	61	MAINT CONST ELECT. UTIL.	18.94	0.26
40	62	MAINT CONST GAS UTIL.	21.52	0.30
41	63	MAINT CONST PETR. PIPE.	7.62	0.11
42	64	MAINT CONST WATER SUPPLY	61.49	0.85
43	65	MAINT CONST SEWER	18.06	0.25
44	66	MAINT CONST LOC. TRANSIT	2.09	0.03
45	67	MAINT CONST MILITARY	52.94	0.73
46	68	MAINT CONST CONSER.,DEV.	18.03	0.25
47	69	MAINT CONST HIGHWAYS	227.22	3.14
48	70	MAINT CONST OIL/GS WELLS	46.48	0.64
49	71	MAINT CONST OTH. N-BLDG.	41.07	0.57
		GRAND TOTAL	7235.55	100.00

TABLE B1-10

RANKED TOTAL ENERGY REQUIREMENTS
FOR NEW BUILDING CONSTRUCTION -- 1967

399-ORDER INDEX	NAME	TOTAL ENERGY (TRILLION BTU)	INPUT FRACTION	CUMULATIVE FRACTION
3	PETRO REFIN PROD	497.37	0.1454	0.1454
206	READY-MIX CONCR	301.92	0.0882	0.2336
240	FAB STRUC STEEL	195.31	0.0571	0.2907
196	BRICKS	105.66	0.0309	0.3216
241	METAL DOORS	101.88	0.0298	0.3513
243	SHEET METAL WORK	95.39	0.0279	0.3792
245	MISC METAL WORK	94.30	0.0276	0.4068
373	RETAIL TRADE	93.95	0.0275	0.4342
135	SAWMILLS	85.88	0.0251	0.4593
184	ASPHALT	85.82	0.0251	0.4844
372	WHOLSALE TRADE	83.93	0.0245	0.5089
217	STEEL PROD	77.18	0.0226	0.5315
230	NONFER WIRE	75.85	0.0222	0.5537
386	MISC PROF SER	61.24	0.0179	0.5716
204	CONCRETE BLOCKS	60.45	0.0177	0.5892
195	CEMENT	55.25	0.0161	0.6054
138	MILLWORK	54.13	0.0158	0.6212
312	LIGHT FIXTURES	50.69	0.0148	0.6360
139	VENEER,PLYWOOD	50.26	0.0147	0.6507
205	CONCRETE PRODUCT	48.74	0.0142	0.6649
208	GYPSUM PRODUCTS	45.83	0.0134	0.6783
188	MISC PLASTICS	43.40	0.0127	0.6910
244	ARCH METAL WORK	43.33	0.0127	0.7037
255	PIPE	43.07	0.0126	0.7163
362	RAILROAD	41.87	0.0122	0.7285
242	FAB PLATE WORK	41.30	0.0121	0.7406
182	PAINT PRODUCTS	40.49	0.0118	0.7524
293	REFRIG MACH	38.79	0.0113	0.7638
183	PAVING	38.25	0.0112	0.7749
239	HEATING EQUIP	34.66	0.0101	0.7851
214	MINERAL WOOL	34.56	0.0101	0.7952
398	BUSINESS TRAVEL	33.64	0.0098	0.8050
160	BUILDING PAPER	30.99	0.0091	0.8141
364	MOTOR FGT TRANSP	30.10	0.0088	0.8229
252	FAB WIRE PRODUCT	28.07	0.0082	0.8311
140	PREFAB WD STRUC	23.60	0.0069	0.8380
227	COPPER ROLLING	23.46	0.0069	0.8448
250	HARDWARE	23.07	0.0067	0.8516
211	ASBESTOS PRODUCT	21.72	0.0063	0.8579
238	PLUMB FITTINGS	20.49	0.0060	0.8639
215	NONCLAY REFRACT	20.04	0.0059	0.8697
384	MISC BUS SERVICE	18.01	0.0053	0.8750
298	SWITCHGEAR	17.24	0.0050	0.8800
117	FLOOR COVERINGS	16.81	0.0049	0.8850
197	CERAMIC TILE	16.56	0.0048	0.8898
4	ELECTRIC UTIL	16.19	0.0047	0.8945
142	WOOD PRODUCTS	16.04	0.0047	0.8992
237	METAL SANIT WARE	15.81	0.0046	0.9038
193	GLASS PRODUCTS	15.66	0.0046	0.9084
21	STONE CLAY MIN	14.89	0.0044	0.9128
199	CLAY PRODUCTS	12.94	0.0038	0.9165
144	WOOD H'HOLD FURN	12.63	0.0037	0.9202
198	CLAY REFRACT	12.34	0.0036	0.9238
313	WIRING DEVICES	12.08	0.0035	0.9274
342	TEMP CONTROLS	11.66	0.0034	0.9308
267	HOISTS, CRANES	11.53	0.0034	0.9342
5	GAS UTILITIES	11.39	0.0033	0.9375
387	AUTO REPAIR	11.10	0.0032	0.9407

TABLE B1-10 (continued)

200	PLUMBING FIXTURE	10.44	0.0031	0.9438
174	MISC CHEM PROD	10.21	0.0030	0.9468
218	IR,STL FOUNDRIES	10.14	0.0030	0.9497
265	ELEVATORS	9.65	0.0028	0.9525
380	REAL ESTATE	8.89	0.0026	0.9551
161	CONV PAPER PROD	6.84	0.0020	0.9571
365	WATER TRANSPORT	6.81	0.0020	0.9591
207	LIME	6.74	0.0020	0.9611
136	HARDWD FLOORING	6.36	0.0019	0.9630
152	MET FIXTURES	6.24	0.0018	0.9648
310	H'HOLD APPLIANCE	6.14	0.0018	0.9666
146	MET H'HOLD FURN	6.13	0.0018	0.9684
151	WOOD FIXTURES	5.91	0.0017	0.9701
279	PUMPS,COMPRESORS	5.91	0.0017	0.9718
209	STONE PRODUCTS	5.15	0.0015	0.9733
377	INSUR CARRIERS	4.82	0.0014	0.9747
307	ELECTRIC H'WARES	4.49	0.0013	0.9761
141	WOOD PRESERVING	4.19	0.0012	0.9773
358	HARD FLOOR COV	3.80	0.0011	0.9784
385	ADVERTISING	3.51	0.0010	0.9794
15	FOR,GRHOUSE,NURS	3.40	0.0010	0.9804
369	COMMUNICATIONS	3.26	0.0010	0.9814
394	NONPROFIT ORG	3.24	0.0009	0.9823
228	ALUM ROLLING	3.20	0.0009	0.9832
213	TREATED MINERALS	3.07	0.0009	0.9841
366	AIR TRANSPORT	3.02	0.0009	0.9850
185	TIRES	2.69	0.0008	0.9858
229	NONFER ROLLING	2.59	0.0008	0.9866
17	AG FOR,FISH SER	2.56	0.0007	0.9873
171	INORG-ORG CHEM	2.56	0.0007	0.9881
374	BANKING	2.48	0.0007	0.9888
187	MISC RUBBER PROD	2.29	0.0007	0.9894
281	BLOWERS	2.29	0.0007	0.9901
137	SPEC PROD SAWMIL	2.19	0.0006	0.9908
210	ABRASIVE PRODUCT	2.04	0.0006	0.9914
246	SCREW MACH PROD	2.02	0.0006	0.9919
266	CONVEYORS	1.97	0.0006	0.9925
397	ST,LOC GOVT ENTR	1.81	0.0005	0.9930
360	SIGNS, ADS	1.58	0.0005	0.9935
130	APPAREL,PURCH MAT	1.57	0.0005	0.9940
286	MACH SHOP PROD	1.56	0.0005	0.9944
212	GASKETS	1.49	0.0004	0.9949
325	ELECTRICAL EQUIP	1.39	0.0004	0.9953
399	OFFICE SUPPLIES	1.22	0.0004	0.9956
371	WATER,SANIT SER	1.17	0.0003	0.9960
113	BROAD FAB MILLS	1.17	0.0003	0.9963
150	PUBLIC BLDG FURN	1.13	0.0003	0.9966
122	COATED FABRICS	1.05	0.0003	0.9969
357	BRUSHES	1.05	0.0003	0.9973
317	R-TV COMMUN EQ	1.05	0.0003	0.9976
247	METAL STAMPINGS	0.96	0.0003	0.9978
56	MAINT CONST OTH. NON-FRM	0.85	0.0002	0.9981
301	WELDING APPARAT	0.82	0.0002	0.9983
220	PRIMARY MET PROD	0.76	0.0002	0.9986
395	POST OFFICE	0.68	0.0002	0.9988
10	FEED GRAINS	0.50	0.0001	0.9989
321	STORAGE BATTERY	0.47	0.0001	0.9990
297	TRANSFORMERS	0.43	0.0001	0.9992
367	PIPE LINE TRANSP	0.29	0.0001	0.9992
324	ENGINE ELEC EQ	0.28	0.0001	0.9993
249	HANDTOOLS	0.27	0.0001	0.9994
158	ENVELOPES	0.26	0.0001	0.9995
216	NONMET MIN PROD	0.23	0.0001	0.9996
262	CONST MACHINERY	0.22	0.0001	0.9996
302	CARBON PRODUCTS	0.18	0.0001	0.9997
308	H'HOLD VACUUMS	0.16	0.0000	0.9997
125	CORDAGE, TWINE	0.13	0.0000	0.9998
346	WATCHES, CLOCKS	0.13	0.0000	0.9998

TABLE B1-10 (continued)

376	SEC, COMMOD BROK	0.12	0.0000	0.9998
361	MISC MFG	0.09	0.0000	0.9999
322	PRIMARY BATTERY	0.08	0.0000	0.9999
271	SPECIAL DIE TOOL	0.07	0.0000	0.9999
165	BOOK PUBLISHING	0.06	0.0000	0.9999
339	TRANSPORT EQUIP	0.06	0.0000	0.9999
299	MOTORS,GENERATOR	0.05	0.0000	0.9999
311	ELECTRIC LAMPS	0.05	0.0000	1.0000
258	FAB METAL PROD	0.03	0.0000	1.0000
309	IND CONTROLS	0.03	0.0000	1.0000
232	BRASS,OTHR CAST	0.03	0.0000	1.0000
133	FAB TEXTILE PROD	0.02	0.0000	1.0000
179	MISC PRINTING	0.02	0.0000	1.0000
328	MOTOR VEH & PART	0.01	0.0000	1.0000
	TOTAL	3421.63	1.0000	1.0000

B2. ESTABLISHMENT OF PRICES PAID BY THE CONSTRUCTION INDUSTRY FOR DIRECT ENERGY IN 1967.

A. SUMMARY

In order to establish overall use of energy according to different categories of building, it has been necessary to convert the dollar figures in the Input/Output transaction charts, established by BEA and used as the basis of the CAC energy matrix, into Btu quantities. Of the five direct energy sectors only three - Refined Petroleum, Electricity, and Natural Gas - show any direct transactions to the 49 Construction sectors. There are no direct transactions to Construction from the Coal Mining or Crude Petroleum sectors.

The average prices of these energy materials have been developed using regional figures, where available; weighting these according to the extent of construction in the regions; and, further, weighting the price per unit of energy according to the kind of energy purchased. On this basis we have established an overall quantity of energy use and have distributed this according to building category.

