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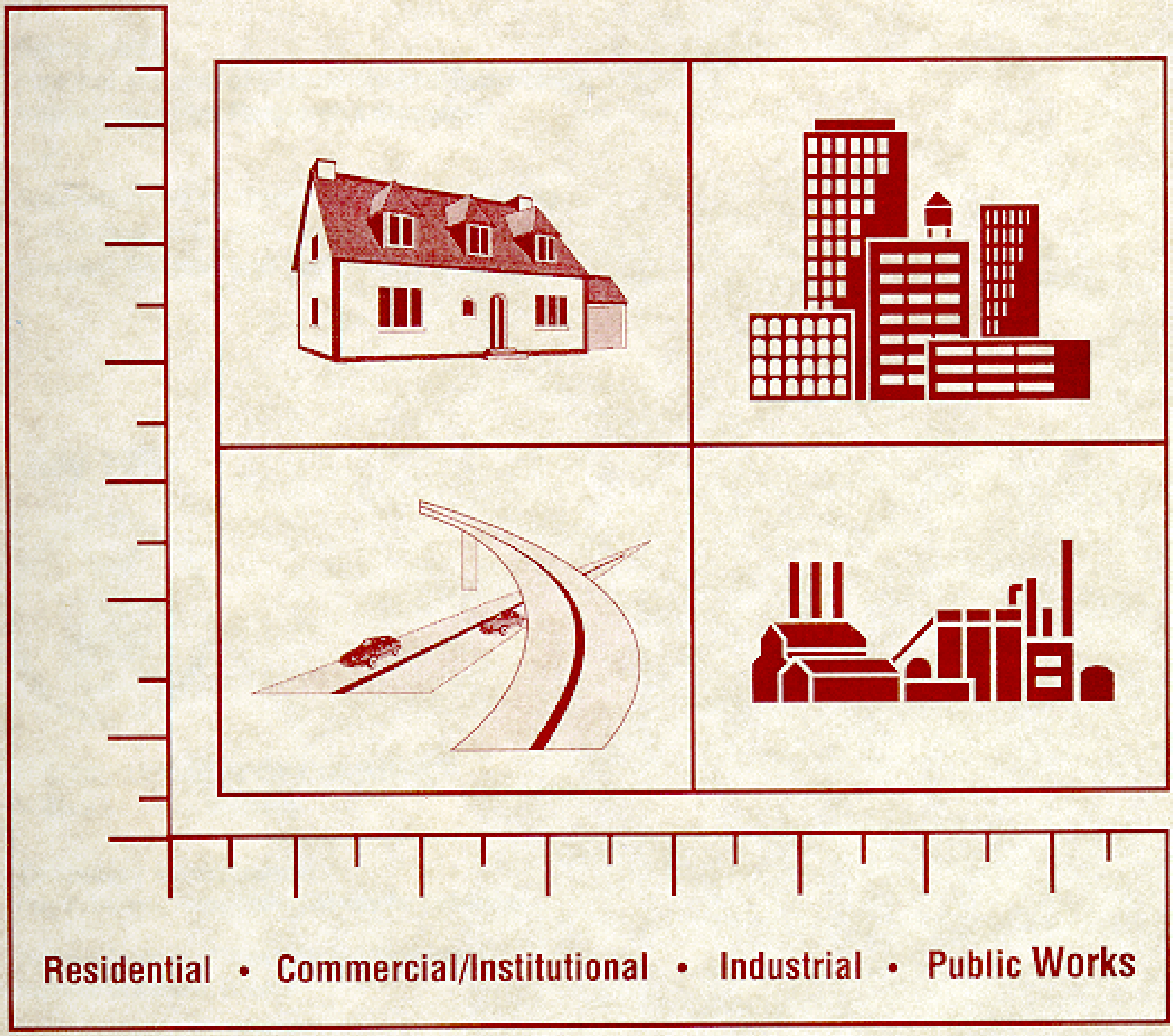
NIST U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards and Technology

Office of Applied Economics
Building and Fire Research Laboratory
Gaithersburg, Maryland 20899

An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs: Baseline Measures of Construction Industry Practices for the National Construction Goals

Robert E. Chapman and Roderick Rennison



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Sponsored by:
National Institute of Standards and Technology
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and
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Gary R. Bachula, Acting Under Secretary for Technology

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Abstract

The Construction and Building Subcommittee of the National Science and Technology Council is developing baseline measures of current construction industry practices and measures of progress with respect to each of the seven National Construction Goals. The seven National Construction Goals are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. Baseline measures and measures of progress are being produced for each of the four key construction industry sectors. The four sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works. This document provides a detailed set of baseline measures for National Construction Goal 2 (reductions in operations, maintenance, and energy costs). As such, it describes data sources, data classifications and hierarchies, and the metrics used to develop the baseline measures. Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed.

Keywords

building economics; building materials; building maintenance; buildings; construction; costs; economic analysis; energy costs; energy consumption; energy conservation; maintenance costs; metrics; operations costs

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Preface

This study was conducted by the Office of Applied Economics in the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST). The study was sponsored by the Construction and Building Subcommittee of the National Science and Technology Council. The BFRL project, of which this study is a part, seeks to develop baseline measures and measures of progress with respect to each of the seven National Construction Goals. These measures are to be disseminated both through publications and, ultimately, electronically via the World Wide Web. The intended audience for this document is the Construction and Building Subcommittee member organizations as well as construction industry representatives and other interested parties.

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Table of Contents

List of Figures

List of Tables

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Executive Summary

The Construction and Building Subcommittee of the National Science and Technology Council has established seven National Construction Goals in collaboration with a broad cross section of the construction industry.[i] Data describing current practices of the US construction industry are needed to establish baselines against which the industry can measure its progress towards achieving the seven National Construction Goals. The Goals are: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. Baseline measures and measures of progress will be produced for each National Construction Goal in each of the four key construction industry sectors. The four sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works.

This document is the first in a series of studies prepared by NIST's Building and Fire Research Laboratory.[ii] It provides a detailed set of baseline measures for National Construction Goal 2, reductions in operations, maintenance, and energy costs. The baseline measures characterize current industry performance for Goal 2. Industry performance in 1994 is used as the reference point from which the values of the baseline measures are calculated. Goal 2 was identified as one of the highest priority National Construction Goals by the construction industry.

Operations, maintenance, and energy (OM&E) costs are a major factor in the life-cycle costs of a constructed facility. In some cases, OM&E costs over the life of a facility exceed its first cost. However, because reductions in OM&E costs are often associated with increased first costs, facility owners may under invest in cost-saving technologies.

> *Operations* is defined as including all non-process or end-product related activities required to operate a building or structure, with the exception of maintenance and repair activities, which are considered separately. Examples of operations components are water consumption, trash removal, and cleaning services.
>
> *Maintenance and Repair* activities include incidental work which keeps a property in working order, without adding value to it. Typical cost components might include roof, plumbing, electrical, or security system maintenance and repair.

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[i] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1995. *Construction and Building: Federal Research and Development in Support of the US Construction Industry*. Washington, DC: National Science and Technology Council.

[ii] A subsequent companion document focuses on National Construction Goal 1. For information on reductions in the delivery time of constructed facilities, see Chapman, Robert E., and Roderick Rennison. 1998. *An Approach for Measuring Reductions in Delivery Time: Baseline Measures of Construction Industry Practices for the National Construction Goals*. NISTIR 6189. Gaithersburg, MD: National Institute of Standards and Technology.

Energy is defined as including all non-process or end-product related energy consumption required to operate a building or structure. Thus energy consumption for manufacturing processes or vehicle or vessel operations is generally excluded. Typically, energy consumption can be categorized by energy source, and by assigned end-use (e.g., space heating, cooling, and lighting).

Reductions in OM&E costs will produce two types of benefits. First, constructed facilities will become more affordable because facility owners and operators are making more cost effective choices among investments (e.g., design configurations) which affect life-cycle costs. Second, these same facilities will better conserve scarce energy resources.

The intended audience for this document is the Construction and Building Subcommittee member organizations, the four sector council member organizations,[iii] construction industry representatives, and other interested parties. In addition, because this document includes both detailed information on the baseline measures for National Construction Goal 2 and a compilation of statistics on the four sectors and the construction industry as a whole, it is anticipated that this document will serve as a resource reference for readers with a wide variety of interests in the construction industry.

This document has nine chapters and seven appendices. Chapter 1 explains the purpose, scope, and general approach. Chapter 2 introduces the National Construction Goals, describes how a well-defined set of metrics is used to develop the baseline measures and measures of progress, and outlines the project approach. Chapter 3 provides an overview of the construction industry. The overview provides the context within which the baseline measures are developed. Chapter 4 presents two data classification schemes. These data classification schemes are used to construct data hierarchies from which key metrics are derived and used to develop the baseline measures. Chapters 5 through 8 present an overview and detailed baseline measures for each of the four construction industry sectors: Chapter 5 covers the residential sector; Chapter 6 covers the commercial/institutional sector; Chapter 7 covers the industrial sector; and Chapter 8 covers the public works sector. The overview of each sector examines the sector size, changes in the sector, and key sector characteristics. The detailed baseline measures examine operations, maintenance, and energy categories separately. The key OM&E baseline measures for each sector are summarized in tabular form at the end of that sector's chapter. Chapter 9 concludes the document with a summary and suggestions for further research. The individual data hierarchies for each construction industry sector are presented in Appendices A through D. Each sector occupies an appendix: Appendix A covers the residential sector; Appendix B covers the commercial/institutional sector; Appendix C covers the industrial sector; and Appendix D covers the public works sector. Three additional appendices are also included as an aid to cross referencing terms,

[iii] The four sector council member organizations are: (1) National Association of Home Builders Research Center (residential); (2) National Institute of Building Sciences (commercial/institutional); (3) Construction Industry Institute (industrial); and (4) American Public Works Association (public works).

statistical information, and other material contained in this document. Appendix E lists the assignment of each state to one of the four census regions: (1) Northeast; (2) Midwest; (3) South; or (4) West. Appendix F lists the two-digit Standard Industrial Classification (SIC) Codes. Appendix G provides a list of acronyms and their definitions.

Chapter 2 provides perspective on the overall effort to develop baseline measures and measures of progress for each of the seven National Construction Goals. First, each National Construction Goal is introduced and described. Next, the process for developing baseline measures for each Goal is described. This process involves: (1) specifying a data-oriented hierarchy; (2) collecting and compiling the key data and supporting information for the base year, 1994; (3) defining metrics for each goal/sector combination; and (4) producing the metrics in a summary form (i.e., figures and tables to depict the metrics). The methods for measuring progress use the baselines as their reference point. Because the National Construction Goals may be specified as targets measured against baseline values, "gap analysis" is the preferred method for defining the measures of progress. The advantage of the gap analysis method is that it employs the same values for each measure as used in computing the baselines. The gap analysis method measures how much of the initial gap (i.e., between the baseline value and the goal value) has been closed by some future date. Criteria are then presented which ensure that the data selected for *analysis* are well-defined, consistent, and replicable. The chapter also outlines a strategy for collecting and disseminating information on each National Construction Goal.

Chapter 3 provides a snapshot of the US construction industry. As such, it provides the context within which the baseline measures are developed. An extensive set of statistics has been compiled on each sector; many of these statistics are included in Chapter 3. These statistics are useful not only as a tool for defining the baseline measures but also as a resource reference for readers with a wide variety of interests in the construction industry.

Chapter 3 contains four sections. Each section deals with a particular topic. The topics progress from general in nature to very specific. First, information on the value of construction put in place is provided to show the size of the construction industry and each of its four sectors—residential, commercial/institutional, industrial, and public works. Second, information on the nature of construction activity for each sector of the industry is presented. The SIC Codes for the construction industry are introduced and described as a means for organizing construction activity. Information on the nature of construction activity includes breakouts between new construction activities, maintenance and repair activities, and additions and alterations. The challenge of developing annual estimates for each sector by nature of construction activity is described. Examples are given which demonstrate how different data sources result in major differences in a particular year's estimates. Third, information on employment in the construction industry is summarized and a series of employment-related statistics are presented. The SIC Codes for the construction industry are used as a means for organizing key employment-related information. Comparisons between employment and output in the construction industry and employment and output in the overall US economy are also included. Fourth, information on cost trends and on other, special considerations, is presented.

The construction industry is a key component of the US economy. Total construction investment represents about 11 percent of Gross Domestic Product. A key indicator of construction activity is the value of new construction put in place. Data published by the US Bureau of the Census, a part of the US Department of Commerce, are used to establish the composition of construction expenditures by type of construction. These expenditures are then assigned to one of the four key construction industry sectors.

Table ES-1 summarizes both the annual sector totals and the sum total. Since 1992, the value of new construction put in place has risen slightly from $393.8 billion in 1992 to $435.5 billion in 1996 in constant 1992 dollars. The largest component of new construction over this period was in the residential sector (about 32 percent of the total), with the smallest component in the industrial sector (about 6 percent).

Table ES-1. Value of New Construction Put in Place in Millions of 1992 Dollars: Sector Totals and Sum Total

Sector	Value of Construction Put in Place ($ Millions)				
	1992	**1993**	**1994**	**1995**	**1996**
Residential	133,658	141,076	156,576	146,167	157,846
Commercial/Institutional	122,960	125,770	128,116	137,006	149,445
Industrial	30,902	27,212	28,161	30,391	29,219
Public Works	106,311	103,762	103,360	101,593	98,973
Total – All Sectors	393,831	397,820	416,213	415,157	435,483

Chapter 4 covers the data classification schemes, how the sectors were defined, how data sources were identified, and how key OM&E data were collected. Data classification hierarchies were developed for each of the four industry sectors. These hierarchies were essential in order to be able to sort data into relevant sectors, to prioritize the data, and to establish data linkages. Initially, an "idealized" hierarchy was developed for each sector. *Idealized hierarchies* were developed with a view to defining for the four industry sectors the extent and key components considered relevant to Goal 2. Within each sector hierarchy, the key components likely to have an impact upon the Goal are examined. The *data oriented hierarchies* represent the modification of the idealized hierarchies to reflect data availability and constraints. This is an important step in ensuring that the baseline measures remain succinct (see Appendices A through D where the data oriented hierarchies are presented). The two primary types of data collected were electronic data and published data. As data were collected, the data oriented hierarchies for each industry sector were refined to reflect data availability constraints. Section 4.2 summarizes the extensive data searches of publicly accessible Federal Agency databases carried out by the authors. A further set of data searches focused upon research, trade, professional, private sector, and academic organizations. In addition, a number of useful data sources have been identified where organizations are systematically collecting and publishing data. The key sources of data and information, including those that are accessible electronically, are listed in Section 4.2 and in the References section.

Chapter 5 describes the residential sector and traces the development of the baseline measures for the residential sector. The baseline measures for the residential sector are based on data published by the US Bureau of the Census and the Energy Information Administration (EIA), a part of the US Department of Energy.

The Census data are used to develop baseline measures for operations costs and maintenance and repair costs for the residential sector. The Census data are drawn from the 1995 American Housing Survey (AHS). The AHS collects data on the nation's housing, including apartments, single-family homes, mobile homes, and vacant housing units. National data are collected every other year; the sample covers approximately 55,000 homes. Data from the 1995 AHS are used to develop the baseline measures for water consumption, trash removal, and maintenance and repair expenditures.

The EIA data are used to develop baseline measures for energy costs for the residential sector. The EIA data are drawn from the 1993 Residential Energy Consumption Survey (RECS), the most recent survey data currently available. The EIA has carried out the RECS triennially since 1984. In the 1993 RECS, data were collected from a representative sample of seven thousand households. The survey collects data on the type of housing unit, year of construction, space heating, water heating, air conditioning, fuels, equipment, appliances, and demographic characteristics of the occupants. Energy consumption and expenditure data are obtained from the household's energy suppliers. The RECS data are linked to weather data for each building. The RECS is the most comprehensive source of national level energy data for the residential sector.

The key baseline measures for the residential sector are summarized in Table ES-2. It is important to note that the data recorded in Table ES-2 are either for 1993 (RECS) or 1995 (AHS) rather than for the reference year 1994. All values recorded in Table ES-2 are annual expenditures per household. Reference to the table shows that energy expenditures are the most significant component of residential OM&E costs. Operations expenditures for water consumption and trash removal are $300 and $180 per annum, respectively. Expenditures for maintenance and repairs are $300 per annum.

Chapter 6 describes the commercial/institutional sector and traces the development of the baseline measures for the commercial/institutional sector. The baseline measures for the commercial/institutional sector are based on data published by the EIA, the International Facilities Management Association, the Building Owners and Managers Association, the Association of Higher Education Facilities Officers, and the Institute of Real Estate Management.

Table ES-2. Selected Baseline Measures for the Residential Sector: Annual Expenditures per Household

Baseline Measure	Value	Year
Water Consumption	$300	1995
Trash Removal	$180	1995
Maintenance and Repair	$300	1995
Space Heating	$419	1993
Air Conditioning	$177	1993
Water Heating	$177	1993
Refrigerators	$124	1993
Appliances	$455	1993

The EIA data are used to define the sector and to generate general baselines. Data from the 1992 and 1995 Commercial Buildings Characteristics Reports were used to focus attention on a select subset of the types of commercial/institutional buildings/facilities surveyed by EIA. These data revealed that educational, mercantile and service, and office buildings accounted for over 60 percent of total commercial/institutional sector floorspace in the US in 1992 and 1995. In addition, data from the 1992 Commercial Buildings Energy Consumption Survey have been used to generate general baselines for energy consumption and expenditures in the commercial/institutional sector. These data are also used to develop information about energy conservation in the commercial/ institutional sector (e.g., participation in energy management programs).

The other sources were used to develop detailed OM&E baseline measures for either the entire sector or one of the three principal components of the commercial/institutional sector (i.e., educational, mercantile and service, and office buildings). Baselines for the entire commercial/institutional sector are based primarily on published data from the International Facility Management Association. Baselines for educational facilities are based on published data from the Association of Higher Education Facilities Officers. Baselines for shopping centers, a key subset of the mercantile and service component, are based on published data from the Institute of Real Estate Management. Baselines for commercial office buildings are based on published data from the Building Owners and Managers Association.

The key baseline measures for the commercial office buildings component of the sector are summarized in Table ES-3. Note that the data recorded in Table ES-3 are for 1995. The table records information on three types of operations costs: administrative, cleaning, and roads/grounds/security. These costs range from $5.49 per rentable square meter for roads/grounds/security to $11.73 per rentable square meter for cleaning. Note that the costs of water consumption/treatment are included under utilities. This differs from the residential sector where the costs of water consumption/treatment were included under operations costs. Maintenance and repair costs averaged $14.20 per rentable square meter. Utilities averaged $19.58 per rentable square meter. As expected, electricity is the primary cost component, representing $17.01 per rentable square meter ($1.58 per rentable square foot).

Table ES-3. Selected Baseline Measures for Commercial Office Buildings: Annual Expenditures for 1995

Baseline Measure	Dollars per Rentable Square	
	Foot	Meter
Administrative	1.03	11.08
Cleaning	1.09	11.73
Roads/Grounds/Security	0.51	5.49
Maintenance and Repair	1.32	14.20
Utilities (including water)	1.82	19.58

Chapter 7 describes the industrial sector and traces the development of the baseline measures for the industrial sector. The industrial sector comprises all manufacturing industries with SIC Codes between 20 and 39 inclusive. The baseline measures for the industrial sector are based on data published by the US Bureau of the Census and EIA. Data published by the International Facilities Management Association for a select set of SIC Codes are also described. The chapter also includes information about energy conservation in the industrial sector (e.g., fuel switching capability within the industrial sector and the level of participation in energy management programs).

The Census carries out a number of surveys of the industrial sector, most notably the Census of Manufactures. The 1992 Census of Manufactures provides a large amount of data relevant to value of shipments, value added by manufacturer, payroll costs, and materials costs. Most of these items are predominantly process-oriented, and are therefore considered to be beyond the scope of this document. The focus of this document is on non-process costs associated with industrial facilities (i.e., facility management components, such as building maintenance and repair, facility HVAC, and lighting costs). Due to the heavy emphasis on process-related activities, the baseline measures for operations costs and maintenance and repair costs for this sector are highly aggregated. Baseline measures are given on the cost for refuse removal, a key component of operations costs, and for the repair of buildings and structures, a key component of maintenance and repair costs. These baselines are presented for the industrial sector in its entirety and for each major two-digit SIC Code within the industrial sector. The aggregate cost of refuse removal was $4.4 billion in 1992. The aggregate cost for repair of buildings and structures was $5.4 billion in 1992.

Energy baselines for the industrial sector are based on the Manufacturing Energy Consumption Survey (MECS). The MECS includes a wealth of information on both process and non-process related energy consumption. The total primary consumption of energy for all purposes in the US industrial sector in 1991 was 21.4 quadrillion kilojoules

(20.3 quadrillion Btu), the vast majority of which was process related. When all energy sources are considered, direct non-process uses accounted for only 12 percent of total energy consumption. The largest non-process end-uses of net electricity and natural gas were facility HVAC, facility lighting, and facility support. Facility HVAC inputs accounted for about 3 percent of all energy inputs, facility lighting accounted for about 1 percent, and facility support accounted for less than one half of 1 percent. Thus non-process facility costs are generally very small compared with process costs.

Chapter 8 describes the public works sector and traces the development of the baseline measures for the public works sector. The public works sector is the most diverse of the four industry sectors. For this reason, it has been divided into a number of sub-sectors. These are *Transportation* (which includes five transportation modes: road, rail, transit, water, and air), *Power Utilities* (which includes the generation and distribution of electricity, gas, and steam), *Water* (which includes the storage, supply, and treatment of water, plus flood and storm water control), and *Pipelines* (which includes pipelines for the transport of petroleum and other commodities except natural gas). The baseline measures for the public works sector are summarized in Table 8-32 in Section 8.3. Brief descriptions of each sub-sector are given in the text that follows.

Transportation plays a pivotal role in the US economy. The Bureau of Transportation Statistics estimates that transportation service in 1993 accounted for about 11 percent of Gross Domestic Product. Governments invest heavily in transportation infrastructure and equipment.

The most widely used form of transportation in the US is the highway. In 1993, all levels of government--federal, state, and local--invested heavily in highways. State government put 92 percent of their transportation funds into highways, local governments 47 percent, and the federal government 32 percent. Almost 90 percent of public investment in highways for 1993 was for construction. The highway network comprises 6.28 million kilometers (3.9 million miles) of public roads, which are operated primarily by state and local governments. The total size of the US highway system has been relatively stable for many years. The public road network is classified according to the traffic functions the roads are intended to serve. The functional types identified in this document are *Interstates, freeways and expressways, arterials, collectors,* and *local roads*.

Table ES-4 shows how state maintenance outlays in 1994 vary by functional system in urban and rural areas. The table also includes, for a select subset of these data, baseline measures normalized on a per-lane kilometer (mile) basis. These baseline measures facilitate comparison of maintenance costs by type of road and geographic location. Table ES-4 shows that the baseline values of annual maintenance costs per-lane kilometer for all state-administered highways are about $1900 ($1894 per-lane kilometer). The baseline values of annual maintenance costs for rural highways are under half those of urban maintenance costs. However, urban and rural Interstate costs are significantly higher than the average for all highways, with annual urban costs of about $5,200 per-lane kilometer and annual rural Interstate costs of about $3,850 per-lane kilometer.

Table ES-4. Baseline Measures for State Highway Maintenance Expenditures: 1994

Functional System	Total Maintenance Cost (Thousands of Dollars)	Estimated Maintenance Cost per Mile (Dollars)	Estimated Maintenance Cost per Lane Mile (Dollars)	Estimated Maintenance Cost per Kilometer (Dollars)	Estimated Maintenance Cost per Lane Kilometer (Dollars)
Urban Interstates/ Freeways and Expressways	926,293	42,769	8,344	26,581	5,186
Urban Arterial	931,289	15,287	-	9,501	-
Urban Collector	80,743	7,768	-	4,828	-
All Urban Highways	***1,938,325***	***17,619***	***5,595***	***10,950***	***3,477***
Rural Interstate	816,351	25,152	6,218	15,632	3,865
Rural Arterial	1,593,794	6,995	-	4,347	-
Rural Collector	1,122,314	4,200	-	2,610	-
All Rural Highways	***3,532,459***	***5,116***	***2,439***	***3,180***	***1,516***
All Highways	**5,470,784**	**6,835**	**3,048**	**4,248**	**1,894**

The power utilities sub-sector provides baseline measures for power generation, including the distribution of natural gas. General information about the size of the sub-sector, in terms of number of operating establishments and kilometers (miles) of pipeline operated, provides the context within which the baselines are developed. The baselines cover water use by the sub-sector, capital expenditures for construction, and expenditures for maintenance and repair by SIC Code.

The water sub-sector provides baseline measures for water supply, treatment, and flood control. The baselines cover capital expenditures for new construction and expenditures for maintenance and repair by SIC Code.

The pipelines sub-sector provides baseline measures for petroleum and other pipelines in the US, excluding natural gas pipelines. General information about the size of the sub-sector, in terms of number of operating establishments and kilometers (miles) of pipeline operated, provides the context within which the baselines are developed. The baselines cover capital expenditures for new construction and expenditures for maintenance and repair by SIC Code.

Chapter 9 discusses additional areas of research that might be of value to government agencies and private bodies who are concerned about reducing OM&E costs. These areas of research are concerned with: (1) accounting for the discrepancies between data which quantify annual construction outputs for new construction, additions and alterations, and maintenance and repair; (2) additional data collection; and (3) evaluations of progress toward achievement of National Construction Goal 2.

1. Introduction

1.1 Background

Data describing current practices of the US construction industry are needed to establish baselines against which industry can measure its progress towards achieving the seven National Construction Goals. The seven National Construction Goals are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries.

Although information having relevance to the seven goals is available, for the most part, this information has such a narrow focus that a consistent set of baseline measures and associated measures of progress can not be produced without first conducting a significant research effort. Specifically, information from a wide variety of data sets needs to be collected, reviewed, analyzed, and critiqued to ensure that the baseline measures and measures of progress which result are:

(1) adequate (i.e., they not only capture the complexities of the US construction industry but also represent a consensus among experts in the field); and

(2) suitable for dissemination to the public.

It is essential to have baseline data and associated measures of progress to determine the success of actions taken to improve the competitiveness of the US construction industry. In addition, baselines and measures of progress will make it possible to demonstrate the benefits of advanced technologies and practices, and to guide decision makers in prioritizing potential programs.

The goal of this project is to develop a suite of products which support the measurement and attainment of the National Construction Goals by the four key construction industry sectors. The four industry sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works. Three basic sets of products are envisioned:

(1) *Baseline Measures*: Develop baseline measures which characterize current industry performance with respect to each of the seven goals. The averages of current practice (defined in this document as industry performance in 1994) will become the baselines for measuring progress towards achieving each of the goals.

(2) *Measures of Progress*: Develop methods for measuring progress. These "results" measures are envisioned as a composite of performance measures offering a means not only for monitoring actual performance but also for marshaling support for improving results.

(3) *Periodic Reports*: Provide information on each of the seven goals. This information will be made available to interested parties both through publications and, ultimately, electronically via the World Wide Web. Potential outlets for the baselines and measures of progress include the Construction and Building Subcommittee member organizations and the four sector council member organizations. [1]

1.2 Purpose

The purpose of this document is twofold. First and foremost, this document provides a detailed set of baseline measures for National Construction Goal 2 (reductions in operations, maintenance, and energy costs). As such, it describes data sources, data classifications and hierarchies, and the metrics used to develop the baseline measures. Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed. This document is the first in a series of studies prepared by NIST's Building and Fire Research Laboratory (BFRL). A subsequent companion document[2] focuses on National Construction Goal 1, reductions in delivery time.

The second purpose of this document is to outline BFRL's strategy for collecting information on each National Construction Goal, for gaining consensus on what information should be included in the baseline measures and measures of progress, and for disseminating information to interested parties. Specifically, a two-phase, four-step process for developing and disseminating the baseline measures and measures of progress is described.

1.3 Scope and Approach

This document has eight chapters and seven appendices in addition to the Introduction. Chapter 2 introduces the National Construction Goals, describes how a well-defined set of metrics is used to develop the baseline measures and measures of progress, and outlines the project approach. Chapter 3 provides an overview of the construction industry. The overview provides the context within which the baseline measures are developed. Chapter 4 presents two data classification schemes; one which is idealized and one which is data driven. These data classification schemes are used to construct data hierarchies from which key metrics are derived and used to develop the baseline measures. Chapters 5 through 8 present the baseline measures for each of the four key construction industry sectors. Chapter 9 concludes the document with a summary and suggestions for further research.

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[1] The four sector council member organizations are: (1) National Association of Home Builders Research Center (Residential); (2) National Institute of Building Sciences (Commercial/Institutional); (3) Construction Industry Institute (Industrial); and (4) American Public Works Association (Public Works).
[2] Chapman, Robert E., and Roderick Rennison. 1998. An Approach for Measuring Reductions in Delivery Time: Baaseline Measures of Construction Industry Practices for the National Construction Goals. NISTIR 6189, Gaithersburg, MD: National Institute of Standards and Technology.

The individual data hierarchies for each construction industry sector are presented in Appendices A through D. Each sector occupies an appendix: Appendix A covers the residential sector; Appendix B covers the commercial/institutional sector; Appendix C covers the industrial sector; and Appendix D covers the public works sector. Three additional appendices are also included as an aid to cross referencing terms, statistical information, and other material contained in this document. Appendix E lists the assignments of each state to one of the four census regions: (1) Northeast; (2) Midwest; (3) South; or (4) West. Appendix F lists the two-digit Standard Industrial Classification (SIC) Codes. SIC Codes are used extensively throughout Chapter 8 which covers the industrial sector. Appendix G provides a list of acronyms and their definitions.

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2. The National Construction Goals: A Tool for Promoting Competitiveness Within the Construction Industry

2.1 Description of the National Construction Goals

The Construction and Building (C&B) Subcommittee has studied research priorities expressed by the construction industry. These priorities translate into the following seven National Construction Goals:

1. 50% Reduction in Delivery Time
2. 50% Reduction in Operation, Maintenance, and Energy Costs
3. 30% Increase in Productivity and Comfort
4. 50% Fewer Occupant-Related Illnesses and Injuries
5. 50% Less Waste and Pollution
6. 50% More Durability and Flexibility
7. 50% Reduction in Construction Worker Illnesses and Injuries

To make the National Construction Goals operational, they are based on the values of a well-defined set of baseline measures. As noted in the Introduction, the values of the baseline measures for each goal are averages of industry performance in 1994. The year 1994 was established as the basis for computing the values of the baseline measures because it was the year when the National Construction Goals were first formulated.[3]

Two priority thrusts, better constructed facilities, and improved health and safety of the construction work force, were defined as the focus of C&B-related research, development, and deployment (RD&D) activities. The objective of the C&B-related RD&D activities is to make technologies and practices capable of achieving the goals under the two priority thrusts available for general use in the construction industry by 2003.

Achievement of the National Construction Goals will: (1) reduce the first costs and life-cycle costs of constructed facilities in the four key construction industry sectors (i.e., residential, commercial/institutional, industrial, and public works); (2) result in better constructed facilities; and (3) result in improved health and safety for both construction workers and occupants of constructed facilities. Achievement of the goals will convey benefits to each of the four construction industry sectors (e.g., housing will become more affordable through reductions in first costs and life-cycle costs). However, depending on the goal and the construction industry sector, the beneficial impacts are expected to vary. To gain a better appreciation of the importance of the National Construction Goals, both individually, and taken together, and of their relationship to the four key construction

[3] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1994. *Rationale and Preliminary Plan for Federal Research for Construction and Building*. NISTIR 5536. Washington, DC: National Science and Technology Council.

industry sectors, a brief description of each goal follows. The descriptions are patterned after those given in the report by Wright, Rosenfeld, and Fowell.[4]

Goal 1: 50% Reduction in Delivery Time

Delivery time is defined as the elapsed time from the decision to construct a new facility until its readiness for service. Delivery time issues affect both industrial competitiveness and project costs. During the initial planning, design, procurement, construction, and start-up process, the needs of the client are not being met. Furthermore, the client's needs evolve over time, so a facility long in delivery may be uncompetitive or unsuitable when it is finished. Delays almost always translate into increased project costs due to inflationary effects, higher financial holding costs, and reduced productivity. Furthermore, the investments in producing the facility cannot be recouped until the facility is operational. Owners, users, designers, and constructors are among the groups calling for technologies and practices to reduce delivery time.

Goal 2: 50% Reduction in Operations, Maintenance, and Energy Costs

Operations, maintenance, and energy (OM&E) costs are a major factor in the life-cycle costs of a constructed facility. In some cases, OM&E costs over the life of a facility exceed its first cost. However, because reductions in OM&E costs are often associated with increased first costs, facility owners and managers may under-invest in cost saving technologies. Furthermore, undue attention on minimizing first costs may result in a facility which is expensive to operate and maintain, wastes energy resources, is inflexible, and rapidly becomes obsolete. Finally, because OM&E costs tend to increase more rapidly than the general rate of inflation, facility owners and operators are often forced to reallocate funds to cover OM&E costs. Reductions in OM&E costs will produce two types of benefits. First, constructed facilities will become more affordable because facility owners and operators are making more cost-effective choices among investments (e.g., design configurations) which affect life-cycle costs. Second, these same facilities will better conserve scarce energy resources.

Goal 3: 30% Increase in Productivity and Comfort

Industry and government studies have shown that the annual salary costs of the occupants of a commercial or institutional building are of the same order of magnitude as the capital cost of the building.[5] Occupant comfort depends largely on the nature of buildings, building furnishings, and indoor environments. The quality of indoor environments also has a large impact on occupant health and productivity. Improvement of the productivity of the occupants (or for an industrial facility, improvement of the productivity of the

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[4] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1995. *Construction and Building: Federal Research and Development in Support of the US Construction Industry*. Washington, DC: National Science and Technology Council.

[5] Building Owners and Managers Association. 1994. *Experience Exchange Report, National Cross-Tabulations, 1994*. Washington, DC: Building Owners and Managers Association.

process housed by the facility) is an important performance characteristic for most constructed facilities.

Goal 4: 50% Fewer Occupant-Related Illnesses and Injuries

Buildings are intended to shelter and support human activities, yet the environment and performance of buildings can contribute to illnesses and injuries for building users. Examples are avoidable injuries caused by fire or natural hazards, slips and falls, disease from airborne microbes, often associated with a workplace environment, and building damage or collapse from fire, earthquakes, or extreme winds. Reductions in illnesses and injuries will increase building users' productivity as well as reduce the costs of medical care and litigation.

Goal 5: 50% Less Waste and Pollution

Improvement of the performance of constructed facilities provides major opportunities to reduce waste and pollution at every step of the delivery process, from raw material extraction to final demolition and recycling of the facility and its contents. Additional reductions come from reduced energy use, reduced water consumption, and reductions in waste water production, which are considered in part by Goal 2.

Goal 6: 50% More Durability and Flexibility

Durability denotes the capability of the constructed facility to continue (given appropriate maintenance) its initial performance over the intended service life. Flexibility denotes the capability to adapt the constructed facility to changes in use or users' needs. Increased durability and flexibility of constructed facilities reduces life-cycle costs and prolongs the economic life of the facility (i.e., the period of time over which an investment in the original facility is considered to be the least-cost alternative for meeting a particular objective).

Goal 7: 50% Reduction in Construction Worker Illnesses and Injuries

Health and safety issues exert a major effect on the competitiveness of the US construction industry. Construction workers die as a result of work-related trauma at a rate which is higher than all other industries except mining and agriculture. Construction workers also experience a higher incidence of nonfatal injuries than workers in other industries. Although the construction workforce represents less than 5 percent of the nation's work force, it is estimated that the construction industry pays about 15 percent of the nation's workers' compensation.[6]

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[6] The Center to Protect Workers' Rights. 1997. *The Construction Chart Book: The US Construction Industry and Its Workers*. Report D1-97. Washington, DC: The Center to Protect Workers' Rights.

2.2 Baseline Measures

As noted earlier, the baseline measures for each goal are averages of industry performance in 1994. Thus, with regard to the baseline measures, 1994 is the "base year." Consequently, data from 1994 drive the data collection effort culminating with the development of the baseline measures for each National Construction Goal.

The process for developing baseline measures used in this project involves: (1) specifying a data-oriented hierarchy; (2) collecting and compiling the key data and supporting information for the base year, 1994;[7] (3) defining metrics for each goal/sector combination; and (4) producing the metrics in a tabular summary form and, where appropriate, producing charts and graphs to depict the metrics. If the goal/sector combination has components and subcomponents, then metrics are defined for each. This process is employed because the metrics represent not only a statement of current construction industry performance but tools for measuring an individual organization's performance as well. By providing a small set of well-defined metrics, individual organizations can construct their own performance baselines. For example, individual organizations can see how a collection of their projects performs vis-à-vis the "national" data. To summarize, the basic philosophy behind the baseline measures is that they are not a static tool whose sole purpose is quantifying the value of the goal but a means for driving performance improvement within individual organizations.

2.3 Measures of Progress

The methods for measuring progress use the baselines as their reference point. The measures of progress employ a method which makes use of both key outputs (i.e., summary measures) and interlinking metrics (i.e., a composite of performance measures including constituent parts and functional relationships). Because the National Construction Goals may be specified as targets measured against baseline values, "gap analysis" is an appropriate method for defining the measures of progress.

To gain a better understanding of how gap analysis may be applied, consider the following case illustration. One component of Goal 7, Construction Worker Illnesses and Injuries, is recordable injuries. If Goal 7 targets a 50% reduction in construction worker illness and injuries, we may adopt an across-the-board reduction of 50% for all components of that goal. Therefore, for this component, the goal is to reduce recordable injuries by 50%. Denote the industry average in 1994 by BR_{94} (i.e., the Baseline value for Recordable injuries). Denote the goal for recordable injuries for 2002 by GR_{02}; it is equal to $0.5*BR_{94}$. Denote the difference between the baseline and the goal (i.e., $BR_{94} - GR_{02}$) by dR_{94}. This difference may be thought of as a gap (i.e., the difference between the actual level and the desired level). Similarly, for some future year, say 1997, whose actual value is R_{97}, the gap becomes dR_{97} (i.e., $R_{97} - GR_{02}$).

[7] If data are available for years in addition to 1994 (e.g., 1992 through 1996), then these data are collected at the same time as the base year data and used to illustrate trends; these data are also used to compute the associated measures of progress.