In toto, about 1.9 percent of the total dollar transactions in the construction sectors was used to purchase energy directly. This sum - $1,093.2 million - purchased a total of 1485 trillion Btu.

B. COMPUTATION OF PRICES PAID BY THE CONSTRUCTION SECTORS FOR DIRECT ENERGY IN 1967.

According to the transactions charted by BEA, there was no direct purchase of coal or crude oil by the Construction Sectors in 1967. Of the remaining direct fuel sectors: Refined Petroleum, Electricity, and Natural Gas, natural gas represented less than one percent of total direct fuel expenditures, and less than 1/100 percent of the total dollar transactions in the 49 Construction

Sectors. Direct purchase of electricity accounted for slightly over four percent of all direct fuel expenditures and approximately 8/100 percent of total dollar transactions; direct purchase of refined petroleum accounted for 95 percent of direct fuel expenditures and 1.8 percent of total dollar transactions.

C. NATURAL GAS

In view of the small percentage of both direct fuel expenditures and total construction expenditures represented by natural gas, and in view of the relatively minor natural gas transactions (quantitatively) in any of the 49 construction sectors, direct energy transfers from the natural gas sector were computed by allocating the previously developed CAC 357-level total among the expanded construction sectors based on their proportional BEA dollar transactions. Price collection for natural gas was attempted, but regional price breakdowns were not available for 1967. Since use of natural gas in construction is restricted to temporary heating purposes, we felt that very little accuracy would be lost if previously developed CAC direct energy flow data were used as mentioned above.

D. ELECTRICITY

Using the Edison Electric Institute's Statistical Year Book for 1967 and the U. S. Department of Commerce 1967 Census of the Construction Industries as sources, figures were obtained for average cost per kilowatt hour and for dollar volume of construction in the United States in 1967, broken down by State, by Region (major and minor) and for the country as a whole. Because the greater volume of construction occurred in more built-up areas, which, typically, have higher utility prices, the average cost/kwh rose as the geographical breakdown became more particular. Because different types of construction work are subject to different electricity rates, averages were computed for three electric service classifications: Commercial/ Industrial: Large Light and Power; Commercial/Industrial: Small Light and Power; and Residential.

<u>All New Construction</u>

It is assumed that the direct electricity purchased by a contractor for new construction - both building and non-building - will be mainly for his home office and thus subject to the Industrial/Commercial: Small Light and Power classification. In the case of building construction, the Contractor will often hook up to the local utility for temporary power at a rate higher than any of the rates we have considered. However, we could find no data regarding either average temporary power rates throughout the country or the percentage of Contractors' electricity costs which temporary power would represent. Although the differential represented by temporary power rates may be quite large (in one specific case , a $30 million hospital project in New York, temporary power costs approximately 60 to 70 percent more per kwh than power supplied at regular Residential or Small Light and Power rates), there is no way of assessing its effect on the overall average price without a great deal more information about the breakdown of Contractors' electricity costs nationwide. The actual effect would be considerably smaller. The Sectors affected would be mainly in the large buildings sectors: High-rise residential, Office Buildings, and Hospital Buildings.

In the Non-building Sectors: Utility Facilities, Oil and Gas Wells, Highways, etc., temporary power needs are comparatively minor. Unless there is enough time pressure to complete a job quickly to necessitate maintaining night shifts, temporary power will show up in the refined petroleum Sector as fuel for the 1 to 2 kw generator, which is generally all that is required.

Maintenance and Repair Construction

Electricity directly purchased for maintenance and repair sectors was divided among the three service classifications because these Sectors consist of work done within existing facilities and include "do-it-yourself" and other "in-house" work. Therefore, only such work as is normally done by outside contractors, e.g., Highways, or within building types which normally receive the Small Light and Power Rate, e.g., Other Non-farm Buildings, was assigned to "Commercial/Industrial: Small Light and Power." Residential Sectors were assigned to the residential classification; all other categories were such as would normally be classified in the Commercial/Industrial: Large Light and Power service classification and were assigned the appropriate average rate.

Conclusion

Tables B2-1 and B2-2 show the detailed data and calculations used to determine average electricity rates paid by the building construction industry in 1967. Prices resulting from the breakdown by state were used by CAC to compute direct electric energy (Btu) used by the construction sectors. The prices were applied to the sectors as follows:

Commercial/Industrial: Large Light & Power (.0101 $/kwhr)	sectors 59-68, 70, 71
Commercial/Industrial: Small Light & Power (.0210 $/kwhr)	sectors 23-54, 56, 69
Residential (.0230 $/kwhr)	sectors 55, 57, 58

These average rates are in 1967 purchaser dollars. Thus, although the total Btu of electricity directly purchased by the construction industry (7.64 trillion Btu on transactions of $45.7 million) agrees closely with CAC's 357 level direct energy transfers (within 6 percent), the distribution of direct energy flows to the 49 construction sectors varied. This resulted mainly from the use of the Large Light and Power service classification, (the rate for which is roughly half that of either of the other two service classifications) which shifted a greater proportion of direct energy into the non-building maintenance and repair sectors than had originally been allocated. These results are considered more accurate than previous direct energy computations for construction in CAC's 357 order model.

E. REFINED PETROLEUM

The variables in our study of Contractors' direct purchase of refined petroleum are quite different from those confronted in the case of direct purchase of electricity. First of all, although there are undoubtedly records of regional prices for the various refined petroleum products within private industry files, these are not available to the general public. We therefore used national average prices for 1967; the only regional difference was a recognition of the fact that temporary heat is generally not needed in the Southern region of the United States.

Secondly, and more important, the Refined Petroleum Sector covers a multitude of petroleum products, each of which has a different Btu content and a different dollar cost per unit of product. In order to determine the Btu content per dollar of Construction transaction, it was necessary first to determine which petroleum products were used by the industry and then their ratio of use in each of the 49 Construction Sectors.

In breaking down refined petroleum use into its various product components, it was necessary first to break out asphalt and road oil. Although these are not used as fuels, but are by-products of the process of refining petroleum, they do have Btu content. They must be taken into account, therefore, since they were considered in the original formation of CAC's full 357 level direct energy transfers table [10], into which the table developed here for the construction industry (Table B1-2) is embedded to form the 399-order expanded I/O model. We therefore subtracted the dollar value of the asphalt and roal oil transactions from the total refined petroleum transactions, accounted for the Btu content of these products, and applied the proper ratio of other refined petroleum to the remainder. (In a sense, we have treated asphalt and road oil as if they were fuels.)

There are mainly four refined petroleum products used as fuel in the Construction Industry.

1. Gasoline:* used for automobiles, pick-up trucks, some electricity generators, and some other small motors.
2. Distillate - Diesel fuel and No. 2 oil: used for large trucks and heavy construction equipment and some electric generators.

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* Although not considered here, it would be interesting to investigate the use of gasoline for automobiles used to bring construction works to the job site. This is reported under personal transportation use and does not show up in the construction sectors. In reality, most construction workers go to the construction site by automobile, first, because many construction sites are remote from public transportation. Second, construction workers commonly have tools and work clothes that they often bring with them: and third, the hours that construction personnel work often require starting jobs before public transportation is available. This amount of automobile use becomes a fairly significant figure. If we assume three and one-half million construction workers working 200 days a year, travelling 10 miles a day by car, getting 15 miles per gallon of gas, and each gallon with an energy content of 140,000 Btu, the total number of Btu involved in this under those assumptions would be 65.33×10^{12} (about one-tenth of one percent of the total U. S. energy requirement in 1967).

3. Residual - No. 6: used for some temporary heat particularly where a permanently installed boiler using No. 6 oil is used for temporary heat during the building process.
4. Propane: used for some temporary heat.

These fuels are used in different proportions by different categories of construction, e.g., one-family residential construction uses virtually no heavy equipment and little or no temporary heat; heavy construction (bridges, dams, highways, etc.) uses no temporary heat and a great deal of heavy equipment. In order to properly assign the percentages of fuels used in the different Construction sectors, we employed the services of a consultant, W. J. Barney Corporation, a large building construction and construction management company in New York City. Other references are: Department of Commerce <u>1967 Census of Construction Industries</u> for regional variations in the dollar volume of construction within the various building categories; Jack Faucett Associates for average prices of petroleum products; and Department of Commerce, Bureau of Economic Analysis ,for information regarding the BEA I/O breakdown with regard to the Construction Industry Sectors.

Although the BEA and Census breakdowns are independent of each other and do not coincide, data from each was used as a proportion of its own total, e.g., the BEA asphalt and road oil transactions were considered as a percentage of BEA total refined petroleum transactions; Census construction receipts in the Southern region of the U. S. were considered as a percentage of Census Construction receipts for the entire U. S. A. (Construction transactions by region for 1967 are shown on Table B2-3.) In our opinion, these percentages remain valid, and they may be applied to either set of data, even though the <u>quantitative</u> information cannot be so transferred from one set to the other.

It should be noted that although asphalt (which is used for driveways and for roofing) represents less than one percent of the total transactions in any of the 49 sectors, it represents a very large percentage of refined petroleum use (24 percent of total for all 49 sectors, but over 49 percent of some individual sectors). Thus, its consideration is important in assuring accuracy of later results.

All prices used in the Refined Petroleum breakdown are 1967 Producer's prices. Prices for Propane and Asphalt/Road Oil come originally from the U. S. Tariff Commission publication Synthetic Organic Chemicals: United States Production and Sales and from the Census of Manufacturers, respectively, and are considered by Faucett to be extremely reliable. Prices of motor gasoline, diesel fuel No. 2 and No. 6 oil, on the other hand, come originally from Platts' Oilgram Price Service and are averages of spot prices. They are considered by Faucett to be "not completely reliable, but still good enough to be recorded." Annual prices in Standard and Poor's Industry Surveys and in the American Petroleum Institute's Annual Review and Facts and Figures also refer back to Platts' Oilgram Price Service and contain spot prices only. Regional prices, available from the U. S. Department of Labor, Bureau of Labor Statistics, do not go back earlier than 1975 and cannot be adapted to the 1967 economy with any assurance of validity.

The resulting direct energy transfers of refined petroleum to the building construction industry turn out to be 15 percent higher than the previously computed CAC 357 level total. Due to the extensive data collection conducted for refined petroleum transfers, the new result (see Table B1-2) is considered more accurate than the old total. (When considered with respect to the direct flows of refined petroleum to all 399 sectors, the difference in the two results drops to less than 1/100 percent.)

Part F below gives details of the computation of cost per Btu of refined petroleum products purchased directly by the building construction industry. As before, these results, when combined with BEA dollar transactions, yield direct energy flows.

F. COMPUTATION OF AVERAGE COST OF REFINED PETROLEUM TO THE CONSTRUCTION INDUSTRY IN 1967 ACCORDING TO TYPE OF CONSTRUCTION

SUMMARY

This section shows the exact computations used to calculate prices paid by the building construction industry for refined petroleum products in 1967 ($/ MM Btu).