This method also enables us to measure how much of the initial gap has been closed. One measure of performance is the percent of the initial gap which has been closed by some future date, say 1997. Denote this amount as $P(dR_{97})$, where:

$$P(dR_{97}) = (1 - (dR_{97} / dR_{94})) * 100$$

The advantage of this measure of performance is that it employs the same values for each measure used in computing the baselines. Although the gap analysis method is simple and straightforward, it offers considerable flexibility. Consequently, it is the recommended method for generating measures of progress.[8]

2.4 Interactions Between the National Construction Goals, the Baseline Measures, and the Measures of Progress

As noted earlier, the objective of the C&B-related RD&D activities is to have *technologies and practices* capable of meeting the goals available in 2003. This objective raises an important issue, namely, the relationships between the baseline measures, the measures of progress, and the goals. Several relationships which warrant consideration are the following. First, it is important to recognize that the goal can always be represented as a function of the baseline measure. Thus, given a baseline "value," a target or goal "value" can be specified. Second, for baseline measures to be most beneficial, they need to be tied to specific "metrics" which are well-defined and able to be used by interested parties (e.g., a specific government agency could substitute its own data into the metric and use it to establish its own "baseline" values). Finally, the measures of progress need to make explicit the relationship between the baseline, the goal, and the current level of improvement.

The previous discussion implies that the form of the baseline measure is important as a "facilitator" of performance (i.e., a linkage to performance-improving technologies and practices). Two forms of baseline measures which may serve as facilitators are point estimates (i.e., an average value) and a distribution of values. Although an *average value*

8The gap analysis method has another advantage in that priorities can be easily incorporated. For example, during the consensus building step, the focus group might feel strongly that one component of an National Construction Goal (NCG) is of greater importance than another. Consequently, progress towards closing the gap on this component would be viewed as more important than progress on another component for that NCG. Multiattribute decision analysis (MADA) provides a well-established tool for assigning priorities to components. (See, American Society for Testing and Materials. 1995. *Standard Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems*. E 1765. Philadelphia, PA: American Society for Testing and Materials.) MADA may also be used to develop a hierarchical relationship among components (i.e., a composite of performance measures including constituent parts and functional relationships). Such an approach would help to analyze how changes in individual metrics (i.e., components at a lower level within the hierarchical relationship) affect the level and rate of change of key outputs (i.e., the highest level metric in the hierarchical relationship).

is a good baseline measure, it collapses a great deal of information into a single reference point. An alternative way to think about a baseline measure is as *the distribution of values* of industry performance in 1994. This approach, while more data intensive, is a great deal more flexible. Over the long term, the key stakeholders (e.g., researchers, innovators, owners, and contractors) can focus on pushing the entire distribution towards a more competitive position (e.g., faster delivery time) rather than just focusing on improving the average value of some "unknown" distribution. It is important to recognize that *the distribution of values* contains not only the mean or average value of the metric which defines the baseline measure, but the highest and lowest values as well. For example, if the percentiles of the distribution are available, an individual organization (e.g., government agency, construction firm, etc.) could calculate a representative set of values and, hence, determine their location within the distribution. This information could then be used for goal setting and for developing measures of progress within a particular organization.

2.5 Project Approach

Developing baseline measures and measures of progress--whether they are based on average values or a distribution--for each National Construction Goal and each construction industry sector is a complex process. Fortunately, some goals are relatively more important to the construction industry, which suggests setting priorities for data collection. The report by Wright, Rosenfeld, and Fowell[9] provides information reflecting the construction industry's priorities. The construction industry's four highest priority goals are Goal 1, Goal 2, Goal 6, and Goal 7. The three lowest priority goals are Goal 3, Goal 4, and Goal 5.

The availability of data and level of sector-specific information are other key considerations. For some goals, there is a well-defined linkage to data (e.g., national/regional statistics or sector-specific information). For other goals, little quantitative information is available. Consequently, a two-phase approach is being employed. The order (i.e., phase) in which the baseline measures and measures of progress are developed is based on three characteristics: (1) the priority of the goal; (2) the availability of data; and (3) the level of sector-specific information. Phase I covers the four highest priority goals. Phase II covers the three lowest priority goals.

This two-phase approach was designed to produce a set of baseline measures and measures of progress in the most timely manner. This approach is summarized in Table 2-1; it combines information on priorities from the construction industry with constraints on data availability and the level of sector-specific information. This approach provides the basis for focusing project resources on those goals where baseline measures and measures of progress: (1) are most needed by the construction industry; (2) can be defined and agreed upon by key construction industry stakeholders; and (3) can be developed in a timely manner. Consequently, these data sets, once developed and disseminated, offer the greatest potential for acceptance and use by the construction industry.

[9]Wright, Rosenfeld, and Fowell. 1995. *Op. Cit.*, p. 10.

Table 2-1. Phases in the Development of Baseline Measures

Phase	National Construction Goals		Data Characteristics	
	Goals Covered	**Priority**	**Data Availability**	**Sector Definition**
I	7	High	Readily Available Well Documented Authoritative Sources	Good Sector Definition
	1,2,6	High	"Pockets" of Good Data	Some Sectors Not Clearly Defined
II	3,4,5	Low	"Composite" Data Types: Either Few Pockets of Good Data Or Total Lack of Data	Some Sectors Not Clearly Defined

For each of the phases shown in Table 2-1, a four-step process is envisioned. The four steps are:

1. Establish Criteria for Data Selection;

2. Identify and Collect Data;

3. Develop Consensus on Key Measures and Supporting Data; and

4. Produce and Disseminate Baseline Measures and Measures of Progress.

In the sections which follow, each step is described briefly and, where appropriate, related to each phase.

2.5.1 Criteria for Data Selection

Criteria are needed to ensure that the data selected for *analysis* are well-defined, consistent, and replicable. Because data are so important to the baseline measures for each goal, BFRL reviewed many potential sources (e.g., journals, technical publications, electronic media) of baseline-related data/information. This review suggested three criteria which must be met by any data in order to be accepted for analysis. These criteria are:

(1) Published by a reliable, nationally-recognized organization and available to the public;

(2) Updated on a regular basis; and

(3) Able to be normalized to account for changes in the building stock and the level of construction activity.

These three criteria are appropriate for establishing the baseline measures for each goal for each of the two phases shown in Table 2-1. These criteria are also appropriate for any data associated with measures of progress for each goal.

2.5.2 Identify and Collect Data

Matching data to goals employs the two phases shown in Table 2-1, beginning with Phase I. The objective of this step is to begin with those goals where data is both well-defined and readily available. This strategy enables us to gain experience from the outset, learn from these experiences, and modify the data collection effort accordingly.

The Phase I effort is divided into three stages. The first stage focused on Goal 7 (i.e., Construction Worker Illnesses and Injuries). In this stage, two hierarchies for classifying data were established prior to initiating the data collection effort. The first hierarchy produced an overlay of the construction industry Standard Industrial Classification (SIC) Codes and the four construction industry sectors used in this study. The second hierarchy was purely data oriented. Both hierarchies produced "workable" baseline measures. The purpose of the first stage was to evaluate if, or how, the data collection effort was to be refined. No refinements were identified.

The second stage focused on the two "highest priority" goals, (Goal 1 and Goal 2. Wherever "pockets" of good data existed (e.g., selected information on delivery time for the residential and industrial sectors), they were collected and analyzed. This stage, like the first, began with the establishment of two data classification hierarchies. A key difference between the first and second stages was the second stage's use of a comprehensive "idealized" sector-specific hierarchy as a starting point. The idealized hierarchy was then modified to reflect data constraints. The resultant data-oriented hierarchy was similar to the purely data-oriented hierarchy produced for Goal 7 but with slightly better sector definition. Completion of the second stage revealed no refinements to the data collection effort. However, several caveats associated with the interpretation of the baseline measures were noted (see Section 2.5.5).

The third stage will focus on Goal 6 (i.e., Durability and Flexibility). It is anticipated that upon completion of the third stage, refinements to the data collection effort will be identified. In particular, whether to establish linkages between durability and flexibility, or to treat the two major components of Goal 6 as separate entities.

The Phase II effort is not planned for initiation until the Phase I effort is nearly completed. This strategy is based on the assumption that experience gained in the Phase I data collection efforts, particularly during the second and third stages, will suggest sources and ways in which data on Phase II's goals can be collected and analyzed.

2.5.3 Consensus on Key Measures and Supporting Data

Gaining consensus is essential if the data are to be useful to the construction industry and hence used to measure improvement towards goal attainment. This "consensus building" step is composed of five parts. The five parts are:

(1) Conduct analytical studies of the "Phase" data and other data recommended by the C&B Subcommittee;

(2) Produce a "Set" of proposed data and derived measures (e.g., baseline measures and measures of progress);

(3) Form a "Focus Group" from the C&B Subcommittee member organizations, industry representatives, and other interested parties to discuss the proposed data and derived measures;

(4) Brief the C&B Subcommittee on progress and solicit feedback; and

(5) Revise the data and derived measures and present findings to the C&B Subcommittee

Data collected on baselines and measures of progress for each phase will go through this step. For the Phase I goals, a single iteration should be sufficient. For the Phase II goals, multiple iterations may be required.

2.5.4 Production and Dissemination of Baseline Measures and Measures of Progress

Based on the focus group discussions and feedback from the C&B Subcommittee, the data sets and derived measures are finalized for each goal. The data are delivered initially in the form of tables and reports. No data are disseminated on individual companies. Potential outlets for the baselines and measures of progress include the C&B Subcommittee member organizations and the four sector council member organizations. In order to reach an even larger audience, data will be incorporated into a computerized delivery system and made available on the World Wide Web.

2.5.5 Limitations of the Project Approach

The project approach described in Sections 2.5.1 through 2.5.4 has two basic limitations. It is important for readers to understand what these limitations are and how they affect the values of the baseline measures presented in this document or other reports focused on the National Construction Goals. The two basic limitations of the project approach are concerned with the availability of data ***and*** the selection of data, information, and metrics for inclusion with (or exclusion from) the baseline measures.

The first limitation to the project approach is concerned with the availability of data. Data availability problems manifest themselves in three ways: (1) unspecified functional relationships between metrics within a given goal (e.g., linkages among components at a lower level in the goal's hierarchy): (2) no data for a specific goal/sector combination; and (3) incommensurate base-year data (e.g., no information is available prior to 1996).

The first two problems are being addressed through research. Extensive research has been done and continues on sources of data. This research has uncovered several research reports that address ways in which components associated with a goal can be modeled. Several research reports providing "point" estimates for a goal/sector component have also been uncovered. Unfortunately, while these reports provide valuable insights, they lack specificity. In the first case, although the research reports imply functional relationships (i.e., a linkage mechanism), the functional form is unspecified. For example, both Goal 3--Productivity and Comfort--and Goal 6--Durability and Flexibility--have two major components. Ideally, these components would be linked via a functional relationship. The alternative is to treat each component as a separate and distinct entity. In the second case, one of a kind "estimates" or "information" are tantamount to no data. There is no opportunity to replicate the results without repeating the research which produced the "estimates" or "information" in the first place.

The third problem, incommensurate base-year data, is being addressed through a set of carefully stated caveats. If data are being collected now which satisfy the criteria for data selection but were not available in 1994 (i.e., the year specified for the baseline measures), then they still represent meaningful metrics. ***The caveats come in regarding how to interpret the values of these metrics.*** In cases where such caveats are made (e.g., delivery time metrics for the three non-residential sectors), they are stated clearly. In addition, guidance is given on how to interpret the values of these metrics vis-à-vis the goal.

The second limitation stems from decisions the project team made regarding what was to be included in or excluded from the baseline measures. Although our objective is to produce baseline measures for each goal/sector combination, it became necessary to include some types of information only at a higher level of aggregation (e.g., at the construction industry level rather than the individual sector level). Similarly, decisions were made to exclude some types of information for which data were available but their inclusion would provide no new insights. In both cases--whether data were included at a higher level of aggregation or excluded from the document--the authors have clearly stated their reasons and given guidance to help readers interpret the results.

2.6 How This Document Helps

This document is part of a series. As such, it provides perspective on the overall effort to develop baseline measures and measures of progress for each of the seven National Construction Goals. It also serves to highlight how these measures and their associated metrics can be used to drive performance improvement.

On a deeper level, this document provides step-by-step descriptions of how to construct a well-defined set of baseline measures, their components, and associated metrics for a specific goal for each of the four construction industry sectors. Information on data classification, data sources, and data collection and analysis provide the underpinnings for the results presented in this document. It is anticipated that once users of this document have understood the vital role of metrics as a process improvement tool, they will see how the National Construction Goals will benefit both their organization and the US construction industry.

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3. Overview of the Construction Industry

The construction industry is a key component of the US economy and is vital to the continued growth of the US economy. Investment in plant and facilities, in the form of construction activity, provides the basis for the production of products and the delivery of services. Investment in infrastructure promotes the smooth flow of goods and services and the movement of individuals. Investment in housing accommodates new households and allow existing households to expand or improve their homes. It is clear that construction activities affect nearly every aspect of the US economy. However, construction activities are also strongly affected by the health of the economy and the associated business cycle.[10]

This chapter provides a snapshot of the US construction industry. As such, it provides the context within which baseline measures are developed, a subject which occupies the remainder of this document. The chapter contains four sections. Each section deals with a particular topic. The topics progress from general in nature to very specific. This progression is described below.

First, information on the value of construction put in place is provided to show the size of the construction industry and each of its four sectors--residential, commercial/ institutional, industrial, and public works. Second, information on the nature of construction activity for each sector of the industry is presented. The Standard Industrial Classification (SIC) Codes for the construction industry are introduced and described as a means for organizing construction activity. Information on the nature of construction activity includes breakouts between new construction activities, maintenance and repair activities, and additions and alterations activities. The challenge of developing annual estimates for each sector by nature of construction activity is described. Examples are given which demonstrate how different data sources result in major differences in a particular year's estimates. Third, information on employment in the construction industry is summarized and a series of employment-related statistics are presented. The SIC Codes for the construction industry are used as a means for organizing key employment-related information. Comparisons between employment and output in the construction industry and employment and output in the overall US economy are also included. Fourth, information on cost trends (e.g., average cost per square foot for residential and non-residential buildings) and on other, special considerations, is presented.

3.1 Value of Construction Put in Place

This section provides information on a key indicator of construction activity, the value of construction put in place. Data published by the US Bureau of the Census are used to establish the composition of construction expenditures by type of construction/function

[10] Readers interested in learning more about construction statistics, their sources and interpretation, are referred to an excellent source document by Rogers (Rogers, R. Mark. 1994. *Handbook of Key Economic Indicators*. Burr Ridge, IL: Irwin Professional Publishing).

(e.g., non-residential/office building). These expenditures are then assigned to the four key construction industry sectors. The reference document used throughout this section is the **Current Construction Reports** series C30 publication *Value of Construction Put in Place*.[11] A brief description of the "C30 report" follows. Special attention is given to the organization of the data in the C30 report and how these data map into the four key construction industry sectors. The section concludes with tabular and graphical summaries of the value of construction put in place.

***Current Construction Reports** Series C30*

Construction expenditures data are published monthly in the **Current Construction Reports** series C30 publication *Value of Construction Put in Place*. Construction expenditures refer to actual construction rather than planned or just initiated activity. It is noteworthy that the C30 report covers both private residential and non-residential construction activities and public sector construction activities.

The value of construction put in place is a measure of the value of construction installed or erected at a site during a given period. For an individual project, this includes: (1) cost of materials installed or erected; (2) cost of labor (both by contractors and force account (i.e., construction done for own use)) and a proportionate share of construction equipment rental; (3) contractor's profit; (4) cost of architectural and engineering work; (5) miscellaneous overhead and office costs chargeable to the project on the owner's books; and (6) interest and taxes paid during construction. Expenses do not include the cost of land nor do they include maintenance and repairs to existing structures or service facilities.

The C30 data are compiled via survey and through indirect estimation. In the context of the C30 survey, construction includes the following: (1) new buildings and structures; (2) additions, alterations, conversions, expansions, reconstruction, renovations, rehabilitations, and major replacements (e.g., the complete replacement of a roof or a heating system); (3) mechanical and electrical installations (e.g., plumbing, heating, electrical work, and other similar building services); (4) site preparation and outside construction of fixed structures or facilities (e.g., sidewalks, highways and streets, water supply lines, sewers, and similar facilities which are built into or fixed to the land); (5) installation of boilers, overhead hoists and cranes, and blast furnaces; (6) fixed, largely site-fabricated equipment not housed in a building (e.g., petroleum refineries and chemical plants); and (7) cost and installation of construction materials placed inside a building and used to support production machinery (e.g., concrete platforms, overhead steel girders and pipes, etc.). ***It is important to note that the C30 survey produces information not only on the value of new construction put in place but also contains an unquantified component for additions and alterations for the non-residential sectors.***
The data presented in the C30 report are divided into two parts: (1) private construction; and (2) public construction. These data are summarized in Table 3-1. The table records

[11] Throughout this chapter, reference is made to the **Current Construction Reports** series C30 publication. These references include both how it is used as the basis for other sets of calculations presented in this chapter and as a vehicle for comparing calculations based on other Census publications.

annual values (in millions of constant 1992 dollars) for the years 1992 through 1996. Separate column headings showing the type of construction/function and the assigned sector--R for residential, C for commercial/institutional, I for industrial, and P for public works--are also included. The sector assignment was made by the authors.

Private construction contains two major components--residential buildings and non-residential buildings--plus a number or subcomponents. Both the two major components and the various subcomponents are shown as headings in the first column of Table 3-1.

The residential buildings component includes new private housing and improvements. New private housing includes new houses, apartments, condominiums, and town houses. New private housing units are classified as “1 unit” or “2 or more units.” The value of improvements put in place are a direct measure of the value of *residential additions and alterations* activities. Consequently, improvements are not included in the "new construction" residential sector totals recorded at the bottom of Table 3-1.

The non-residential buildings component includes industrial, office buildings, hotels and motels, and “other commercial” (e.g., shopping centers, banks, service stations, warehouses, and other categories). Also falling under the non-residential buildings component are religious, educational, hospital and institutional, and “miscellaneous” non-residential buildings.

Rounding out the private construction component are farm non-residential, public utilities, and “all other private.” These are generally of a non-residential nature but are not part of non-residential buildings. Farm non-residential construction includes structures such as barns, storage houses, and fences. Land improvements such as leveling, terracing, ponds, and roads are also a part of this subcomponent. Privately owned public utilities construction is categorized by industry rather than function of the building or structure. This subcomponent includes expenditures made by utilities for telecommunications, railroads, petroleum pipelines, electric light and power, and natural gas. “All other private” includes privately owned streets and bridges, sewer and water facilities, airfields, and similar construction.

For public construction, there are two major components--building and non-building. Both the two major components and the various subcomponents are shown as headings in the first column of Table 3-1. The building component contains subcomponents similar to those for private construction, with educational buildings being the largest subcomponent. Expenditures for the non-building component overwhelmingly consist of outlays for highways and streets, with sewer systems being a distant second subcomponent.

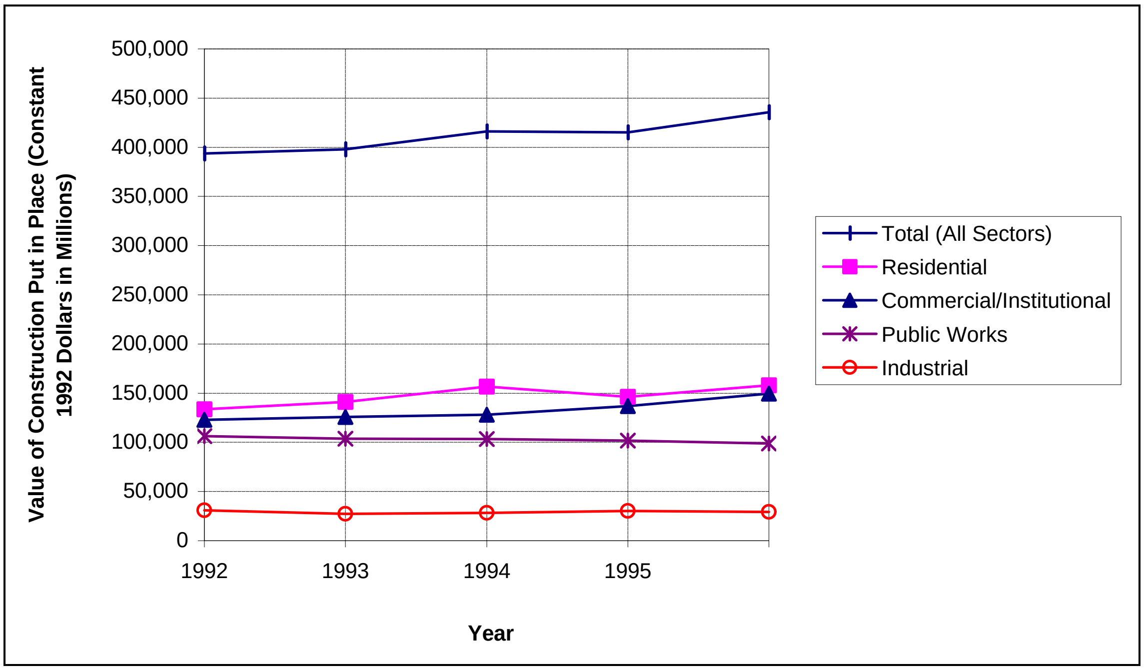
To get the "new construction" sector totals, which appear in the bottom portion of Table 3-1, each subcomponent was assigned to a sector and summed. The sector assignments are recorded in the second column of Table 3-1. Reference to the bottom portion of the table reveals that sector totals vary considerably, with residential being the largest and industrial the smallest.

Table 3-1. Value of New Construction Put in Place: 1992 to 1996

Type of Construction	Assigned Sector	VALUE OF CONSTRUCTION PUT IN PLACE (SERIES C30) Constant 1992 Dollars in Millions				
		1992	1993	1994	1995	1996
Total construction		*451,998*	*461,078*	*480,965*	*474,426*	*493,587*
Private construction		336,126	347,851	367,265	359,411	378,150
Residential buildings		187,687	200,502	218,005	201,682	212,069
New housing units		129,522	137,243	153,250	142,413	153,965
1 unit	R	116,419	126,960	140,416	126,773	136,516
2 or more units	R	13,103	10,283	12,833	15,640	17,449
Improvements		58,165	63,259	64,755	59,268	58,104
Nonresidential buildings		105,615	106,729	111,416	120,627	130,394
Industrial	I	29,027	25,554	26,803	29,043	28,003
Office	C	20,271	20,197	20,553	22,891	24,099
Hotels, motels	C	3,690	4,405	4,308	6,351	10,263
Other commercial	C	29,172	31,292	34,756	38,098	41,301
Religious	C	3,483	3,748	3,584	3,864	3,961
Educational	C	4,475	4,484	4,471	4,908	5,790
Hospital and institutional	C	11,485	12,050	11,377	10,051	10,460
Miscellaneous	C	4,011	5,000	5,565	5,421	6,516
Farm nonresidential	C	2,396	3,271	3,008	2,693	2,736
Public utilities	P	36,859	34,120	32,074	31,767	30,842
Telecommunications	P	9,005	9,468	9,785	10,071	10,420
Other public utilities	P	27,854	24,652	22,289	21,696	20,422
Railroads	P	2,926	3,056	3,186	3,202	4,030
Electric light and power	P	17,184	15,096	13,877	12,656	11,191
Gas	P	6,895	5,536	4,308	5,004	4,291
Petroleum pipelines	P	849	965	918	834	910
All other private	P	3,569	3,229	2,763	2,644	2,109
Public construction		115,872	113,227	113,700	115,014	115,437
Buildings		49,988	46,813	45,177	47,832	49,415
Housing and development	R	4,136	3,833	3,326	3,754	3,881
Industrial	I	1,875	1,658	1,358	1,348	1,216
Educational	C	20,645	18,465	17,593	19,237	20,131
Hospital	C	3,383	3,579	3,787	3,854	3,981
Other	C	19,949	19,279	19,114	19,638	20,207
Highways and streets	P	33,132	34,164	36,151	33,500	33,297
Military facilities	P	2,502	2,405	2,196	2,729	2,225
Conservation and development	P	5,946	5,771	6,091	5,773	5,244
Sewer systems	P	9,658	8,622	8,592	8,975	9,060
Water supply facilities	P	5,170	4,868	4,443	4,923	5,121
Miscellaneous public	P	9,475	10,583	11,050	11,282	11,075
New Construction						
SECTOR TOTALS and SUMMARY						
Residential (R)		133,658	141,076	156,576	146,167	157,846
Commercial/Institutional (C)		122,960	125,770	128,116	137,006	149,445
Industrial (I)		30,902	27,212	28,161	30,391	29,219
Public Works (P)		106,311	103,762	103,360	101,593	98,973

Table 3-1 highlights an important distinction between the residential sector and the three non-residential sectors. Reference to the "Residential Buildings" component of the table (i.e., the entry immediately below the heading **Private Construction**) for the year 1992 produces a value of $187,687 million. This value differs from the value for the residential sector, $133,658 million, given immediately below the heading of **SECTOR TOTALS and SUMMARY** in the bottom portion of the table. The reason for the difference is due to the *exclusion* of the value of private residential improvements (i.e., additions and alterations) and the *inclusion* of the value of public housing and development. Because the values given in the bottom portion of Table 3-1 are estimates of the values of *new construction put in place*, it is necessary to net out the value of residential improvements. While this is a straightforward process for the private residential sector, no specific information on additions and alterations is published in the C30 report for either the three non-residential sectors or for public housing and development. Consequently, we have assumed that the values for additions and alterations for the three non-residential sectors and for public housing and development are zero. This implies that the sector totals for commercial/institutional, industrial, and public works are the values of *new construction put in place* for each of the years 1992 through 1996. A rationale for this assumption is given in the next section, which covers the nature of construction activities.

Figure 3-1. Value of New Construction Put in Place: 1992 to 1996



The Table 3-1 sector totals and the overall construction industry totals for the value of *new construction put in place* are shown graphically in Figure 3-1. The horizontal axis of the figure records the year, from 1992 through 1996. The vertical axis records the value of new construction put in place, in millions of constant 1992 dollars. Each trace is keyed to designate either the sector or the overall total.

3.2 Nature of Construction Activity

The nature of construction activity may be conveniently classified as either new construction, additions and alterations, or maintenance and repair. Definitions of each are as follows.

> *New construction* activities include the complete original building of structures and essential service facilities and the initial installation of integral equipment such as elevators and plumbing, heating, and air-conditioning supplies and equipment.
>
> *Additions and alterations* include construction work which adds to the value or useful life of an existing building or structure, or which adapts a building or structure to a new or different use. Included are major replacements of building systems such as the installation of a new roof or heating system and the resurfacing of streets or highways. This contrasts to the repair of a hole in a roof or the routine patching of highways and streets, which would be classified as maintenance and repair.
>
> *Maintenance and repair* activities include incidental construction work which keeps a property in ordinary working condition. Excluded are trash and snow removal, lawn maintenance and landscaping, cleaning and janitorial services.

This section presents information from three different data sources: (1) the **1992 Census of the Construction Industry**; (2) **Current Construction Reports** series C30, *Value of Construction Put in Place*; and (3) **Current Construction Reports** series C50, *Expenditures for Residential Improvements and Repairs*. Although each data source provides insights into the nature of construction activity, they differ in degree of detail, frequency of publication, and sector coverage. Brief descriptions of the **1992 Census of the Construction Industry** and the "C50 report" are given in the text that follows. Readers seeking information on the C30 report are referred to Section 3.1 of this document. Statistics from each source are also presented and, where appropriate, comparisons are made.

1992 Census of the Construction Industry

The Census of the Construction Industry is conducted every five years. The construction industry is one of seven industries tabulated as part of the Economic Census. The Economic Census is highly detailed. However, because the Economic Census is performed only in years ending with 2 or 7, 1992 is the latest year for which such highly detailed construction industry data are available.

The census of the construction industry enumerates establishments with paid employees engaged primarily in one of the following three areas: (1) ***constructing new homes and other buildings***; (2) ***heavy construction***, such as highways; and (3) ***special trades***, such as plumbing and electrical work. Most construction establishments are described as contractors (e.g., general contractors and special trades contractors), but the census also includes operative builders who construct buildings or other structures on their own account to be sold when completed.

A "construction establishment" is defined as a relatively permanent office or other place of business where the usual business activities related to construction are conducted. With some exceptions, a relatively permanent office is one that has been established for the management of more than one project or job and which is expected to be maintained on a continuing basis. Such "establishment" activities include, but are not limited to, estimating, bidding, purchasing, supervising, and operation of the actual construction work being conducted at one or more construction sites. The census did not require separate construction reports for each project or construction site. However, companies with more than one construction establishment were required to submit a separate report for each such establishment operated during all or any part of 1992.

For purposes of the census, construction establishments are classified by kind of business according to the principal work performed. There are three major Standard Industrial Classification (SIC) Groups--two-digit SIC Codes--in the construction industry:

15 Building construction--general contractors and operative builders

16 Heavy construction other than building construction--contractors

17 Special trade contractors

These major SIC Groups are sub-divided into 13 three-digit SIC Codes which in turn are sub-divided into 26 four-digit SIC Codes. Table 3-2 provides a description of each of the 26 four-digit SIC Codes. Part A of the table covers the two-digit SIC Codes 15 (building construction--general contractors and operative builders) and 16 (heavy construction other than building construction--contractors); Part B of the table covers the two-digit SIC Code 17 (special trade contractors).

Data tabulated in **the 1992 Census of the Construction Industry** provide information grouped by the types of buildings, structures, or other facilities being constructed or worked on by construction establishments in 1992. Respondents were instructed to classify each building, structure, or other facility in terms of its function. For example, a restaurant building was to be classified in the restaurant category whether it was designed as a commercial restaurant building or an auxiliary unit of an educational institution. If respondents worked on more than one type of building or structure in a multi-building complex, they were instructed to report separately for each building or type of structure. If they worked on a building that had more than one purpose (e.g., office and residential), they were asked to classify the building by major purpose. In addition, all respondents were requested to report the percentage of the value of construction work done for new construction, additions and alterations, and maintenance and repair activities for each type of building, structure, or facility.

The detailed breakout for new construction, additions and alterations, and maintenance and repair activities provided by the 1992 census is noteworthy because prior to 1987, construction receipts only were collected. In 1987 and 1992, the value of construction work was collected to better measure actual construction activity done during the year. This conceptual change was made because receipts during a calendar year may include advance payments or payments for work done in a prior year, and thus not accurately reflect construction work done during the census year. For certain key industries, such as operative builders and developers, receipts and work done may also differ because receipts do not include work contractors perform for their own account and use, which can be substantial.

At the time of the 1992 census, there were about 1.4 million construction establishments, and about one third of them had paid employees. Establishments without payroll, typically one-person operations or partnerships, were not surveyed by the US Bureau of the Census. The Bureau of the Census did, however, obtain a limited amount of data on self-employed construction workers from the administrative records of other Federal agencies.

Current Construction Reports *Series C50,* *Expenditures for Residential Improvements and Repairs*

The C50 report is published quarterly; it presents improvement and repair expenditures by property owners for residential properties. Data presented in the C50 report are based on personal interviews obtained from household members as part of the Consumer Expenditure Surveys conducted by the Bureau of the Census for the Bureau of Labor Statistics. These data cover single and multi-unit structures, publicly- and privately-owned structures, non-farm and farm properties, and residential properties which are occupied by owners or renters or are vacant.[12]

The expenditures covered in the C50 report are those connected with construction activity intended to maintain or improve the property. These expenditures involve expenses for maintenance and repair, additions, alterations, and major replacements which are made to the property by the owners. Included are all costs, for both the inside and outside of the house, whether on the main dwelling, on other structures on the property incidental to the residential use of the main dwellings, or for the grounds on which the structures are erected.

[12] Expenditures made by renters are not included in the C50 report. A study of renters' expenditures conducted in 1989 showed that they accounted for less than one percent of all expenditures for improvements and repairs.

Table 3-2. Four-Digit SIC Codes for the Construction Industry

Part A: Two-Digit SIC Codes 15 (Building Construction - General Contractors and Operative Builders) and 16 (Heavy Construction Other than Building Construction - Contractors)

SIC Code	Label	Description
1521	General contractor - single-family houses	Includes townhouses, repair of mobile homes on site, and assembly of premanufactured and modular units
1522	General contractors - residential buildings other than single-family	Includes hotels, motels, and dormitories
1531	Operative builders	Condominiums, cooperative apartments, and singe-family houses built by developers to sell, instead of as contractors working for other companies
1541	General contractors - industrial buildings and warehouses	Includes grain elevators and automobile assembly, pharmaceutical manufacturing, and aluminum plants
1542	General contractors - nonresidential buildings, other than industrial buildings and warehouses	Commercial, institutional, religious, and amusement and recreational buildings
1611	Highway and street construction, except elevated highways	Roads, streets, alleys, public sidewalks, guardrails, parkways, and airports (general and special-trade contractors)
1622	Bridge, tunnel, and elevated highway construction	Bridges, viaducts, elevated highways, and highway, pedestrian, and railway tunnels (general construction)
1623	Water, sewer, pipeline, and communications and power-line construction	Includes transmission towers (general and special-trade contractors)
1629	Heavy construction, not elsewhere classified	For instance, athletic fields, blasting (except building demolition), canals, dams, hydroelectric plants, land clearing, nuclear reactor containment, petroleum refineries, piers (general and special-trade contractors)

Part B: Two-Digit SIC Code 17 (Special Trade Contractors)

SIC Code	Label	Description
1711	Plumbing, heating, and air conditioning	Includes drainage system installation, cesspool, and septic tank; lawn sprinkler system; sewer hookups for buildings; solar heating; and related sheet metal work
1721	Painting and paper hanging	Excludes roof painting
1731	Electrical work	Covers work on site, including installation of telephones and alarms
1741	Masonry, stone setting, and other stone work	Excludes foundation digging and concrete work
1742	Plastering, drywall, acoustical, and insulation work	Includes installation of lathing and other accessories to receive plaster
1743	Terrazzo, tile, marble, and mosaic work	Excludes manufacture of precast terrazzo steps, benches, and other terrazzo articles
1751	Carpentry work	Includes on-site installation of cabinets, folding doors, framing, ship joinery, store fixtures, trim and finish, and prefab windows and doors
1752	Floor laying, and other floor work, not elsewhere classified	Includes laying and removal of carpet, finishing of parquet flooring, installation of asphalt tile. Excludes ceramic floor tile, concrete floors
1761	Roofing, siding, and sheet metal work	Includes metal ceilings skylight, gutter, and downspout installation; roof painting and spraying
1771	Concrete work	Includes private driveways and walks of all materials. Excludes concrete foundations, excavations, public sidewalks, and highways
1781	Water well drilling	Excludes oil- or gas-field water intake wells
1791	Structural steel erection (ironwork)	Includes similar products of prestressed or precast concrete and placing of concrete reinforcement
1793	Glass and glazing work	Excludes automotive
1794	Excavation work	Includes grading (except for highways, streets and airport runways) and incidental concrete work
1795	Wrecking and demolition	Includes concrete breaking for streets and dismantling of steel oil tanks. Excludes marine wrecking and demolition
1796	Installation or erection of building equipment, not elsewhere classified	Includes elevators, pneumatic tube systems, small incinerators, dust-collecting equipment, and revolving doors. Also includes dismantling and maintenance
1799	Special trade contractors, not elsewhere classified	Includes construction of swimming pools and fences, house moving, shoring work, fireproofing, and sandblasting and steamcleaning of building exteriors

As a general principle, expenses connected with items not permanently attached or affixed to some part of the house or property are outside the scope of the C50 report. Thus, expenses connected with the repair or replacement of household appliances (e.g., stoves, refrigerators, etc.) are excluded, as are costs connected with house furnishings. While the costs of appliances are excluded, the construction costs of building-in such appliances (e.g., the cost of building-in a wall oven) are included in the scope of the C50 report. Expenditures for grading, draining, fencing, and paving are included, but the costs of landscaping are not included in the C50 report.

The kinds of expenditures included cover work done under contract or with hired labor, and the costs of purchasing or renting tools and equipment for purposes of carrying out jobs which fall within the scope of the C50 report. However, no attempt is made to estimate or include the value of labor in 'do-it-yourself' jobs.

The types of expenditures are classified broadly as either maintenance and repair or construction improvements. Maintenance and repair expenditures represent current costs for incidental maintenance and repair activities which keep a property in ordinary working condition, rather than additional investment in the property. Expenditures for construction improvements are capital expenditures which add to the value or useful life of a property. Improvements are further classified as additions to residential structures (e.g., enlargement of the structure by adding a room), alterations within residential structures (e.g., changes or improvements made within or on the structure), additions and alterations on property outside residential structures (e.g., laying or improving walks or driveways), and major replacements (e.g., a roof replacement).

Summary of Key Data Sets and Selected Comparisons

At this point, it is useful to compare the three data sets and examine the differing values for new construction, maintenance and repair, and additions and alterations which result for a single year (1992) or across years for a single sector (residential). The first set of comparisons and data summaries are for the **1992 Census of the Construction Industry** (CCI) and the estimates for new construction, maintenance and repair, and additions and alterations "derived" from the *C30--Value of Construction Put In Place*--report (VIP). The second set of comparisons and data summaries trace annual expenditure estimates for residential maintenance and repair and additions and alterations "derived" from the C30 report data alongside data published in the C50 report.

The Bureau of the Census recognizes that only about two-thirds of the construction as defined in VIP is actually done by the construction industry as defined by the CCI.[13] Examples of construction work included within the VIP estimates but excluded from the CCI are architectural and engineering design and force-account construction. Also outside the scope of the CCI is work done by non-employers (i.e., self-employed

[13] US Department of Commerce. 1997. *Overview of Construction Statistics Programs*. Draft Mimeo. Washington, DC: US Bureau of the Census.

construction workers). Thus, in developing comparisons between VIP and CCI data, estimates and assumptions have to be made for these differences.[14]

The VIP, C30 report data, were used as the basis for deriving estimates for new construction, maintenance and repair, and additions and alterations expenditures for each sector for each year between 1992 and 1996. Information from the CCI was used to construct a series of multipliers; one set for each sector. One component of each sector's set of multipliers recorded the ratio of maintenance and repair expenditures to new construction expenditures. The other component of each sector's set of multipliers recorded the ratio of expenditures for additions and alterations to new construction expenditures. To develop a framework for deriving these estimates, it was necessary to make eight assumptions. These assumptions are as follows; they are enumerated from A.1 to A.8.

A.1 Expenditures for new residential construction for each year, derived from the C30 report data, equal expenditures for private residential buildings *plus* expenditures for public housing and development *less* expenditures for residential improvements (see Table 3-1).

A.2 Expenditures for new non-residential construction for each year, derived from the C30 report data, equal the unadjusted sector expenditure totals (see Table 3-1).[15]

A.3 Multipliers for maintenance and repair activities for each sector for each year are a fixed proportion equal to the ratio of that sector's CCI expenditures for maintenance and repair activities to that sector's CCI expenditures for new construction.

A.4 Multipliers for additions and alterations for each sector for each year are a fixed proportion equal to the ratio of that sector's CCI expenditures for additions and alterations to that sector's CCI expenditures for new construction.