GENERAL INFORMATION

1. Construction types are in accordance with the U. S. Department of Commerce, 1967 Census of Construction Industries[4] Applicable CAC Sectors for each construction type are listed with each type.
2. "Asphalt Transactions" include both asphalt and road oil.
3. All dollar amounts are in $ million 1967 producer's dollar. All energy amounts are in MMBtu (million Btu).
4. Computation of cost of energy ($/MMBtu) of each of the refined petroleum products considered:

Product	MMBtu/bbl	U.S. Average Cost 1967 $/bbl	U.S. Average Cost 1967 $/MMBtu
Asphalt/Road Oil	6.640	$3.063	$0.46
Gasoline	5.248	5.210	0.99
Diesel Fuel No. 2	5.7475	4.408	0.77
No. 6	6.287	2.492	0.40
Propane	4.011	2.309	0.58

COMPUTATIONS ACCORDING TO CONSTRUCTION TYPE

1. SINGLE-FAMILY RESIDENTIAL: FARM BUILDINGS

Applicable to CAC Sectors: 23, 27, 48, 49, 55, 57, 58.

Computation of Refined Petroleum breakdown in these sectors:

$$\frac{\text{A. Asphalt Transactions from applicable CAC Sectors}}{\text{B. Total Ref. Pet. Trans. from applicable CAC sectors}} = \frac{\$36.6}{\$83.8} = 43.7\%$$

C. Other Refined Petroleum in these sectors = 100% - 43.7% = 56.3%

D. Breakdown of Refined Petroleum other than asphalt:

Gasoline: 100% x 56.3% = 56.3% total refined petroleum

Computation of Refined Petroleum cost: $/MMBtu these sectors:

Product % x Product Cost ($/MMBtu) = Contribution of Product to Weighted average cost: $/MMBtu

Asphalt/Road Oil:	43.7% x $0.46 =	$0.20102
Gasoline:	56.3% x $0.99 =	0.55737
		$0.75839

Say: $0.758/MMBtu these sectors

2. MULTI-FAMILY RESIDENTIAL; OTHER RESIDENTIAL; OFFICE & BANK BUILDINGS; OTHER NON-FARM BUILDINGS

Applicable to CAC Sectors: 24, 25, 26, 28, 29, 31, 38.

Computation of Refined Petroleum Breakdown in these sectors:

$$\frac{\text{A. Asphalt Transactions from CAC applicable sectors}}{\text{B. Total Refined Petro. from CAC applicable sectors}} = \frac{\$46.0}{\$97.7} = 47.1\%$$

C. Other Refined Petroleum in these sectors = 100% - 47.1% = 52.9%

D. Breakdown of Refined Petroleum Other than Asphalt:

	% of product use by region of U.S.	
Petroleum Product	Northeast; North-Central & West (D_1)	South (D_2)
Gasoline	30%	32.6%
Diesel/#2	62%	67.4%
#6	4%	--
Propane	4%	--
	100%	100.0%

E. Breakdown of Construction Transactions in these sectors by region of U.S. (Census of Construction Industries)

E_1: Northeast; North-Central & West: 72%

E_2: South: 28%

F. Computation of Other Refined Petroleum breakdown weighted regionally:

$(C \times D_1 \times E_1) + (C \times D_2 \times E_2)$ = % of Other Refined Petroleum in those sectors.

Gasoline:	.529 (.30 x 72) + .529(.326 x 28) =	16.2551
Diesel/#2:	.529 (.62 x 72) + .529(.674 x 28) =	33.5979
#6:	.529 (.04 x 72) =	1.5235
Propane:	.529 (.04 x 72) =	1.5235
		52.9000

G. Computation of Refined Petroleum cost: $/MMBtu in these sectors:

Product % x Product $/MMBtu = Contribution of Product to weighted average cost in $/MMBtu

Asphalt/Road Oil:	47.1% x	$0.46 =	$0.21666
Gasoline:	16.3% x	0.99 =	0.16137
Diesel/#2	33.6% x	0.77 =	0.25872
#6:	1.5% x	0.40 =	0.00600
Propane:	1.5% x	0.58 =	0.00870
			$0.65145

Say $0.651 per MMBtu in these sectors

3. INDUSTRIAL & WAREHOUSE BUILDINGS

Applicable to CAC Sectors: 30, 32.

Computation of Refined Petroleum Breakdown in these sectors:

A. Asphalt Transactions from applicable CAC sectors:
B. Total Ref. Pet. Trans. from applicable CAC sectors: $= \frac{\$10.6}{\$29.7} =$ 35.7%

C. Other Refined Petroleum in these sectors = 100% - 35.7% = 64.3%

D. Breakdown of Refined Petroleum other than Asphalt:

Petroleum Product	% of product use by region of U.S.	
	Northeast; North-Central & West (D_1)	South D_2
Gasoline	20%	22%
Diesel/#2	70%	78%
#6	--	--
Propane	10%	--
	100%	100%

E. Breakdown of Construction Transactions in these sectors by region of U.S. (from Census of Construction Industries)

E_1: Northeast; North-Central & West: 73.9%

E_2: South: 26.1%

100.0%

F. Computation of Other Refined Petroleum breakdown weighted regionally:

$(C \times D_1 \times E_1) + (C \times D_2 \times E_2)$ = % of Other Refined Petroleum in in these sectors.

Gasoline	(.643 x .20 x 73.9) + (.643 x .22 x 26.1)	= 13.2
Diesel/#2	(.643 x .70 x 73.9) + (.643 x .78 x 26.1)	= 46.4
Propane	(.643 x .10 x 73.9)	= 4.7
		64.3

G. Computation of Refined Petroleum cost: $/MMBtu in these sectors:

Product % x Product $/MMBtu = Contribution of Product to weighted average cost in $/MMBtu

Asphalt/Road Oil:	35.7% x $0.46	= $0.16422
Gasoline:	13.2% x 0.99	= 0.13068
Diesel/#2:	46.4% x 0.77	= 0.35728
Propane:	4.7% x 0.58	= 0.02726
		$0.67944

Say $0.679 per MMBtu in these sectors

4. <u>STORES; RESTAURANTS; PUBLIC GARAGES/SERVICE STATIONS</u>

Applicable to CAC Sectors: 33, 34.

Computation of Refined Petroleum Breakdown in these sectors:

$$\frac{\text{A. Asphalt Transactions from applicable CAC sectors:}}{\text{B. Total Ref. Pet. Trans. from applicable CAC sectors:}} = \frac{\$11.7}{\$27.3} = 42.9\%$$

C. Other Refined Petroleum in these sectors = 100% - 42.9% = 57.1%

D. Breakdown of Refined Petroleum other than Asphalt:

	% of product use by region of U.S.	
Petroluem Product	Northeast; North-Central & West (D_1)	South (D_2)
Gasoline	30%	35.3%
Diesel/#2	55%	64.7%
#6	--	--
Propane	15%	--
	100%	100.0%

E. Breakdown of Construction Transactions in these sectors by region of U.S. (from Census of Construction Industries)

E_1: Northeast; North-Central; West: 71.9%

E_2: South: 28.1%

100.0%

F. Computation of Other Refined Petroleum breakdown weighted regionally:

$(C \times D_1 \times E_1) + (C \times D_2 \times E_2)$ = % of Other Refined Petroleum in these sectors.

Gasoline:	(.571 x .30 x 71.9) + (.571 x .353 x 28.1)	=	17.98
Diesel/#2:	(.571 x .55 x 71.9) + (.571 x .647 x 28.1)	=	32.96
Propane:	(.571 x .15 x 71.9)	=	6.16
			57.10

4 Con't

G. Computation of Refined Petroleum cost: $/MMBtu in these sectors:

Product % x Product $/MMBtu = Contribution of Product to weighted average cost in $/MMBtu

Asphalt/Road Oil:	42.90%	x	$0.46	=	$0.197340
Gasoline:	17.98%	x	0.99	=	0.178002
Diesel/#2	32.96%	x	0.77	=	0.253792
Propane:	6.16%	x	0.58	=	0.035728
					$0.664862

Say $0.665 per MMBtu in these sectors

5. RELIGIOUS BUILDINGS; EDUCATIONAL BUILDINGS; AMUSEMENT & RECREATIONAL FACILITIES

Applicable to CAC Sectors: 35, 36.

Computation of Refined Petroleum Breakdown in these sectors:

A. Asphalt Transactions from applicable CAC sectors:
B. Total Ref. Pet. Trans. from applicable CAC sectors:

$$\frac{A}{B} = \frac{\$22.2}{\$48.8} = 45.5\%$$

C. Other Refined Petroleum in these sectors = 100% - 45.5% = 54.5%

D. Breakdown of Refined Petroleum other than Asphalt:

Petroleum Product	% of product use by region of U.S.: Northeast; North-Central & West (D_1)	South (D_2)
Gasoline	15%	16.7%
Diesel/#2	75%	83.3%
#6	2%	--
Propane	8%	--
	100%	100.0%

E. Breakdown of Construction Transactions in these sectors by region of U.S. (from Census of Construction Industries)

E_1: Northeast; North-Central; West: 72.4%

E_2: South: 27.6%

100.0%

F. Computation of Other Refined Petroleum breakdown weighted regionally:

$(C \times D_1 \times E_1) + (C \times D_2 \times E_2)$ = % of Other Refined Petroleum in these sectors.

Gasoline:	(.545 x .15 x 72.4) + (.545 x .167 x 27.6) =	8.43
Diesel/#2:	(.545 x .75 x 72.4) + (.545 x .833 x 27.6) =	42.12
#6:	(.545 x .02 x 72.4) =	.79
Propane:	(.545 x .08 x 72.4) =	3.16
		54.50

5 Con't

G. Computation of Refined Petroleum cost: $/MMBtu in these sectors:

Product % x Product $/MMBtu = Contribution of Product to weighted average cost in $/MMBtu

Asphalt/Road Oil:	45.50%	x	$0.46	=	$0.209300
Gasoline:	8.43%	x	0.99	=	0.083457
Diesel/#2:	42.12%	x	0.77	=	0.324324
#6:	0.79%	x	0.40	=	0.003160
Propane:	3.16%	x	0.58	=	0.018328
					$0.638569

Say $0.639 per MMBtu in these sectors

6. HOSPITAL/INSTITUTIONAL BUILDINGS

Applicable to CAC Sector: 37

Computation of Refined Petroleum Breakdown in this sector:

A. Asphalt Transactions from applicable CAC sector: = $5.7
B. Total Ref. Pet. Trans. from applicable CAC sector: $11.5 = 49.6%

C. Other Refined Petroleum in this sector = 100% - 49.6% = 50.4%

D. Breakdown of Refined Petroleum other than Asphalt:

Petroleum Product	% of product use by region of U.S.: Northeast; North-Central & West (D_1)	South (D_2)
Gasoline:	10%	11.1%
Diesel/#2:	80%	88.9%
#6:	8%	--
Propane:	2%	--
	100%	100.0%

E. Breakdown of Construction Transactions in this sector by region of U.S. (from Census of Construction Industries)

E_1: Northeast; North-Central; West: 72.4%

E_2: South: 27.6%

100.0%

F. Computation of Other Refined Petroleum breakdown weighted regionally:

$(C \times D_1 \times E_1) + (C \times D_2 \times E_2)$ = % of Other Refined Petroleum in this sector.