A.5 Expenditures for residential maintenance and repair activities in a given year equal that year's new construction value as defined in A.1 times the fixed proportion multiplier for the residential sector defined in A.3.

A.6 Expenditures for non-residential maintenance and repair activities for a given sector in a given year equal that year's new construction value as defined in A.2 times the fixed proportion multiplier for the appropriate non-residential sector as defined in A.3.

[14] *Ibid.*, p.26.
[15] Note that the C30 report data contain an unquantified component for additions and alterations.

A.7 Expenditures for residential additions and alterations in a given year equal that year's new construction value as defined in A.1 times the fixed proportion multiplier for the residential sector defined in A.4.

A.8 Expenditures for non-residential additions and alterations for a given sector in a given year equal that year's new construction value as defined in A.2 times the fixed proportion multiplier for the appropriate non-residential sector as defined in A.4.

Figure 3-2 shows the results of applying these assumptions to the C30 report (VIP) data for 1992 and plotting them side-by-side with the CCI data. Notice that each component--new construction, maintenance and repair, and additions and alterations--is higher for the "derived" VIP data than for the CCI data. The underlying assumptions, however, are plausible because the CCI contains only about two-thirds of the construction activity covered in the VIP (e.g., CCI only includes establishments with payroll and excludes items such as architectural and engineering services which in 1992 amounted to approximately $50 billion).

The "derived" total for all construction expenditures shown in Figure 3-2 may be broken down into its constituent parts. This break down is shown in Figure 3-3 for the year 1992. Reference to Figure 3-3 reveals that 61 percent, or $393.8 billion, of all construction expenditures are associated with the value of new construction put in place. Expenditures for additions and alterations amounted to $156.5 billion, or 24 percent of the total. Expenditures for maintenance and repair activities amounted to $93.3 billion, or 15 percent of the total.

When assumptions A.5 and A.6 are applied, annual estimates for the value of maintenance and repair expenditures for each sector result. These sector estimates are plotted, as multi-year traces keyed to each sector, in Figure 3-4. These "derived" estimates exhibit a slight upward trend. Maintenance and repair expenditures in the commercial/institutional sector are the highest in each year while maintenance and repair expenditures in the industrial sector are the lowest in each year.

When assumptions A.7 and A.8 are applied, annual estimates for the value of expenditures for additions and alterations for each sector result. These sector estimates are plotted, as multi-year traces keyed to each sector, in Figure 3-5. As was the case for maintenance and repair expenditures, expenditures for additions and alterations exhibit a slight upward trend. Reference to Figure 3-5 reveals that the dollar value of expenditures for additions and alterations in the commercial/institutional sector are about two to three times the amount for the other sectors.

Figure 3-2. Total Value of Construction Work: Comparison of Value Put in Place and 1992 Census of the Construction Industry

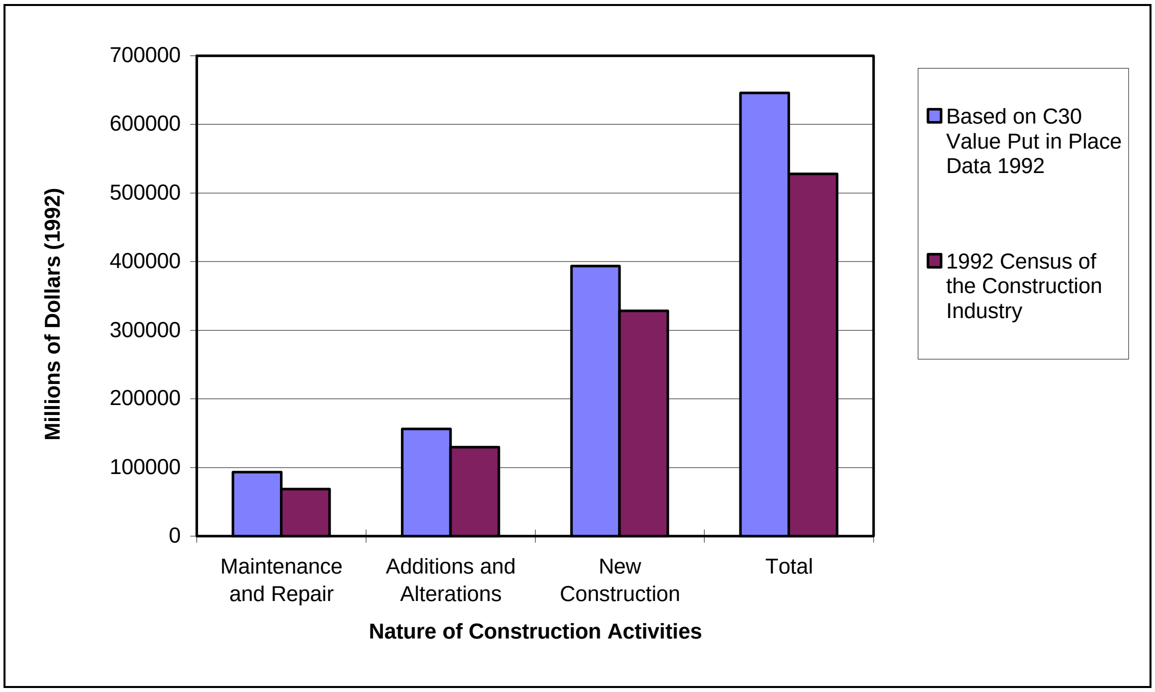


Figure 3-3. Distribution of Total Construction Expenditures in 1992 by Nature of Construction Activity

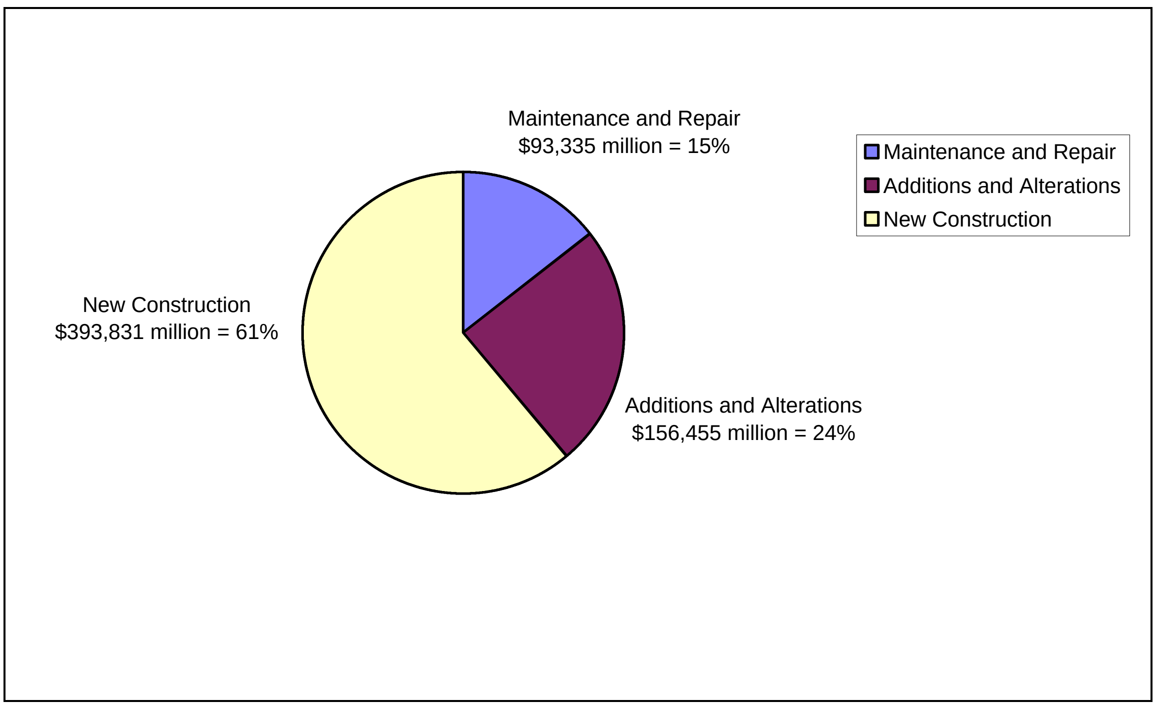


Figure 3-4. Annual Expenditures for Maintenance and Repair Activities by Sector

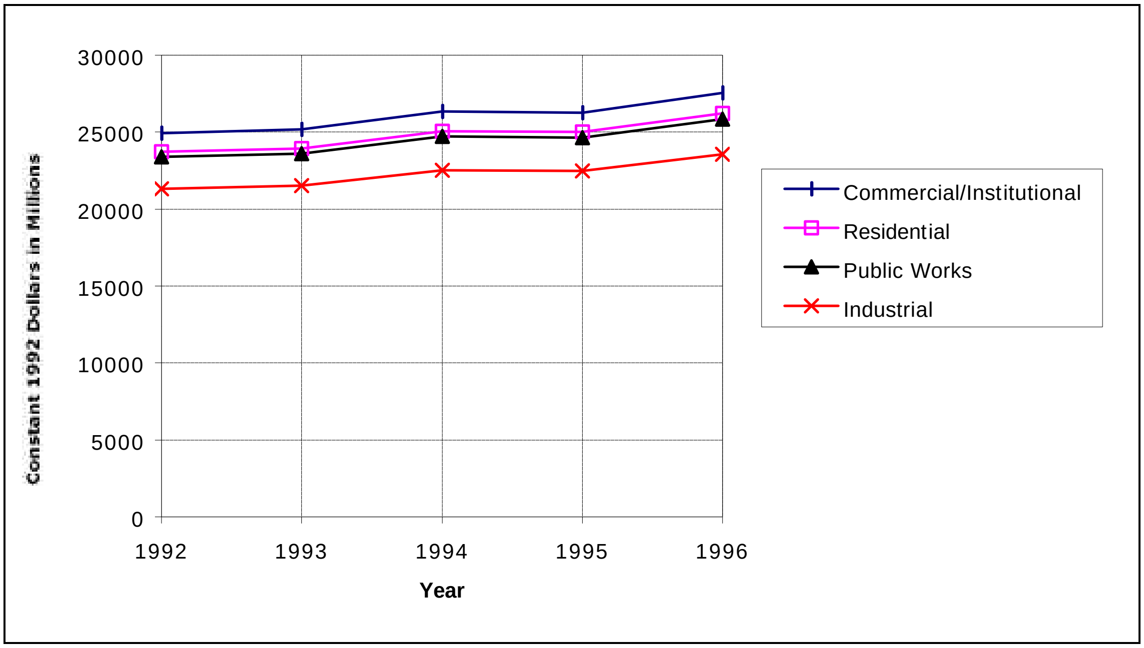
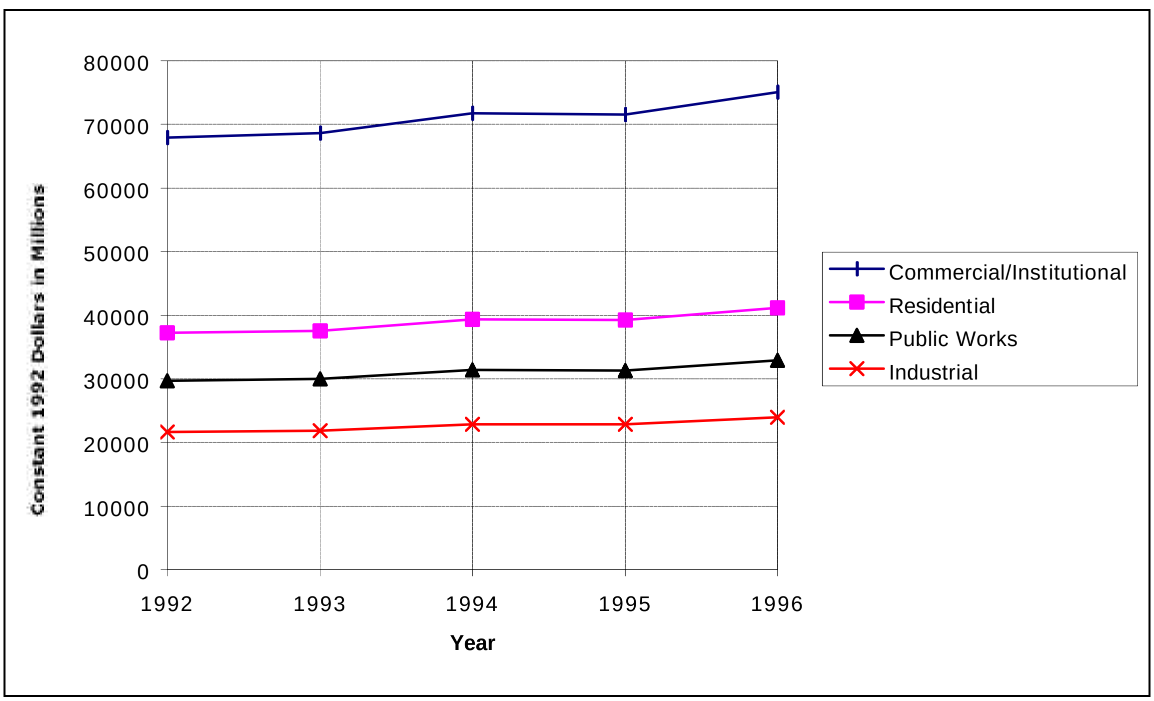


Figure 3-5. Annual Expenditures for Additions and Alterations by Sector



Although information on expenditures for maintenance and repairs and additions and alterations is not available for all four construction industry sectors, such information is available for the residential sector via the C50 report. Figure 3-6 shows these data side-by-side with the derived C30 data. Figure 3-6 consists of a series of bar charts; four bars for each year. For each year, maintenance and repair expenditures are the two leftmost bars and expenditures for additions and alterations are the two rightmost bars. For each two-bar set (i.e., maintenance and repair ***or*** additions and alterations), the left-hand bar records the annual combined total for estimates derived from the C30 report data and the CCI multipliers (i.e., based on assumptions A.1, A.3, A.4, A.5, and A.7). Similarly, for each two-bar set, the right-hand bar records the annual combined total for data published in the C50 report. The values underlying each year's set of bars are given in Table 3-3. Reference to Figure 3-6 and Table 3-3 shows that the estimated values for the C30/CCI derived data are about two-thirds of the expenditures resulting from the C50 report data. There are two plausible explanations for these differences. First, the CCI does not capture information on construction establishments without employees. Although such establishments are not expected to be major players in the non-residential sector, they are often very active in the residential maintenance and repair and additions and alterations markets. These activities are captured through the C50 survey process. Second, the CCI does not capture information on materials and equipment purchases by residential property owners for use in maintenance and repair and additions and alterations activities. Because the C50 survey is aimed at residential property owners, it captures information on purchases of materials and equipment.

Table 3-3. Comparison of Derived Data and Household Survey Data for Total Expenditures on Improvements and Maintenance and Repairs in the Residential Sector

Residential Sector	Value (Millions of Current 1992 Dollars) By Year				
	1992	1993	1994	1995	1996
Maintenance and Repair (Derived Data)	23,709	23,949	25,057	24,993	26,217
Improvements (Derived Data)	37,204	37,581	39,319	39,219	41,139
Total (Derived Data)	60,913	61,530	64,376	64,212	67,356
Maintenance and Repair (C50 Data)	45,121	40,198	39,731	37,338	32,113
Improvements (C50 Data)	58,580	64,208	66,671	61,837	67,636
Total (C50 Data)	103,734	104,405	106,402	99,733	99,749

For the non-residential sectors, it is unclear whether the estimates derived from the C30/CCI data can be expected to exhibit a similar trend (i.e., are about two-thirds of the value resulting from a survey of the respective sector) or not. Consequently, we have adopted a conservative approach and opted to use the estimates derived from the C30/CCI data for each of the four construction industry sectors. These data are plotted as multi-year traces in Figure 3-7. Detailed estimates by year, by sector, and by nature of construction activity are recorded in Table 3-4.

Figure 3-6. Comparison of Derived Data and Household Survey Data for Total Expenditures on Improvements and Maintenance and Repairs in the Residential Sector

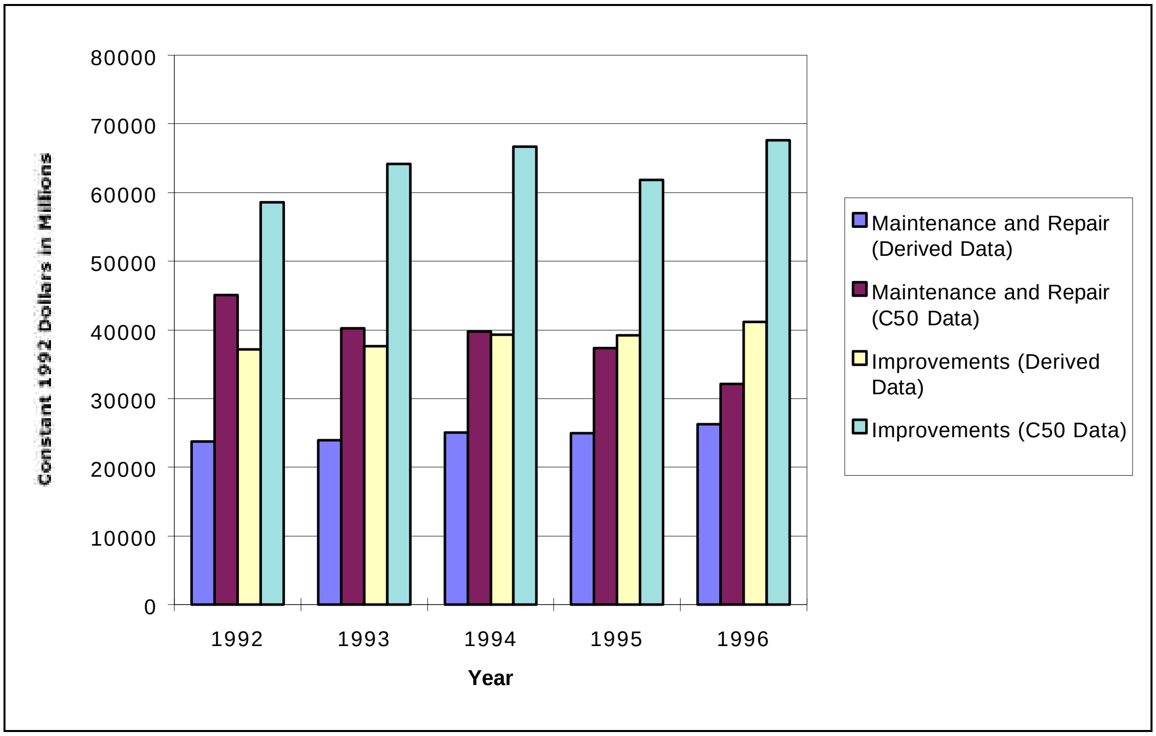


Figure 3-7. Total Value of Construction Work

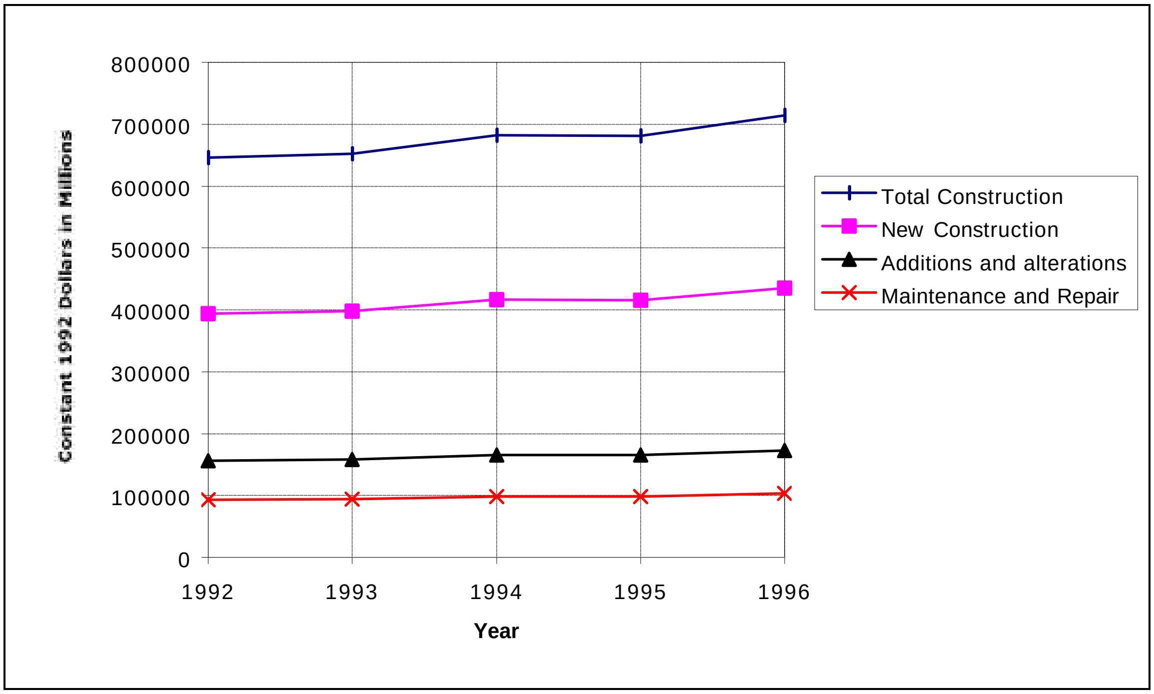


Table 3-4. Value of Construction Work in Millions of Constant 1992 Dollars: 1992 to 1996

Part A: Total Value of Construction Work: 1992 to 1996

DERIVED DATA - ALL SECTORS	Total Construction	New Construction	Additions and alterations	Maintenance and Repair
1992	645,769	393,831	156,455	93,335
1993	652,310	397,820	158,040	94,280
1994	682,469	416,213	165,347	98,639
1995	680,738	415,157	164,928	98,389
1996	714,067	435,483	173,002	103,206

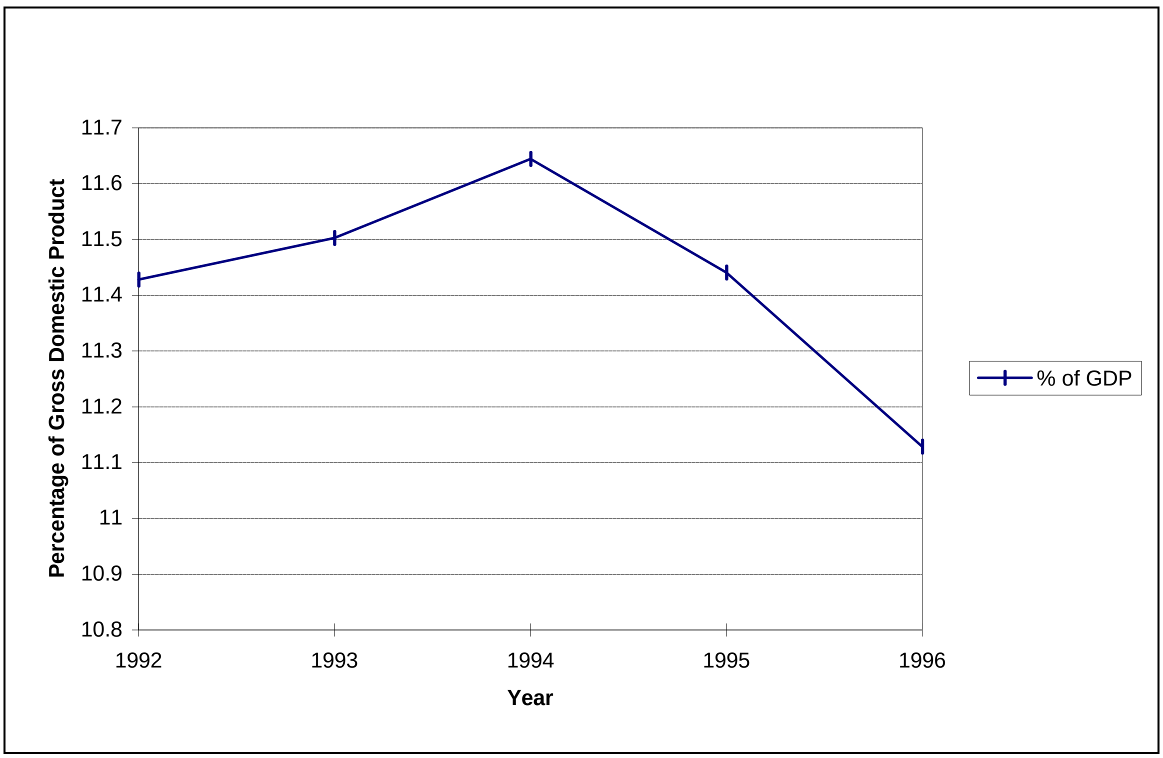
Part B: Value of Construction Work by Sector and by Nature of Construction Activity: 1992 to 1996

NEW CONSTRUCTION	All Sectors	Residential	Commercial/ Institutional	Industrial	Public Works
1992	393,831	133,658	122,960	30,902	106,311
1993	397,820	141,076	125,770	27,212	103,762
1994	416,213	156,576	128,116	28,161	103,360
1995	415,157	146,167	137,006	30,391	101,593
1996	435,483	157,846	149,445	29,219	98,973
DERIVED DATA - MAINTENANCE/ REPAIR					
1992	93,335	23,709	24,931	21,310	23,385
1993	94,280	23,949	25,183	21,526	23,622
1994	98,639	25,057	26,348	22,521	24,714
1995	98,389	24,993	26,281	22,464	24,651
1996	103,206	26,217	27,568	23,564	25,858
DERIVED DATA - ADDITIONS/ ALTERATIONS					
1992	156,455	37,204	67,904	21,632	29,715
1993	158,040	37,581	68,592	21,851	30,016
1994	165,347	39,319	71,764	22,861	31,404
1995	164,928	39,219	71,581	22,803	31,324
1996	173,002	41,139	75,086	23,919	32,858

Importance of the Construction Industry to the US Economy

The relative importance of the construction industry to the overall US economy is shown in Figure 3-8. Figure 3-8 uses the estimated annual values of all construction activities--new construction, maintenance and repair, and additions and alterations--based on the C30/CCI data and the published figures for the US gross domestic product (GDP) to create a measure of the construction industry's relative importance. The metric which is plotted in Figure 3-8 is the percent of GDP accounted for by all expenditures for construction activities. It is worth noting that while expenditures for all construction activities have been increasing in each year (in constant 1992 dollar terms), the construction industry's relative importance peaked in 1994 and has been declining since then. Reference to Figure 3-1 shows that 1994 was a year in which the value of new residential construction put in place was particularly strong. To gain a better understanding of how the construction industry interacts with the rest of the US economy, it is useful to turn to the labor market.

Figure 3-8. Relative Importance of the Construction Industry to the US Economy

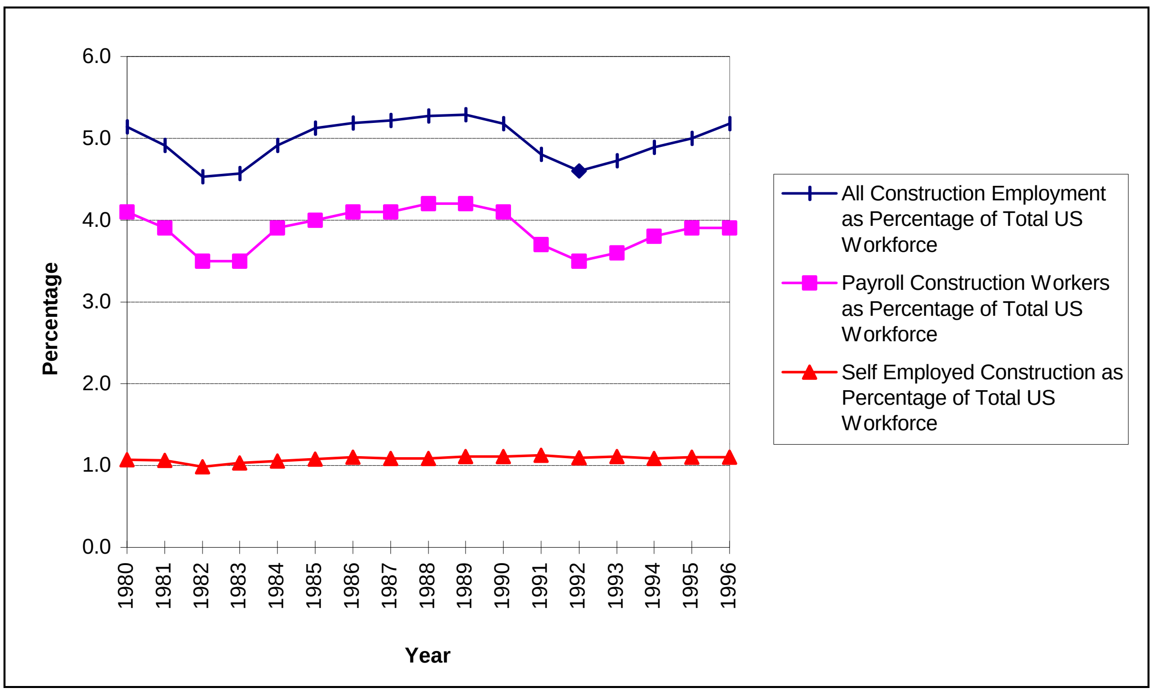


3.3 Employment in Construction

Construction tends to be a cyclical activity that can have a significant impact on the national economy, and an even greater impact on various local economies. Construction activity has a significant impact on local employment due to secondary effects on construction supply and service industries.

Figure 3-9 illustrates the cyclical nature of construction activity. Figure 3-9 records employment in construction as a percent of overall employment in the US civilian work force for the years 1980 through 1996. Because the construction work force consists of a large number of self-employed workers, Figure 3-9 also includes multi-year traces which divide the construction work force into its two constituent parts. The first part records the percentage of the US civilian work force associated with construction establishments with employees. The second part records the percentage of the US civilian work force associated with self-employed construction workers.

Figure 3-9. Construction Employment as a Proportion of the Total US Civilian Workforce



Source: Bureau of Labor Statistics, National Employment Data, and US Industrial Outlook

Figure 3-9 shows the impact of recessions very clearly, as these are years when sharp declines in the construction work force relative to the rest of the US civilian work force occur. Notice that most of the declines and increases shown in Figure 3-9 are due to construction establishments with employees. The percentage of self-employed workers hovers around one percent throughout the 15 year period. The relative increase in employment in the construction industry between 1992 and 1996 shown in Figure 3-9 and its interaction with the rest of the economy can better be understood through reference to and comparison with Figures 3-8 and 3-1. In Figure 3-8, the relative importance of the construction industry vis-à-vis the rest of the economy reached a peak in 1994. Thus, one would expect a positive influence of the overall economy on the construction industry labor market leading up to that peak. Reference to Figure 3-1 shows strong increases in the value of new commercial/institutional construction put in place from 1994 through 1996. This upward trend was reinforced by a strong performance in 1996 for the residential sector.

Table 3-5 provides detailed employment information for a single year, 1992. The data presented in Table 3-5 are from the **1992 Census of the Construction Industry**. Table 3-5 is organized around the three two-digit SIC Codes and 26 four-digit SIC Codes described earlier (see Table 3-2). The table lists a specific segment or subsegment of the construction industry in the leftmost column. Immediately to the right is the corresponding two-digit or four-digit SIC Code for the segment or subsegment of the construction industry. The four remaining columns record information on the number of establishments with payroll, the total number of employees in thousands, the value of construction work in millions of 1992 dollars, and value added in millions of 1992 dollars. It is important to recognize that only construction establishments with employees are included in these figures. Consequently, the values shown in Table 3-5 differ from those given in Section 3.2 where data from the C30 report were used to compute the total value of construction work (see Figure 3-2 for a comparison of the two sets of totals).

Data from the **1992 Census of the Construction Industry** are used here because they provide the necessary level of detail to link employment and output information. For example, a key measure of productivity within the construction industry is value added per employee. The information in Table 3-5 is very useful in characterizing employment and output in the construction industry. One such characterization is illustrated through a series of four pie charts and one bar chart.

Figure 3-10 summarizes information on the number of establishments and the percentage of all construction establishments within each of the three two-digit SIC Codes. Note that SIC Code 17, special trade contractors, account for nearly two-thirds of all construction establishments. By contrast, heavy construction contractors, SIC Code 16, are only six percent of the total number of construction establishments.

Figure 3-11 summarizes information on the number of employees and the percentage of all construction employment within each of the three two-digit SIC Codes. Note that the percentage of employment in SIC Code 16, heavy construction contractors, amounts to 17 percent of the total, implying that establishments in this segment of the construction industry tend to be larger than for SIC Codes 15 and 17.

Figure 3-12 summarizes information on the value of construction work and the percentage of the total value (i.e., $528.1 billion) within each of the three two-digit SIC Codes. Note that general building contractors, SIC Code 15, and special trade contractors, SIC Code 17, each account for 41 percent of the total.

Table 3-5. Employment and Output Figures for the Construction Industry: 1992

Industry	SIC Code	Establishments with Payroll (1000's)	Total Employees (1000's)	Value of Construction Work (Million Dollars)	Value Added (Million Dollars)
All industries, total	**(X)**	**572.9**	**4,668**	**528,106**	**234,618**
General building contractors	**15**	**168.4**	**1,097**	**215,629**	**63,117**
Single-family houses	1521	107.5	404	48,633	17,183
Other residential buildings	1522	6.5	49	7,835	2,454
Operative builders	1531	17.0	114	44,588	15,289
Industrial buildings and warehouses	1541	7.7	123	20,586	6,438
Nonresidential buildings, n.e.c.	1542	29.7	407	93,987	21,754
Heavy construction contractors	**16**	**37.2**	**799**	**95,571**	**49,165**
Highway and street construction	1611	10.1	257	35,332	15,711
Bridge, tunnel, and elevated highway	1622	1.0	44	7,198	3,078
Water, sewer, and utility lines	1623	10.2	194	20,205	11,734
Heavy construction, n.e.c.	1629	15.8	304	32,837	18,642
Special trade contractors	**17**	**367.3**	**2,772**	**216,905**	**122,336**
Plumbing, heating, air-conditioning	1711	75.4	613	56,902	29,432
Painting and paperhanging	1721	32.0	163	8,690	5,855
Electrical work	1731	54.0	487	40,259	23,548
Masonry and other stonework	1741	22.6	148	8,458	5,146
Plastering, drywall, insulation	1742	18.6	207	14,056	8,143
Terrazzo, tile, marble, and mosaic work	1743	6.5	34	2,439	1,358
Carpentry	1751	38.2	178	12,852	6,760
Floorlaying and other floor work	1752	10.2	49	4,428	2,166
Roofing, siding, and sheet metal work	1761	27.6	216	16,788	8,906
Concrete work	1771	26.1	193	14,423	7,703
Water well drilling	1781	3.6	19	1,727	995
Structural steel erection	1791	3.8	58	4,952	3,021
Glass and glazing work	1793	4.6	32	2,724	1,424
Excavation work	1794	13.9	77	6,870	4,340
Wrecking and demolition work	1795	1.0	13	1,059	775
Installing building equipment, n.e.c.	1796	3.9	83	6,611	4,494
Special trade contractors, n.e.c.	1799	25.3	204	13,667	8,270

Figure 3-10. Number of Establishments with Payroll by Two-Digit SIC Code: 1992

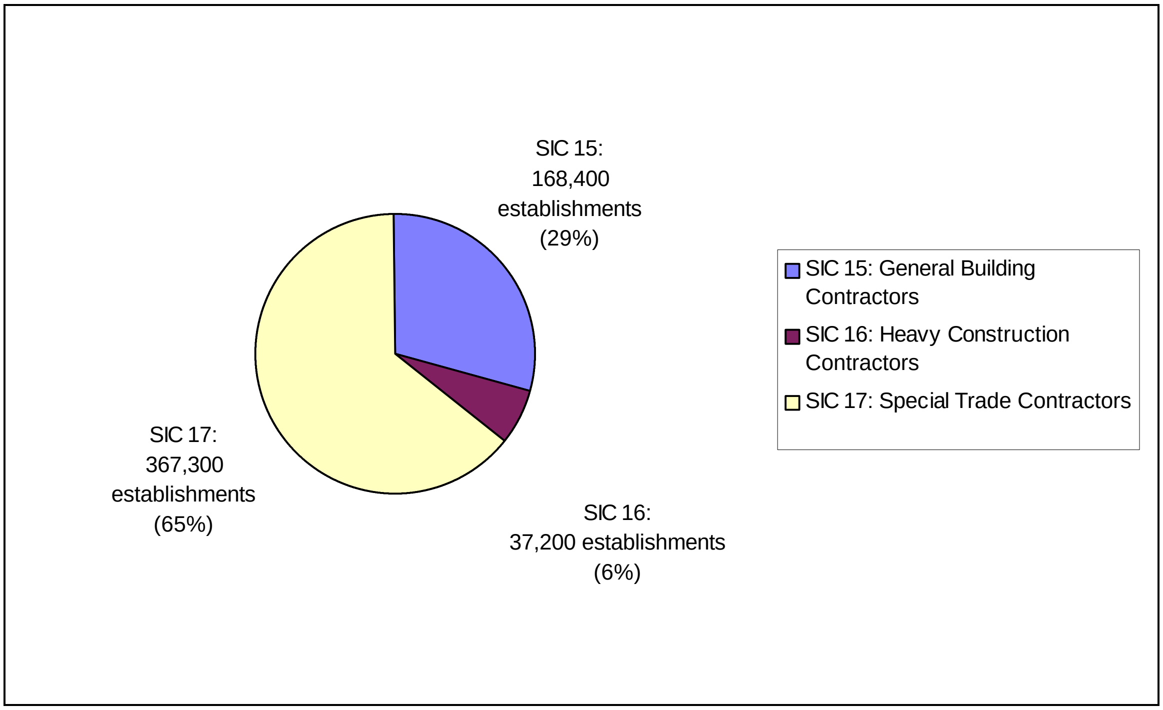


Figure 3-11. Number of Employees for Establishments with Payroll by Two-Digit SIC Code: 1992

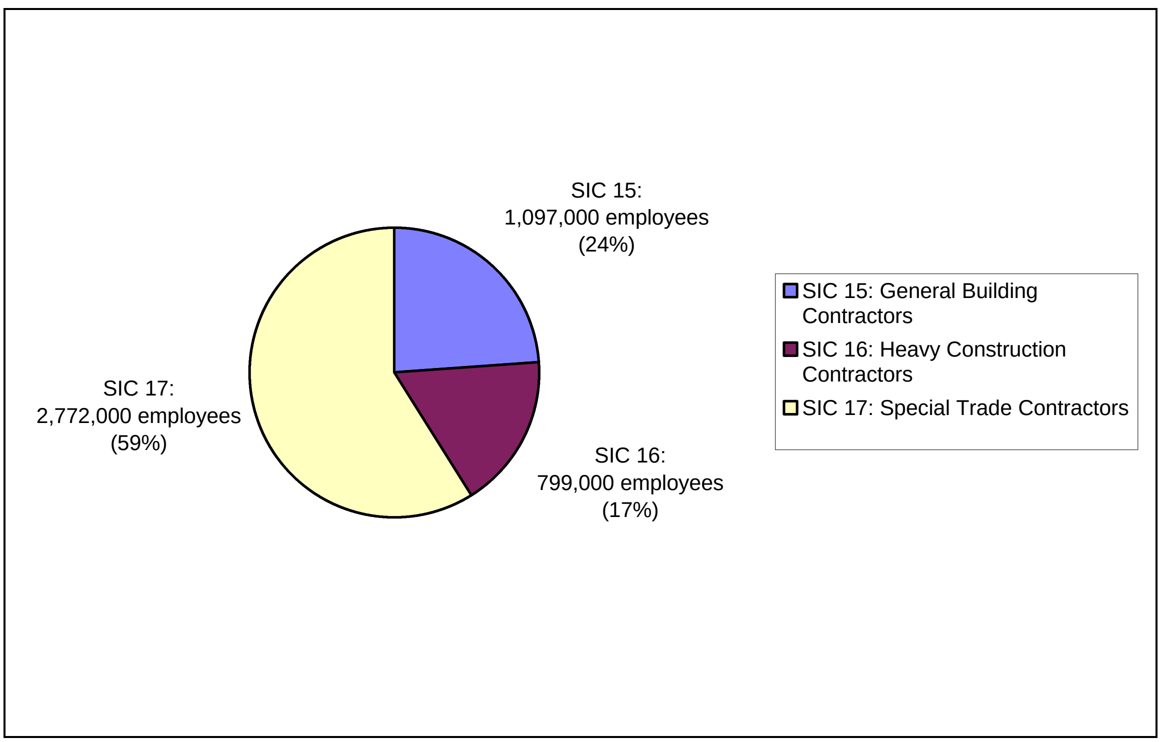


Figure 3-12. Value of Construction Work for Establishments with Payroll by Two-Digit SIC Code: 1992

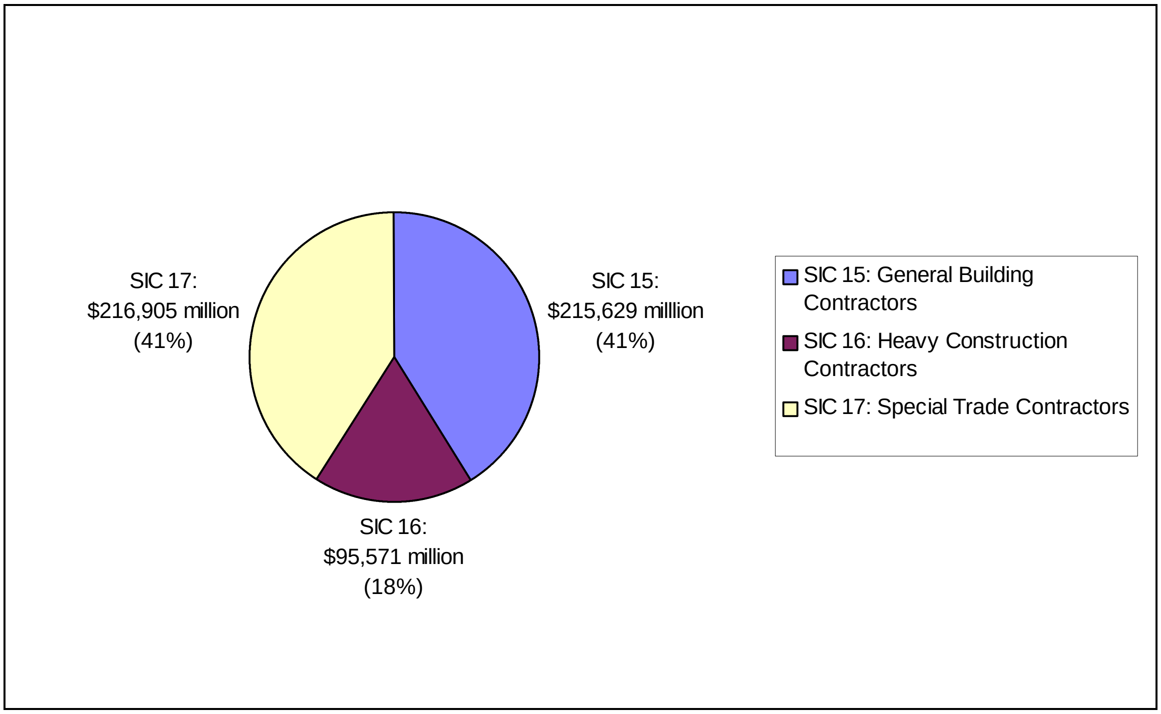


Figure 3-13 summarizes information on value added and the percentage of the total value added (i.e., $234.6 billion) within each of the three two-digit SIC Codes. Figure 3-14 factors employment into the calculation; it records value added per employee in thousands of 1992 dollars.