Gasoline:	(.504 x .10 x 72.4) + (.504 x .111 x 27.6)	= 5.19%
Diesel/#2:	(.504 x .80 x 72.4) + (.504 x .889 x 27.6)	= 41.56%
#6:	(.504 x .08 x 72.4)	= 2.92%
Propane:	(.504 x .02 x 72.4)	= 0.73%
		50.40%

6 Con't

G. Computation of Refined Petroleum cost: $/MMBtu in this sector:

Product % x Product $/MMBtu = Contribution of Product to weighted average cost in $/MMBtu

Asphalt/Road Oil:	49.60%	x	$0.46	=	$0.228160
Gasoline:	5.19%	x	0.99	=	0.051381
Diesel/#2:	41.56%	x	0.77	=	0.320012
#6:	2.92%	x	0.40	=	0.011680
Propane:	.73%	x	0.58	=	0.004234
					$0.615467

Say $0.615 per MMBtu in this sector

7. <u>NON-BUILDING FACILITIES; NON-BUILDING MAINTENANCE & REPAIR</u>

Applicable to CAC Sectors: 39-47, 50-54, 59-71.

Computation of Refined Petroleum Breakdown in these sectors:

$$\frac{\text{A. Asphalt Transactions from applicable CAC sectors:}}{\text{B. Total Ref. Pet Trans. from applicable CAC sectors:}} = \frac{\$133.8}{\$707.3} = 18.9\%$$

C. Other Refined Petroleum in these sectors = 100% - 18.9% = 81.1%

Gasoline: 5% x 81.1 = 4.06% of total refined petroleum.
Diesel/#2: 95% x 81.1 = 77.04% of total refined petroleum.
81.10%

Computation of Refined Petroleum cost: $/MMBtu these sectors:

Product % x Product $/MMBtu = Contribution of Product to weighted average cost in $/MMBtu

Asphalt/Road Oil:	18.9 %	x	$0.46	=	$0.086940
Gasoline:	04.06%	x	0.99	=	0.040194
Diesel/#2:	77.04%	x	0.77	=	0.593208
					$0.720342

<u>Say: $0.720/MMBtu these sectors</u>

8. REPAIR & MAINTENANCE - NON-RESIDENTIAL BUILDINGS

Applicable to CAC Sector 56

Computation of Refined Petroleum Breakdown in this sector:

A. Asphalt Transactions from applicable CAC sectors:
B. Total Ref. Pet. Trans. from applicable CAC sectors: $= \frac{\$7.2}{\$31.4} = 22.9\%$

C. Other Refined Petroleum in these sectors = 100% - 22.9% = 77.1%

D. Breakdown of Refined Petroleum other than Asphalt:

Gasoline: 95% x 77.1 = 73.2% of total refined petroleum
Diesel/#2: 5% x 77.1 = 3.9% of total refined petroleum
77.1%

Computation of Refined Petroleum cost: $/MMBtu in this sector

Product % x Product $/MMBtu = Contribution of Product to weighted average cost in $/MMBtu

Asphalt/Road Oil:	22.9%	x	$0.46	=	$0.105340
Gasoline:	73.2%	x	0.99	=	0.724680
Diesel/#2:	3.9%	x	0.77	=	0.030030
					$0.860050

Say: $0.860/MMBtu this sector

TABLE B2-1. 1967 AVERAGE ELECTRICITY RATES BY STATE AND REGION

	COMMERCIAL/INDUSTRIAL CLASS						RESIDENTIAL CLASS		
	Large Light & Power			Small Light & Power					
	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh
ME	18,803	1,540	.0122	20,071	724	.0277	38,652	1,350	.0286
NH	14,883	1,070	.0139	12,013	388	.0310	30,465	1,043	.0292
VT	8,135	566	.0144	8,649	372	.0233	18,366	812	.0226
MA	116,086	7,300	.0159	131,480	4,773	.0275	197,503	6,624	.0298
RI	22,350	1,407	.0159	14,297	469	.0305	31,069	1,025	.0303
CT	64,225	4,737	.0136	74,538	3,150	.0237	113,439	4,583	.0248
New England	244,482	16,620	.0147	261,048	9,876	.0264	429,494	15,437	.0278
NY	261,834	25,166	.0104	521,399	20,422	.0255	579,725	19,440	.0298
NJ	153,885	13,147	.0117	181,833	7,621	.0239	233,559	8,967	.0260
PA	333,693	31,480	.0106	214,326	10,348	.0207	387,997	17,003	.0228
Mid-Atlantic	749,412	69,793	.0107	917,558	38,391	.0239	1,201,281	45,410	.0265
TOTAL NORTHEAST	993,894	86,413	.0115	1,178,606	48,267	.0244	1,630,775	60,847	.0268
OH	367,759	43,038	.0085	217,636	10,019	.0217	381,430	16,094	.0237
IN	166,519	14,938	.0111	104,036	4,803	.0217	204,468	9,109	.0224
IL	223,372	20,991	.0106	332,645	14,692	.0226	398,961	15,099	.0264
MI	231,405	21,143	.0109	191,674	8,363	.0229	305,383	13,188	.0232
WI	96,557	7,747	.0125	88,268	3,896	.0227	166,544	7,748	.0215
East North-Central	1,085,612	107,857	.0101	934,259	41,773	.0224	1,456,786	61,238	.0238
MN	83,141	6,187	.0134	66,362	2,505	.0265	151,916	6,363	.0239
IA	50,595	4,135	.0122	70,817	2,744	.0258	126,856	4,903	.0259
MO	99,956	8,397	.0119	109,889	4,712	.0233	181,397	7,105	.0255
ND	5,124	259	.0198	17,322	738	.0235	29,319	1,154	.0254
SD	4,818	336	.0143	17,288	643	.0269	31,424	1,228	.0256
NE	17,801	1,663	.0107	38,530	2,259	.0171	60,287	2,833	.0213
KS	46,766	4,288	.0109	64,561	3,084	.0209	88,606	3,552	.0249
West North-Central	308,201	25,265	.0122	384,769	16,685	.0231	669,805	27,138	.0247
TOTAL NORTH-CENTRAL	1,393,813	133,122	.0105	1,319,028	58,458	.0226	2,126,591	88,376	.0241

Source: Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry for 1967.

TABLE B2-1 (continued)

	COMMERCIAL/INDUSTRIAL CLASS						RESIDENTIAL CLASS		
	Large Light & Power			Small Light & Power					
	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh
DE	17,672	2,050	.0086	14,322	689	.0208	20,953	842	.0249
MD & DC	92,762	7,996	.0116	131,368	6,372	.0206	137,206	5,836	.0235
VA	57,864	6,020	.0096	95,676	5,276	.0181	156,790	7,657	.0205
WV	63,953	7,877	.0081	29,461	1,512	.0195	54,727	2,458	.0223
NC	102,967	12,111	.0085	91,329	5,633	.0162	189,268	10,290	.0184
SC	69,082	9,327	.0074	49,281	3,000	.0164	95,782	4,993	.0192
GA	77,824	8,901	.0087	106,339	5,420	.0196	148,534	8,636	.0172
FL	98,142	8,923	.0110	198,265	8,809	.0225	324,053	14,980	.0216
South Atlantic	580,266	63,205	.0092	716,041	36,711	.0195	1,127,313	55,692	.0202
KT	120,756	20,648	.0058	45,815	2,322	.0197	98,068	4,866	.0202
TN	157,036	30,349	.0052	36,210	2,854	.0127	131,218	14,398	.0091
AL	106,774	16,753	.0064	57,732	3,340	.0173	113,098	7,891	.0143
MS	38,028	4,353	.0087	42,491	2,408	.0176	70,417	4,011	.0176
East South-Central	422,594	72,103	.0059	182,248	10,924	.0167	412,801	31,166	.0132
AR	42,467	4,957	.0086	44,729	2,077	.0215	69,291	2,805	.0247
LA	72,523	8,940	.0081	85,761	4,092	.0210	143,984	6,337	.0227
OK	40,950	4,076	.0100	69,424	3,448	.0201	100,285	3,877	.0259
TX	244,812	29,579	.0083	316,159	17,703	.0179	431,170	19,720	.0219
West South-Central	400,752	47,552	.0084	516,073	27,320	.0189	744,730	32,739	.0227
TOTAL SOUTH	1,403,612	182,860	.0077	1,414,362	74,955	.0189	2,284,844	119,597	.0191

TABLE B2-1 (continued)

	COMMERCIAL/INDUSTRIAL CLASS						RESIDENTIAL CLASS		
	Large Light & Power			Small Light & Power					
	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh	Revenues ($Thous)	Sales (Mil Kwh)	Rate $/Kwh
MT	18,362	4,338	.0042	17,692	936	.0189	26,705	1,310	.0204
ID	24,822	4,255	.0058	27,403	1,930	.0142	31,912	1,962	.0163
WY	12,029	1,207	.0100	15,994	898	.0178	12,496	501	.0249
CO	22,716	1,955	.0116	64,557	3,125	.0207	70,350	2,697	.0261
NM	12,907	1,189	.0109	32,682	1,606	.0203	29,131	1,094	.0266
AZ	37,510	3,221	.0116	61,025	3,377	.0181	64,432	2,778	.0232
UT	18,495	1,471	.0126	23,985	1,202	.0200	30,253	1,345	.0225
NV	9,280	1,525	.0061	24,453	1,539	.0159	21,494	1,470	.0146
Mountain	156,121	19,161	.0081	267,791	14,613	.0183	286,773	13,157	.0218
WA	68,695	22,149	.0031	72,713	6,507	.0112	130,980	12,712	.0103
OR	35,867	9,242	.0039	54,967	4,334	.0127	92,454	7,743	.0119
CA	292,519	31,749	.0092	600,967	34,521	.0174	592,981	27,755	.0214
Pacific	397,081	63,140	.0063	728,647	45,362	.0161	816,415	48,210	.0169
AK	1,550	84	.0185	10,415	307	.0339	11,738	348	.0337
HI	18,688	1,263	.0148	17,062	530	.0322	26,772	990	.0270
Alaska & Hawaii	20,238	1,347	.0150	27,477	837	.0328	38,510	1,338	.0288
TOTAL WEST	573,440	83,648	.0069	1,023,915	60,812	.0168	1,136,698	62,705	.0181
TOTAL UNITED STATES	4,364,759	486,043	.0090	4,935,911	242,492	.0204	7,183,908	331,525	.0217