Reference to Figure 3-14 reveals that SIC Code 16, heavy construction contractors, has the highest average value added per employee, $61.5 thousand, and SIC Code 17, special trade contractors, has the lowest value added per employee, $44.1 thousand. That SIC Code 16 is the highest should come as no surprise. Establishments within SIC Code 16 tend to be larger on the average than for SIC Codes 15 and 17 and accounted for a "relatively" larger percentage share of overall value added. For example, for SIC Code 16, the percentage share of overall value added exceeded the percentage share of overall employment. While for SIC Codes 15 and 17, their percentage shares of value added were either approximately equal or less than the percentage shares of overall employment.

Figure 3-13. Value Added for Establishments with Payroll by Two Digit SIC Code: 1992

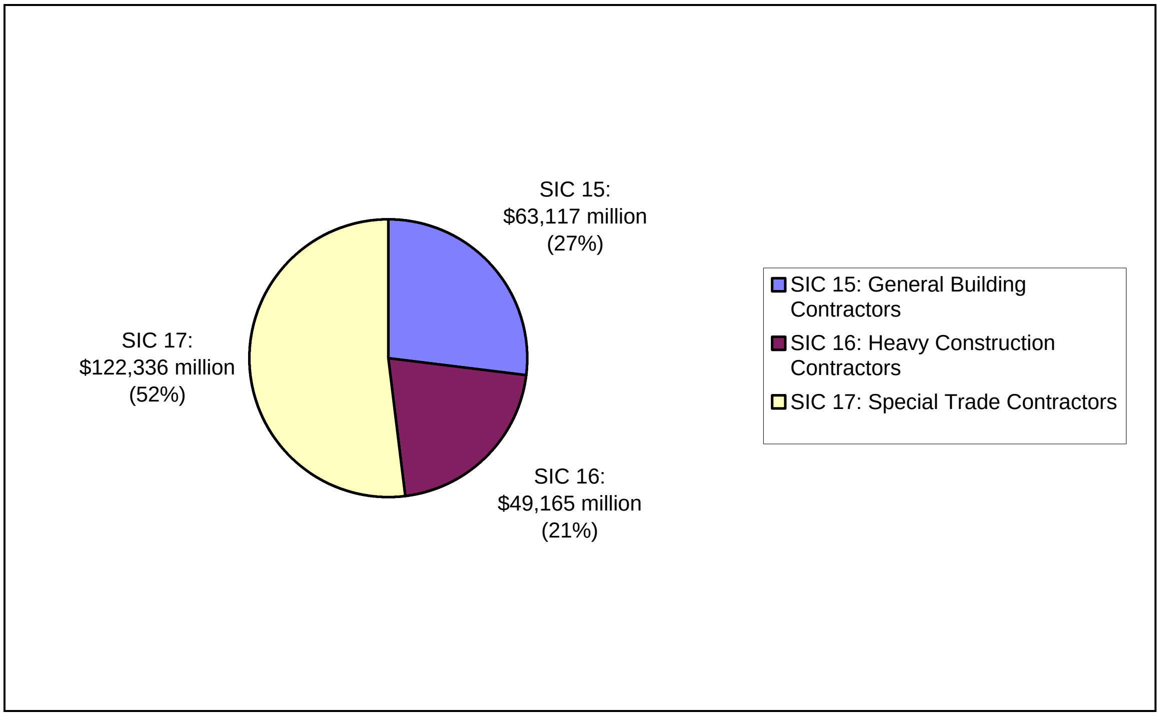
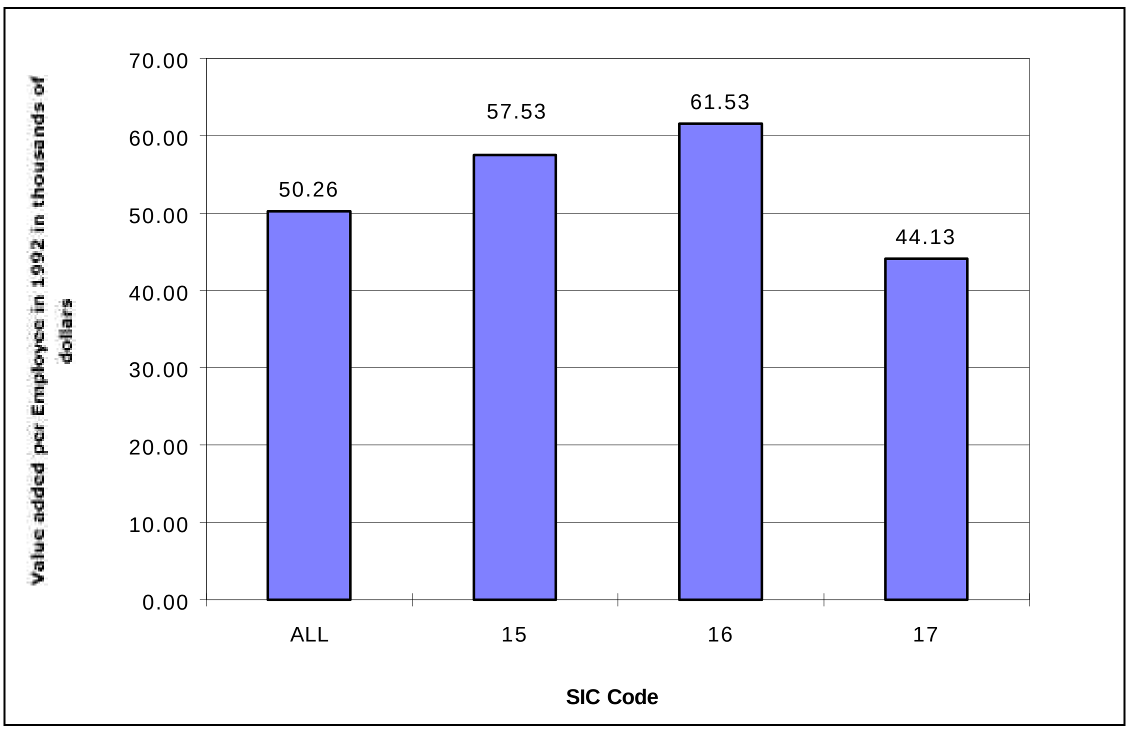


Figure 3-14. Value Added per Employee for Establishments with Payroll: 1992



3.4 Special Considerations

The purpose of this section is twofold. First, it provides information on cost trends. This information builds on the material presented in the earlier sections. As such, it promotes a better understanding of interactions between the construction industry and the rest of the US economy. Second, this section introduces information that has relevance to the National Construction Goal of reducing operations, maintenance, and energy costs but is general in nature.

Trends in Residential and Non-Residential Construction Costs

In Sections 3.2 and 3.3, information is presented and discussed on the relative importance of the construction industry and on interactions between employment and output in the construction industry and the overall US economy. Both sets of information included trends which showed the cyclical nature of construction activity. Figure 3-15 provides a different perspective on the same issue; namely, trends in per unit construction costs (i.e., costs per square meter and costs per square foot). Figure 3-15 consists of three multi-year traces: (1) all buildings; (2) residential buildings; and (3) non-residential buildings. The cost trend data cover the 15 year period 1980 through 1995. Reference to Figure 3-15 shows an upward trend for residential buildings modulated by the business cycle. For non-residential buildings, the upward trend is more heavily modulated by the business cycle (see Figures 3-8 and 3-9 for purposes of comparison).

Figure 3-15. Average Cost per Square Foot and per Square Meter of New Construction and Major Additions to Buildings

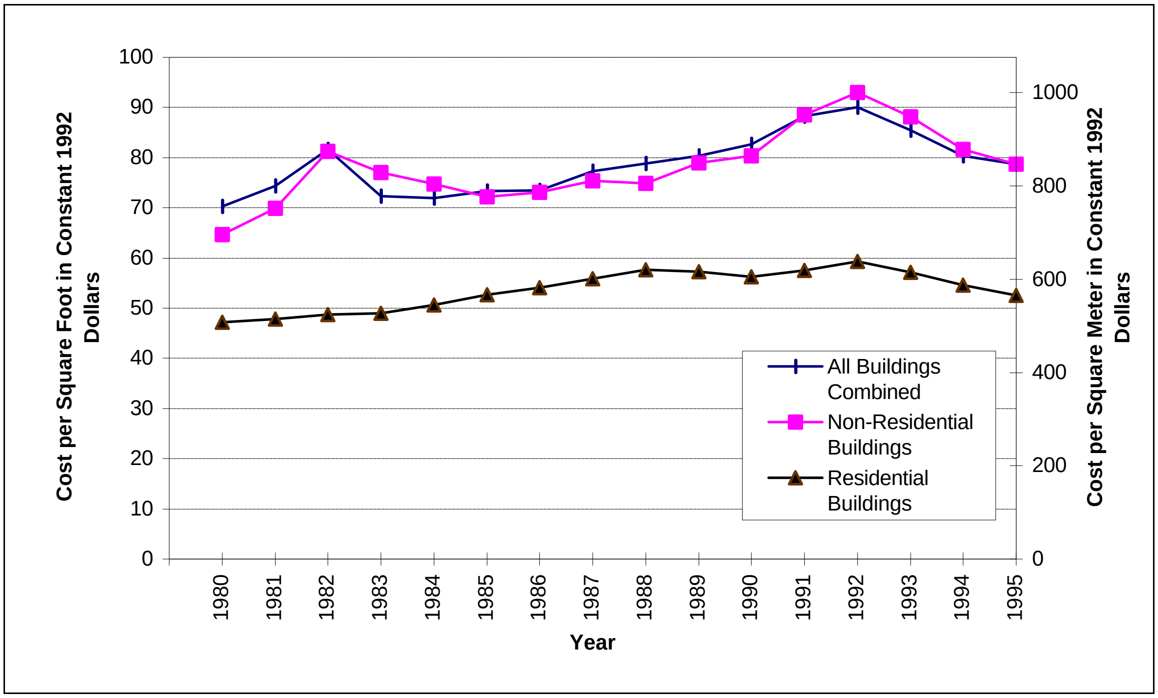


Table 3-6 records the data used to produce each multi-year trace. The table is divided into three parts: Part A covers all buildings; Part B covers residential buildings; and Part C covers non-residential buildings. The leftmost column in each part of Table 3-6 records the year. The remainder of the table records the construction contract value in billions of constant 1992 dollars, the floor space in millions of square feet, the construction cost in dollars per square foot, the floor space in millions of square meters, and the cost in dollars per square meter.

Table 3-6. Information Used to Compute Average Cost per Square Foot and Average Cost per Square Meter Figures

Part A: All Buildings

	ALL BUILDINGS				
YEAR	**Construction Contract Value (Billion Constant 1992 Dollars)**	**Floorspace (Million Square Feet)**	**Floorspace (Million Square Meters)**	**Construction Cost (Dollars/Square Foot)**	**Construction Cost (Dollars/Square Meter)**
1980	218.0	3,102	288.2	70.27	756.13
1981	208.6	2,805	260.6	74.36	800.11
1982	200.5	2,455	228.1	81.65	878.59
1983	244.8	3,387	314.7	72.26	777.57
1984	263.4	3,661	340.1	71.94	774.08
1985	282.5	3,853	357.9	73.32	788.87
1986	289.2	3,935	365.6	73.49	790.77
1987	290.3	3,756	348.9	77.30	831.75
1988	283.4	3,594	333.9	78.86	848.58
1989	282.7	3,516	326.6	80.40	865.13
1990	249.4	3,020	280.6	82.60	888.75
1991	232.4	2,634	244.7	88.24	949.43
1992	252.2	2,799	260.0	90.10	969.51
1993	261.7	3,062	284.5	85.48	919.72
1994	274.0	3,410	316.8	80.35	864.54
1995	271.3	3,448	320.3	78.68	846.61

Part B: Residential Buildings

	RESIDENTIAL BUILDINGS				
YEAR	**Construction Contract Value (Billion Constant 1992 Dollars)**	**Floorspace (Million Square Feet)**	**Floorspace (Million Square Meters)**	**Construction Cost (Dollars/Square Foot)**	**Construction Cost (Dollars/Square Meters)**
1980	86.7	1,839	170.8	47.16	507.48
1981	74.7	1,562	145.1	47.79	514.26
1982	70.2	1,440	133.8	48.74	524.40
1983	111.5	2,276	211.4	48.98	527.00
1984	117.1	2,311	214.7	50.68	545.33
1985	122.4	2,324	215.9	52.68	566.79
1986	134.1	2,481	230.5	54.05	581.57
1987	127.9	2,288	212.6	55.90	601.52
1988	125.6	2,181	202.6	57.59	619.71
1989	121.1	2,115	196.5	57.25	615.99
1990	102.3	1,817	168.8	56.31	605.88
1991	95.1	1,653	153.6	57.51	618.79
1992	110.6	1,864	173.2	59.33	638.44
1993	119.4	2,091	194.3	57.12	614.62
1994	123.6	2,266	210.5	54.54	586.81
1995	114.2	2,172	201.8	52.59	565.81

Part C: Non-Residential Buildings

	NON-RESIDENTIAL BUILDINGS				
YEAR	Construction Contract Value (Billion Constant 1992 Dollars)	Floorspace (Million Square Feet)	Floorspace (Million Square Meters)	Construction Cost (Dollars/Square Foot)	Construction Cost (Dollars/Square Meter)
1980	81.7	1,263	117.3	64.69	696.11
1981	86.9	1,243	115.5	69.87	751.84
1982	82.4	1,015	94.3	81.21	873.83
1983	85.6	1,111	103.2	77.07	829.25
1984	100.9	1,350	125.4	74.74	804.22
1985	110.4	1,529	142.0	72.22	777.11
1986	106.3	1,454	135.1	73.08	786.32
1987	110.8	1,469	136.5	75.39	811.25
1988	105.8	1,413	131.3	74.90	805.90
1989	110.6	1,400	130.1	78.97	849.70
1990	96.7	1,203	111.8	80.41	865.23
1991	86.8	981	91.1	88.48	952.09
1992	87.0	936	87.0	92.95	1000.13
1993	85.6	971	90.2	88.16	948.60
1994	93.4	1,144	106.3	81.67	878.72
1995	100.4	1,276	118.5	78.66	846.41

Definitions of Key Types of Operations, Maintenance, and Energy Cost Issues

Previous sections of this document have focused primarily upon new construction, improvements, or maintenance and repair costs when considering reductions in operations maintenance, and energy costs. The purpose of this section is to address general operations and energy issues which are relevant to all four sectors of the construction industry.

At this point, it is important to define what is meant by ‘operations and energy’ in this context. ‘Operations’ is defined as including all non-process or end-product related activities required to operate a building or structure, with the exception of maintenance and repair activities, which are considered separately. Thus, process-related operations components (e.g., raw materials inputs, plant/machinery operations, or production labor payroll costs) are generally excluded from this document, except where these provide some valuable insight, or cannot be separated from non-process activities. Typically, operations components might include the following:

- water consumption
- trash removal/environmental costs
- cleaning services/janitorial
- pest control
- security services/life safety costs
- roads and grounds maintenance/snow removal
- administrative expenses (i.e., in-house services and external contract services, legal, professional, and accounting services, etc.)

In some cases, fixed operations components may also be included, such as:

- real estate and other taxes
- insurance
- leasing expenses

'Energy' is defined as including all non-process or end-product related energy consumption required to operate a building or structure. Thus energy consumption for manufacturing processes is generally excluded. Typically, energy consumption can be categorized by energy source (i.e., electricity, coal, gas, oil, etc.) and by assigned end-use, such as space heating, cooling, and lighting.

Wherever possible, operations and energy data are normalized on a 'per building', 'per employee' or 'per unit area' basis to allow meaningful comparisons to be made.

This section will now consider information relevant to the construction industry as a whole for three specific components. These are (1) water consumption, (2) other operations data, and (3) energy consumption. Detailed data relevant to each industry sector is provided in Chapters 5 through 8 of this document.

Water Consumption

Water consumption data for the US is collected by the United States Geological Survey (USGS). Data for total water withdrawals and consumptive use for 1980, 1985, and 1990 (1995 data not presently available) are shown in Figure 3-16. Reference to Figure 3-16 indicates that both total withdrawals and consumption have remained relatively stable over this period at approximately 1,514 billion liters (400 billion gallons) per day, and 379 billion liters (100 billion gallons) per day respectively.

Table 3-7 Part A and Part B records the data used to produce the figure for total water withdrawals for 1990. The data are sorted by region, source, and type of withdrawal. The table indicates that in 1990, ground water withdrawals accounted for approximately twenty percent of water withdrawals, with the remainder from surface water sources. The latter can be attributed largely to steam and electric utility consumption, and to irrigation.

Figure 3-17 shows the relative rates of withdrawal and consumption for the domestic, commercial, industrial, and power generation sectors in 1990. Reference to the figure indicates that whilst power generation requires a very high rate of withdrawal, its rate of consumption is comparatively low. In fact, the highest consumer of water within the four sectors shown is the domestic sector. The difference between the amount for total consumption in 1990 shown on Figure 3-16, and the sum of the sectors for Figure 3-17 is attributable principally to water withdrawals for irrigation purposes, which are not considered in this document.

Table 3-7. Total Offstream Water Use by Water Resources Region: 1990

Part A: Millions of Gallons per Day

REGION	Population (in thousands)	Per Capita Use Freshwater (in Gallons/Day)	WITHDRAWALS (in Million Gallons/Day)								
			Ground Water			Surface Water			Total		
			Fresh	Saline	Total	Fresh	Saline	Total	Fresh	Saline	Total
New England	12,797	370	694	0	694	4,040	9,160	13,200	4,730	9,160	13,900
Mid Atlantic	41,541	508	2,640	1.2	2,640	18,500	26,500	44,900	21,100	26,500	47,600
South Atlantic-Gulf	34,732	962	7,110	9.1	7,120	26,300	10,800	37,100	33,400	10,800	44,200
Great Lakes	21,405	1,510	1,210	4.9	1,220	31,200	6.5	31,200	32,400	11	32,400
Tennessee	3,911	2,350	305	0	305	8,900	0	8,900	9,200	0	9,200
Upper Mississippi	21,270	977	2,620	4.2	2,630	18,200	0	18,200	20,800	4.2	20,800
Lower Mississippi	7,167	2,510	8,340	0	8,340	9,630	1,120	10,800	18,000	1,120	19,100
Souris-Red-Rainy	672	439	130	0	130	166	0	166	295	0	295
Missouri Basin	10,048	3,730	8,490	37	8,530	29,000	0	29,000	37,500	37	37,500
Arkansas-White-Red	8,250	1,870	7,420	291	7,710	7,990	0	7,990	15,400	291	15,700
Texas-Gulf	15,239	886	5,480	400	5,880	8,020	4,610	12,600	13,500	5,010	18,500
Rio Grande	2,229	2,690	2,140	39	2,180	3,850	0	3,850	6,000	39	6,030
Upper Colorado	625	11,300	127	28	155	6,950	0	6,950	7,080	28	7,110
Lower Colorado	4,747	1,630	3,080	0.6	3,080	4,670	0.6	4,670	7,750	1.2	7,750
Great Basin	2,182	3,300	1,970	19	1,990	5,230	93	5,320	7,200	112	7,310
Pacific Northwest	8,912	4,070	9,780	0	9,780	26,500	36	26,500	36,300	36	36,300
California	29,442	1,200	14,400	310	14,700	21,000	11,400	32,400	35,400	11,700	47,200
Alaska	550	517	64	48	112	221	308	529	284	357	641
Hawaii	1,108	1,070	589	0.6	590	600	1,550	2,150	1,190	1,550	2,740
Caribbean	3,624	161	159	1.2	160	426	2,620	3,040	585	2,620	3,200
Total	252,336	1,340	79,400	1,220	80,600	259,000	68,200	327,000	339,000	69,400	408,000

Part B: Millions of Liters per Day

REGION	Population (in thousands)	Per Capita Use Freshwater (in Liters/Day)	WITHDRAWALS (in Million Liters/Day)								
			Ground Water			Surface Water			Total		
			Fresh	Saline	Total	Fresh	Saline	Total	Fresh	Saline	Total
New England	12,797	1,401	2,627	0	2,627	15,293	34,674	49,967	17,905	34,674	52,617
Mid Atlantic	41,541	1,923	9,993	5	9,993	70,030	100,313	169,964	79,872	100,313	180,185
South Atlantic-Gulf	34,732	3,642	26,914	34	26,952	99,556	40,882	140,438	126,432	40,882	167,315
Great Lakes	21,405	5,716	4,580	19	4,618	118,104	25	118,104	122,647	42	122,647
Tennessee	3,911	8,896	1,155	0	1,155	33,690	0	33,690	34,826	0	34,826
Upper Mississippi	21,270	3,698	9,918	16	9,956	68,894	0	68,894	78,736	16	78,736
Lower Mississippi	7,167	9,501	31,570	0	31,570	36,453	4,240	40,882	68,137	4,240	72,301
Souris-Red-Rainy	672	1,662	492	0	492	628	0	628	1,117	0	1,117
Missouri Basin	10,048	14,120	32,138	140	32,289	109,777	0	109,777	141,953	140	141,953
Arkansas-White-Red	8,250	7,079	28,088	1,102	29,185	30,245	0	30,245	58,295	1,102	59,431
Texas-Gulf	15,239	3,354	20,744	1,514	22,258	30,359	17,451	47,696	51,103	18,965	70,030
Rio Grande	2,229	10,183	8,101	148	8,252	14,574	0	14,574	22,712	148	22,826
Upper Colorado	625	42,775	481	106	587	26,309	0	26,309	26,801	106	26,914
Lower Colorado	4,747	6,170	11,659	2	11,659	17,678	2	17,678	29,337	5	29,337
Great Basin	2,182	12,492	7,457	72	7,533	19,798	352	20,138	27,255	424	27,671
Pacific Northwest	8,912	15,407	37,021	0	37,021	100,313	136	100,313	137,410	136	137,410
California	29,442	4,542	54,510	1,173	55,645	79,493	43,154	122,647	134,003	44,289	178,671
Alaska	550	1,957	242	182	424	837	1,166	2,002	1,075	1,351	2,426
Hawaii	1,108	4,050	2,230	2	2,233	2,271	5,867	8,139	4,505	5,867	10,372
Caribbean	3,624	609	602	5	606	1,613	9,918	11,508	2,214	9,918	12,113
Total	252,336	5,072	300,561	4,618	305,103	980,419	258,164	1,237,826	1,283,251	262,707	1,544,443

For the residential sector, data produced by the Bureau of Economic Analysis tracks the change in personal consumption expenditures for water and sanitary services for US households. Figure 3-18 shows the change in total expenditures for water and sanitary services since 1980. An upward trend in costs is clearly visible.

For the remaining industry sectors, no general, industry-wide data have been located comparing total costs for water consumption. However, by assuming a cost of $0.79 per thousand liters ($3.00 per thousand gallons) for public supply water deliveries and sanitary services, it is possible to derive an approximation of total water expenditures within the commercial sector.

In the commercial sector, over seventy percent of total water deliveries are from the public supply. Therefore, assuming a cost of $0.79 per thousand liters ($3.00 per thousand gallons), and based upon the USGS total withdrawal rate of 31,381 million liters (8,290 million gallons) per day for 1990, water expenditures for 1990 are estimated to be $9.08 billion. This compares with a total of approximately $27.9 billion for the residential sector in the same year.

In the industrial and power generation sectors, it is not considered to be appropriate to apply this assumption. This is because, in the industrial sector, public supply water deliveries account for only approximately eighteen percent of total withdrawals; in the power generation sector, the figure is less than one percent. It is highly likely that the unit water costs vary significantly compared with the residential and commercial sectors, particularly in the power generation sector. No other sources of data have been found which provide aggregated water consumption cost information for these two sectors.

Other Operations Data

A second data source which merits examination is the **1992 Census of Service Industries** (CSI), conducted by the US Bureau of the Census. SIC Code 73 of the CSI (Business Services), includes various businesses which are associated with building operations.

In particular, SIC Code 734 (Services to Dwellings and Other Buildings) includes data for establishments primarily engaged in providing disinfecting and termite, insect, rodent, and other pest control services (SIC Code 7342). Data are also available for establishments providing building cleaning and maintenance services, not elsewhere classified (SIC Code 7349), which includes window cleaning, janitorial services, floor waxing, and office cleaning (it does not include building repair work or construction related maintenance work). Finally, security systems services (SIC Code 7382) considers establishments primarily engaged in selling, monitoring, and maintaining security systems devices, such as burglar and fire alarms in any type of building.

Figure 3-16. Total US Water Withdrawals and Consumptive Use: 1980 to 1990

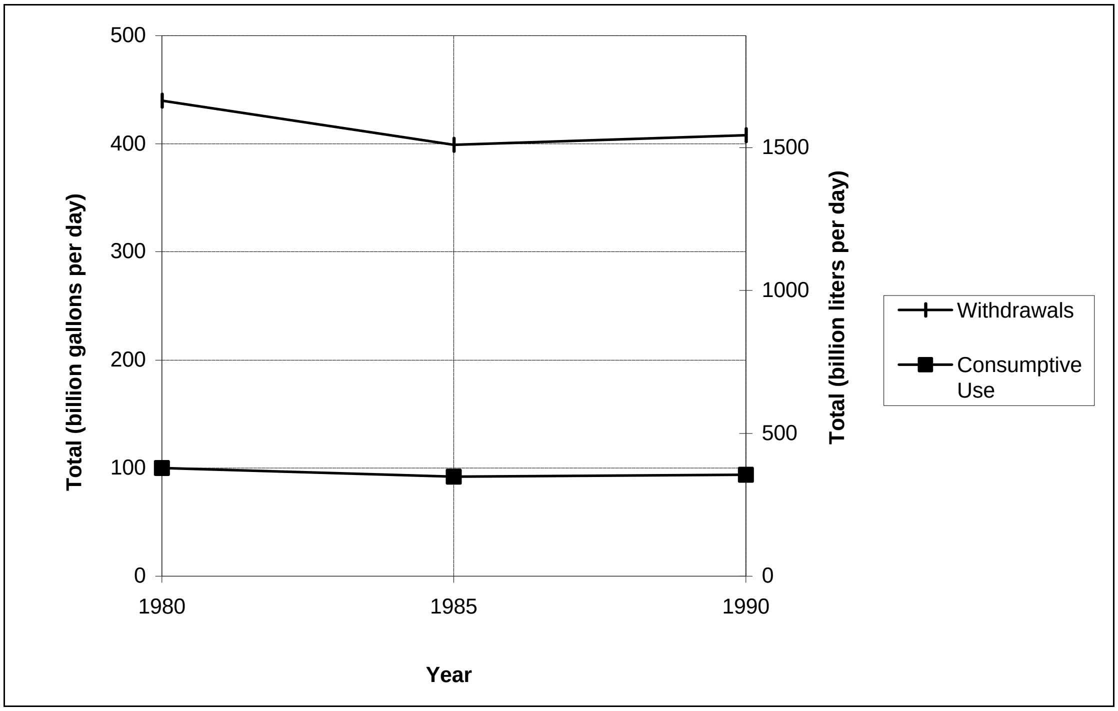


Figure 3-17. Comparison of Water Supply and Consumption in the Domestic, Commercial, Industrial and Power Generation Sectors: 1990

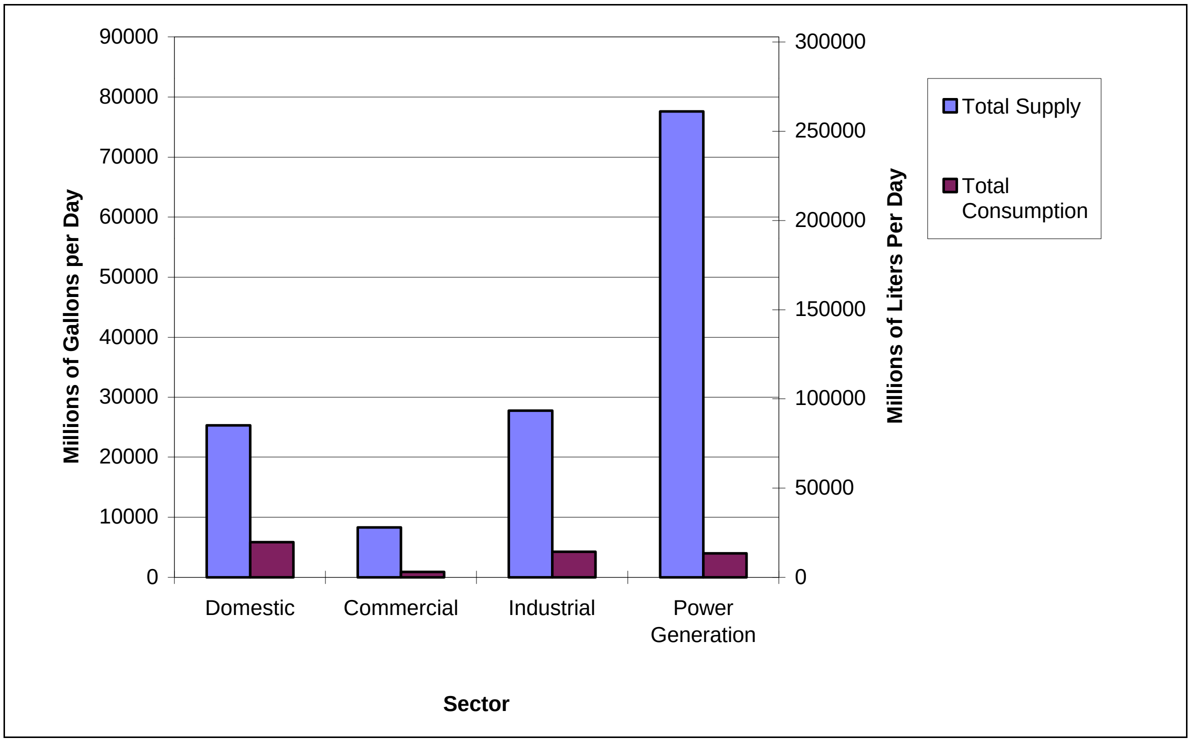
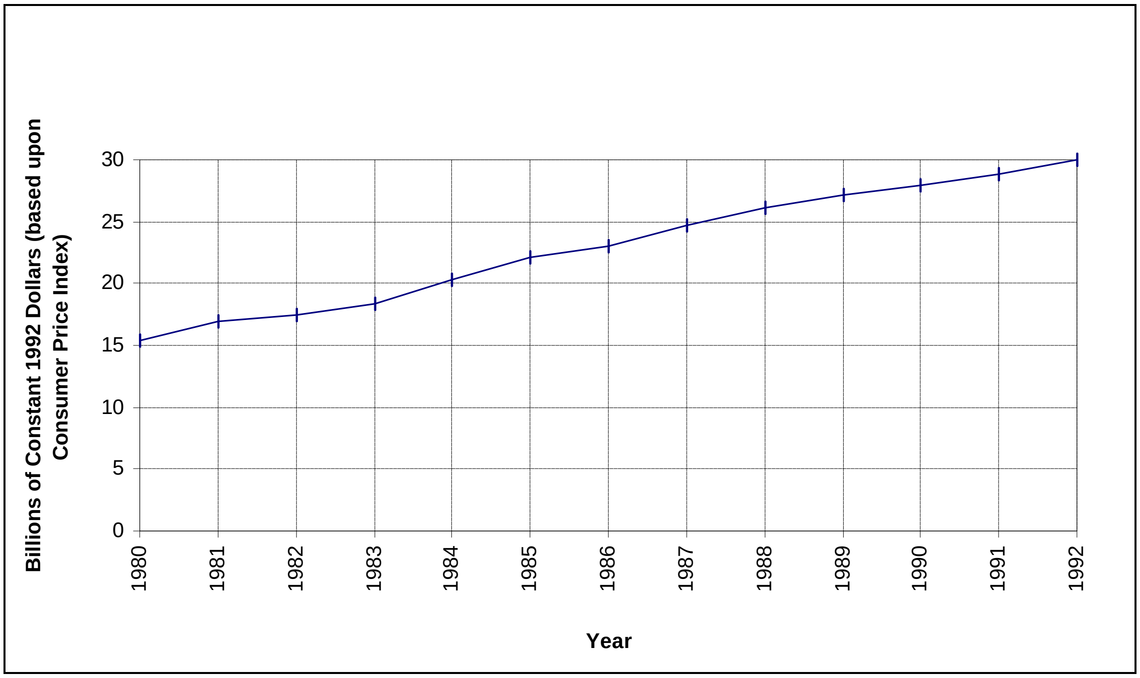


Figure 3-18. Personal Consumption Expenditures for Water and Sanitary Services for US Households: 1980 to 1992



The data which are collected typically provide information on number of establishments, number of employees, receipts and payroll expenditures, rather than data specific to construction sectors or on a per-square meter (per-square foot) basis. However, the information is useful for ball-parking some building operations costs across all industry sectors. Table 3-8 shows selected data extracted from the 1992 CSI.

Table 3-8. Costs of Operation Data from the Census of Service Industries: 1992

SIC Code	Type of Industry	Number of Establishments	Receipts ($1,000)	Number of Employees	Payroll ($1,000)
7342	Disinfecting and Pest Control Services	10,300	3,736,447	70,545	1,454,168
7349	Building Cleaning and Maintenance Services	47,349	15,266,279	747,399	7,710,022
7382	Security Systems Services	2,968	3,414,640	51,755	1,183,008

Energy Consumption

The final issue which merits special consideration is that of energy consumption in the US across all industry sectors. Data published by the Energy Information Administration are used to compare energy consumption between different sectors. The reference document used in this section is the *Annual Energy Review 1996* (AER)[16].

Data presented in the AER are categorized by industry sector in a way that varies slightly from that used in this document. The AER defines three sectors, the residential, commercial, and industrial sectors, which are very similar to those used in this document. However, a fourth sector, the transportation sector, is defined in the AER, which is a sub-sector of the public works sector in this document (refer to Chapter 4 for further details of sector definitions). At a general level, the AER combines data for the residential and commercial sectors.