TABLE B2-2. 1967 AVERAGE ELECTRICITY COST TO CONSTRUCTION INDUSTRY

	1967 NET CONST RECEIPTS BY STATE, REGION, & COUNTRY		% OF TOTAL NET CONSTRUCTION RECEIPTS x AVERAGE ELECTRIC RATE PER CLASS (AVERAGE COST OF ELECTRICITY PRORATED BY AMOUNT OF CONSTRUCTION IN AREA)		
	Net Constr * Receipts ($Thous)	% of Total Net Receipts	Commercial & Industrial Class		Residential
			Lg Lt & Power	Sm Lt & Power	
ME	232,197	0.3	.0000366	.0000831	.0000858
NH	223,399	0.3	.0000417	.0000930	.0000876
VT	126,433	0.2	.0000288	.0000466	.0000452
MA	1,838,013	2.7	.0004293	.0007425	.0008046
RI	338,067	0.5	.0000795	.0001525	.0001515
CT	1,135,311	1.6	.0002176	.0003792	.0003968
New England	3,893,420	5.6	.0008232	.0014784	.0015568
NY	6,038,566	8.7	.0009048	.0022185	.0025926
NJ	2,543,258	3.7	.0004329	.0008843	.0009620
PA	4,133,954	5.9	.0006254	.0012213	.0013452
Mid-Atlantic	12,715,778	18.3	.0019581	.0043737	.0048495
TOTAL NORTHEAST	16,609,198	23.9	.0027485	.0058316	.0064052
OH	3,529,794	5.1	.0004335	.0011067	.0012087
IN	1,675,362	2.4	.0002664	.0005208	.0005376
IL	4,390,894	6.3	.0006678	.0014238	.0016632
MI	2,967,588	4.3	.0004687	.0009847	.0009976
WI	1,385,860	2.0	.0002500	.0004540	.0004300
East North-Central	13,949,498	20.1	.0020301	.0045024	.0047838
MN	1,572,418	2.3	.0003082	.0006095	.0005497
IA	909,232	1.3	.0001586	.0003354	.0003367
MO	1,483,849	2.1	.0002499	.0004893	.0005355
ND	187,157	0.25	.0000495	.0000588	.0000635
SD	161,002	0.2	.0000286	.0000538	.0000512
NE	594,453	0.9	.0000963	.0001539	.0001917
KS	697,843	1.0	.0001090	.0002090	.0002490
West North Central	5,605,954	8.05	.009821	.0018596	.0019884
TOTAL NORTH CENTRAL	19,555,452	28.15	.0029558	.0063619	.0067842

*Source: U.S. Department of Commerce, 1967 Census of Construction Industries

TABLE B2-2 (continued)

	1967 NET CONST RECEIPTS BY STATE, REGION, & COUNTRY		% OF TOTAL NET CONSTRUCTION RECEIPTS x AVERAGE ELECTRIC RATE PER CLASS (AVERAGE COST OF ELECTRICITY PRORATED BY AMOUNT OF CONSTRUCTION IN AREA)		
	Net Constr Receipts ($Thous)	% of Total Net Receipts	Commercial & Industrial Class: Lg Lt & Power	Commercial & Industrial Class: Sm Lt & Power	Residential
MT	187,083	0.25	.0000105	.0000473	.0000510
ID	239,075	0.3	.0000174	.0000426	.0000489
WY	109,553	0.15	.0000150	.0000267	.0000374
CO	814,026	1.2	.0001392	.0002484	.0003132
NM	275,372	0.4	.0000436	.0000812	.0001064
AZ	520,039	0.75	.0000870	.0001358	.0001740
UT	341,502	0.5	.0000630	.0001000	.0001125
NV	259,493	0.4	.0000244	.0000636	.0000584
Mountain	2,476,143	3.95	.0003200	.0007229	.0008611
WA	1,446,503	2.1	.0000651	.0002352	.0002163
OR	669,283	0.95	.0000371	.0001207	.0001131
CA	7,372,453	10.6	.0009752	.0018444	.0022684
Pacific	9,488,239	13.65	.0008600	.0021977	.0023069
AK	167,363	0.25	.0000463	.0000848	.0000843
HI	355,630	0.5	.0000740	.0001610	.0001350
Alaska & Hawaii	522,993	0.75	.0001125	.0002460	.0002160
TOTAL WEST	12,757,375	18.35	.0012662	.0030828	.0032214
TOTAL USA	$69,520,058	100.0			
COLUMN TOTALS EQUAL AVERAGE ELECTRIC RATE ($/KWH) TO CONSTRUCTION INDUSTRY IN 1967		By State Breakdown:	$0.0100549 (Say $0.0101)	$0.0209707 (Say $0.0210)	$0.0230081 (Say $0.0230)
		By Minor Area Breakdown:	$0.0095720	$0.0209610	$0.0224542
		By Major Area Breakdown:	$0.0092497	$0.0208707	$0.022064
		By National Average (No. Breakdown):	$0.0090	$0.0204	$0.0217

TABLE B2-2 (continued)

	1967 NET CONST RECEIPTS BY STATE, REGION, & COUNTRY		% OF TOTAL NET CONSTRUCTION RECEIPTS X AVERAGE ELECTRIC RATE PER CLASS (AVERAGE COST OF ELECTRICITY PRORATED BY AMOUNT OF CONSTRUCTION IN AREA)		
	Net Constr Receipts ($Thous)	% of Total Net Receipts	Commercial & Industrial Class		Residential
			Lg Lt & Power	Sm Lt & Power	
DE	460,179	0.65	.0000559	.0001352	.0001619
MD & DC	1,795,666	2.6	.0003016	.0005356	.0006111
VA	1,436,112	2.05	.0001968	.0003711	.0004203
WV	509,469	0.75	.0000608	.0001463	.0001673
NC	1,522,692	2.2	.0001870	.0003564	.0004048
SC	917,365	1.3	.0000962	.0002132	.0002496
GA	1,467,453	2.1	.0001827	.0004116	.0003612
FL	2,357,902	3.4	.0003740	.0007650	.0007344
South Atlantic	10,466,838	15.05	.0013846	.0029348	.0030401
KT	787,794	1.13	.0000655	.0002226	.0002283
TN	1,223,057	1.75	.0000910	.0002223	.0001593
AL	863,900	1.25	.0000800	.0002163	.0001788
MS	431,627	0.62	.0000539	.0001091	.0001091
East South Central	3,306,378	4.75	.0002803	.0007933	.0006270
AR	451,448	0.6	.0000516	.0001290	.0001482
LA	1,232,592	1.8	.0001458	.0003780	.0004086
OK	698,238	1.0	.0001000	.0002010	.0002590
TX	4,442,539	6.4	.0005312	.0011456	.0014016
West South Central	6,824,817	9.8	.0008232	.0018522	.0022246
TOTAL SOUTH	20,598,033	29.6	.0022792	.0055944	.0056536

TABLE B2-3. 1967 TRANSACTIONS ($ MIL) (GROSS CONSTRUCTION RECEIPTS) BY REGION SHOWING REGION AS PERCENTAGE OF SECTOR & SECTOR AS PERCENTAGE OF TOTAL*

SECTOR	NORTHEAST	%	NORTH-CENT	%	SOUTH	%	WEST	%	TOTAL	%
1-Family Residence	4,127.636	22.3	5,215.568	28.2	5,520.280	29.9	3,605.988	19.5	18,469.472	19.9
Multi-Family Res.	1,543.050	30.3	1,382.189	27.2	1,328.812	26.1	833.921	16.4	5,087.972	5.5
Other Residences	422.147	21.8	480.396	24.8	733.948	37.8	304.063	15.7	1,940.554	2.1
Indus & Warehouses	3,479.205	24.4	4,793.765	33.6	3,707.913	26.1	2,273,178	15.9	14,254.061	15.4
Office & Bank	1,473.791	27.5	1,335.967	24.9	1,451.279	27.0	1,106.509	20.6	5,367.546	5.8
Stores/Rest/Pub. Gar/Service Sta.	802.797	20.3	1,173.206	29.7	1,110.301	28.1	869.443	22.0	3,955.747	4.3
Religious Buldgs.	489.926	26.0	625.917	33.2	534.560	28.3	235.282	12.5	1,885.685	2.0
Educational	2,211.898	27.5	2,203.627	27.4	2,208.695	27.4	1,432.705	17.8	8,056.925	8.7
Hospital/Inst.	980.565	27.2	1,013.889	28.1	993.712	27.6	617.441	17.1	3,605.607	3.9
Amusement	226.724	27.7	194.962	23.9	225.042	27.5	170.445	20.9	817.173	0.9
Farm	21.623	13.3	103.091	63.4	28.510	17.5	9.333	5.7	162.557	0.2
Other Non-Res.	58.221	26.6	54.020	24.7	70.300	32.1	36.205	16.6	218.746	0.2
Non-building	5,054.320	21.1	5,867.656	24.5	7,523.456	31.4	5,544.869	23.1	23,990.281	25.9
Miscellaneous	1,183.603	24.8	1,229.201	25.7	1,593.661	33.4	769.211	16.1	4,775.676	5.2
Total	22,075.506	23.8	25,673.454	27.7	27,030.449	29.2	17,808.593	19.2	92,588.002	100.0

*Source: U.S. Department of Commerce, <u>1967 Census of Construction Industries</u>

Residential = 27.5%
Other Bldg = 41.4%
Non-Bldg = 25.9%
Misc = 5.2%

V C

Supporting Calculations for Part III, Section B.1

APPENDIX C

SUPPORTING CALCULATIONS FOR PART III, Section B.1

This section describes two types of calculations crucial to the analyses discussed in Part III, Section B.1 of the text. The first involves the energy embodied in margins on goods and services purchased by a particular sector, while the second involves allocation of the total energy intensity of a given sector among its direct purchases from other sectors. Both types of computations are especially important in various stages of the hybrid analyses discussed in the text.

MARGIN FACTORS

The margin factor of sector i with respect to sector j ($MF_{i/j}$) is the total primary energy embodied in the margins (trade and transportation costs) of sector i goods delivered to sector j per dollar of sector i goods purchased. It is calculated as follows:

$$MF_{i/j} = \frac{\sum_{m=1}^{8} M_{i,j,x_m} \; EPS_{x_m}}{DA_{ij}}$$

where M_{i,j,x_m} is the m^{th} margin on sector i goods purchased by sector j (dollars), EPS_{x_m} is the total primary energy intensity of the m^{th} margin sector (Btu/$), and $DA_{i,j}$ is the direct allocation of sector i goods to sector j (Btu if i is an energy sector, dollars otherwise). All of the above are derived from the CAC Energy I/O Model.[1] $MF_{i/j}$ is expressed in Btu/$.

Margin factors are used at several points in the analyses of Part III, Section B.1. For instance, in computing the total energy per unit of various materials delivered to the New Building Construction job site, the margin factor for a given material sector with respect to New Building Construction was added to the total energy intensity of the material sector. This new total (in Btu/$), which includes the energy cost of delivery to the job site, was multiplied by the price ($/unit) of the material as given in the Census of Manufactures (CM). The resulting Btu/unit figures are shown in Tables B-1 to B-19 in the text. (Tables App C1 and App C2 in this appendix, show margins on purchases by New Building Construction and corresponding margin factors, respectively.)

Margin factors were also used in the hybrid analyses of Section B.1. In energy-costing the wood casement window, the margin factor of glass with respect to the Millwork sector was used to account for energy embodied in delivery of glass to the Millwork "job site." Likewise, in order to account for energy embodied in delivery of a wood window unit to the New Building Construction job site, the margin factor of Millwork with respect to New Building Construction was applied to the CM price of wood casement windows.

PARTIAL ENERGY INTENSITIES

The total energy intensity of a given sector represents the direct and indirect energy embodied in one unit of the sector's output. (The unit of output is Btu for energy sectors, dollars otherwise.) This total energy embodiment can be distributed among the direct purchases made by the given sector. A set of "partial" energy intensities ($PEPS_{i,j}$) is computed, each one reflecting the total energy embodied in purchases of sector i goods by sector j per unit of sector j's output. The calculation is done as follows:

$$PEPS_{i,j} = \frac{TT_{ij} \quad EPS_i}{GDO_j}$$

where $TT_{i,j}$ is the total transaction from sector i to sector j (in dollars or Btu depending on sector i), EPS_i is the total primary energy intensity of sector i (in Btu/$ or Btu/Btu), and GDO_j is the gross domestic output of sector j (dollars or Btu). It can be shown that the partial intensities of a given sector sum to its total intensity, i.e., $\sum_i PEPS_{i,j} = EPS_j$.