Figure 3-19 shows the total energy consumption in quadrillion joules (quadrillion British thermal units (Btu) for the different industry sectors between 1992 and 1996 as a series of line traces. As previously mentioned, combined data for the residential and commercial sectors are presented. Table 3-9 Part A and Part B records the source data for Figure 3-19. It also shows the proportional consumption of the different principal fuel sources (i.e., coal, petroleum, and natural gas) within each of the industry sectors, as well as the electrical system energy losses. These losses are calculated as the difference between the total energy input at electric utilities, and the total energy content of electricity sold to end-use consumers. Since a large proportion of these losses are attributable to the electrical generation process, these losses are apportioned amongst the different sectors according to total end use consumption of energy by each sector. Figure 3-19 indicates that the total energy consumption within the residential, commercial, industrial, and transportation sectors is rising steadily, and that this rise is reflected across all sectors.

In order to be able to differentiate between commercial and residential energy use, data in the AER from a different survey, the **Residential Energy Consumption Survey** (RECS), have been used to generate Figure 3-20, which shows the total consumption of energy by the residential sector between 1980 and 1993. Examination of data for 1992 and 1993, and comparison of Figures 3-19 and 3-20 indicates that residential energy consumption accounts for approximately one-third of combined residential and commercial energy consumption.

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[16] US Department of Energy. 1997. *Annual Energy Review 1996*. DOE/EIA - 0384(96). Washington, DC: Energy Information Administration.

Figure 3-19. Energy Consumption by Sector

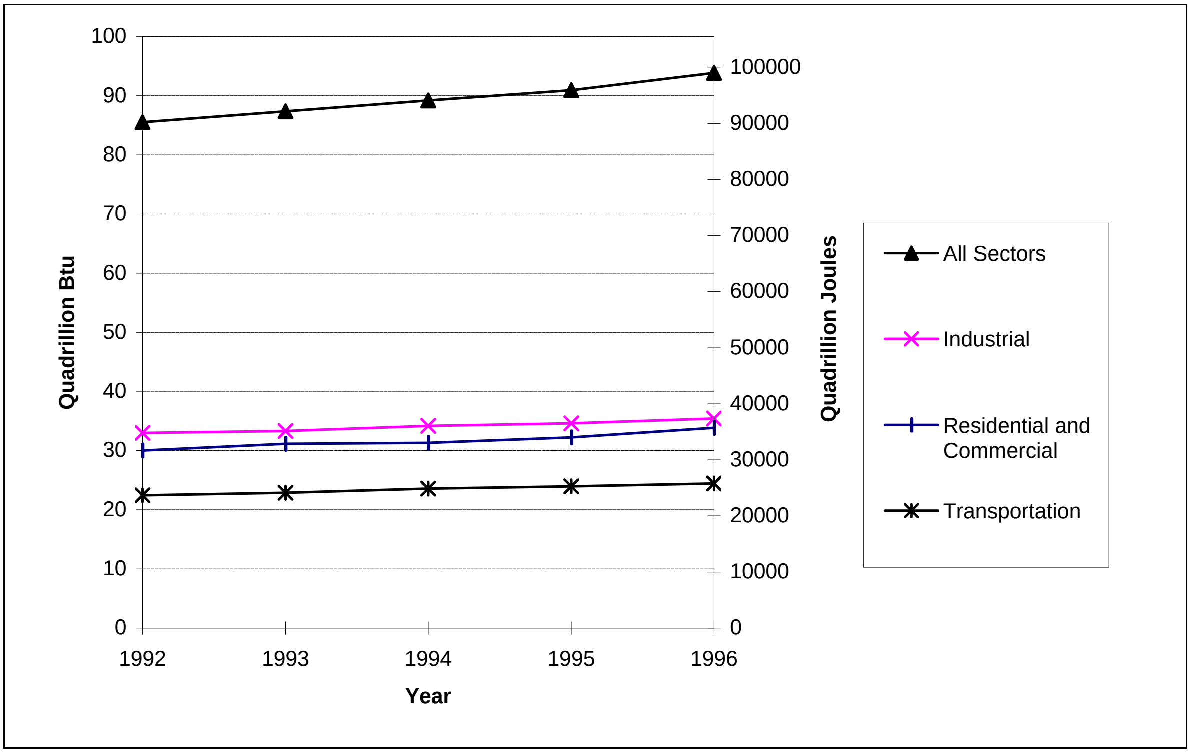

Figure 3-20. Energy Consumption in the Residential Sector

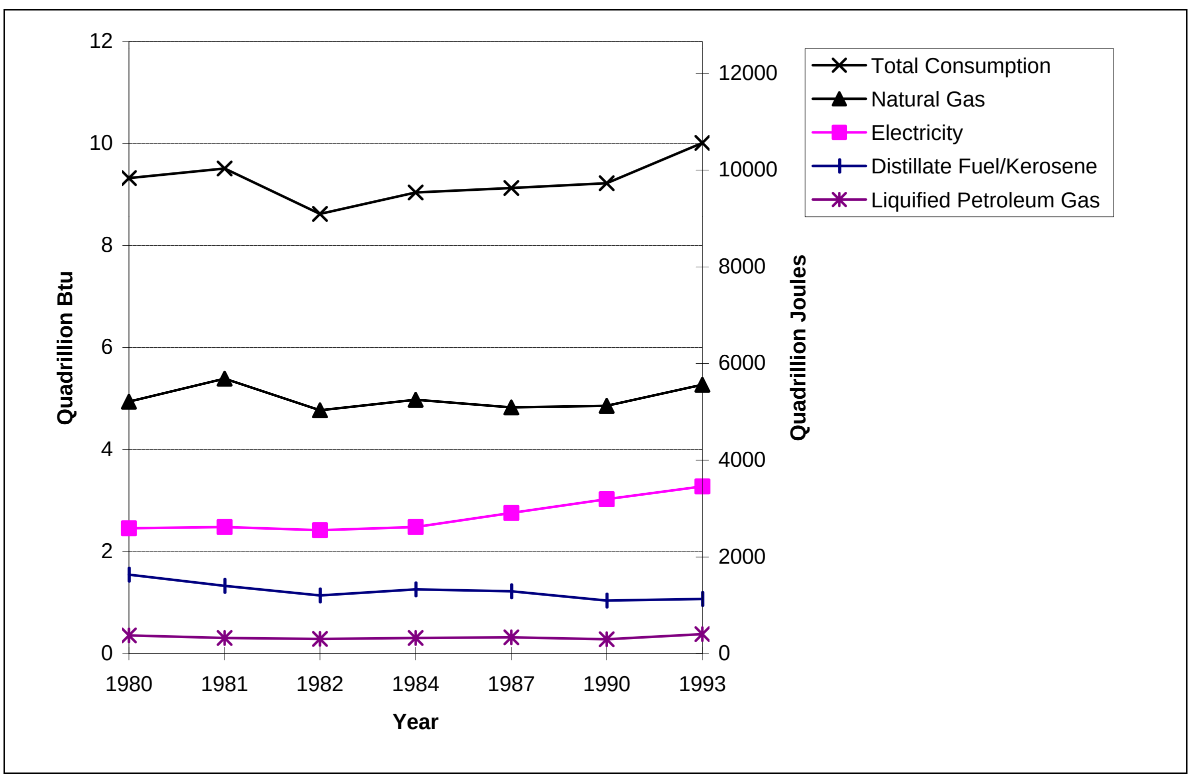

Table 3-9. Energy Consumption by Sector

Part A: Quadrillion Btu

	RESIDENTIAL AND COMMERCIAL					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	0.14	7.73	2.13	6.10	13.21	30.00
1993	0.14	8.04	2.14	6.42	13.74	31.13
1994	0.14	7.97	2.09	6.56	13.88	31.29
1995	0.13	8.09	2.12	6.81	14.39	32.26
1996	0.14	8.73	2.22	7.04	15.04	33.88
	INDUSTRIAL					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	2.51	8.97	8.64	3.32	7.19	33.01
1993	2.50	9.41	8.45	3.33	7.14	33.30
1994	2.51	9.56	8.85	3.44	7.28	34.19
1995	2.48	10.06	8.69	3.46	7.30	34.60
1996	2.40	10.31	9.11	3.47	7.41	35.43
	TRANSPORTATION					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	N/A	N/A	21.81	N/A	N/A	22.46
1993	N/A	N/A	22.20	N/A	N/A	22.88
1994	N/A	N/A	22.82	N/A	N/A	23.57
1995	N/A	N/A	23.20	N/A	N/A	23.96
1996	N/A	N/A	23.66	N/A	N/A	24.43
	ALL SECTORS					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	2.65	16.70	23.94	9.42	20.40	85.52
1993	2.64	17.45	24.34	9.75	20.88	87.34
1994	2.65	17.53	24.91	10.00	21.16	89.21
1995	2.61	18.15	25.32	10.27	21.69	90.94
1996	2.54	19.04	25.88	10.51	22.45	93.81

Part B: Quadrillion Joules

	RESIDENTIAL AND COMMERCIAL					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	147.7	8155.6	2247.3	6435.8	13937.3	31651.7
1993	147.7	8482.6	2257.8	6773.5	14496.5	32843.9
1994	147.7	8408.8	2205.1	6921.2	14644.2	33012.7
1995	137.2	8535.4	2236.7	7184.9	15182.3	34036.1
1996	147.7	9210.6	2342.2	7427.6	15868.0	35745.3
	INDUSTRIAL					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	2648.2	9463.9	9115.7	3502.8	7585.9	34827.4
1993	2637.6	9928.1	8915.2	3513.3	7533.1	35133.4
1994	2648.2	10086.3	9337.2	3629.4	7680.8	36072.4
1995	2616.5	10613.9	9168.4	3650.5	7701.9	36504.9
1996	2532.1	10877.6	9611.6	3661.0	7818.0	37380.6
	TRANSPORTATION					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	N/A	N/A	23010.8	N/A	N/A	23696.6
1993	N/A	N/A	23422.2	N/A	N/A	24139.7
1994	N/A	N/A	24076.4	N/A	N/A	24867.7
1995	N/A	N/A	24477.3	N/A	N/A	25279.1
1996	N/A	N/A	24962.6	N/A	N/A	25775.0
	ALL SECTORS					
Year	**Coal**	**Natural Gas**	**Petroleum**	**Electricity**	**Losses**	**Total**
1992	2795.9	17619.4	25258.0	9938.6	21523.1	90228.4
1993	2785.3	18410.7	25680.1	10286.8	22029.6	92148.6
1994	2795.9	18495.1	26281.4	10550.6	22325.0	94121.5
1995	2753.7	19149.3	26714.0	10835.4	22884.2	95946.8
1996	2679.8	20088.3	27304.8	11088.6	23686.0	98974.8

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4. Developing Baseline Measures for Reductions in Operations, Maintenance, and Energy (OM&E) Costs

4.1 Data Classification Schemes

The first stage in developing baseline measures for Goal 2 (i.e., reductions in OM&E costs) involved establishing data classification hierarchies for each of the four industry sectors. These hierarchies were essential in order to be able to sort data into relevant sectors, to prioritize the data, and to establish data linkages. Initially, an "idealized" hierarchy was developed for each sector, on the premise that there would be no limitations upon data availability. However, as the data collection effort progressed, these "idealized" hierarchies were modified to reflect data availability and format constraints.

4.1.1 Industry Oriented

The industry oriented, or "idealized" hierarchies were developed with a view to defining for the four industry sectors the extent and key components considered relevant to Goal 2. The hierarchies for each sector divided operations, maintenance, and energy into three distinct areas, and then listed the key components within each of these areas. A brief description of each hierarchy, outlining the extent and key components of each sector, as defined in this document, is given below.

Residential Sector

The residential sector, was taken to comprise all permanent single and multi-unit structures, as well as mobile homes or trailers in the United States. These can be grouped according to whether the buildings are site (or 'stick') built, or modular/manufactured units. Housing can be further categorized by geographic location, type, size, and age.

Residential "operations" is defined in this hierarchy as encompassing three core areas:

(1) water consumption/wastewater removal
(2) domestic waste
(3) other (e.g., taxes and insurance)

These operations costs are influenced by factors such as environmental, legislative, and taxation requirements.

Residential "maintenance" is defined as encompassing both the building shell and building equipment. The four principal maintenance categories are defined as:

(1) heating ventilation and air conditioning (HVAC)
(2) electrical and security
(3) plumbing
(4) building structure/roof

Maintenance costs are influenced by factors such as the design life of the system or shell and its current age and condition, serviceability criteria, budget constraints, and legislative and safety requirements.

Residential “energy” is defined as covering the consumption of basic fuel types such as electricity, natural gas, and renewable sources. Energy consumption can be apportioned by end-use, which, for residential structures, can be conveniently grouped under the headings space heating, air conditioning, water heating, and appliances. Factors affecting end use consumption include equipment/system type, degree of automation/feedback control, maintenance, and climatic zone (i.e., heating degree days (HDD) and cooling degree days (CDD)), as well as building shell characteristics and occupant comfort levels. Many of these factors are impacted by design, cost, aesthetic, and legislative requirements.

Commercial/Institutional Sector

The commercial/institutional sector was taken to comprise the following generic types of building/facility, as defined by the Energy Information Administration (EIA):

- Farm Buildings
- Food Sales
- Food Service
- Health Care
- Laboratories
- Lodging
- Mercantile and Service
- Office
- Public Assembly
- Public Order and Safety
- Religious Worship
- Skilled Nursing
- Warehouse
- Other

Certain facilities, such as utilities, communications and transportation, are included under ‘services’ by organizations such as the International Facilities Management Association (IFMA). However, for the purposes of this document, these are considered as being part of the public works sector. Similarly, buildings within the manufacturing sector (e.g., computing, electronics, consumer products) are considered as being part of the industrial sector in this document. Commercial/institutional facilities can be categorized primarily by geographic location, type and size of facility, age, number of employees, and hours of operation.

Commercial/institutional "operations" is defined in this hierarchy as encompassing six core areas[17]:

(1) water consumption/wastewater removal
(2) waste collection/disposal, and building cleaning
(3) roads, grounds, and security
(4) administration (management fees, payroll, professional fees, etc.)
(5) fixed expenses (real estate and other taxes, insurance, etc.)
(6) leasing costs

These operations costs are all influenced to some extent by environmental, legislative, and taxation requirements.

Commercial/institutional "maintenance" is defined as encompassing both the building shell, and building equipment. The eight principal maintenance categories are defined as:

(1) payroll (in-house maintenance staff)
(2) elevator
(3) heating ventilation and air conditioning (HVAC)
(4) electrical
(5) plumbing
(6) building structure/roof
(7) fire/life safety
(8) other

Maintenance costs are influenced by factors such as the design life of the system or shell and its current age and condition, serviceability criteria, budget constraints, and legislative and safety requirements.

Commercial/institutional "energy" is defined as covering the consumption of basic fuel types such as electricity, fuel oil, natural gas, purchased steam, and chilled water. Energy consumption can be apportioned by end-use, which can be conveniently grouped under the headings space heating, cooling/air conditioning, water heating, and process end use. Factors affecting end use consumption are dependent upon building function (number of employees, hours of operation, percentage of floor space heated and lit, type of end product or service), equipment/system type, climatic zone, use of demand-side management systems, degree of automation/feedback control, and frequency of maintenance. In addition, building shell characteristics, such as roof and wall construction, percentage of wall area which is glazed, and conservation features will also have an impact upon end-use consumption. Many of these factors are impacted by design, cost, aesthetic, and legislative requirements.

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[17] For detailed definition for each of these categories, refer to Building Owners and Managers Association 1996. *Experience Exchange Report*, Terms and Definitions pp. xi-xii.

Industrial Sector

The industrial sector was taken to comprise all manufacturing industries with Standard Industrial Classification (SIC) Codes between 20 and 39 inclusive. These SIC Codes are as follows:

- SIC 20 - Food and Kindred Products
- SIC 21 - Tobacco Products
- SIC 22 - Textile Mill Products
- SIC 23 - Apparel and Other Textile Products
- SIC 24 - Lumber and Wood Products
- SIC 25 - Furniture and Fixtures
- SIC 26 - Paper and Allied Products
- SIC 27 - Printing and Publishing
- SIC 28 - Chemicals and Allied Products
- SIC 29 - Petroleum and Coal Products
- SIC 30 - Rubber and Miscellaneous Plastic Products
- SIC 31 - Leather and Leather Products
- SIC 32 - Stone Clay and Glass Products
- SIC 33 - Primary Metal Products
- SIC 34 - Fabricated Metal Products
- SIC 35 - Industrial Machinery and Equipment
- SIC 36 - Electronic and Other Equipment
- SIC 37 - Transportation Equipment
- SIC 38 - Instruments and Related Products
- SIC 39 - Miscellaneous Manufacturing Industries

Note that all mining industries (which includes off-shore exploration and extraction activities) are excluded from this document. All transportation, communications, electric power generation/distribution, and sanitary services are included in the public works sector for this document. Industrial facilities can be characterized primarily by geographic location, size of facility (e.g., by capacity as a function of installed cost), and type/function.

Industrial "operations" is defined in this hierarchy as encompassing both process and non-process operations. Process operations include plant, labor, and materials components which are directly related to the production process or end-product. Non-process operations include those operations which are not directly related to the production process or end product. The latter would typically include non-production workers and associated infrastructure components.

Plant process operations components include capital expenditures for new plant and machinery as well as fixed costs such as taxation, insurance and depreciation. Similarly, labor costs can be divided between production workers (process operations) and all other employees (non-process operations). Materials costs are dependent upon the industrial process which is being performed. These operational costs are all influenced to some extent by environmental, legislative, and taxation requirements.

Industrial "maintenance" is defined as encompassing both buildings and related structures, and the machinery and equipment associated with them. It is not always possible to differentiate between process related and non-process related maintenance components. For the building component, the maintenance components and factors influencing those components are very similar to those for commercial buildings. For machinery and equipment, maintenance requirements are likely to be affected by factors such as the design life of the system and its current age and condition, serviceability criteria, budget constraints, and legislative and safety requirements. These will vary greatly depending upon the particular industry which is being considered.

Industrial "energy" is defined as covering the consumption of basic fuel types such as electricity, natural gas, and coal, as well as byproduct energy such as waste gas and pulping liquor. Energy consumption can be apportioned by end-use, which can be conveniently grouped as follows:

(1) indirect use (e.g., boiler fuel)
(2) direct process use (heating, cooling, machine drive, and electro-chemical)
(3) direct non-process use (HVAC, lighting, non-process electrical generation, etc.)
(4) non-assigned end-use

Factors affecting end use consumption are dependent upon manufacturing process/building function, equipment/system type, climatic zone, use of demand side management systems, degree of automation/feedback control, and frequency of maintenance. In addition, building shell characteristics, and the ability to switch between different fuel types will also have an impact upon end-use consumption. Many of these factors are impacted by design, cost, safety, and legislative requirements.

Public Works Sector

For this document, the public works sector has been divided into a number of sub-sectors, which are broadly aligned with the SIClassification Codes, as follows:

- **Transportation** (SIC 40, 41, 42, 44, 45). This sub-sector includes transportation by road, rail, transit, water, and air.
- **Communications** (SIC 48). This sub-sector includes communication masts and other structures, and associated cabling and related services.
- **Power Utilities** (SIC 49). This sub-sector includes the generation and distribution of electricity, gas and steam (electric, gas, coal, nuclear, and other types of power station). It includes the distribution of natural gas.
- **Water** (SIC 44, 49). This sub-sector includes the storage, supply, and treatment of water, plus flood and storm water control.

- **Solid Waste** (SIC 42, 44). This sub-sector includes the collection and disposal of solid waste materials (domestic and industrial).
- **Pipelines** (SIC 46). This sub-sector includes pipelines for the transport of petroleum and other commodities except natural gas.

The extent of the industry oriented hierarchy for each of these sub-sectors is considered in more detail below.

Transportation Sub-Sector

This sub-sector was taken to comprise the US highway and bridge network, rail network, transit systems, airports and associated infrastructure, and navigable rivers, canals, related structures and ports. Highways and bridges can be relatively easily categorized by type of operating authority, functional type, and geographic location. Railroads can be categorized by geographic location and by class of railroad. Categorization of transit systems, airports, waterways, and ports is more difficult, given that many do not share common characteristics and cannot be easily compared.

Transportation "operations" is defined in this hierarchy as encompassing building operations components, and network management/administration components. While building operations components can be relatively easily defined, using a similar approach to that used for the commercial sector, it is more difficult to define network management components. Both sets of components are influenced to some extent by environmental, legislative, and taxation issues.

Transportation "maintenance" for roads can be subdivided into constituent components (pavement, earthworks, drainage, structures, signs and lighting, etc.) depending upon whether the work is highway widening, reconstruction, or new construction. Rail and transit "maintenance" can be subdivided into maintenance of stations/buildings, tracks, structures, and rolling stock. Airport "maintenance" can be similarly divided into buildings (shells and systems) and pavements (runways). Waterway "maintenance" components principally comprise dredging, earthworks, and structures. For all building related issues within the transportation sub-sector, the maintenance components and factors influencing those components are very similar to those for commercial buildings. Similarly, many of the maintenance factors are impacted by design, cost, safety, and legislative requirements.

Transportation "energy" is defined as covering the consumption of basic fuel types such as gasoline, diesel, and aviation fuel, as well as consumption of electricity and other sources associated with building energy consumption, and highway lighting, for example. In this document, the consumption of energy within the transportation sub-sector will be ignored given that the majority of the end-use consumption is attributable to vehicle, vessel, or aircraft usage, rather than energy consumption required by the supporting infrastructure.

Communications Sub-Sector

This sub-sector was taken to comprise telephone, TV and broadcast, and cable and pay TV services. While there is a certain amount of construction effort involved in this sector, it has been decided to omit this sub-sector from the document, given that much of the work in this sector is either not directly construction related, or is considered elsewhere in this document (e.g., manufacture of components and pre-fabricated structures, cabling and other specialized electrical installation work).

Power Utilities Sub-Sector

This sub-sector is defined as encompassing electricity, gas, or steam generation and distribution for the primary fuel sources (electric, gas, coal, nuclear, and other). Power generation plants can be categorized by generating capacity, size (as a function of installed cost), and geographic location. It is more difficult to categorize power distribution systems, other than by type of system used (buried or catenary) and geographic location.

Power utilities "operations" is defined in this hierarchy in a similar way to the industrial sector. "Operations" thus encompasses both process and non-process operations. Process operations encompass the electrical generation process, which includes plant, labor, and materials components. Plant operations components include capital expenditures for new plant and machinery as well as fixed costs such as taxation, insurance, and depreciation. Labor costs can be divided into production workers (process operations) and all other employees (non-process operations). Process materials costs are dependent upon the type of power station which is being considered. Non-process operational components include all non-process related infrastructure operations costs. Both process and non-process operational costs are all influenced to some extent by environmental, legislative, and taxation requirements.

Power utilities "maintenance" is defined as encompassing both buildings and related structures, and the machinery and equipment associated with them. For buildings, the maintenance components and factors influencing those components are very similar to those for commercial buildings. For machinery and equipment, maintenance requirements are likely to be affected by factors such as the design life of the system and its current age and condition, serviceability criteria, budget constraints, and legislative and safety requirements.

Power utilities "energy" is defined as covering both process related and non-process related energy consumption. Process related energy considers the energy consumption in the electricity generation process, and the delivery of electricity through the distribution system. Non-process related energy consumption includes components such as building HVAC and lighting. This has been ignored as it is likely to be a very small component of total energy consumption associated with the direct process use. Factors affecting end use consumption are primarily dependent upon type of process, equipment/system type, consumer demand and the management thereof. Many of these factors are impacted by cost, safety, and legislative requirements.

Water Sub-Sector

This sub-sector was taken to comprise water storage (dams, reservoirs, and associated hydro-electric power (HEP) projects), supply (domestic, commercial, industrial, and power generation), treatment (sewage etc.), and flood control/storm water management. Water storage systems are considered only where there is an associated end-use in the form of HEP generation. Categorization is then in terms of installed generation capacity. Water supply and treatment systems can be categorized by end-user and geographic location. Flood control/storm water management can be categorized to some extent by nature of work and geographic area.

Water "operations" is defined in this hierarchy as encompassing network management/administration and water consumption/treatment components. While water consumption can be relatively easily defined for each of the four sectors, it is much more difficult to define network management components. The latter operational components in particular are influenced by environmental, legislative, and taxation requirements.

Water "maintenance" components include dam and reservoir maintenance, pumping station and water treatment works maintenance, pipe repair, and flood control maintenance/river engineering. The latter component is assumed to include waterway dredging works. Many of the maintenance factors are impacted by design, cost, safety, and legislative requirements.

"Energy" is defined as covering the non-process related consumption of electricity for water treatment and distribution systems. Because non-process related consumption of energy is relatively small, it will not be considered in this document.

Solid Waste Sub-Sector

This sub-sector was taken to comprise the collection and disposal of solid domestic, commercial, and industrial waste at processing facilities and landfill sites. Although there is some construction related activity within this sub-sector (particularly in terms of earthworks for landfill sites/repositories), this will be covered in a future report relating to National Construction Goal 5 (Reduction in Waste and Pollution).

Pipelines Sub-Sector

This sub-sector is defined as comprising all pipelines for the transportation of petroleum and other commodities except natural gas (considered as part of the power utilities sub-sector). Pipelines can be characterized by type, size, and geographic location.

There are no "operations" defined in the hierarchy.

Pipeline "maintenance" comprises damage repair and preventive maintenance.

There are no defined "energy" components within the hierarchy (pumping and heating costs are ignored in this document).

4.1.2 Data Oriented

The data oriented hierarchies represent the modification of the idealized hierarchies to reflect data availability and constraints. Furthermore, the hierarchies reflect the relative importance attributed to data, in that certain elements of the idealized hierarchy may not be covered by the data oriented hierarchy even though data may be available. This is an important step in ensuring the baseline measures remain succinct. The hierarchies are provided in Appendices A through D[18]. The data oriented hierarchies are presented as overlays on the idealized hierarchies. This highlights the extent of the data coverage within each sector. A brief description of the differences between the data oriented and idealized hierarchies for each sector is given below.

Residential Sector

The residential sector for the data oriented hierarchy is identical to that shown on the idealized hierarchy. The sector components described in the industry oriented hierarchy are also applicable. However, it is not considered to be necessary to differentiate between site built and manufactured housing for this Goal.

Within the "operations" section of the data oriented hierarchy, it is not considered to be practical to address water conservation, taxation, legislative, or environmental issues. However, the two hierarchies are identical at a higher, less detailed level.

The "maintenance" section of the two hierarchies match very closely, although, as with the "operation"' section, it is not considered to be practical to address legislative, safety, and serviceability factors for this Goal.

Within the "energy" section of the hierarchies, there is close relationship between the data and industry oriented hierarchies at the higher levels, whilst at the lower level it is not considered to be practical to address building shell design, aesthetic or legislative requirements. However, there will be some consideration of recommended energy efficiency ratings for generic types of residential heating and cooling equipment and appliances. In addition, it is not considered to be desirable to address energy issues in the data oriented hierarchy in the same level of detail shown in the industry oriented hierarchy, even though very detailed data exists.

[18] The four appendices are organized as follows: Appendix A covers the residential sector; Appendix B covers the commercial/institutional sector; Appendix C covers the industrial sector; Appendix D covers the public works sector.

Commercial/Institutional Sector

The commercial/institutional sector for the data oriented hierarchy is very similar to that shown on the idealized hierarchy. However, in practice, it has been found that different organizations tend to group facilities very differently, thus it is often difficult to compare data from different sources. Where comparisons are made between data from different sources in this document, the assumptions which have been made are clearly stated. The sector components described in the industry oriented hierarchy are also applicable. However, given the diversity of building types within this sector, it is not always practical to consider all components in great detail.

Within the “operations” section of the data oriented hierarchy, data exist for certain types of buildings (such as commercial office buildings) which have similar scope to the idealized hierarchy. However, for some other types of buildings, such as religious buildings, no detailed data have been found. Generally speaking, it is not considered to be practical to address water conservation, taxation, legislative, or environmental requirements.

The “maintenance” section of the two hierarchies match very closely for certain types of buildings, although, as with the “operations”’ section, the availability of data is highly variable, and it is generally not considered to be practical to address legislative, safety, and serviceability factors for this Goal.

Within the “energy” section of the hierarchies, there is close relationship between the data and industry oriented hierarchies, even at a relatively detailed component level. However, at the lower level of the hierarchy, it is not considered to be practical to address building shell design, aesthetic, or legislative requirements. In addition, it is not considered to be desirable to address energy requirements in the data oriented hierarchy in the same level of detail shown in the industry oriented hierarchy, even though very detailed data exists.

Industrial Sector

The industrial sector for the data oriented hierarchy is very similar to that shown on the idealized hierarchy. There is some scope for categorizing industrial facilities by size, number of employees, and dollar value of business carried out, but it is generally not possible to categorize facilities by installed cost, except where data for new facilities have been collected.

Within the “operations” section of the data oriented hierarchy, it is generally not considered to be necessary to address process related operations factors, such as materials usage, although it is considered useful to characterize operational costs on a ‘dollar value added’ basis for each SIC Code. However, non-process related operations factors, such as expenditures for refuse and hazardous waste disposal are considered, but expenditures for other services such as legal and accounting services are excluded. At an aggregated SIC Code level, water consumption for both the process and non-process components is considered. As with the commercial sector, it is not considered to be practical to address water conservation, taxation, legislative, or environmental requirements.

The “maintenance” section of the two hierarchies match very closely. As with the idealized hierarchy, it is generally not considered to be practical to differentiate between process and non-process related maintenance components. At a high level in the data oriented hierarchy, maintenance for buildings and equipment are considered separately. At an aggregated SIC Code level, maintenance expenditures for HVAC, plumbing, elevators, and carpentry are considered. As with the “operations” section, it is not considered to be practical to address legislative, safety, and serviceability factors for this Goal.

Within the “energy” section of the hierarchies, there is close relationship between the data and industry oriented hierarchies even at a relatively detailed component level. However, when considering end-use consumption, this document will focus only upon that element which is non-process related. In particular, the document will examine energy consumption for facility HVAC, lighting, and other support services. It is not considered to be practical to address design, safety, or legislative requirements.

Public Works Sector

Transportation Sub-Sector

The transportation sub-sector for the data oriented hierarchy is very similar to that shown on the idealized hierarchy. The components described in the industry oriented hierarchy are also applicable. However, in the case of airports and ports, it is not considered to be meaningful to provide aggregated data relating to operations, maintenance, and energy costs, as there are likely to be large variations between different facilities.

Within the “operations” section of the data oriented hierarchy, it is not considered to be practical to address the issue of network administration costs, nor is it necessary to consider building operations costs, as the latter are described in the commercial sector for similar types of building.
The “maintenance” section of the two roads hierarchies match very closely, but for “maintenance” within the rail, transit, air, and water sectors, information is either available at a very detailed level, or aggregates cost components at a more general level in a way that does not match the idealized hierarchy. Maintenance issues such as fleet maintenance and control systems maintenance may be included in these aggregated costs, but for the purposes of this document it is considered desirable to exclude them, as they are not directly construction related.

Within the “energy” section of the hierarchies, there is close relationship between the data and industry oriented hierarchies even at a relatively detailed component level. However, this document will not address energy issues for this sub-sector, for the reasons described previously.

Communications Sub-Sector

For the reasons previously described, this sub-sector will not be considered in this document.

Power Utilities Sub-Sector

The power utilities sub-sector for the data oriented hierarchy is identical to that shown on the idealized hierarchy. However, this document will focus primarily upon aggregated data for all utilities.

Within the "operations" section of the data oriented hierarchy, it is generally not considered to be desirable to address the issue of process related operations, with the exception of water consumption, where it is not possible to differentiate between process and non-process consumption. Selected non-process operations components, such as hazardous waste removal are considered in this hierarchy.

The "maintenance" section of the two hierarchies match very closely, although, as with the "operations" section, it is not considered to be practical to address legislative, safety, and serviceability factors for this Goal.

Within the "energy" section of the hierarchies, there will be some general consideration of the efficiency of the electrical generation and distribution process. However, it is not considered to be practical to address other process or non-process related energy factors described in the idealized hierarchy.

Water Sub-Sector

The water sub-sector for the data oriented hierarchy is very similar to that shown on the idealized hierarchy.

Within the "operations" section of the data oriented hierarchy, water consumption within the domestic, commercial, industrial, and power generation sectors will be considered. The consumption includes both process and non-process related components. This can be further divided into freshwater and saline usage.

The "maintenance" issues in the data oriented hierarchy are identical to those described in the idealized hierarchy.

For the reasons already given, no consideration will be made of energy issues in this sub-sector.

Solid Waste Sub-Sector

For the reasons already described, this sub-sector will not be considered in this document.

Pipelines Sub-Sector

The pipelines sub-sector for the data oriented hierarchy is identical to that shown on the idealized hierarchy. However, pipelines are not categorized by size.

For the "maintenance" section of the two hierarchies, aggregated data describing overall maintenance and repair expenditures will be considered.

As has already been noted, no operations or energy hierarchies are defined for this sub-sector.

4.2 Data Collection and Analysis

The two primary types of data collected were electronic data and published data. Electronic data were collected from the World Wide Web and from various CD-ROM's. Published data were collected from NIST libraries and from publicly accessible libraries and data warehouses on the World Wide Web. Information gleaned from telephone conversations, meetings, and workshops/seminars was often the catalyst in successfully locating relevant published or electronic information. As data were collected, the data oriented hierarchies for each industry sector were refined to reflect data availability constraints.

The authors carried out extensive data searches of publicly accessible federal agency databases for information relevant to Goal 2. These searches frequently involved browsing lists of current and historic research activities/reports which have been, or are presently being carried out, and included the following Executive Agencies:

- Department of Agriculture (Water Management Research Laboratory)
- Department of Commerce (Economics and Statistics Administration, Economic Development Administration, National Oceanic and Atmospheric Administration, National Telecommunications and Information Administration, Technology Administration)
- Department of Defense (Advanced Research Projects Agency, Defense Logistics Agency, Defense Technical Information Center, US Air Force, US Army Corps of Engineers, Office of Naval Research)
- Department of Energy (Energy Efficiency and Renewable Energy Network, Energy Information Administration, Fissile Materials Disposition, Fossil Energy, Human Resource and Administration, Oak Ridge National Laboratory)
- Department of Housing and Urban Development
- Department of the Interior (US Geological Survey)
- Department of Labor (Bureau of Labor Statistics)
- Department of Transportation (Bureau of Transportation Statistics, Federal Aviation Administration, Federal Highway Administration, Federal Railroad Administration, Federal Transit Administration, Federal Maritime Administration)

Searches of Independent Agency databases such as the Environmental Protection Agency, Federal Emergency Management Agency, General Services Administration, National Performance Review, and the Nuclear Regulatory Commission were also performed.

A second set of data searches focused upon research, trade, and professional organizations, some of which are listed below:

- American Association of Cost Engineers
- American Public Works Association
- American Society for Heating, Refrigeration and Air-Conditioning Engineers
- American Society of Civil Engineers
- Associated Builders and Contractors
- Associated General Contractors of America
- Association of Energy Engineers
- Building Research Establishment (UK)
- Civil Engineering Research Foundation
- Construction Industry Institute
- Construction Industry Research and Information Association (UK)
- Council for Continuous Improvement
- Design Build Institute of America
- European Construction Institute (UK)
- Institute of Real Estate Management
- Industrial Technology Institute
- Infrastructure Technology Institute
- Institution of Civil Engineers (UK)
- Inter Agency Benchmarking and Best Practices Council
- International Facilities Management Association
- Manufactured Housing Institute
- National Association of Manufacturers
- National Association of Homebuilders
- National Center for Manufacturing Sciences
- National Housing Institute
- National Institute of Building Sciences
- Strategic Planning Institute

A third set of data searches examined private sector organizations, some of which are listed below:

- The Benchmarking Exchange
- Logistics Management Institute
- Independent Project Analysis
- RS Means
- DuPont
- McGraw Hill

- Journal of Management in Engineering
- American Productivity and Quality Center
- The Strategic Planning Institute

The final search focused upon academic institutions such as:

- Massachusetts Institute of Technology
- University of Texas at Austin
- University of Illinois at Urbana
- Center for Integrated Facility Engineering at Stanford University
- Loughborough University of Technology (UK)

The results of this extensive information search suggest that there is a great deal of information available relating to Goal 2. Unfortunately, much of this information is not useful for establishing baseline measures or measures of progress. This is because the methods used for data collection, the size of the survey sample, or the frequency of reporting are highly variable. The exception comes where data collection is being done by a federal agency as part of its mission. For example, both the US Bureau of the Census and the Energy Information Administration have a responsibility to collect and disseminate information relating to the construction industry and the built environment. However, a number of useful data sources have been identified where organizations are systematically collecting and publishing data from a relatively large population that is broadly representative of the whole of the US. It is also possible that a number of federal agencies have detailed operations maintenance and energy cost databases which could prove useful for Goal 2, but if these exist, they have not been located by the authors. A similar comment applies to private organizations, some of which are thought to have extensive databases relating to the construction sector, though it is not known how much of this information relates to OM&E costs, nor whether it is representative of national averages for establishing baselines. This information is likely to be available only on a commercial fee for service basis.

A detailed description of the data sources used in establishing baselines and measures of progress for each sector is given in Chapters 5 through 8 of this document.

Prior to any data analysis being performed, all relevant electronic and published information was imported into spreadsheet files so that it could be easily manipulated. This approach also enabled charts and tables to be generated relatively rapidly. Initially, a large number of charts were produced from the raw data, which assisted in identifying trends in the data. These charts also helped in prioritizing the data prior to developing the baseline measures.

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5. OM&E Measures for the Residential Sector

5.1 Key Considerations for the Residential Sector

This section of the document addresses the issue of data sources, availability, and constraints in the residential sector, and summarizes the key data sources which are used for developing the baseline measures. The section also provides an overview of the residential sector.

5.1.1 Data Considerations: Sources, Availability, and Constraints

Preliminary data searches for the residential sector focused upon organizations such as the Department of Housing and Urban Development (HUD), the National Association of Home Builders (NAHB), and the Manufactured Housing Institute (MHI). These searches indicated that while these organizations are carrying out their own research about the US housing industry, they are making use of information collected by the US Bureau of the Census or the Energy Information Administration when considering housing at a national level. It therefore seemed appropriate to examine the source data provided by the US Bureau of the Census and Energy Information Administration in detail for the development of the baseline measures.

Data from the US Bureau of the Census

The US Bureau of the Census (USBC) carries out a number of surveys of the US housing sector, and reports periodically upon a wide variety of related issues. Surveys/reports of particular interest are the **American Housing Survey**, the **Census of Housing**, the **Current Construction Reports**, and the **Property Owners and Managers Survey**. These are considered in more detail below.