Partial intensities were used in computing the assembly energy for a wood window unit in the hybrid analyses of Section B.1. The figure for total energy embodied in direct fuel purchases by sector 138, Millwork, (8,487 Btu/$) is the sum of five partial intensities ($PEPS_{e,138}$, where e ranges over the 5 energy sectors) plus a factor to account for any margin energy costs on direct fuel purchases. (This last additional factor is similar conceptually with the margin factors described earlier, but includes only the margins on direct fuel purchases by Millwork and expresses margin energy content per dollar of Millwork output in order to be consistent with the definition of partial energy intensity.)

Partial energy intensities were also used to determine the energy cost of overhead inputs to Millwork for the hybrid analyses (5,860 Btu/$). As with direct fuel purchases, the partial energy intensities for sectors considered as overhead to the Millwork activity were summed, and an additional factor for margins was added in.

These calculations and the hybrid analyses described in Section B.1 of the text allowed us to develop some relationships between size and energy embodiment for selected wood window units. The results are plotted in Table App C3.

TABLE APP C1

MARGINS ON PURCHASES BY NEW BUILDING CONSTRUCTION
(1967, MILLIONS OF DOLLARS)

399-ORDER INDEX	NAME	TRANSPORTATION	TRADE	TOTAL MARGINS
3	PETRO REFIN PROD	17.80	144.50	162.30
11	FEED GRAINS	2.20	10.30	12.50
15	FOR, GRHOUSE, NURS	4.10	7.00	11.10
21	STONE CLAY MIN	67.70	2.80	70.50
113	BROAD FAB MILLS	0.20	0.70	0.90
117	FLOOR COVERINGS	6.20	20.60	26.80
122	COATED FABRICS	0.10	1.00	1.10
125	CORDAGE, TWINE	0.10	0.40	0.50
132	APPAREL, PURCH MAT	0.90	4.00	4.90
135	SAWMILLS	161.80	746.50	908.30
136	HARDWD FLOORING	13.90	67.20	81.10
137	SPEC WOOD SAWMILL	7.00	20.30	27.30
138	MILLWORK	19.10	469.40	488.50
139	VENEER, PLYWOOD	74.10	292.50	366.60
140	PREFAB WD STRUC	4.70	85.80	90.50
141	WOOD PRESERVING	4.20	2.30	6.50
142	WOOD PRODUCTS	12.70	76.10	88.80
144	WOOD HOUSEHOLD FURN	7.10	14.60	21.70
146	MET HH (UPHOLD) FURN	1.70	6.50	8.20
150	PUBLIC BLDG FURN	0.60	2.30	2.90
151	WOOD FIXTURES	1.30	12.40	13.70
152	MET FIXTURES	3.00	7.50	10.50
158	FERTILIZERS	0.10	0.70	0.80
159	BUILDING PAPER	22.80	122.10	144.90
161	CONV PAPER PROD	1.10	11.40	12.50
165	BOOK PUBLISHING	0.00	0.20	0.20
171	INORGANIC CHEM	0.20	0.40	0.60
174	MISC CHEM PROD	2.80	6.10	8.90
182	PAINT PRODUCTS	10.60	194.70	205.30
183	PAVING	1.10	4.93	[illegible]
184	ASPHALT	16.20	51.30	67.50
185	TIRES	0.10	9.60	9.70
187	MISC RUBBER PROD	0.30	8.40	8.70
188	MISC PLASTICS	20.[illegible]	110.[illegible]	130.[illegible]
193	GLASS PRODUCTS	5.[illegible]	55.[illegible]	61.[illegible]
195	CEMENT	10.[illegible]	17.[illegible]	[illegible]
196	BRICKS	55.70	63.40	119.10
197	CERAMIC TILE	8.80	31.40	40.20
198	CLAY REFRAC	8.20	3.10	11.30
199	CLAY PRODUCTS	10.50	10.10	20.60
200	PLUMBING FIXTURES	7.90	45.00	52.90
202	CONCRETE BLOCKS	26.70	127.80	154.50
203	CONCRETE PRODUCTS	[illegible]	75.60	79.10
204	READY MIX CONC	[illegible]	[illegible]	31.[illegible]
207	LIME	3.20	7.60	[illegible]
208	GYPSUM PRODUCTS	53.[illegible]	60.00	113.10
209	STONE PRODUCTS	5.50	17.00	22.50
210	ABRASIVE PRODUCTS	[illegible]	12.60	13.30
211	ASBESTOS PRODUCTS	26.20	69.50	95.70
212	GASKETS	[illegible]	1.90	[illegible]
213	TREATED MINERALS	4.10	9.30	13.40
214	MINERAL WOOL	34.[illegible]	51.80	85.80
215	NONCLAY REFRACT	15.[illegible]	5.10	19.10
216	NONMET MIN PROD	0.30	0.50	[illegible]
217	STEEL PROD	34.10	48.00	82.10
219	IR, STL FOUNDRIES	2.80	2.80	5.60
220	PRIMARY NFER PROD	0.20	2.80	3.00
222	COPPER ROLLING	6.70	6.60	13.30
223	ALUM ROLLING	0.40	0.60	1.00

TABLE APP CI (continued)

229	NONFER ROLLING	0.40	0.70	1.10
230	NONFER WIRE	18.00	45.20	63.20
237	METAL SANIT WARE	9.70	54.20	63.90
238	PLUMB FITTINGS	5.50	91.60	97.10
239	HEATING EQUIP	14.90	167.80	182.70
240	FAB STRUC STEEL	86.90	73.70	160.60
241	METAL DOORS	13.90	207.50	221.40
242	FAB PLATE WORK	9.00	15.40	24.40
243	SHEET METAL WORK	16.30	125.60	141.90
244	ARCH METAL WORK	4.30	31.20	35.50
245	MISC METAL WORK	6.80	95.40	102.20
246	SCREW MACH PROD	0.20	10.30	10.50
247	METAL STAMPINGS	0.20	0.20	0.40
249	HANDTOOLS	0.20	0.90	1.10
250	HARDWARE	6.50	142.40	148.90
252	FAB WIRE PRODUCT	4.70	43.30	48.00
255	PIPE	10.80	104.60	115.40
262	CONST MACHINERY	0.60	0.50	1.10
265	ELEVATORS	2.90	12.40	15.30
266	CONVEYORS	0.60	1.80	2.40
267	HOISTS, CRANES	2.50	7.80	10.30
271	SPECIAL DIE TOOL	0.0	0.20	0.20
279	PUMPS,COMPRESORS	4.80	38.20	43.00
281	BLOWERS	0.40	3.20	3.60
286	MACH SHOP PROD	0.60	2.20	2.80
293	REFRIG MACH	12.60	59.70	72.30
297	TRANSFORMERS	0.40	0.30	0.70
298	SWITCHGEAR	3.90	24.00	27.90
301	WELDING APPARAT	0.10	2.40	2.50
307	ELECTRIC H'WARES	0.30	8.80	9.10
308	H'HOLD VACUUMS	0.0	1.10	1.10
310	H'HOLD APPLIANCE	1.40	9.80	11.20
311	ELECTRIC LAMPS	0.0	0.10	0.10
312	LIGHT FIXTURES	14.70	128.80	143.50
313	WIRING DEVICES	4.00	31.00	35.00
317	R-TV COMMUN EQ	0.0	0.60	0.60
321	STORAGE BATTERY	0.30	0.70	1.00
322	PRIMARY BATTERY	0.0	0.20	0.20
324	ENGINE ELEC EQ	0.0	1.40	1.40
325	ELECTRICAL EQUIP	0.40	8.70	9.10
339	TRANSPORT EQUIP	0.0	0.30	0.30
342	TEMP CONTROLS	1.20	20.40	21.60
346	WATCHES, CLOCKS	0.0	0.40	0.40
357	BRUSHES	0.30	3.60	3.90
358	HARD FLOOR COV	4.50	12.40	16.90
360	SIGNS, ADS	0.90	6.30	7.20
361	MISC MFG	0.0	0.10	0.10
398	BUSINESS TRAVEL	3.50	155.80	159.30
399	OFFICE SUPPLIES	0.50	3.30	3.80

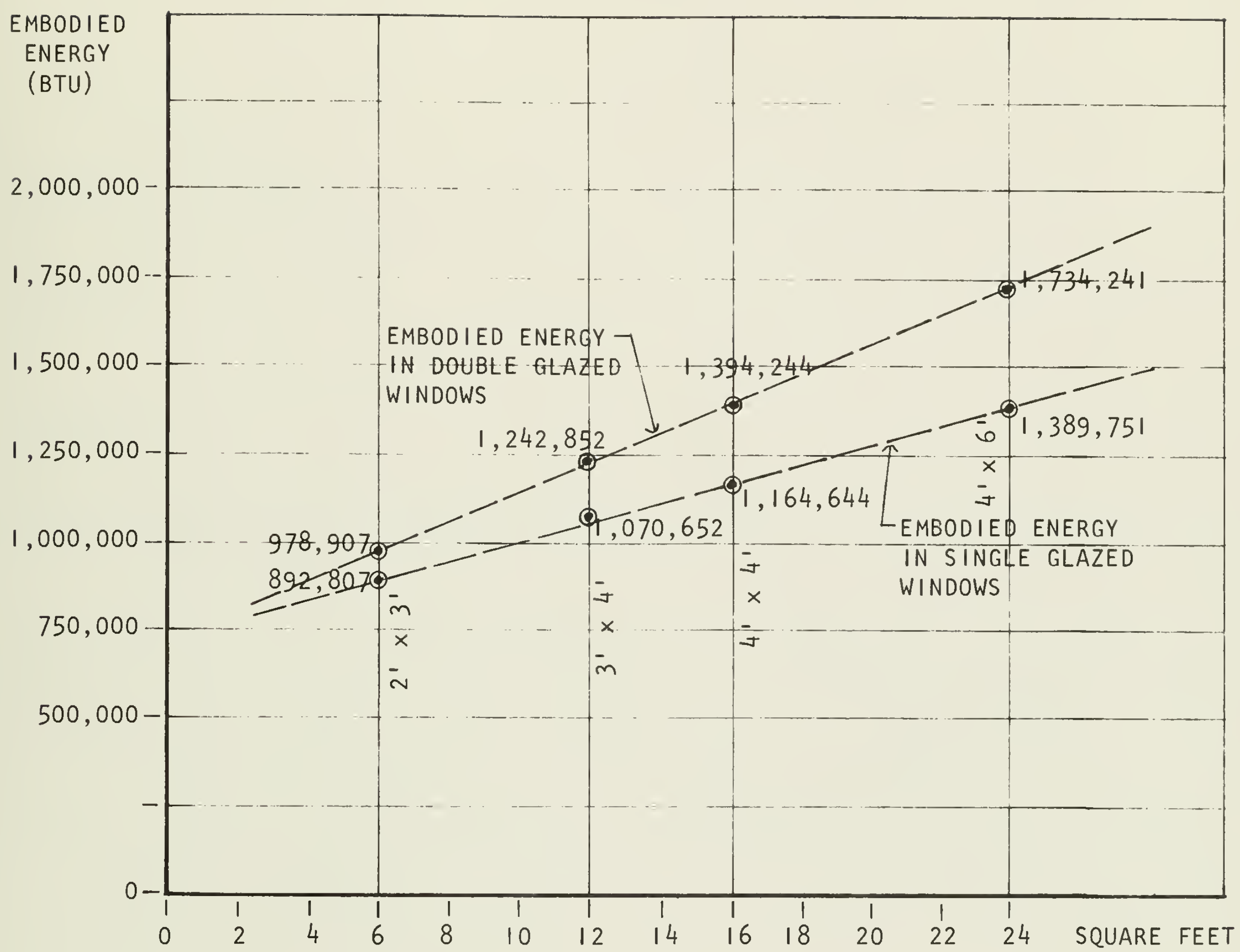
TABLE APP C2

INFORMATION FOR COMPUTING TOTAL ENERGY COST
PER PHYSICAL UNIT FOR 399-ORDER PRODUCTS
INCLUDING DELIVERY TO NEW BUILDING CONSTRUCTION JOB SITE
(1967; BTU/BTU IN ENERGY SECTORS, BTU/$ ELSEWHERE)

399-ORDER INDEX	NAME	MARGIN FACTOR
3	PETRO REFIN PROD	0.0180
10	FEED GRAINS	68566.6875
15	FOR,GRHOUSE,NURS	8823.7227
21	STONE CLAY MIN	31022.5313
113	BROAD FAB MILLS	3132.1252
117	FLOOR COVERINGS	5795.5625
122	COATED FABRICS	3572.3965
125	CORDAGE, TWINE	9376.7227
130	APPAREL,PURCH MAT	6404.1055
135	SAWMILLS	29742.8477
136	HARDWD FLOORING	30459.3906
137	SPEC PROD SAWMIL	22107.2188
138	MILLWORK	15764.9453
139	VENEER,PLYWOOD	21353.2656
140	PREFAB WD STRUC	7746.1172
141	WOOD PRESERVING	8096.6523
142	WOOD PRODUCTS	16005.2578
144	WOOD H'HOLD FURN	3647.8523
146	MET H'HOLD FURN	4798.0313
150	PUBLIC BLDG FURN	6458.8711
151	WOOD FIXTURES	4773.1250
152	MET FIXTURES	7143.7891
158	ENVELOPES	9794.0469
160	BUILDING PAPER	35151.2539
161	CONV PAPER PROD	7233.7266
165	BOOK PUBLISHING	5450.6133
171	INORG-ORG CHEM	2893.4485
174	MISC CHEM PROD	6864.8320
182	PAINT PRODUCTS	22358.8086
183	PAVING	2954.5588
184	ASPHALT	15222.1406
185	TIRES	12635.9961
187	MISC RUBBER PROD	12999.5703
188	MISC PLASTICS	11477.2031
193	GLASS PRODUCTS	15248.3320
195	CEMENT	17477.0117
196	BRICKS	17864.7227
197	CERAMIC TILE	10547.3828
198	CLAY REFRACT	8631.1055
199	CLAY PRODUCTS	17253.2813
200	PLUMBING FIXTURE	18051.7500
204	CONCRETE BLOCKS	13683.3711
205	CONCRETE PRODUCT	6259.7695
206	READY-MIX CONCR	655.2708
207	LIME	37482.0273
208	GYPSUM PRODUCTS	19998.1172
209	STONE PRODUCTS	8925.9570
210	ABRASIVE PRODUCT	16668.7891
211	ASBESTOS PRODUCT	21756.6797
212	GASKETS	12191.3438
213	TREATED MINERALS	28482.6094
214	MINERAL WOOL	19088.1719
215	NONCLAY REFRACT	8953.0430
216	NONMET MIN PROD	16178.1211
217	STEEL PROD	13909.8125
218	IR,STL FOUNDRIES	2515.3203
220	PRIMARY MET PROD	21765.1992

TABLE APP C2 (continued)

227	COPPER ROLLING	2642.8328
228	ALUM ROLLING	3479.0054
229	NONFER ROLLING	2192.7620
230	NONFER WIRE	3290.4475
237	METAL SANIT WARE	16315.5742
238	PLUMB FITTINGS	12861.7539
239	HEATING EQUIP	13984.6953
240	FAB STRUC STEEL	5704.0938
241	METAL DOORS	9304.1914
242	FAB PLATE WORK	2951.5793
243	SHEET METAL WORK	6410.1289
244	ARCH METAL WORK	3828.7742
245	MISC METAL WORK	5541.7266
246	SCREW MACH PROD	15851.4766
247	METAL STAMPINGS	1889.4775
249	HANDTOOLS	10262.4492
250	HARDWARE	17484.5742
252	FAB WIRE PRODUCT	9775.6172
255	PIPE	7398.8867
262	CONST MACHINERY	16421.4727
265	ELEVATORS	3453.1846
266	CONVEYORS	2372.7427
267	HOISTS, CRANES	2527.2820
271	SPECIAL DIE TOOL	5450.6133
279	PUMPS,COMPRESORS	15602.8789
281	BLOWERS	3578.8032
286	MACH SHOP PROD	4555.5000
293	REFRIG MACH	5000.5313
297	TRANSFORMERS	5923.0938
298	SWITCHGEAR	3310.5688
301	WELDING APPARAT	9051.6445
307	ELECTRIC H'WARES	5031.2266
308	H'HOLD VACUUMS	13867.4961
310	H'HOLD APPLIANCE	5914.8398
311	ELECTRIC LAMPS	3220.8174
312	LIGHT FIXTURES	7504.3906
313	WIRING DEVICES	8009.2578
317	R-TV COMMUN EQ	648.0911
321	STORAGE BATTERY	7709.1680
322	PRIMARY BATTERY	5450.6133
324	ENGINE ELEC EQ	10767.1932
325	ELECTRICAL EQUIP	15645.0352
339	TRANSPORT EQUIP	17714.4883
342	TEMP CONTROLS	2921.0698
345	WATCHES, CLOCKS	4723.8633
357	BRUSHES	8775.7578
358	HARD FLOOR COV	14573.5430
360	SIGNS, ADS	12685.4453
361	MISC MFG	2361.9326
398	BUSINESS TRAVEL	16377.6602
399	OFFICE SUPPLIES	8342.6172



CENTER FOR ADVANCED COMPUTATION University of Illinois Urbana IL 61801	**ENERGY IN BUILDING CONSTRUCTION** ERDA Contract No. E (11-1)-2791		date 30 Dec 76
and **RICHARD G. STEIN AND ASSOCIATES, ARCHITECTS** 588 Fifth Avenue New York NY 10036	Subject Energy Embodiment for Wood Casement Windows (per Window Area)	by **CAC** **RGS & A**	file **App C3**

V

D

Energy Flow Model -Methology & Schematic Diagram

APPENDIX D

Energy Flow Model

The following is a technical discussion of the Energy Flow Model described in Section E.

Conventions

The data which are used in the development of the Flow Model conform to several significant conventions.

A. New Building Construction is considered to sell only to Final Demand. That is, there are no inter-industry transactions involving sales from New Building Construction to other industries. Because of this total demand for Primary Energy resource resulting from the eventual demand for embodied energy by the entire New Building Construction sector will equal the total embodied energy in the transactions from New Building Construction to Final Demand.

B. All Primary Energy resources exist in four basic forms. These are Coal, Crude Petroleum, Non-fossil Electricity (electricity generated from sources other than the eventual products of Coal and Crude Petroleum) and Imported Products which are considered to have the same energy value as that which would be required as if these products were manufactured domestically. Primary Energy resources are considered to originate in their respective energy industry sectors. Coal for example, is considered to originate in the Coal Mining sector. Because of this the only demand which Coal makes for Primary Energy resources is for that energy resource which is required to mine and process the coal. The demand for the coal itself (the product of Coal Mining) is considered to occur at the transaction between the Coal Industry and the direct users of coal such as Electric Utilities or the Steel Industry.

C. Final Demand is the ultimate user. When the transaction occurs transferring the product to the ultimate user, all energy embodied in that product will have been used and no further energy requirements need be anticipated.

Schematic Model

A schematic model has been developed showing an energy flow pattern through n stages from Equivalent Primary Energy* to New Building Construction. The graphic model is divided into stages represented by columns 1, 2, 3, 4, n-3, n-2, n-1, and n; and sets of transactions between stages are represented by flow paths and identified as 1*2, 2*3, etc. The stages (columns) represent processes which occur within industries and the flows represent transactions between industries.

The graphic model has a vertical scale representing units of energy. (See legend). There is no horizontal scale.

Five characteristic forms of energy are represented in the stages. These are:

1. The actual content of products in an energy sector, such as the heat which would be produced by burning a gallon of oil.

2. Embodied energy in energy products resulting from the extraction and manufacturing processes. The sum of these first two energy forms represent the total energy value of energy products.

*Equivalent primary energy is the total primary energy which would be required to produce the designated output, in this case New Building Construction, if all of the products which eventually go into that output were produced domestically. In other words, products which are imported are assumed to make the same demand for primary energy as the same product would if it were manufactured domestically.

3. The actual energy content of energy product sold to non-energy industries such as the actual energy released by the burning of a gallon of oil by the steel industry.

4. The non-useful energy embodied in energy products consumed by non-energy industries such as the energy which was required to extract, process and transport the gallon of oil consumed by the steel industry described above.

   Items 3 and 4 represent the total energy involved in direct transactions between energy industries and non-energy industries (the embodiment of energy into non-energy products).

5. The energy which has already been embodied in non-energy materials or products consumed by the industries in each particular stage.

Two characteristic forms of energy are shown in the <u>flow</u> portions of the diagram. These are:

1. The total energy involved in the transfer of energy products, that is, the actual energy content of the energy product itself plus the energy embodied in that product as a result of all extraction, processing and transportation to that point.

2. The energy embodied in non-energy products.

The actual values for three stages have been extracted from 1967 data. These are stages 1, n-1 and n. The remaining stages and the interstage flows are hypothetical and intended only to represent the type of information which would be generated by a total flow analysis. The hypothetical non-energy sectors have been greatly simplified for clarity and the flow between Stage 4 and Stage n-3 has been assumed as a single step.

Description of graphic model

Stage 1 represents the primary energy equivalent of an economy with no imports.

Transaction 1*2 indicates the portion of the primary energy equivalents of stage 1 which are replaced by imports. In this hypothetical case, all energy imports are considered to replace demand for crude petroleum and all non-energy imports are considered to replace demand for coal.

Stage 2 represents the actual domestic primary energy plus the primary energy equivalent of energy and non-energy imports.

Flow 2*3 represents all transactions between primary energy sectors and all energy sectors including primary energy sectors. No other transactions are considered. For example, in this hypothetical case, coal sold directly to electric utility industries for electricity generation is shown. However, coal which would be sold directly to the steel industry is simply carried forward for a later transaction.