The **American Housing Survey** collects data on the nation’s housing, including apartments, single-family homes, mobile homes, and vacant housing units. It provides data on housing characteristics, such as income, housing and neighborhood quality, housing costs, equipment and fuels, and size of the housing unit. National data are collected every other year, and data for selected Metropolitan Areas (MA’s) is collected about every four years. The sample covers approximately 55,000 homes. Data are available for years up to and including 1995.

The **Census of Housing** provides detailed information on housing characteristics. The survey is carried out every ten years; data from the 1990 survey are available at present. Housing characteristics such as number of units, plumbing facilities, tenure, value, rent, fuels, heating equipment, and so forth are examined. Every home in the US is asked the basic questions in the survey, whilst approximately one sixth of all houses in the US are asked more detailed survey questions relating to issues such as income and housing expenses.

The **Current Construction Reports** comprise a series of periodic surveys, which include the following monthly surveys:

- Series C20 - *Housing Starts* - provides data on the number of new privately owned housing units started in the US, by number of units in the structure, and census region, and data on the number of mobile homes shipped.
- Series C22 - *Housing Completions* - provides data on the number of new privately owned housing units completed in the US, by number of units in the structure, and census region.
- Series C25 - *New Home Sales* - provides data on the sales of new single-family homes in the US
- Series C30 - *Value of Construction Put in Place* - provides data on new private and public housing construction, as well as residential improvements in the US (refer to Chapter 3 for further details)
- Series C40 - *Building Permits* - provides data on the number of privately owned housing units started in the US, as well as the number of houses where building permit authorization was given, by number of units in structure, and census region. There is some commonality with the C20 data.

In addition, the **Current Construction Reports** include a quarterly series:

- Series C50 - *Expenditures for Residential Improvements and Repairs* - provides data on expenditures by property owners for improvements and repairs (refer to Chapter 3 for further details).

The **Property Owners and Managers Survey** was carried out between 1995-1996 and provides data on the maintenance and repair of rental housing in the US. The survey covers both single-family and multi-family homes. It examines issues such as annual maintenance and repair expenditures, and types of maintenance program used.

Selected data from USBC are available through its Internet site (URL: http://www.census.gov), or via electronic or paper publications. Inquiries by the authors indicate that customized data searches conducted by USBC can be carried out on a fee for service basis, provided that confidentiality criteria for the source data are not breached.

In this document, data from the USBC have been used to characterize the size and nature of the residential sector, and to provide some information on operations and maintenance costs. Where specific data constraints have been found, these have been identified in the text.

One publication which makes extensive use of data from the USBC, but which, on occasion provides data in a slightly different form to that used by USBC in its own publications, is the *Statistical Abstract of the United States*, which is published annually. Where appropriate, this document makes use of data provided in the 1996 and 1997 versions of the *Statistical Abstract* (the 1997 version has very recently become available, and can be viewed at the USBC Internet site). The *Statistical Abstract* also uses a variety of other sources when compiling its statistics. Details of the sources used are presented in Appendix I of the *Statistical Abstract*. Data from the *Statistical Abstract* have been used to characterize the size of the residential sector, and to provide information on personal consumption expenditures for a variety of operations and maintenance components within the sector. The *Statistical Abstract* has also been used where price deflators/indices were needed to adjust statistics for this document.

Data from the Energy Information Administration

The Energy Information Administration (EIA) - a part of the US Department of Energy - carries out the **Residential Energy Consumption Survey (RECS)**, which is a national survey that collects data on energy use in the residential sector. The **RECS** has been carried out triennially since 1984. In the 1993 **RECS** (the most recent survey data currently available), data were collected from a sample of seven thousand households, representative of the approximately 100 million households in the US. The survey collects data on the type of housing unit, year of construction, space heating, water heating, air conditioning, fuels, equipment, appliances, and demographic characteristics of the occupants. Energy consumption and expenditure data are obtained from the household's energy suppliers. **RECS** data are linked to weather data for each building. The RECS is the most comprehensive source of national level energy data for the residential sector.

The EIA produces a number reports from the **RECS** survey data. These include *Housing Characteristics 1993, Household Energy Consumption and Expenditures 1993,* and *Residential Lighting: Use and Potential Savings 1993.* EIA also produces the *1996 Renewable Energy Annual*, which includes information relating to solid waste generation in the residential sector.

Data from EIA are available through its Internet site (URL: http://www.eia.doe.gov), or through paper or electronic publications, including the *EIA Energy InfoDisc Volume 2, No.1, 1997,* which provides energy data for all four industry sectors. Energy data provided by EIA are very detailed.

In this document, data from the EIA reports *Housing Characteristics 1993* and *Household Energy Consumption and Expenditures 1993* have been used both to characterize the residential sector, and to develop energy cost and consumption baselines for the residential sector. The highly detailed nature of the data means that there are no data constraints.

Data from Other Sources

A wide variety of other data sources were examined. A brief description of some of these sources is given below:

- The Manufactured Housing Institute (MHI) provides comparative data for site-built and manufactured housing. This information is based upon data from USBC, as well as other sources. These data can be found on the MHI Internet site (URL: http://www.mfghome.org). No other sources of national data for the manufactured housing sector were identified by the authors. The MHI also provides some useful definitions of the different types of manufactured housing (see http://www/mfghome.org/media/definemh.html), which have been used in this document. Selected data from MHI have been used in this document to compare the size of the manufactured and site built markets, and to compare installed costs.

- The Federal Energy Management Program (FEMP - a part of the Department of Energy) provides a series of energy efficiency recommendations for selected residential appliances, some of which are included in this document. These recommendations can be found on the FEMP Internet site (URL: http://www.eren.doe.gov/femp/procurement/begin.html). Similar information on the US government 'Energy Star' energy efficiency rating system for household appliances is provided at http://www.energystar.gov. The FEMP Internet site also provides information about Federal Energy Saver showcase facilities. FEMP is a part of the Department of Energy's Energy Efficiency and Renewable Energy Network (EREN), which provides a range of energy-related information, covering such issues as sustainability in building, building efficiency, intelligent building systems and so forth. A source list of associated organizations is provided on the EREN network at http://www.eren.doe.gov/buildings/energy_savers/sourcelist.html.

- The US Army Corps of Engineers (USACE) publishes *its Annual Summary of Operations*, more commonly referred to as the *'Red Book'*, which provides data on maintenance and repair costs for army facilities, including family housing. In 1996, the Army had 54,823 family houses (21,926 square meters/236,012 square feet), with an average age of 34 years. The *1996 Red Book* provides data on new construction, operations, and maintenance cost trends for this housing. This information is provided on the USACE internet site (URL: http//www.usacpw.belvoir.army.mil/pubs/RedBook). While this information is interesting, it has not been included in this document for two reasons. Firstly, the army housing stock is probably not representative of the US civilian housing sector. Secondly, trends in operation, maintenance, and energy costs are likely to be very heavily influenced by annual funding appropriations, and are therefore unlikely to compare with civilian spending trends.

- The United States Geological Survey (USGS) provides data on water consumption by the residential sector in the US. These data are available on the USGS Internet site (URL: http://www.usgs.gov). Data relevant to the residential sector are included in this document.

- The Institute of Real Estate Management (IREM) publishes a variety of reports/analyses of certain parts of the US housing sector. These include *the Income*

Expenses Analysis: Conventional Apartments, the *Income and Expense Analysis: Federally Assisted Apartments*, and the *Expense Analysis: Condominiums, Cooperatives and PUD's.* Information from these reports has not been included in this document, principally because apartments and condominiums represent a relatively small proportion of the total US housing stock.

5.1.2 Overview of the Residential Sector

The overview of the residential sector presented in this section of the document expands upon that which is presented in Chapter 3 of this document. This section examines the total size of the US residential sector, and how the housing stock is divided between the different types of structure, such as single-family housing, apartments, and mobile homes. It also examines a number of key characteristics of the housing sector, such as the age, size, and geographic distribution of housing. A number of figures are then presented which indicate how the residential sector is changing over time. Finally, some comparisons between site-built and manufactured housing are made.

Data from the *1995 American Housing Survey Current Housing Reports H150/95RV* have been used to generate Figure 5-1. Figure 5-1 shows that the total number of housing units in the US in 1995 numbered approximately 110 million, of which approximately 66 percent were single-family (one unit) houses. Of the 72.4 million single-family homes, approximately 90 percent were detached units. Mobile homes and trailers represented approximately seven percent of the total housing stock. A more detailed breakdown of homes in the US, by number of units in the structure, is shown in Figure 5-2. Reference to the figure indicates that there were significantly more multi-unit structures containing only two to four units compared with structures containing either five to nine units, 10 to 19 units, 20 to 49 units, or 50 or more units.

Figure 5-3 indicates the geographic distribution of occupied housing by type/number of units and census region in 1995. Reference to the figure shows that while there is a significantly larger number of single-family homes in the south and mid-west census regions, compared with in the north and west, multi-unit housing is more evenly distributed across all four census regions. Approximately half of all mobile homes or trailers are located in the south census region. A description of the census regions, as defined by the US Bureau of the Census, is provided in Appendix E of this document. Data from the *American Housing Survey* also indicate that approximately half of all homes in the US are in city locations, with the remaining half relatively evenly distributed between town, suburban and rural/open country locations.

Figure 5-4 and Figure 5-5 are based upon data from the *1995 American Housing Survey*, and show some of the key characteristics of homes in the US. Reference to Figure 5-4, which shows the age structure of the housing stock, indicates that approximately seven percent of houses are less than five years old, and approximately nine percent are greater than 75 years old. The highest number of houses were built between the years 1960-1969, with the median age between these years. Figure 5-5 shows the size characteristics of occupied detached single-family homes and mobile homes in 1995. The figure indicates that the median size was (161 square meters) 1,732 square feet. Comparison with 1993 data indicates that the median size has remained relatively stable (160 square meters/1,725 square feet in 1993). A comparison of median unit size across the four census regions indicates that in 1995, the median unit area was higher in the northeast and mid-west compared with the south and west.

Figure 5-6 is based upon data from the EIA report *Housing Characteristics 1993* and shows the number of households with various types of external wall construction. Reference to the figure shows that brick, wood and siding predominate, except in the west census region, where wood and stucco dominate. There is comparatively little use of other wall materials such as concrete or block-work across all census regions. Similar data for type of foundation construction (not presented graphically in this document), indicates that approximately 33 percent of all occupied detached single-family homes have full basements, 12 percent have partial basements, 26 percent have crawl spaces, 27 percent have concrete slabs/rafts, and the remainder have other types of foundation.

Figure 5-7, Figure 5-8 and Figure 5-9 are based upon data from the *Statistical Abstract of the United States 1997*, and show how the residential sector has been changing since 1980. All three figures indicate that the rate of change in the size of the housing sector, measured as a function of privately-owned housing units started, is modulated by the business cycle, which has been discussed in Chapter 3 of this document.

Reference to Figure 5-7, which shows the number of new privately-owned housing units started, indicates that a peak rate of approximately 1.8 million new units per year was reached in the mid 1980's, but that this output level declined in the early 1990's to approximately 1.0 million units per year, before starting to recover more recently. This trend is reflected both in the single-family and multi-unit housing markets. However, the recovery in the multi-unit market since the early 1990's has been significantly slower than that in the single-family-housing market.

This trend is also reflected in Figure 5-8, which shows the number of new privately financed, non-furnished rental apartments with greater than five units completed as a percentage of total privately owned units started in the US, for the US as a whole, and how this percentage is broken down by census region. However, it appears that apartment construction in the south and east is more heavily influenced by the business cycle than that in the northeast and mid-west, despite the similarity in total number of apartments in each census region (refer to Figure 5-3). In all regions, there has been a significant decline in the percentage of new apartments placed as a function of total new private housing in the US. Therefore, it would appear that the relative importance of apartment building in the residential sector has declined since the mid-1980's. For single-family housing, data showing how the total number of new units placed varies between the different census regions have not been located. However, this information may be available from USBC for a fee.

Figure 5-9 shows the number of mobile homes placed for residential use as a percentage of total new privately owned units started in the US, and how this percentage is distributed within the four census regions. Reference to the figure indicates that the mobile home market has recovered its share of the private housing market which was lost during the mid 1980's, but that mobile homes placed still only represent approximately 20 percent of all private housing constructed. In addition, any changes in the market appear to be occurring principally in the south census region, where approximately half of all mobile homes are located, as opposed to the other three census regions, where the market appears to be relatively stable.

Finally, Figure 5-10, which is based upon data from the Manufactured Housing Institute, shows the number of manufactured housing units shipped and number of new mobile homes placed in the US as a percentage of new privately owned housing units started. Reference to the figure indicates that manufactured housing has increased its market share since 1986, and in 1996 represented approximately 24 percent of all new units placed. The figure also shows that the majority of manufactured homes are mobile homes. Manufactured housing is clearly a significant element of the US housing market.

The figures presented in this section show that single-family housing represents approximately two-thirds of total US homes, and accounts for approximately three-quarters of all new privately owned housing starts in the US. In Chapter 3, Figure 3-15 showed that there is an upward trend in constant dollar construction costs for residential buildings. We would also expect this trend to be reflected in the median sales price of single-family homes in the US.

Figure 5-11, which is based upon data from the *Statistical Abstract of the United States 1997*, shows the median sales price of new single-family homes in the US. Sales prices have been adjusted to a 1992 base year, using a price index for personal consumption expenditures from the *Statistical Abstract*. Reference to the figure indicates that sales prices, like construction costs, tend to be rising in the residential sector. The most significant fluctuations in single-family sales prices have occurred in the northeast and west census regions, while in the south and mid-west, prices have been more stable.

Part A and Part B Table 5-1 of are based on data from the Manufactured Housing Institute. They show the comparative costs of site built versus manufactured housing (based upon the price of the structure) between 1990 and 1996. Although these data have not been adjusted to a common base year, they indicate that there are a similarities in cost growth between the site built and manufactured housing industries. These data suggest that the cost per square meter (foot) of manufactured homes is significantly lower than that of site built homes. However, these figures should be viewed with caution, as it is difficult to assess whether a like-for-like comparison is necessarily being made.

Figure 5-1. Size of US Housing Sector by Type of Structure: 1995

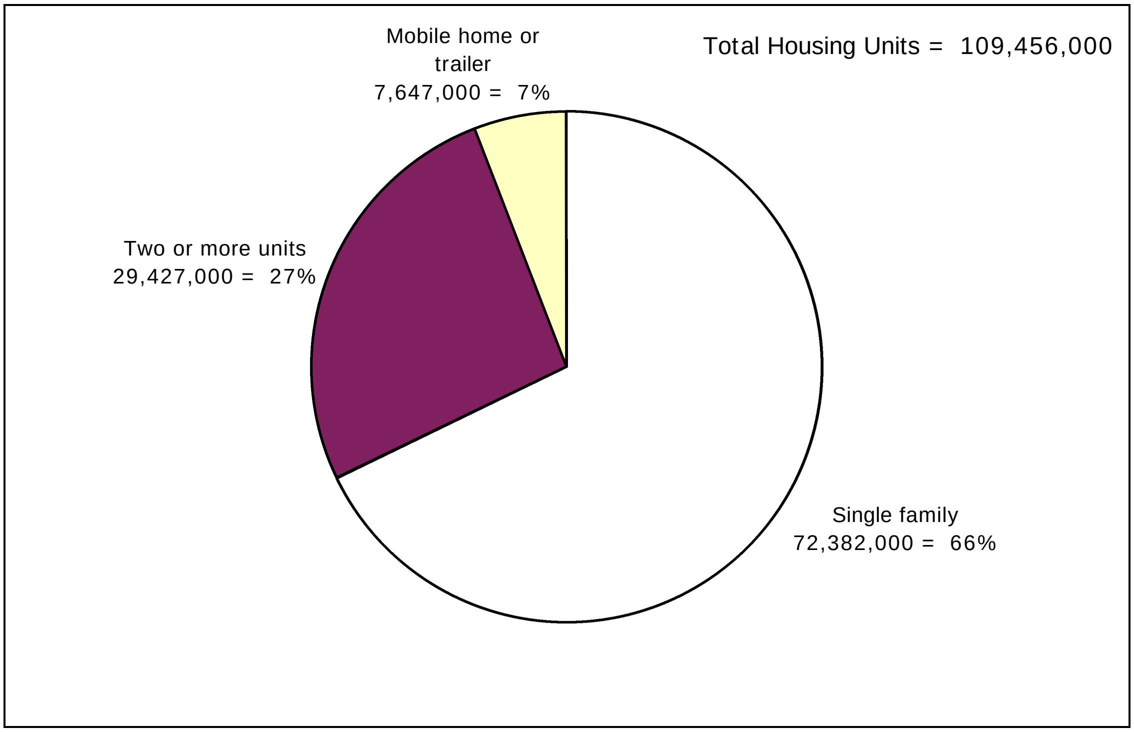


Figure 5-2. Total US Housing - Detailed Description of Types of Structure: 1995

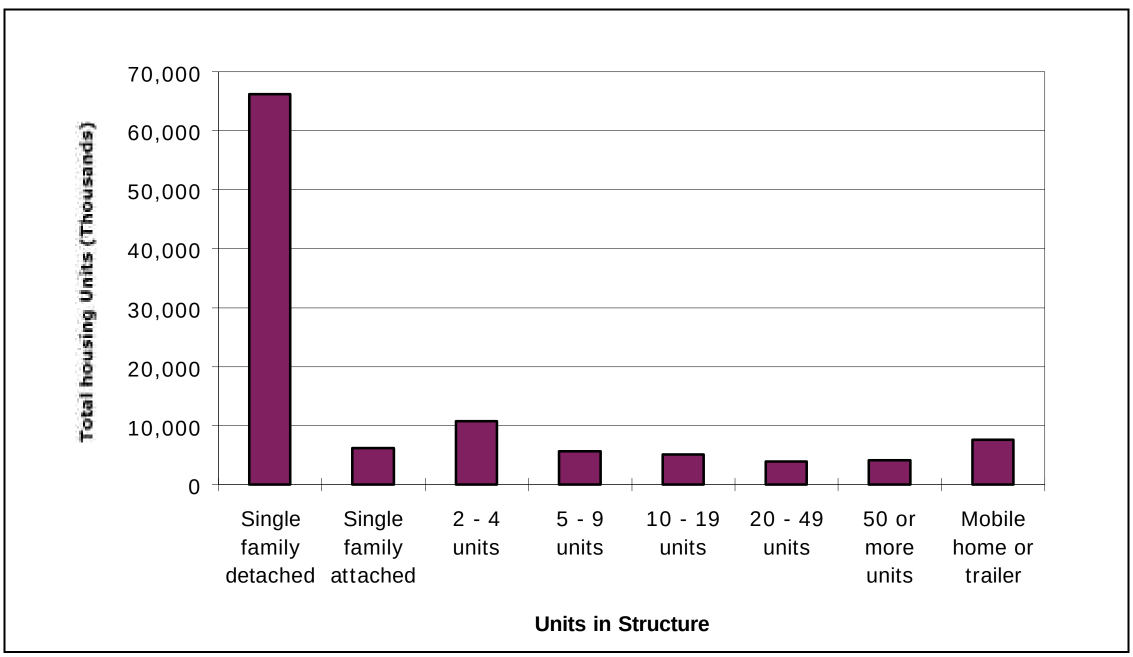


Figure 5-3. Occupied Housing Units by Census Region: 1995

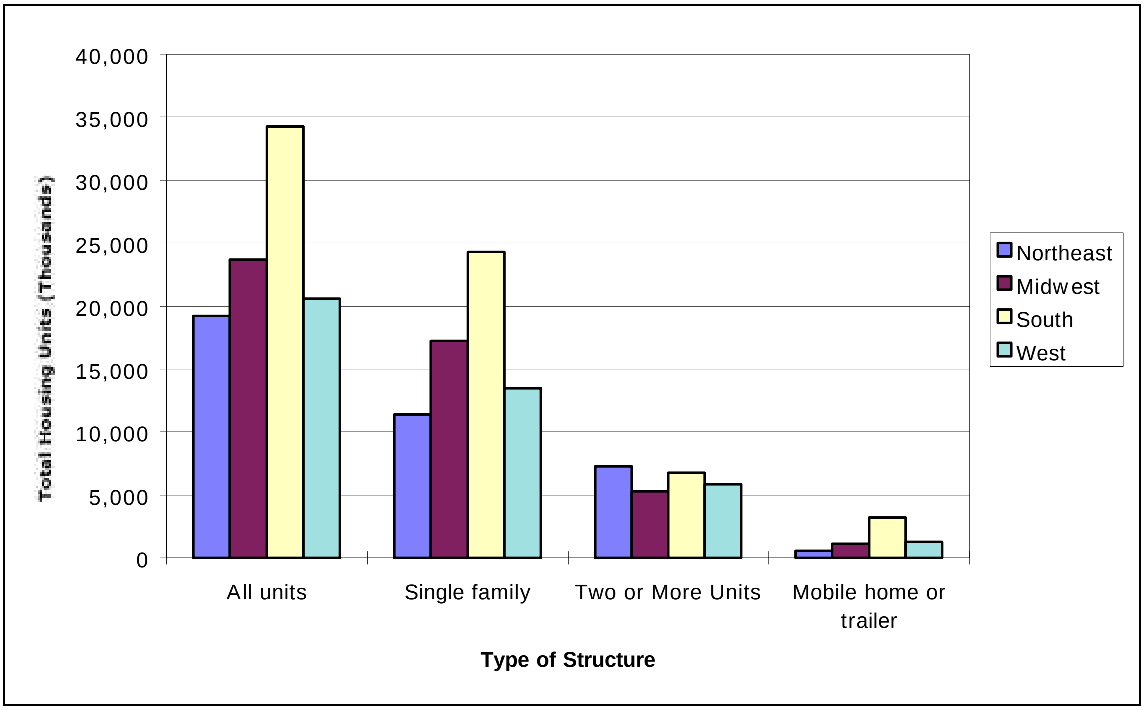


Figure 5-4. Total Housing Units by Age of Structure: 1995

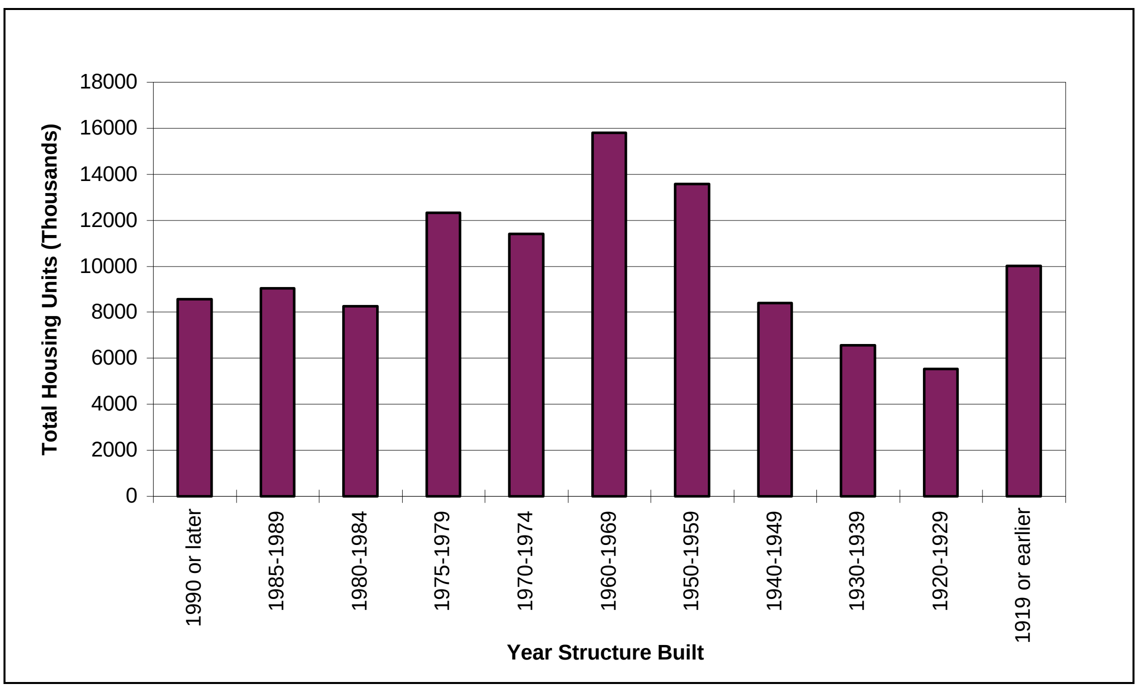


Figure 5-5. Size of Occupied Detached Single Family Homes and Mobile Homes: 1995

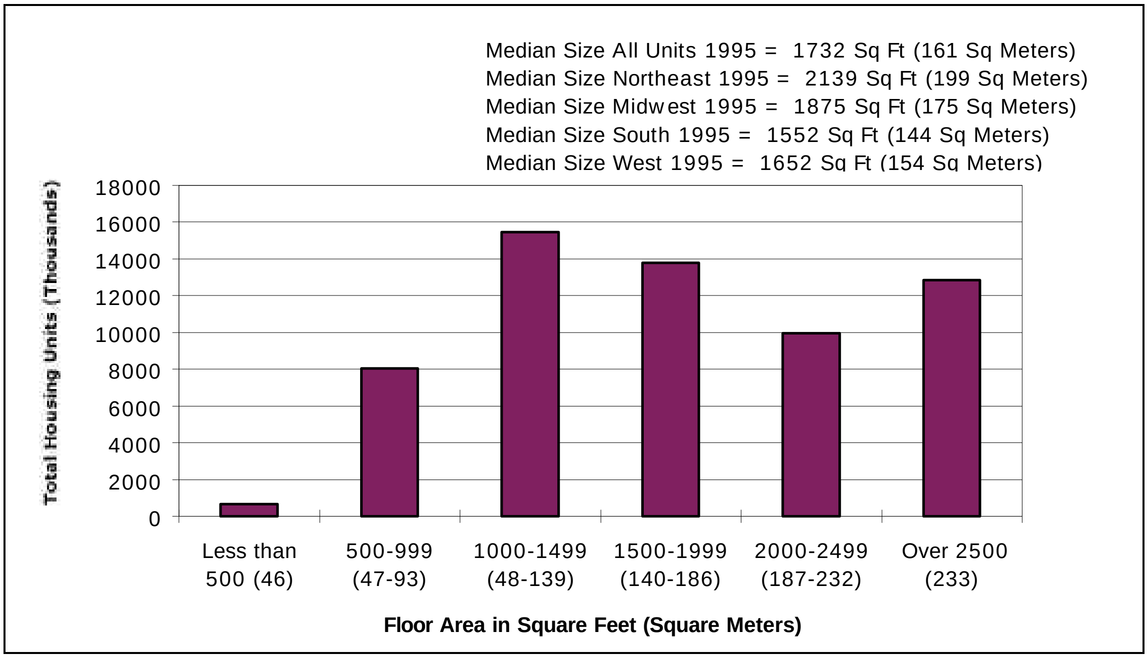


Figure 5-6. External Wall Construction (All Households): 1993

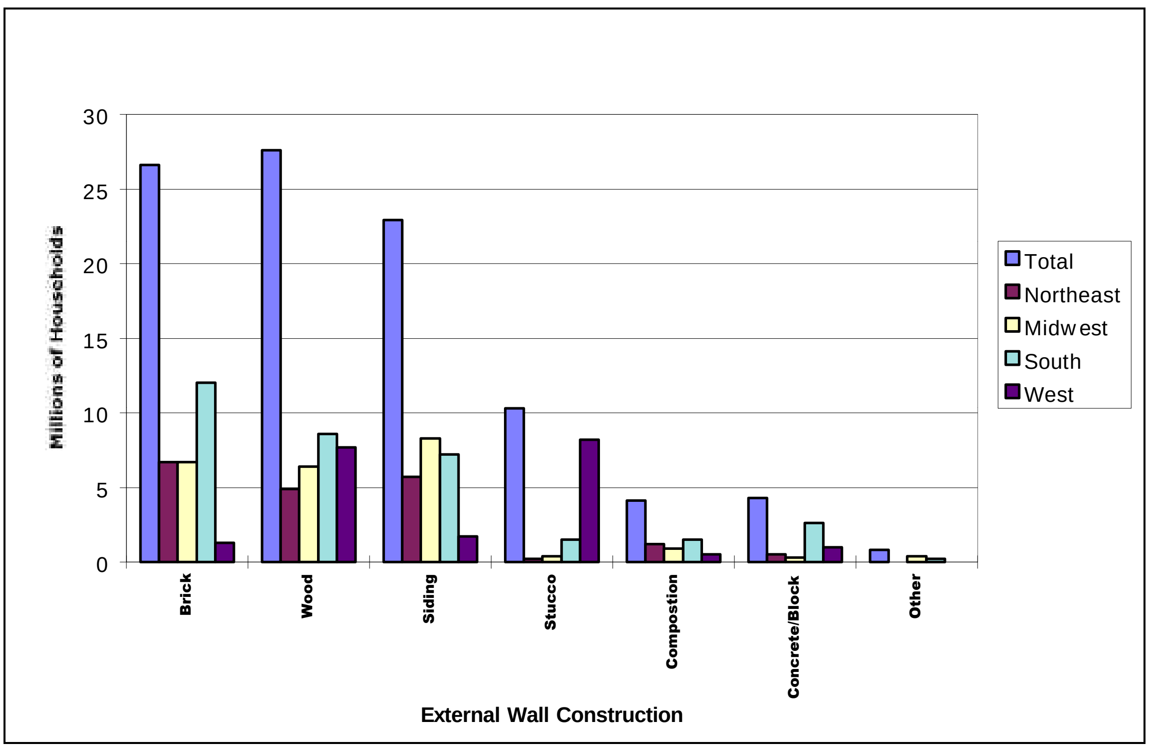


Figure 5-7. New Privately-Owned Housing Units Started

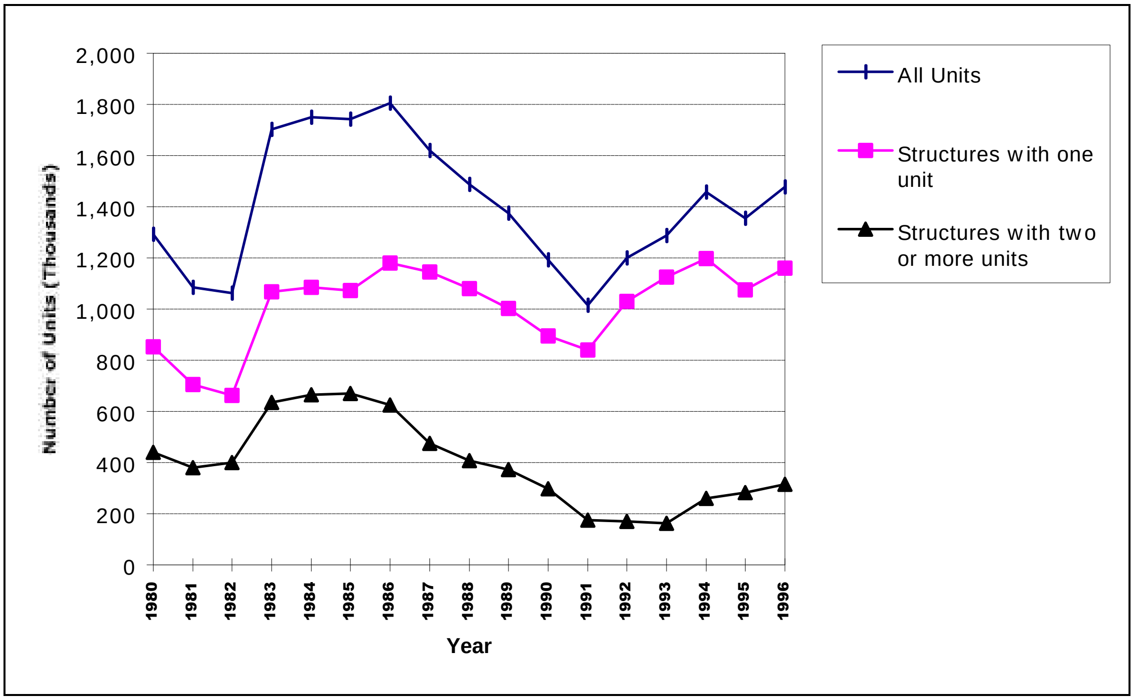


Figure 5-8. New Apartments Completed as a Percentage of Total New Privately-Owned Housing Units Started

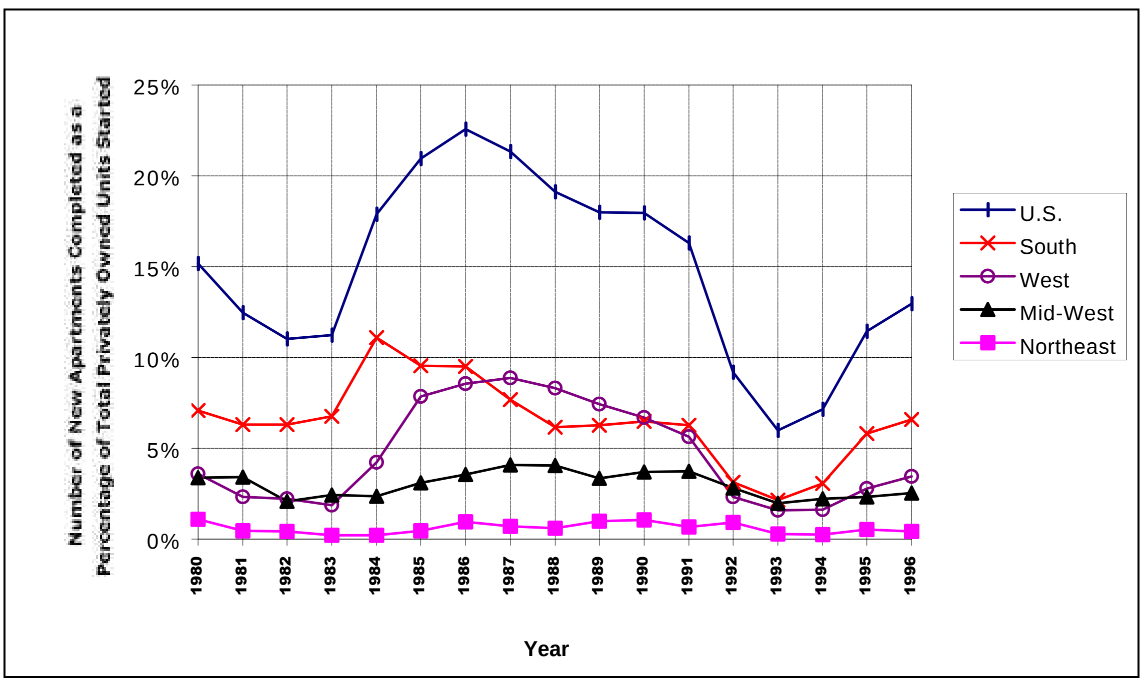


Figure 5-9. New Mobile Homes Placed as a Percentage of Total New Privately-Owned Housing Units Started

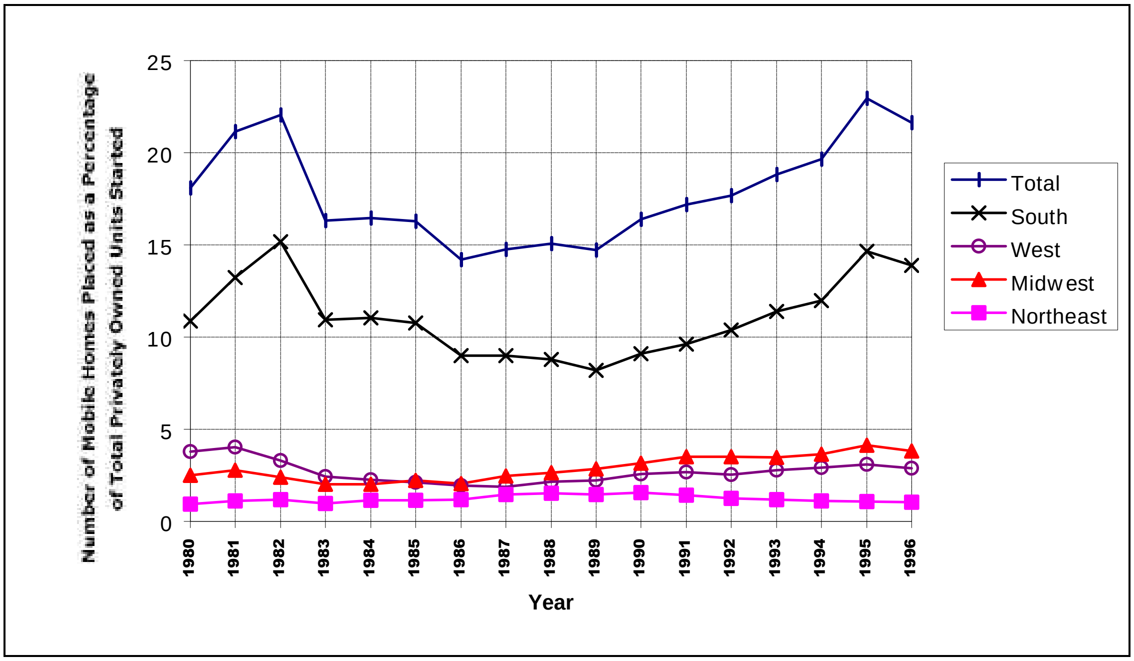


Figure 5-10. Manufactured Housing Shipped and New Mobile Homes Placed as a Percentage of New Privately-Owned Housing Started

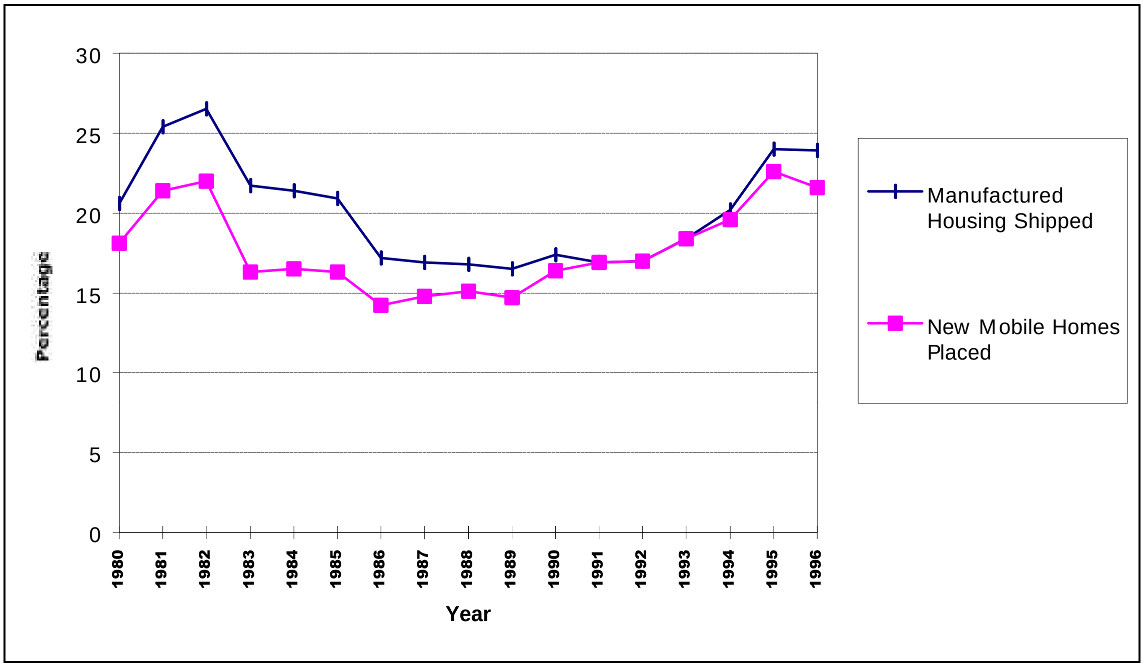


Figure 5-11. Median Sales Price of New Privately-Owned Single Family Housing

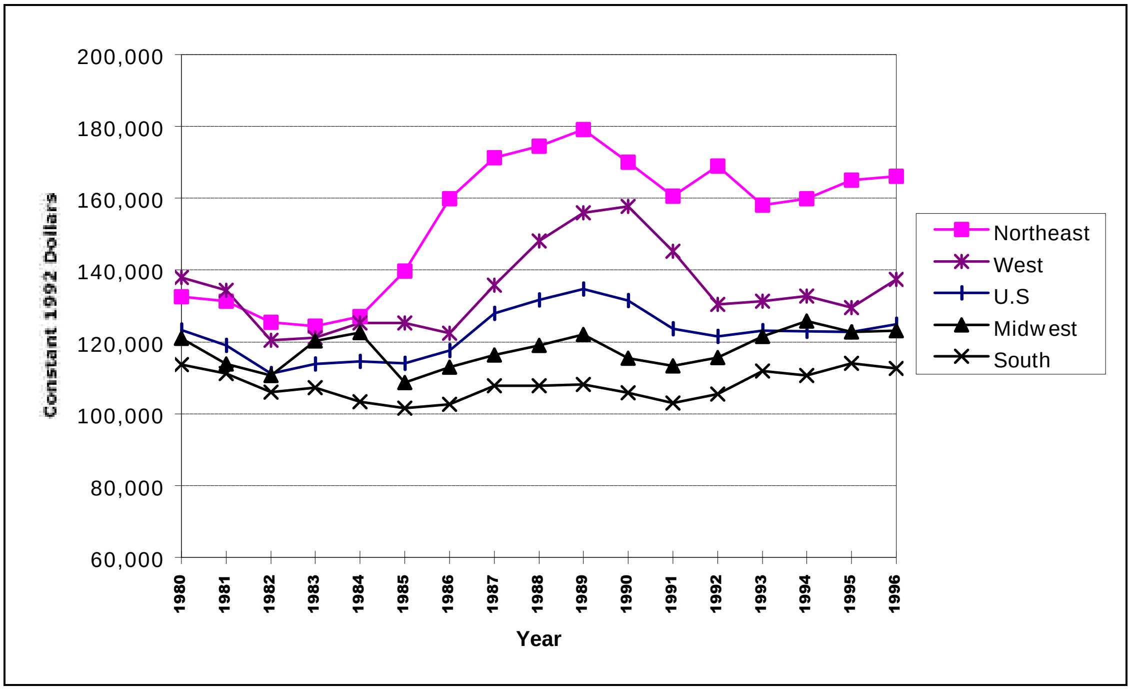


Table 5-1. Comparative Costs of Site-Built and Manufactured Housing

Part A: Dollars per Square Foot

TYPE OF HOUSING	COST (Dollars/Square Foot)						
Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*
Manufactured Housing	23.07	22.61	22.63	23.55	25.19	26.79	27.83
Site Built Housing	54.80	53.20	51.59	52.88	54.65	56.28	58.66

Part B: Dollars per Square Meter

TYPE OF HOUSING	COST (Dollars/Square Meter)						
Year	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*
Manufactured Housing	248	243	243	253	271	288	299
Site Built Housing	590	572	555	569	588	606	631

5.2 Baseline Measures for the Residential Sector

This section of the document describes in detail the baseline measures for operations, maintenance, and energy costs in the residential sector. In addition, it also considers energy conservation measures within the residential sector.