Stage 3 indicates the configuration of energy industries plus imports following the transfer of all primary energy to the energy sectors which will eventually transfer energy products to the non-energy industries. The hypothetical electric industry in Stage 3 is now composed of the contributions from non-fossil electric generation plus the contributions of coal used for electric generation. It is assumed here that electric utilities do not use crude petroleum directly.

Flow 3*4 represents the transfer of non-primary energy products to energy sectors. At this point the oil and natural gas (non-primary energy products) which are burned to generate electricity are added to the Electric sector. However, the electricity which is used in the manufacture of refined petroleum and gas is subtracted from the Electric sector.

Stage 4 represents the final arrangement of energy products prior to their sale to non-energy industries and includes non-energy imports which have been carried forward directly from Sector 2.

Flow 4*n-3 represents all sales from energy sectors to non-energy sectors which are three transactions removed from new Building Construction. All energy products which are not transferred at this point are simply carried forward for later transactions.

Stage n-3 represents all non-energy sectors which are three transactions removed from New Building Construction plus all energy products which are being carried forward for later transactions. Since the non-energy sectors in Stage n-3 are the first non-energy sectors in the total flow pattern, all energy inputs except imports will be contained in the actual and embodied energy of energy products.

Flow n-3*n-2 represents all transactions between sectors which are three transactions removed from New Building Construction and sectors which are two transactions removed from New Building Construction plus the carrying forward of energy products which are not utilized in stage n-2.

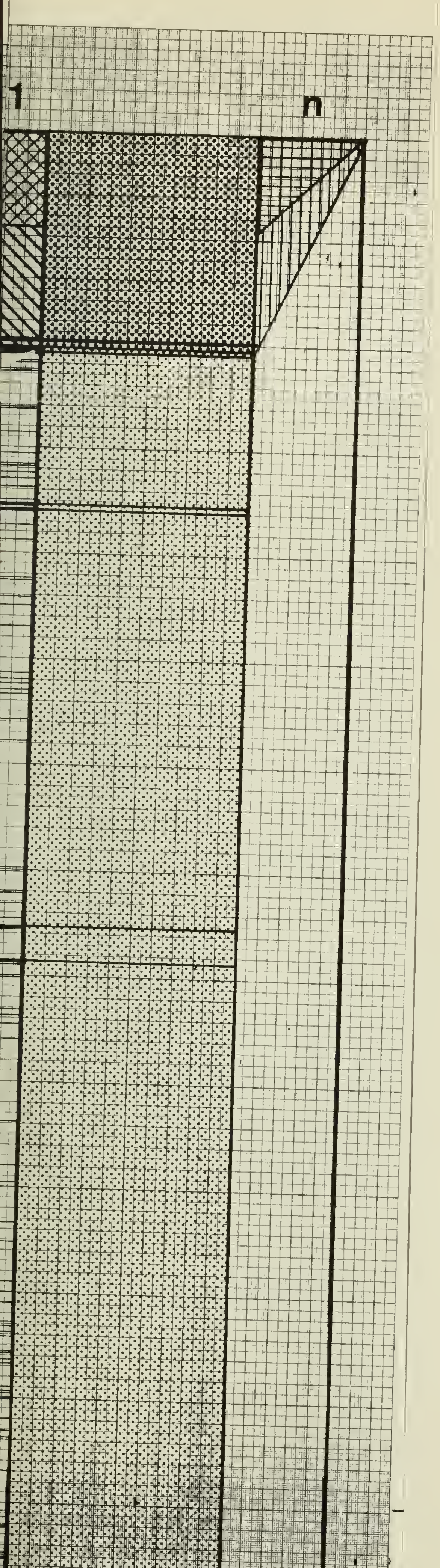
Stage n-2 represents all non-energy industries which are two transactions removed from New Building Construction plus the energy products being carried forward. The non-energy products of Stage n-2 differ from those of n-3 in that a portion of their energy input may result from the energy embodied in non-energy products.

Flow n-2*n-1 represents all transactions between sectors two transactions removed from New Building Construction and sectors which are one transaction removed (i.e. which sell directly to New Building Construction).

Stage n-1 represents the configuration of all non-energy industries which transact directly with New Building Construction and the energy products which have been carried forward from previous stages to be sold directly to New Building Construction. In the graphic representation, all sectors which will transfer ten trillion Btu or more to New Building Construction have been represented. This includes 61 sectors and accounts for a 94.97 percent of all energy which is eventually embodied in New Building Constructions through purchases of energy and non-energy products. The numbers to the left of the column representing stage n-1 indicate the CAC 399 order index number followed by the total embodied energy in trillion Btu. This is presented in tabular form in Table B1-10, pages 140 - 142 (Total Energy Requirements for New Building Construction-1967 printout).

Flow n-1*n represents the transactions directly to New Building Construction.

Stage n represents the total energy committed to New Building Construction. The actual energy content indicated is that energy which is used in the processes of building construction. The embodied energy component of energy products is that energy which is required to deliver the energy needed for New Building Construction. These two sectors represent the total energy involved in energy product purchases directly by New Building Construction. The remaining portion of Stage n represents the total energy embodied in all non-energy products consumed by New Building Construction.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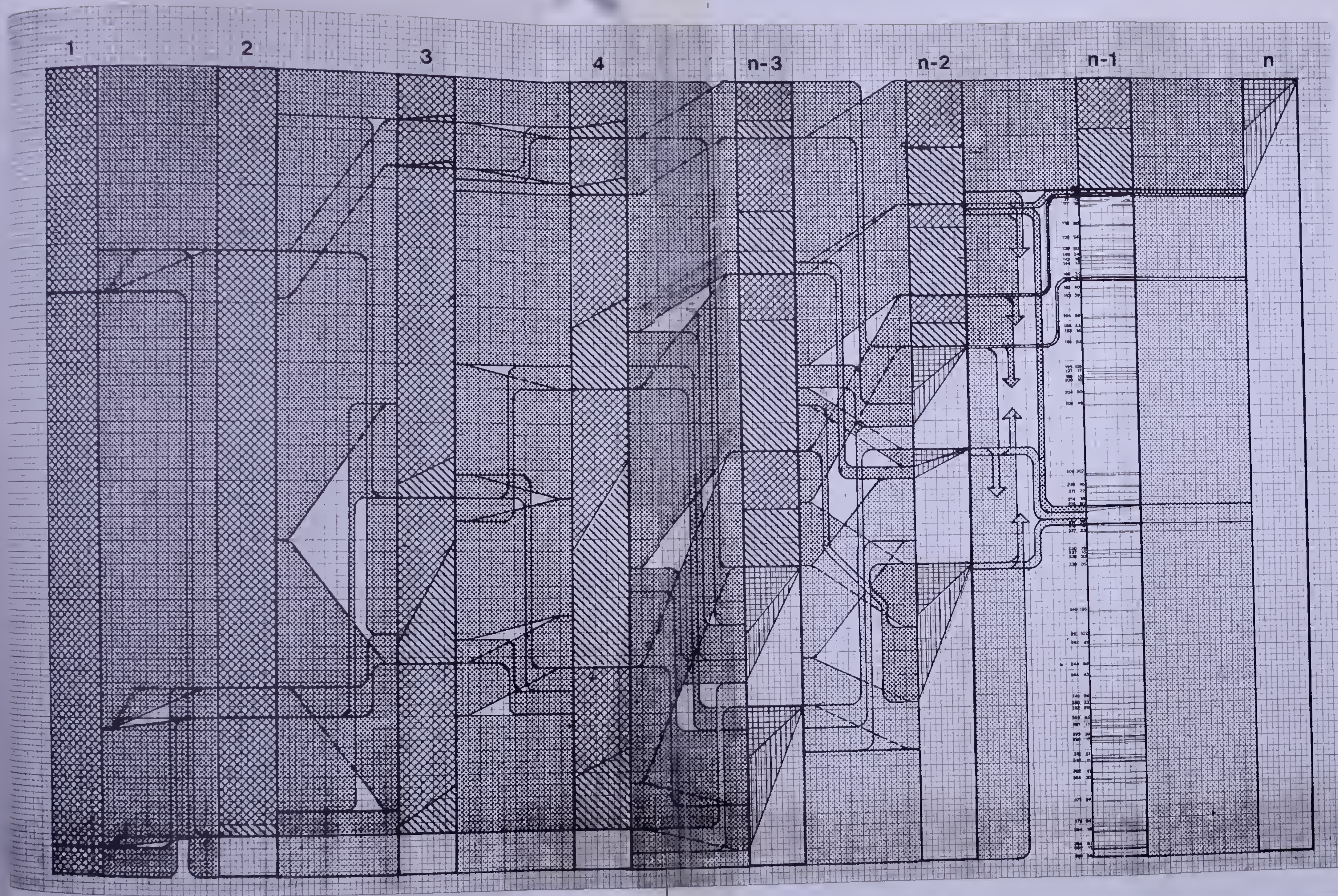
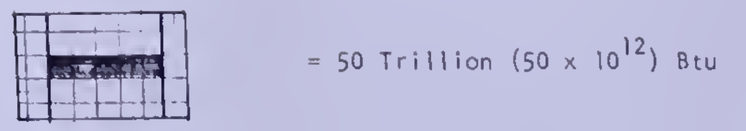
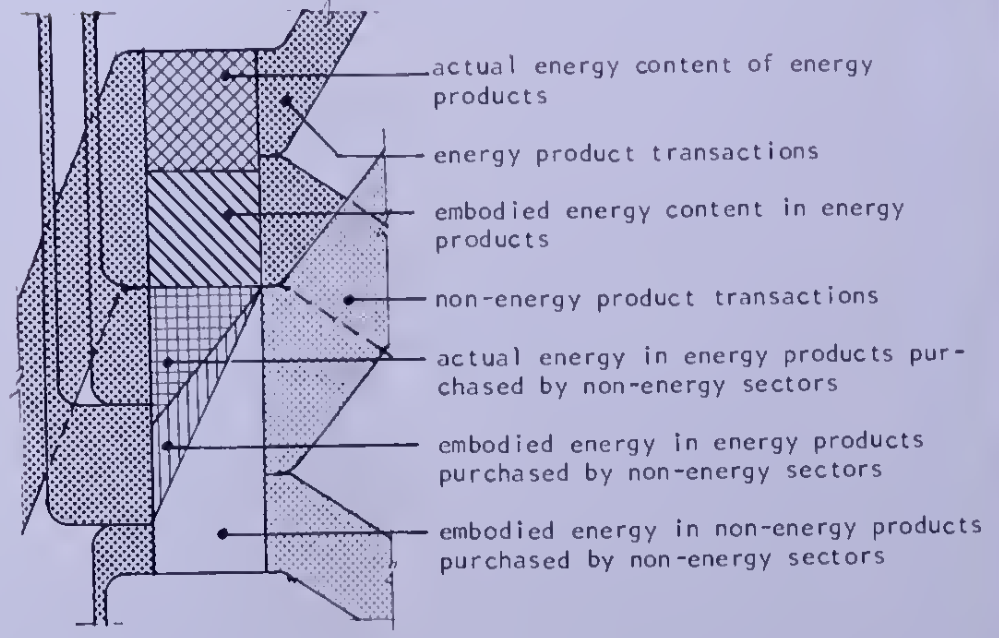
n





SCALE



KEY

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	Subject Schematic Energy-Flow Model	by CAC RGS & A	file **App D·1**