5.2.1 Baseline Measures for Operations Costs

In Section 3.4 of this document, a general definition of operations is provided, while in Section 4.1.1 and 4.1.2, the components within this general definition are described in detail. To recap, baseline measures for operations costs will consider *water consumption*, *domestic waste*, and *other operations costs*.

Data from the **American Housing Survey** 1993 and 1995 have been used to generate Figure 5-12, which gives an overview of the comparative monthly costs for operations, maintenance and energy on a per household basis for 1993 and 1995. Reference to Figure 5-12 shows that while median monthly water and trash costs are lower than other operations components, such as insurance and taxes, as well as routine maintenance and energy costs, they are still significant. The figure shows that the median monthly cost for water was $25 in 1995 (a $2 increase since 1993). Other data from the **American Housing Survey** shows that the median cost for those houses which were built within the last four years was $27 in 1995. Within the four census regions, the highest cost was in the west ($30 median), and the lowest cost was in the mid-west ($23 median). Water costs in urban areas were slightly higher than those in rural areas ($26 compared with $23). These 1995 water figures are based upon 48,826,000 occupied units of the total 97,693,000 in the US, where water is paid for separately. In Section 3.4 of this document, Figure 3-18 showed how the total personal consumption expenditures for water and sanitary services have increased since 1980, to a value of approximately $30 billion in 1992. This figure, which is based upon different source data, appears to be consistent with the **American Housing Survey** data ($23/month x 12 months x 97,693,000 = $27 billion, based upon median monthly water cost).

Similar figures for median trash costs (where these are paid for separately) are $15 in 1995 (a $1 increase since 1993). In 1995, the median trash costs for housing units constructed within the last four years was $16. Within the four census regions, the highest cost was in the mid-west ($17), and the lowest cost was in the mid-west and south ($14). Similar comparisons between urban and rural locations indicate that median urban trash costs are $16 compared with $14 for rural locations.

Table 5-2, which is based upon 1990 data from the US Geological Survey, examines freshwater consumption by the residential sector in more detail. It shows total water withdrawals by the domestic/residential sector, both from the public water supply, and from self-supplied sources. The table indicates that self-supplied withdrawals are modest compared to those provided by the public supply system.

Figure 5-12. Monthly Household Costs

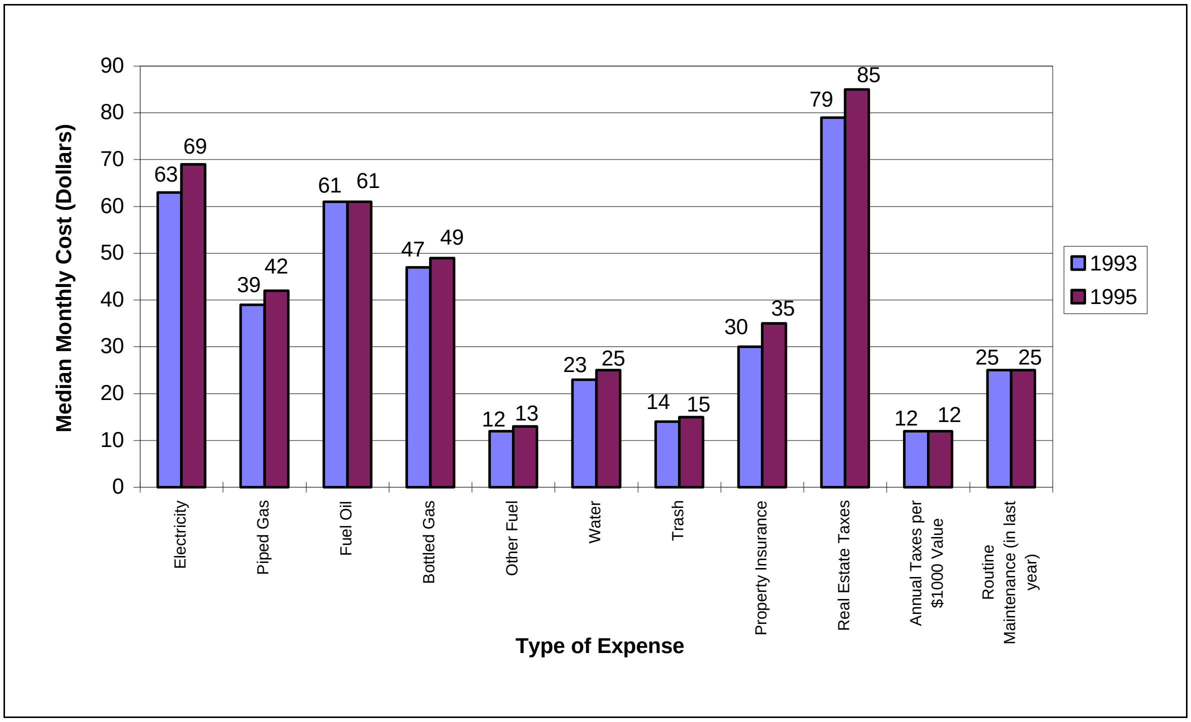


Table 5-2. Domestic Freshwater Use: 1990

Part A: Million Gallons per Day

	Self Supplied					Public Supply				
		Source								
Region	**Population in Thousands**	**Ground Water (Mgal/Day)**	**Surface Water (Mgal/Day)**	**Total (Mgal/Day)**	**Per Capita Use (Gal/Day)**	**Population Served in Thousands**	**Water Deliveries (Mgal/Day)**	**Per Capita Use (Gal/Day)**	**Water Deliveries (Mgal/Day)**	**Consumptive Use (Mgal/Day)**
New England	2,220	169	0	169	76	10,600	713	67	882	124
Mid Atlantic	6,470	396	0	396	61	35,100	3,270	93	3,660	415
South Atlantic-Gulf	6,990	659	0	659	94	27,700	2,790	100	3,450	815
Great Lakes	3,820	282	1	283	74	17,600	1,400	80	1,690	235
Ohio	5,390	352	8	360	67	16,500	1,050	64	1,410	191
Tennessee	883	56	0	56	63	3,030	252	83	308	43
Upper Mississippi	4,340	371	0	371	85	16,900	1,530	90	1,900	401
Lower Mississippi	1,230	90	0	90	74	5,940	698	117	788	151
Souris-Red-Rainy	211	22	0	22	105	461	45	99	68	25
Missouri Basin	1,700	138	1	139	82	8,350	925	111	1,060	400
Arkansas-White-Red	1,380	118	0	118	85	6,870	705	103	823	267
Texas-Gulf	700	79	0	79	113	14,500	2,060	142	2,140	760
Rio Grande	311	23	0	23	75	1,920	282	147	305	142
Upper Colorado	137	10	0	10	74	488	83	169	93	34
Lower Colorado	363	37	2	39	108	4,380	722	165	761	363
Great Basin	145	13	3	15	106	2,040	432	212	448	165
Pacific Northwest	1,830	212	8	220	120	7,080	960	136	1,180	186
California	4,200	210	103	313	74	25,200	3,690	146	4,000	1,020
Alaska	174	6	1	7	40	376	30	79	36	4
Hawaii	53	9	1	10	189	1,060	126	119	136	68
Caribbean	208	4	5	8	40	3,420	163	48	171	74
Total	42,800	3,260	132	3,390	79	210,000	21,900	105	25,300	5,880

Part B: Million Liters per Day

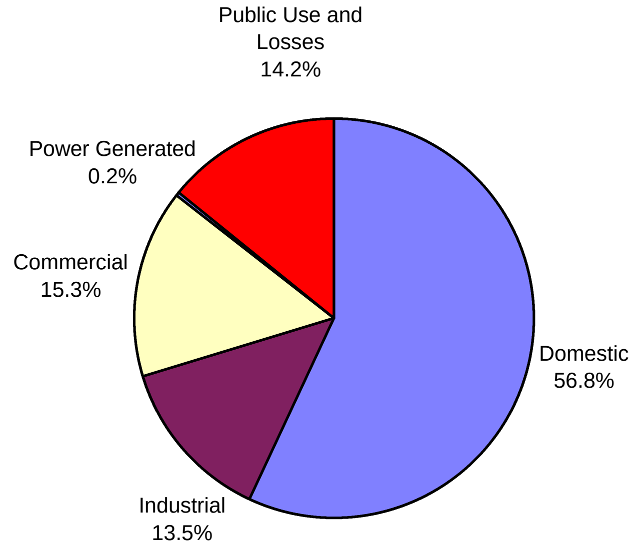
	Self Supplied					Public Supply				
		Source								
Region	Population in Thousands	Ground Water (Mliter/Day)	Surface Water (Mliter/Day)	Total (Mliter/Day)	Per Capita Use (Liter/Day)	Population Served in Thousands	Water Deliveries (Mliter/Day)	Per Capita Use (Liter/Day)	Water Deliveries (Mliter/Day)	Consumptive Use (Mliter/Day)
New England	2,220	640	0	640	288	10,600	2,699	254	3,339	469
Mid Atlantic	6,470	1,499	0	1,499	231	35,100	12,378	352	13,855	1,571
South Atlantic-Gulf	6,990	2,495	0	2,495	356	27,700	10,561	379	13,060	3,085
Great Lakes	3,820	1,067	4	1,071	280	17,600	5,300	303	6,397	890
Ohio	5,390	1,332	31	1,363	254	16,500	3,975	242	5,337	723
Tennessee	883	212	0	212	238	3,030	954	314	1,166	163
Upper Mississippi	4,340	1,404	0	1,404	322	16,900	5,792	341	7,192	1,518
Lower Mississippi	1,230	341	0	341	280	5,940	2,642	443	2,983	572
Souris-Red-Rainy	211	83	0	83	397	461	170	375	257	95
Missouri Basin	1,700	522	4	526	310	8,350	3,501	420	4,013	1,514
Arkansas-White-Red	1,380	447	0	447	322	6,870	2,669	390	3,115	1,011
Texas-Gulf	700	299	0	299	428	14,500	7,798	538	8,101	2,877
Rio Grande	311	87	0	87	284	1,920	1,067	556	1,155	538
Upper Colorado	137	37	1	38	280	488	314	640	352	129
Lower Colorado	363	140	8	148	409	4,380	2,733	625	2,881	1,374
Great Basin	145	49	10	57	401	2,040	1,635	803	1,696	625
Pacific Northwest	1,830	803	29	833	454	7,080	3,634	515	4,467	704
California	4,200	795	390	1,185	280	25,200	13,968	553	15,142	3,861
Alaska	174	23	3	26	151	376	114	299	136	14
Hawaii	53	32	5	37	715	1,060	477	450	515	257
Caribbean	208	14	17	31	151	3,420	617	182	647	280
Total	42,800	12,340	500	12,833	299	210,000	82,900	397	95,771	22,258

Figure 5-13 shows that the domestic sector accounts for 56.8 percent of all deliveries from the public water supply. Public use and losses account for a further 14 percent of all water deliveries.

The USGS data show that total water deliveries in the residential sector total 108,592 million liters (28,690 million gallons) per day with consumptive use totaling 22,256 million liters (5,880 million gallons) per day. Thus over 75 percent of all water delivered to the residential sector is returned to the public supply to be treated and re-used. USGS estimates per capita use from the public supply to be 397 liters per (day 105 gallons per day) This is consistent with data previously presented. Based upon a cost of $0.79 per thousand liters ($3 per thousand gallons), one would expect a typical monthly household water cost to be approximately equal to $25[19]. Assuming that residential water consumption has accounted for a similar proportion of total public supply deliveries since 1980, when total annual deliveries were 129 billion liters (34 billion gallons), it is reasonable to assume that residential consumption is steadily increasing, given that total public supply deliveries had risen to 155 billion liters (41 billion gallons) in 1990.

[19] The calculation is based upon $3.00 per thousand gallons and the average per capita usage for the population of the US divided by the total number of households in the US as follows: [(3/1000)x105x30x(254,159,000/97,6993,000)] = $25 per month.

Figure 5-13. Deliveries from Public Water Supply: 1990



A range of data relating to residential waste, which is one constituent of municipal solid waste, are available from the Environmental Protection Agency (EPA) (URL: http://www.epa.gov). A good source of information is the **Municipal Solid Waste Factbook**, which is available in electronic form from the EPA Internet site. Data from this Factbook show an upward trend both in the total volume of waste generated, and the per capita generation rate since 1980. Total municipal solid waste generation has risen from 138.2 million metric tons (152.4 million tons) in 1980 to 189.7 million metric tons (209.1 million tons) in 1994, with a corresponding increase in per capita generation from 1.68 kilograms (3.7 pounds) per person per day in 1980 to 2.00 kilograms (4.4 pounds) per person per day in 1994. This upward trend is predicted to continue in the future. Clearly, the residential sector has a large part to play in reducing household waste. This issue will be addressed in more detail in a future report on National Construction Goal 5 (50% Less Waste and Pollution).

5.2.2 Baseline Measures for Maintenance Costs

In Section 3.4 of this document, a general definition of 'maintenance' is provided, while in Sections 4.1.1 and 4.1.2, the components included within this general definition are described. In addition, Section 3.2 of this document explains in detail what is included in the **Current Construction Reports Series C50** (*Expenditures for Residential Improvements and Repairs*), which is the primary source of information for this particular section of the document.

Data from the **C50 Series** have been used to generate Figure 5-14, Figure 5-15, Table 5-3, Table 5-4, and Table 5-5, which are described below.

Figure 5-14 shows expenditures for all residential properties (i.e., single and multi-unit structures) in constant 1992 dollars between 1980 and 1996 for additions and alterations, major replacements (together these are referred to as 'improvements'), and maintenance and repairs, as a series of line traces. Reference to Figure 5-14 indicates that total expenditures (i.e., improvements plus maintenance and repairs) increased significantly between 1980 and 1985, but since that time have remained relatively constant at about $110 billion per annum in constant 1992 dollars. However, when the individual components of this total are examined, it is apparent that expenditures on improvements are rising steadily, while maintenance and repair expenditures appear to be falling. Maintenance and repair expenditures have fallen from approximately $55 billion in 1990 to approximately $35 billion in 1996.

If we examine Figure 5-15, which shows the total dollar expenditure per household on maintenance and repairs and improvements between 1990 and 1996 (based upon data from the **Housing Vacancy Survey**, which produces data that are slightly different from the **American Housing Survey** data regarding total number of housing units), we see that the line trace is very similar to that for all households combined. This is because the rate of change of the size of the housing sector is relatively slow, hence it does not modify the trend in the line trace appreciably. Given that this is also the case for the different types of housing unit within the US housing sector (i.e., single or multi-unit), it is reasonable to assume that the trends shown in Figures 5-14 and Figure 5-16 are also representative of changes in expenditures on a per household basis between 1990 and 1996. It is also worth noting that the figures for median maintenance and repair expenditures per household provided by the 1993 and 1995 **American Housing Survey** are consistent with the **C50 Series** data, even though the definitions used in the survey are slightly different.

Figure 5-16 compares total expenditures for maintenance and repair and improvements for owner occupied single unit structures with those for all other properties. Reference to the figure indicates that while total expenditures for single unit structures appear to have risen, those for all other properties appear to have fallen since 1990. In addition, given that the approximate ratios of single unit properties to all other properties is approximately 1:2 for total expenditures, which is the same ratio as that for total number of households in the US, it is evident that the total per household cost for maintenance and repair is of the same order of magnitude for both single unit and other properties. Table 5-3 shows the source data used to derive Figure 5-15 and Figure 5-16.

Figure 5-14. Expenditures by All Residential Properties for Improvements and Maintenance and Repairs

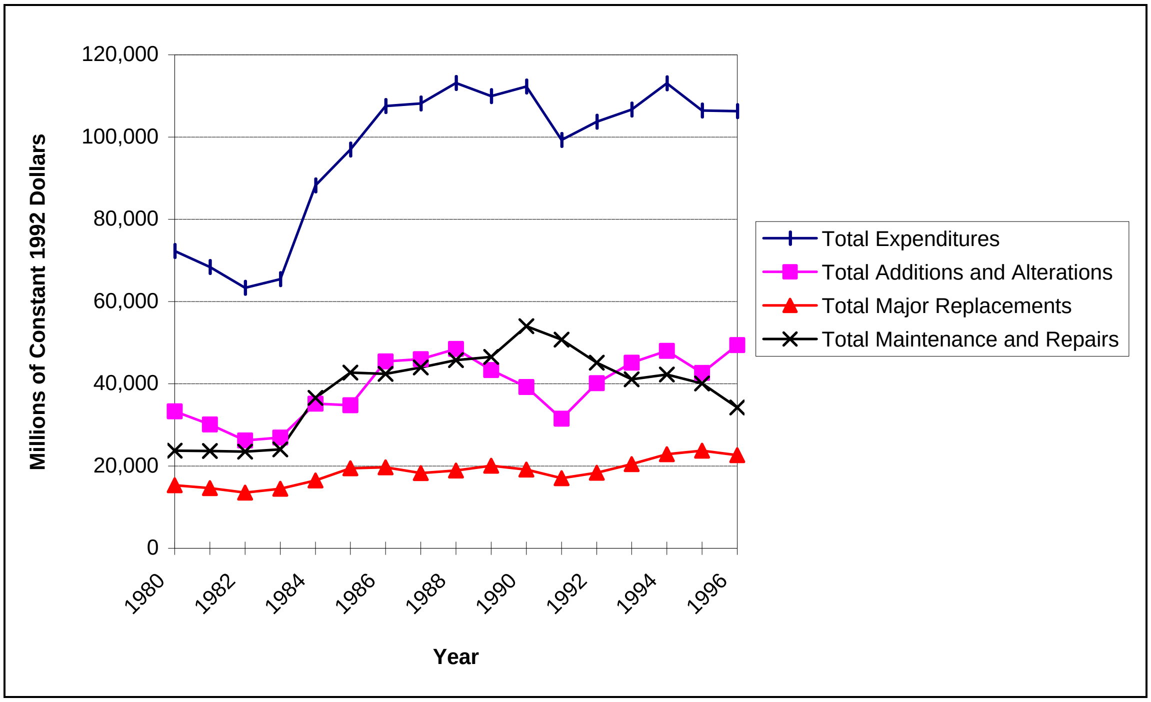


Figure 5-15. Total Expenditures per Household for Improvements and Maintenance and Repairs

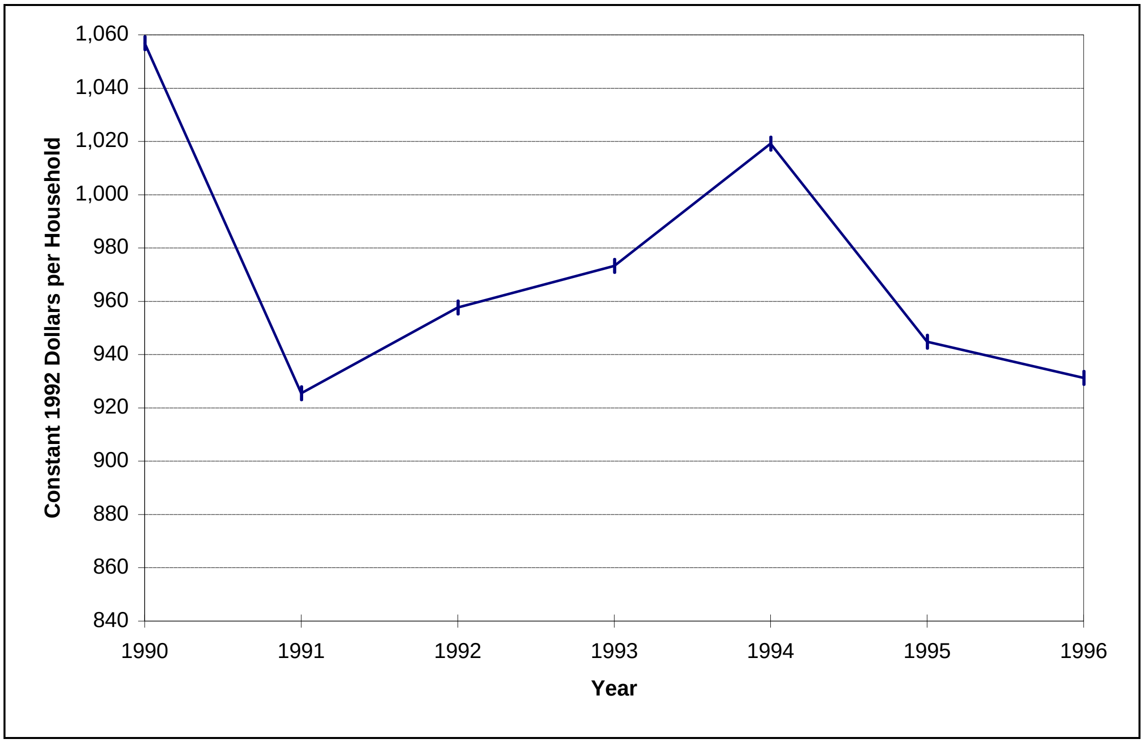


Figure 5-16. Total Expenditures for Improvements and Maintenance and Repairs by Type of Unit

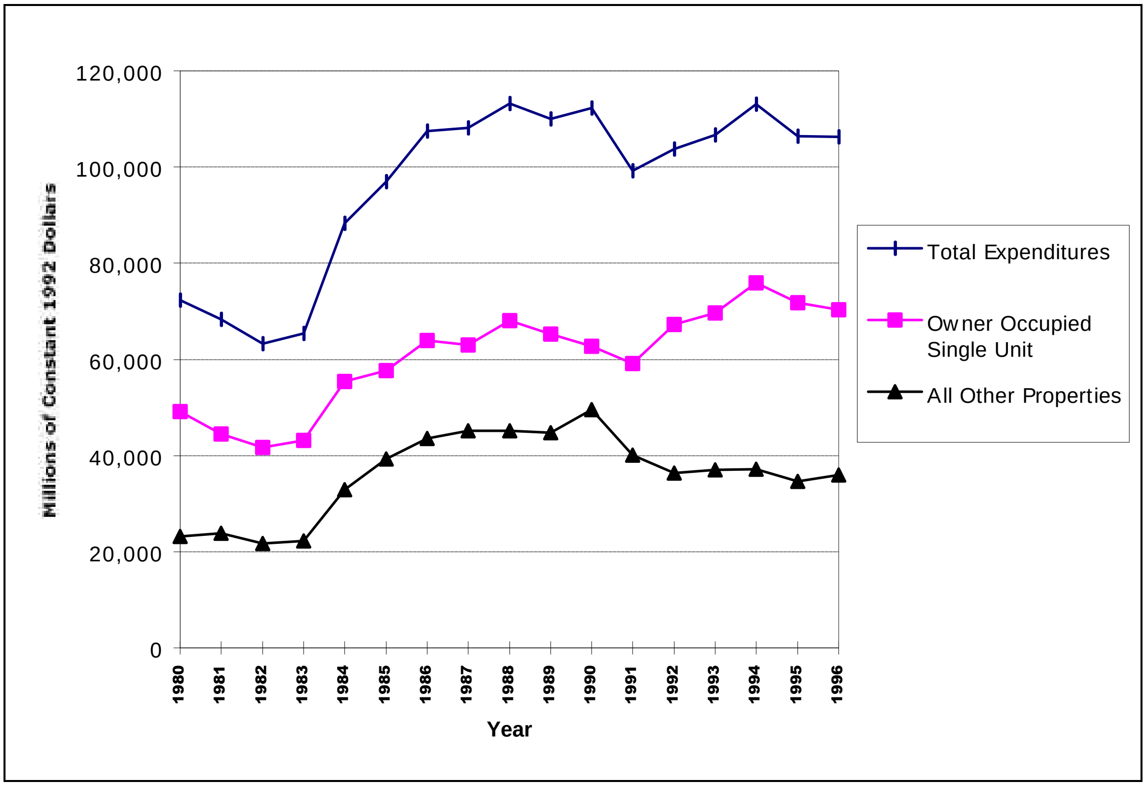


Table 5-3. Summary of Expenditures for Additions and Alterations, Major Replacements, and Maintenance and Repairs: 1980 to 1996

Expenditures in Millions of Constant 1992 Dollars	Total Expenditures			Additions and Alterations All Units				Major Replacements All Units	Maintenance and Repairs All Units
	All Units	One Unit with Owner	Other Properties	To Structures			Outside Structures		
				Total	Additions	Alterations	Total		
1980	72,334	49,142	23,192	33,305	6,530	17,472	9,304	15,323	23,707
1981	68,368	44,546	23,821	30,111	4,667	17,622	7,822	14,625	23,632
1982	63,317	41,631	21,686	26,246	3,692	14,974	7,581	13,570	23,500
1983	65,414	43,159	22,255	26,900	6,289	15,490	5,121	14,458	24,056
1984	88,277	55,383	32,894	35,195	7,599	18,325	9,271	16,530	36,551
1985	96,963	57,672	39,290	34,760	4,791	21,260	8,711	19,490	42,712
1986	107,521	63,963	43,558	45,480	8,690	24,964	11,827	19,667	42,374
1987	108,194	63,010	45,185	45,975	10,991	24,887	10,096	18,256	43,963
1988	113,150	68,060	45,090	48,496	12,682	25,405	10,410	18,903	45,750
1989	109,971	65,245	44,726	43,367	7,443	25,211	10,713	20,072	46,531
1990	112,325	62,787	49,539	39,190	9,006	23,060	7,123	19,162	53,973
1991	99,284	59,128	40,155	31,501	8,056	16,365	7,079	17,045	50,737
1992	103,734	67,316	36,418	40,186	6,783	22,700	10,704	18,393	45,154
1993	106,680	69,685	36,996	45,110	12,566	24,409	8,135	20,497	41,074
1994	113,074	75,956	37,118	47,998	9,483	28,185	10,330	22,853	42,223
1995	106,434	71,820	34,614	42,624	7,563	25,629	9,432	23,739	40,071
1996	106,300	70,387	35,911	49,447	11,132	27,809	10,505	22,630	34,222

Table 5-4 compares the distribution of maintenance and repair and improvement expenditures across the four census regions. Table 5-4 shows that the highest total expenditures between 1994 and 1996 were in the south and mid-west, with significantly lower total expenditures in the northeast and west. In the south, this is due both to higher expenditures on maintenance and repairs, and expenditures on improvements compared with other census regions.

Table 5-4. Expenditures by Census Region - All Owner Occupied Single Units

Type of Expenditure (Millions of Constant 1992 Dollars)	Year	Northeast	Midwest	South	West
Total Expenditures	**1994**	16,670	20,450	21,913	16,923
	1995	14,599	19,793	23,001	14,427
	1996	12,671	18,013	23,409	16,295
Maintenance and Repairs	**1994**	5,752	5,214	7,677	5,187
	1995	4,785	5,276	9,268	4,998
	1996	3,744	4,506	6,631	3,796
Improvements	**1994**	10,918	15,237	14,237	11,736
	1995	9,814	14,517	14,162	9,430
	1996	8,926	13,508	16,778	12,499

Table 5-5 examines the changes in expenditures for maintenance and repairs and major replacements, grouped by major job description, between 1993 and 1996. While it is difficult to detect trends over such a relatively short period, the major replacements data suggest that there has been an escalation in expenditures for roofing and siding for owner occupied units in the US. At the same time, maintenance and repair expenditures for roofing and siding appear to be stable or falling. This suggests that there is some linkage between the two data sets, which would be expected.

Figure 5-17, which is based upon data from the 1993 **American Housing Survey**, shows the number of households carrying out repairs over two years by cost category, for selected types of repair. The figure indicates that approximately ten percent of all households carried out some form of roof repair over two years. For more than two-thirds of these houses, the costs of these repairs exceeded $500.

Finally, Figure 5-18, which is based upon data from the **Property Owners and Managers Survey**, compares the use of different types of maintenance program for single-family detached homes. The figure indicates that while 71 percent of all properties handle all maintenance immediately, 10 percent postpone most maintenance. Future survey data will allow us to see how homeowners are changing their approach to maintenance and repair, and whether there is any correlation between type of program in use and maintenance and repair expenditure fluctuations.

Table 5-5. Expenditures by Type of Job - All Owner Occupied Units: 1993 to 1996

Type of Job	Millions of Constant 1992 Dollars			
	1993	1994	1995	1996
Major Replacements - Total	13,987	15,599	17,486	16,699
Plumbing	1,630	1,780	1,903	1,214
HVAC	3,281	2,767	4,778	3,440
Siding	1,151	961	1,006	1,710
Roofing	2,961	3,961	3,980	4,821
Driveways and Walkways	749	860	417	423
Windows	1,810	2,445	2,321	2,803
Doors	944	1,137	972	912
Other	1,462	1,687	2,109	1,377
Maintenance and Repairs - Total	21,801	24,747	25,028	20,060
Painting and Papering	6,731	6,556	6,347	6,703
Plumbing	1,972	2,895	2,174	2,114
HVAC	1,655	1,658	1,612	1,891
Electrical	476	542	586	387
Siding	575	489	559	223
Roofing	2,666	2,398	2,766	1,545
Flooring	762	1,465	1,350	1,011
Windows and Doors	346	840	692	476
Materials to have on hand	1,936	2,231	1,896	2,451
Other	4,681	5,673	7,045	3,259

Figure 5-17. Number of Owner Occupied Households Carrying Out Repairs Over Two Years: 1993

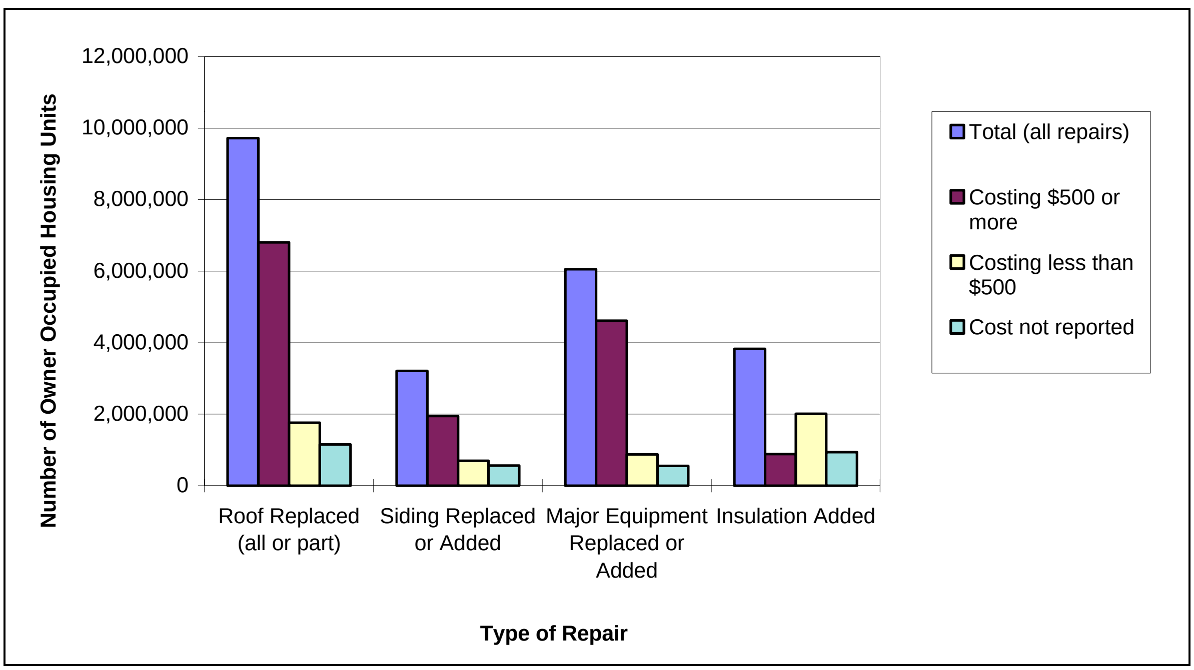
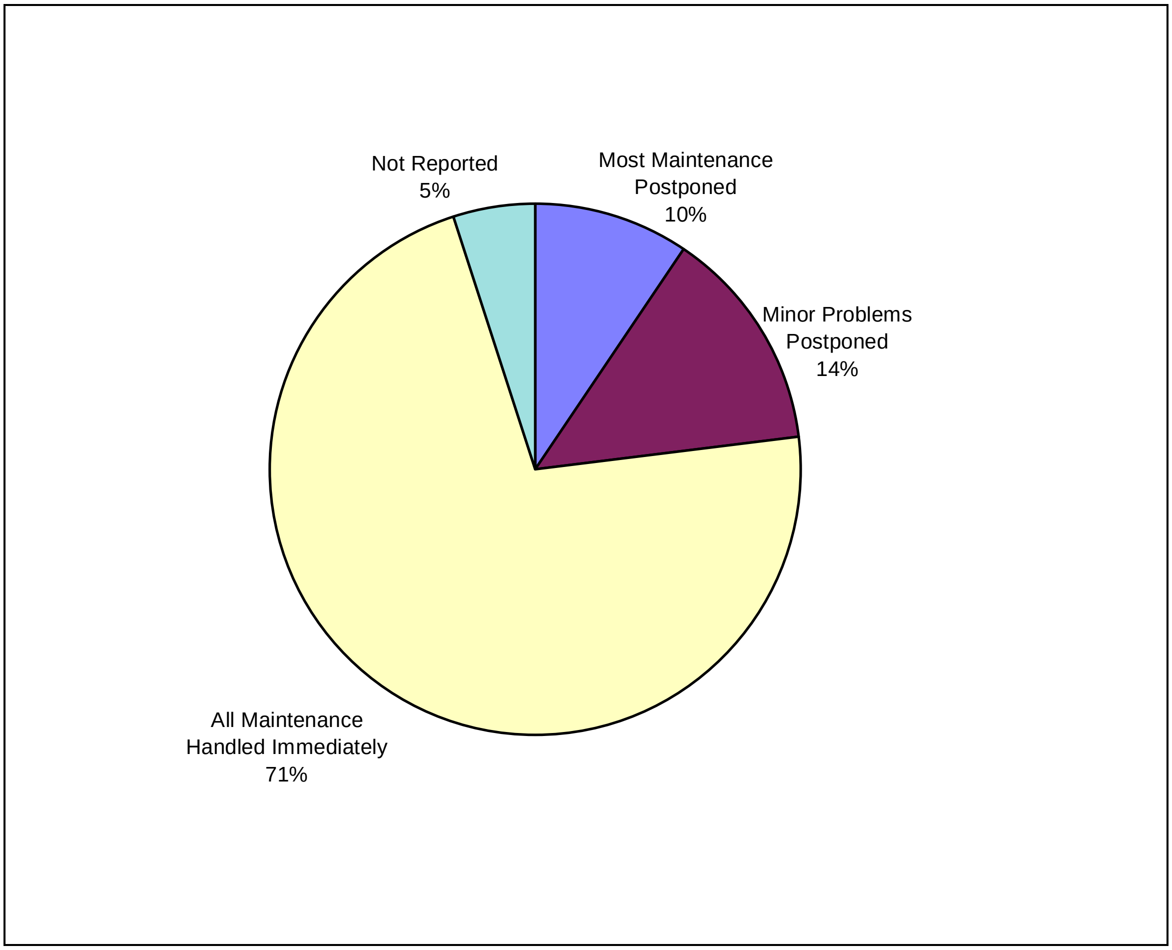


Figure 5-18. Comparison of Maintenance Programs for Single-Family Detached Homes



5.2.3 Baseline Measures for Energy Costs

In Section 3.4 of this document, a general definition of energy is provided, while in Sections 4.1.1 and 4.1.2, the components included within the general definition for the residential sector are described in detail. To recap, baseline measures for energy costs consider energy consumption and expenditures by end-use classification.

Data from the 1993 **Residential Energy Consumption Survey (RECS)** have been used to generate Figures 5-19 through 5-29 and Tables 5-6 through 5-8. Tables 5-6 through 5-8 provide selected source data which have been used to generate the figures in this section.

Figure 5-19 shows the total consumption of energy from all energy sources by end-use for all housing, single-family housing, mobile homes, and multi-family housing. The figure shows that space heating accounts for over 50 percent of all energy consumed by the residential sector.

Figure 3-20, which is presented in Chapter 3 of this document, showed the consumption of energy between 1980 and 1993 for the residential sector. It indicated that the total consumption of energy has increased from around 9.8 quadrillion kilojoules (9.3 quadrillion Btu) to around 10.5 quadrillion kilojoules (10.0 quadrillion Btu) over this time.

Table 5-6. Total Energy Consumption and Expenditures - All Energy Sources

Part A: Energy Consumption and Expenditures in Quadrillion Btu/Billion Dollars

CHARACTERISTICS	Space Heating		Air Conditioning		Water Heating		Refrigerator		Appliances	
	Consumption (quadrillion Btu)	Expenditures (billion dollars)	Consumption (quadrillion Btu)	Expenditures (billion dollars)	Consumption (quadrillion Btu)	Expenditures (billion dollars)	Consumption (quadrillion Btu)	Expenditures (billion dollars)	Consumption (quadrillion Btu)	Expenditures (billion dollars)
Total U.S. Households	5.32	39.67	0.46	11.33	1.83	16.99	0.46	11.98	1.94	43.95
Census Region and Division										
Northeast	1.49	11.39	0.04	1.39	0.43	4.17	0.08	2.66	0.35	10.10
New England	0.40	3.12	0.01	0.24	0.11	1.17	0.02	0.64	0.09	2.60
Middle Atlantic	1.09	8.27	0.03	1.15	0.32	3.00	0.06	2.02	0.26	7.51
Midwest	1.92	12.09	0.08	1.90	0.52	4.06	0.11	2.59	0.50	10.48
East North Central	1.41	8.69	0.05	1.26	0.39	2.84	0.07	1.88	0.35	7.55
West North Central	0.52	3.40	0.03	0.64	0.14	1.22	0.03	0.71	0.15	2.93
South	1.21	11.09	0.31	7.11	0.51	5.89	0.19	4.38	0.73	15.19
South Atlantic	0.56	5.83	0.14	3.46	0.22	3.20	0.09	2.18	0.34	7.71
East South Central	0.25	2.19	0.05	0.97	0.09	1.01	0.04	0.66	0.14	2.38
West South Central	0.40	3.08	0.11	2.69	0.20	1.68	0.06	1.54	0.25	5.10
West	0.70	5.09	0.03	0.92	0.36	2.87	0.09	2.35	0.37	8.18
Mountain	0.28	1.73	0.01	0.37	0.10	0.81	0.02	0.55	0.10	2.04
Pacific	0.42	3.36	0.02	0.56	0.26	2.06	0.06	1.80	0.26	6.13
Largest Populated States										
California	0.27	2.07	0.02	0.53	0.21	1.51	0.04	1.47	0.18	4.92
Florida	0.05	0.88	0.06	1.44	0.04	0.89	0.03	0.78	0.11	2.59
New York	0.51	3.95	0.01	0.50	0.16	1.51	0.02	1.01	0.12	3.76
Texas	0.23	1.85	0.07	1.65	0.12	1.03	0.04	0.97	0.15	3.19
Urban Status										
Urban	4.11	30.17	0.36	9.18	1.50	13.02	0.36	9.70	1.50	34.53
Central City	1.56	11.18	0.13	3.19	0.62	5.05	0.13	3.73	0.54	12.19
Suburban	2.54	19.00	0.24	5.99	0.88	7.97	0.22	5.97	0.96	22.34
Rural	1.21	9.49	0.10	2.15	0.33	3.97	0.10	2.27	0.45	9.41
Climate Zone										
Under 2,000 CDD and Over 7,000 HDD	0.69	4.39	0.01	0.26	0.17	1.66	0.03	0.79	0.18	3.80
5,500 to 7,000 HDD	2.11	14.28	0.07	1.67	0.59	4.89	0.11	3.05	0.54	12.05
4,000 to 5,499 HDD	1.35	10.77	0.10	2.57	0.44	4.20	0.10	2.75	0.44	10.22
Under 4,000 HDD	0.60	5.03	0.08	1.85	0.31	2.84	0.08	2.27	0.32	7.72
2,000 CDD or More and Under 4,000 HDD	0.57	5.20	0.21	4.98	0.31	3.41	0.12	3.12	0.46	10.16
Type of Housing Unit										
Single-Family	4.31	31.36	0.37	8.87	1.33	12.09	0.35	8.97	1.56	34.99
Detached	3.96	28.47	0.33	7.92	1.19	10.82	0.32	8.02	1.42	31.79
Attached	0.36	2.89	0.04	0.95	0.14	1.27	0.03	0.94	0.14	3.19
Mobile Home	0.22	1.93	0.03	0.82	0.07	1.11	0.02	0.55	0.11	2.30
Multifamily	0.79	6.37	0.06	1.63	0.43	3.79	0.08	2.46	0.27	6.67
2 to 4 Units	0.48	3.59	0.02	0.43	0.17	1.43	0.03	0.86	0.11	2.61
5 or More Units	0.31	2.79	0.04	1.20	0.26	2.36	0.06	1.61	0.16	4.05
Heated Floorspace										
Fewer than1,000	0.94	7.72	0.08	2.04	0.45	4.48	0.11	3.00	0.38	8.41
1,000 to 1,999	2.05	15.72	0.21	5.03	0.76	7.10	0.19	5.02	0.83	18.80
2,000 to 2,999	1.39	9.93	0.11	2.61	0.39	3.48	0.10	2.53	0.45	10.38
3,000 or More	0.94	6.30	0.07	1.64	0.22	1.93	0.06	1.42	0.28	6.36
Year of Construction										
1939 or Before	1.69	11.17	0.04	1.11	0.42	3.57	0.09	2.36	0.39	8.76
1940 to 1949	0.45	3.04	0.02	0.50	0.13	1.14	0.03	0.86	0.14	3.01
1950 to 1959	0.81	5.76	0.06	1.53	0.27	2.26	0.07	1.85	0.29	6.73
1960 to 1969	0.82	6.03	0.08	1.85	0.29	2.45	0.07	1.94	0.29	6.62
1970 to 1979	0.73	6.21	0.10	2.32	0.31	3.21	0.09	2.26	0.37	8.18
1980 to 1984	0.26	2.54	0.06	1.45	0.14	1.56	0.04	1.11	0.17	3.89
1985 to 1987	0.19	1.75	0.04	1.05	0.10	1.04	0.03	0.65	0.11	2.56
1988 to 1990	0.18	1.65	0.03	0.77	0.08	0.96	0.02	0.52	0.11	2.33
1991 to 1993	0.18	1.51	0.03	0.75	0.08	0.81	0.02	0.43	0.09	1.87

Part B: Energy Consumption and Expenditures in Quadrillion Joules/Billion Dollars

CHARACTERISTICS	Space Heating		Air Conditioning		Water Heating		Refrigerator		Appliances	
	Consumption (quadrillion Joules)	Expenditures (billion dollars)	Consumption (quadrillion Joules)	Expenditures (billion dollars)	Consumption (quadrillion Joules)	Expenditures (billion dollars)	Consumption (quadrillion Joules)	Expenditures (billion dollars)	Consumption (quadrillion Joules)	Expenditures (billion dollars)
Total U.S. Households	5612.90	39.67	485.33	11.33	1930.75	16.99	485.33	11.98	2046.81	43.95
Census Region and Division										
Northeast	1572.03	11.39	42.20	1.39	453.67	4.17	84.40	2.66	369.27	10.10
New England	422.02	3.12	10.55	0.24	116.06	1.17	21.10	0.64	94.96	2.60
Middle Atlantic	1150.01	8.27	31.65	1.15	337.62	3.00	63.30	2.02	274.31	7.51
Midwest	2025.71	12.09	84.40	1.90	548.63	4.06	116.06	2.59	527.53	10.48
East North Central	1487.63	8.69	52.75	1.26	411.47	2.84	73.85	1.88	369.27	7.55
West North Central	548.63	3.40	31.65	0.64	147.71	1.22	31.65	0.71	158.26	2.93
South	1276.62	11.09	327.07	7.11	538.08	5.89	200.46	4.38	770.19	15.19
South Atlantic	590.83	5.83	147.71	3.46	232.11	3.20	94.96	2.18	358.72	7.71
East South Central	263.76	2.19	52.75	0.97	94.96	1.01	42.20	0.66	147.71	2.38
West South Central	422.02	3.08	116.06	2.69	211.01	1.68	63.30	1.54	263.76	5.10
West	738.54	5.09	31.65	0.92	379.82	2.87	94.96	2.35	390.37	8.18
Mountain	295.42	1.73	10.55	0.37	105.51	0.81	21.10	0.55	105.51	2.04
Pacific	443.12	3.36	21.10	0.56	274.31	2.06	63.30	1.80	274.31	6.13
Largest Populated States										
California	284.87	2.07	21.10	0.53	221.56	1.51	42.20	1.47	189.91	4.92
Florida	52.75	0.88	63.30	1.44	42.20	0.89	31.65	0.78	116.06	2.59
NewYork	538.08	3.95	10.55	0.50	168.81	1.51	21.10	1.01	126.61	3.76
Texas	242.66	1.85	73.85	1.65	126.61	1.03	42.20	0.97	158.26	3.19
Urban Status										
Urban	4336.28	30.17	379.82	9.18	1582.58	13.02	379.82	9.70	1582.58	34.53
Central City	1645.89	11.18	137.16	3.19	654.13	5.05	137.16	3.73	569.73	12.19
Suburban	2679.84	19.00	253.21	5.99	928.45	7.97	232.11	5.97	1012.85	22.34
Rural	1276.62	9.49	105.51	2.15	348.17	3.97	105.51	2.27	474.78	9.41
Climate Zone										
Under 2,000 CDD and Over 7,000 HDD	727.99	4.39	10.55	0.26	179.36	1.66	31.65	0.79	189.91	3.80
5,500 to 7,000 HDD	2226.17	14.28	73.85	1.67	622.48	4.89	116.06	3.05	569.73	12.05
4,000 to 5,499 HDD	1424.33	10.77	105.51	2.57	464.22	4.20	105.51	2.75	464.22	10.22
Under 4,000 HDD	633.03	5.03	84.40	1.85	327.07	2.84	84.40	2.27	337.62	7.72
2,000 CDD or More and Under 4,000 HDD	601.38	5.20	221.56	4.98	327.07	3.41	126.61	3.12	485.33	10.16
Type of Housing Unit									0.00	
Single-Family	4547.29	31.36	390.37	8.87	1403.22	12.09	369.27	8.97	1645.89	34.99
Detached	4178.02	28.47	348.17	7.92	1255.52	10.82	337.62	8.02	1498.18	31.79
Attached	379.82	2.89	42.20	0.95	147.71	1.27	31.65	0.94	147.71	3.19
Mobile Home	232.11	1.93	31.65	0.82	73.85	1.11	21.10	0.55	116.06	2.30
Multifamily	833.49	6.37	63.30	1.63	453.67	3.79	84.40	2.46	284.87	6.67
2 to 4 Units	506.43	3.59	21.10	0.43	179.36	1.43	31.65	0.86	116.06	2.61
5 or More Units	327.07	2.79	42.20	1.20	274.31	2.36	63.30	1.61	168.81	4.05
Heated Floorspace										
Fewer than1,000	991.75	7.72	84.40	2.04	474.78	4.48	116.06	3.00	400.92	8.41
1,000 to 1,999	2162.86	15.72	221.56	5.03	801.84	7.10	200.46	5.02	875.70	18.80
2,000 to 2,999	1466.53	9.93	116.06	2.61	411.47	3.48	105.51	2.53	474.78	10.38
3,000 or More	991.75	6.30	73.85	1.64	232.11	1.93	63.30	1.42	295.42	6.36
Year of Construction										
1939 or Before	1783.04	11.17	42.20	1.11	443.12	3.57	94.96	2.36	411.47	8.76
1940 to 1949	474.78	3.04	21.10	0.50	137.16	1.14	31.65	0.86	147.71	3.01
1950 to 1959	854.60	5.76	63.30	1.53	284.87	2.26	73.85	1.85	305.97	6.73
1960 to 1969	865.15	6.03	84.40	1.85	305.97	2.45	73.85	1.94	305.97	6.62
1970 to 1979	770.19	6.21	105.51	2.32	327.07	3.21	94.96	2.26	390.37	8.18
1980 to 1984	274.31	2.54	63.30	1.45	147.71	1.56	42.20	1.11	179.36	3.89
1985 to 1987	200.46	1.75	42.20	1.05	105.51	1.04	31.65	0.65	116.06	2.56
1988 to 1990	189.91	1.65	31.65	0.77	84.40	0.96	21.10	0.52	116.06	2.33
1991 to 1993	189.91	1.51	31.65	0.75	84.40	0.81	21.10	0.43	94.96	1.87

Table 5-7. Energy Expenditures per US Household, by End Use - All Energy Sources

CHARACTERISTICS	All Uses		Space Heating		Air Conditioning		Water Heating		Refrigerators		Appliances	
	Households (millions)	Expenditures (dollars)	Households (millions)	Expenditures (dollars)	Households (millions)	Expenditures (dollars)	Households (millions)	Expenditures (dollars)	Households (millions)	Expenditures (dollars)	Households (millions)	Expenditures (dollars)
Total U.S. Households	96.6	1283	94.6	419	64.0	177	95.9	177	96.4	124	96.6	455
Census Region and Division												
Northeast	19.5	1526	19.1	595	10.9	127	19.3	216	19.4	137	19.5	519
New England	5.1	1532	4.9	634	2.1	111	5.0	234	5.1	126	5.1	512
Middle Atlantic	14.4	1523	14.2	582	8.8	131	14.3	210	14.3	141	14.4	521
Midwest	23.3	1336	23.2	521	16.4	116	23.3	174	23.3	111	23.3	450
East North Central	16.4	1358	16.3	533	10.8	117	16.4	174	16.4	115	16.4	461
West North Central	6.9	1282	6.9	492	5.6	114	6.9	176	6.9	103	6.9	422
South	33.5	1305	32.8	338	29.4	242	33.2	178	33.4	131	33.5	454
South Atlantic	17.3	1292	16.8	346	15.0	231	17.1	187	17.3	126	17.3	445
East South Central	6.0	1200	5.9	373	5.3	185	5.9	170	6.0	110	6.0	396
West South Central	10.1	1391	10.1	304	9.2	291	10.1	167	10.1	152	10.1	504
West	20.4	953	19.4	263	7.2	128	20.2	142	20.3	116	20.4	402
Mountain	5.4	1025	5.3	327	2.1	175	5.3	151	5.4	102	5.4	382
Pacific	15.0	928	14.1	238	5.1	109	14.9	139	15.0	120	15.0	409
Largest Populated States												
California	11.1	944	10.6	195	4.4	120	11.1	136	11.1	132	11.1	442
Florida	5.6	1182	5.3	165	5.1	281	5.5	162	5.6	141	5.6	466
New York	6.8	1577	6.7	590	3.9	128	6.7	224	6.8	149	6.8	552
Texas	6.4	1349	6.4	288	5.8	287	6.4	161	6.4	151	6.4	494
Urban Status												
Urban	75.8	1275	74.4	405	50.3	183	75.3	173	75.7	128	75.8	456
Central City	30.6	1156	29.9	374	18.9	168	30.4	166	30.5	122	30.6	399
Suburban	45.2	1356	44.6	426	31.3	191	44.9	177	45.1	132	45.2	494
Rural	20.8	1312	20.2	471	13.7	157	20.6	193	20.8	110	20.8	452
Climate Zone												
Under 2,000 CDD and Over 7,000 HDD	8.7	1254	8.5	517	4.0	64	8.6	193	8.7	91	8.7	437
5,500 to 7,000 HDD	26.5	1356	26.3	543	15.5	108	26.4	185	26.5	115	26.5	455
4,000 to 5,499 HDD	22.4	1361	22.1	488	16.0	160	22.2	189	22.3	123	22.4	456
Under 4,000 HDD	17.8	1107	17.2	292	10.3	179	17.7	160	17.8	128	17.8	434
2,000 CDD or More and Under 4,000 HDD	21.2	1268	20.5	253	18.1	275	21.0	162	21.1	147	21.2	479
Type of Housing Unit												
Single-Family	66.8	1442	65.5	479	45.1	197	66.3	182	66.7	134	66.8	524
Detached	59.5	1464	58.3	488	39.9	198	59.0	183	59.4	135	59.5	535
Attached	7.3	1266	7.2	403	5.2	183	7.3	174	7.3	129	7.3	437
Mobile Home	5.6	1203	5.4	357	3.7	221	5.5	200	5.6	99	5.6	412
Multifamily	24.2	863	23.6	269	15.1	108	24.1	158	24.2	102	24.2	275
2 to 4 Units	8.0	1112	7.9	454	3.9	110	8.0	179	8.0	107	8.0	326
5 or More Units	16.2	740	15.8	177	11.2	107	16.1	147	16.2	99	16.2	250
Heated Floorspace												
Fewer than 1,000	29.3	876	28.1	275	17.2	119	28.9	155	29.2	103	29.3	287
1,000 to 1,999	40.2	1286	39.6	397	27.4	183	40.0	178	40.1	125	40.2	468
2,000 to 2,999	17.8	1622	17.7	561	12.8	205	17.8	196	17.8	142	17.8	582
3,000 or More	9.3	1901	9.2	685	6.6	249	9.2	208	9.3	153	9.3	685
Year of Construction												
1939 or Before	20.3	1327	19.7	566	9.9	112	20.1	178	20.3	116	20.3	431
1940 to 1949	6.9	1242	6.8	450	3.8	132	6.9	166	6.9	126	6.9	437
1950 to 1959	13.1	1387	12.8	450	8.4	182	13.0	173	13.1	142	13.1	515
1960 to 1969	15.0	1257	14.7	410	10.6	175	14.9	164	15.0	129	15.0	441
1970 to 1979	18.1	1222	17.7	352	12.4	188	18.0	179	18.1	125	18.1	451
1980 to 1984	8.5	1247	8.3	306	6.7	217	8.5	184	8.5	131	8.5	460
1985 to 1987	5.5	1284	5.5	320	4.7	223	5.5	190	5.5	118	5.5	466
1988 to 1990	4.7	1322	4.6	356	3.8	201	4.7	204	4.7	111	4.7	494
1991 to 1993	4.5	1200	4.5	338	3.8	197	4.5	180	4.5	96	4.5	419

Table 5-8. Average Consumption and Expenditures for All Major Energy Sources

Characteristics	Consumption		Expenditures	
	1000 Btu per square foot	1000 Joules per square meter	Dollars per square foot	Dollars per square meter
Total U.S. Households	55	624629	0.68	7.32
Census Region and Division				
Northeast	60	681414	0.74	7.96
New England	59	670057	0.73	7.85
Middle Atlantic	60	681414	0.75	8.07
Midwest	62	704128	0.62	6.67
East North Central	64	726841	0.63	6.78
West North Central	56	635986	0.58	6.24
South	52	590559	0.76	8.18
South Atlantic	45	511060	0.75	8.07
East South Central	53	601916	0.67	7.21
West South Central	62	704128	0.86	9.25
West	46	522417	0.58	6.24
Mountain	57	647343	0.59	6.35
Pacific	42	476990	0.58	6.24
Largest Populated States				
California	41	465633	0.59	6.35
Florida	31	352064	0.71	7.64
New York	64	726841	0.84	9.04
Texas	57	647343	0.81	8.72
Urban Status				
Urban	56	635986	0.69	7.42
Central City	63	715485	0.75	8.07
Suburban	52	590559	0.66	7.10
Rural	54	613273	0.67	7.21
Climate Zone				
Over 7,000 HDD	56	635986	0.57	6.13
5,500 to 7,000 HDD	62	704128	0.65	6.99
4,000 to 5,499 HDD	55	624629	0.69	7.42
Under 4,000 HDD	49	556488	0.69	7.42
2,000 CDD or More and Under 4,000 HDD	49	556488	0.79	8.50
Type of Housing Unit				
Single-Family	52	590559	0.63	6.78
Detached	52	590559	0.63	6.78
Attached	53	601916	0.7	7.53
Mobile Home	84	953979	1.23	13.23
Multifamily	69	783626	0.89	9.58
2 to 4 Units	83	942623	0.93	10.01
5 or More Units	60	681414	0.86	9.25
Heated Floorspace				
square feet (square meters)				
Fewer than 1,000 (Fewer than 93)	81	919909	1.06	11.41
1,000 to 1,999 (93 to 186)	59	670057	0.76	8.18
2,000 to 2,999 (187 to 279)	50	567845	0.6	6.46
3,000 or More (280 or More)	39	442919	0.44	4.73
Year of Construction				
1939 or Before	65	738198	0.66	7.10
1940 to 1949	67	760912	0.74	7.96
1950 to 1959	60	681414	0.73	7.85
1960 to 1969	57	647343	0.69	7.42
1970 to 1979	50	567845	0.7	7.53
1980 to 1984	46	522417	0.72	7.75
1985 to 1987	44	499704	0.66	7.10
1988 to 1990	43	488347	0.62	6.67
1991 to 1993	40	454276	0.53	5.70

Figure 5-19. Total Energy Consumption by End Use and Type of Housing

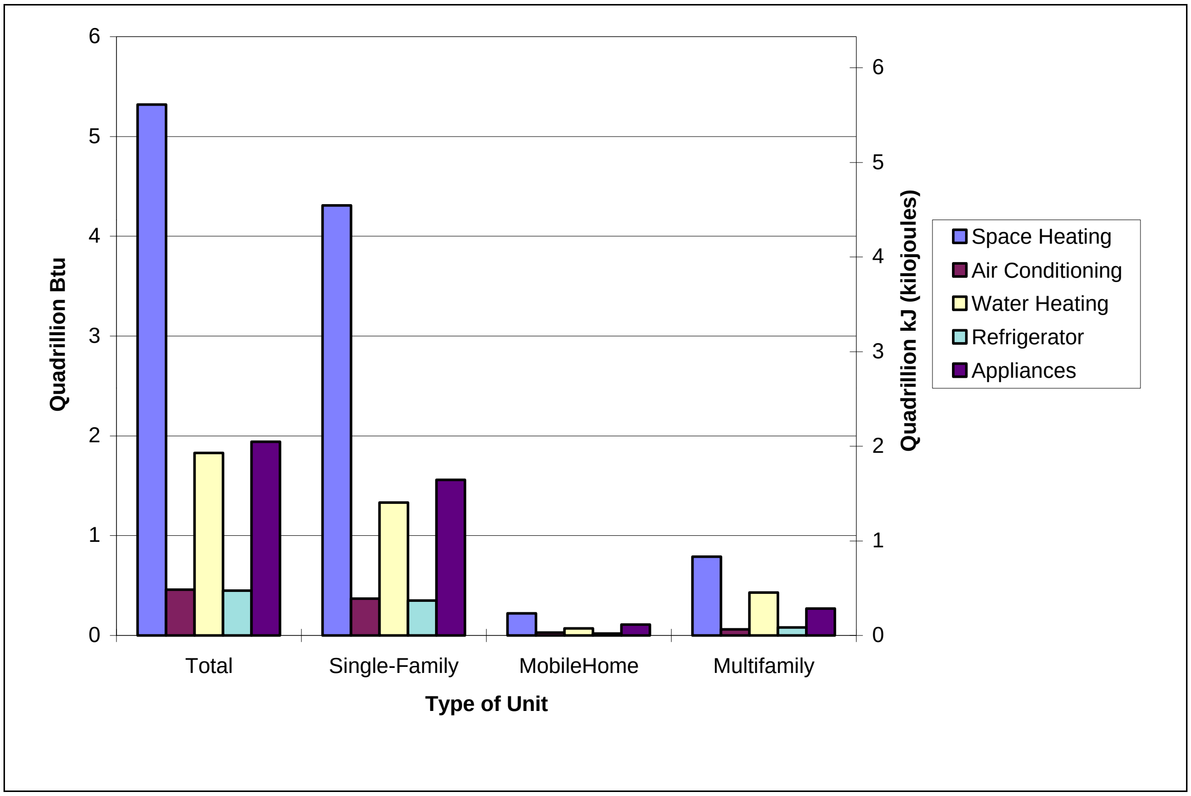


Figure 5-20 shows the total energy consumption by end-use in each of the four census regions. Reference to the figure indicates that space heating is the dominant end-use consumer, irrespective of census region. Figure 5-21 shows the total expenditures per US household for energy consumption, by end use, for the same types of structure shown in Figure 5-19. Comparison of the two figures indicates that while space heating is the largest consumer of energy, expenditures for household appliances are of a similar magnitude to those for space heating for single-family homes. This is due primarily to the high cost of electricity compared with other fuel sources, and the fact that natural gas is the dominant fuel source for space heating (refer to Section 5.2.4 for further details about household appliances and equipment). Data from the **RECS** shows that expenditures for electricity in the residential sector, are generally around four times greater than those for natural gas and fuel oil (for single family housing approximately \$22.8 per million kilojoules (\$24 per million Btu) for electricity, compared with approximately \$5.7 per million kilojoules (\$6 per million Btu) for natural gas and fuel oil respectively). Furthermore, these cost differentials are reflected across all four census regions and housing types. Figure 5-21 also indicates that per household expenditures decrease as the number of units in the structure increases. However, this observation must be viewed with caution, as it does not account for the floor space of the unit - a factor considered later in this section.

Figure 5-20. Total Energy Consumption by End Use and Census Region

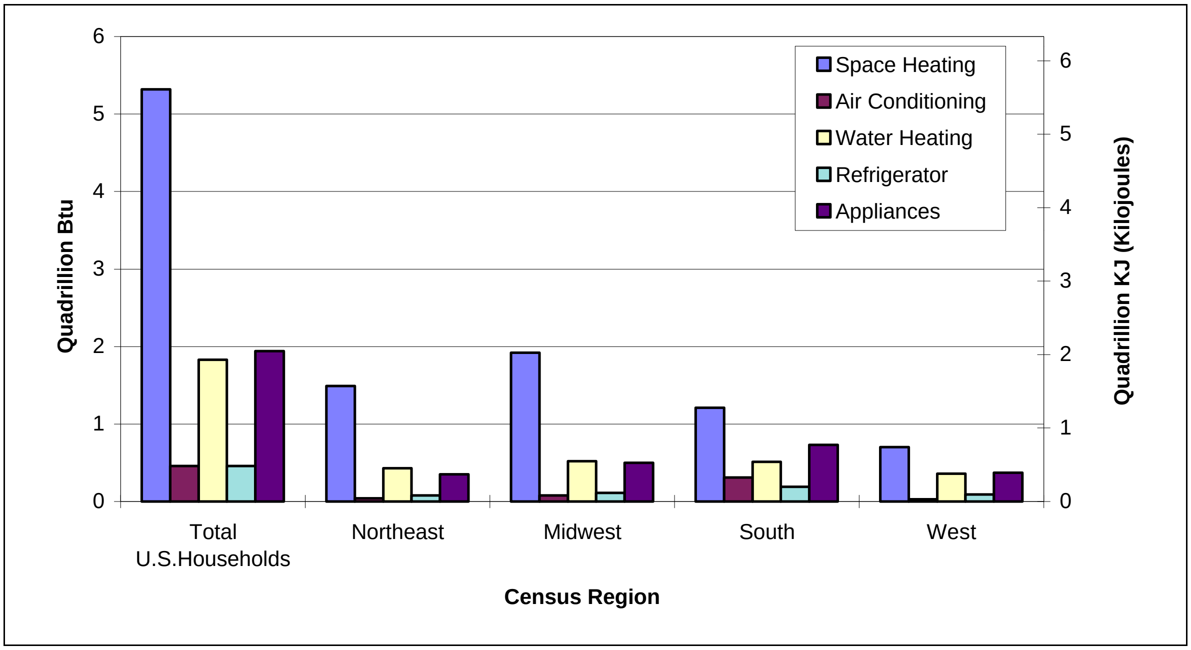


Figure 5-21. Energy Expenditures per Household by End Use and Type of Unit

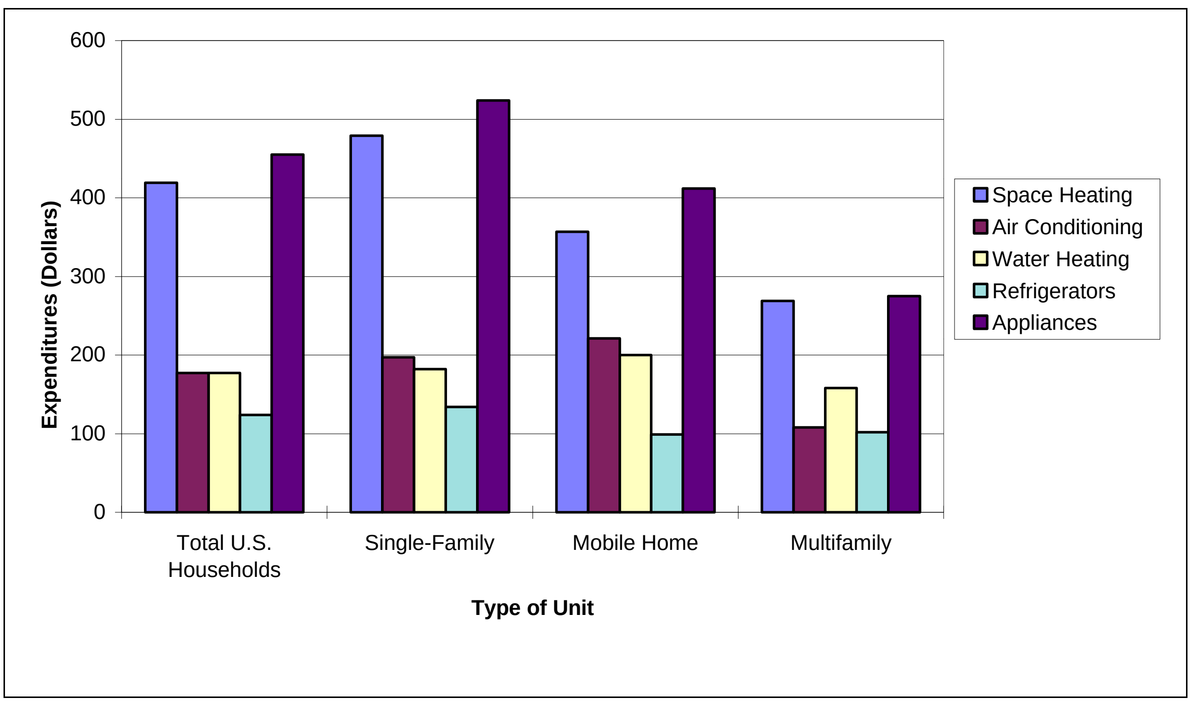


Figure 5-22. Energy Expenditures per Household by End Use and Census Region

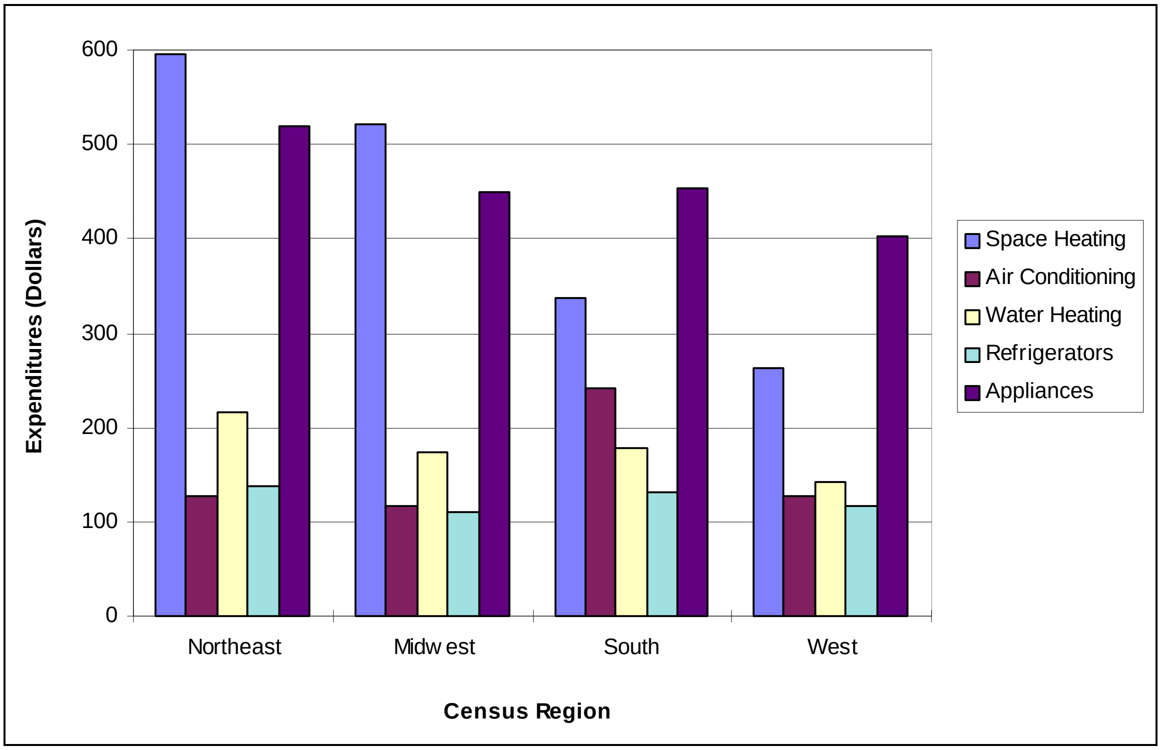


Figure 5-22 presents similar information to that shown in Figure 5-20, except that expenditures per household are shown. As expected, space heating costs are higher in the northeast and mid-west compared with the south and west, while air conditioning costs in the south are nearly double those in the three other census regions.

Figure 5-23 shows the total consumption of energy for all houses by year of construction and energy end use. Figure 5-25 indicates that properties built before 1980 consume significantly more total energy than those built after 1980. In particular, total energy consumption for space heating in buildings constructed before 1980 is higher. However, cross reference to Figure 5-4 shows that the consumption profile shown in Figure 5-23 is due in part to the age distribution of the US housing stock. Figure 5-24 explores this issue in greater detail. It shows the total energy expenditures per household by end use and year of construction. Reference to Figure 5-24 indicates that annual expenditures for space heating in older buildings are generally higher than in newer buildings, as suggested in Figure 5-23. However, the annual expenditures for air conditioning, water heating, refrigerators and appliances shown in Figure 5-24 are generally either similar across the age spectrum, or higher in newer buildings. In particular, air conditioning expenditures are significantly higher in newer buildings, probably due to a higher percentage of newer buildings having air conditioning equipment. The data suggest that newer buildings are not significantly cheaper to operate than older buildings, as might have been expected. However, this observation does not necessarily tell us whether building efficiency is higher in newer homes, as the data do not account for the trend towards larger single family homes, which would result in higher operating costs. Therefore, this section will examine unit area costs in more detail, to account for differences in building size across the housing stock.

Figure 5-23. Total Energy Consumption by End Use and Year of Construction

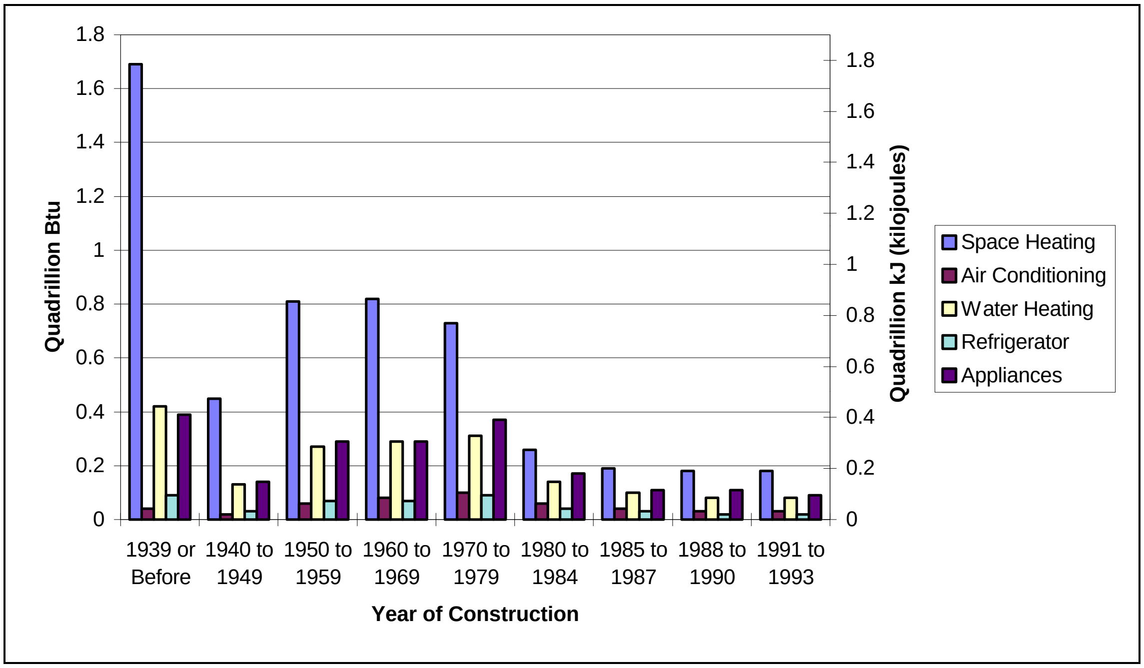


Figure 5-24. Energy Expenditures per Household by End Use and Year of Construction

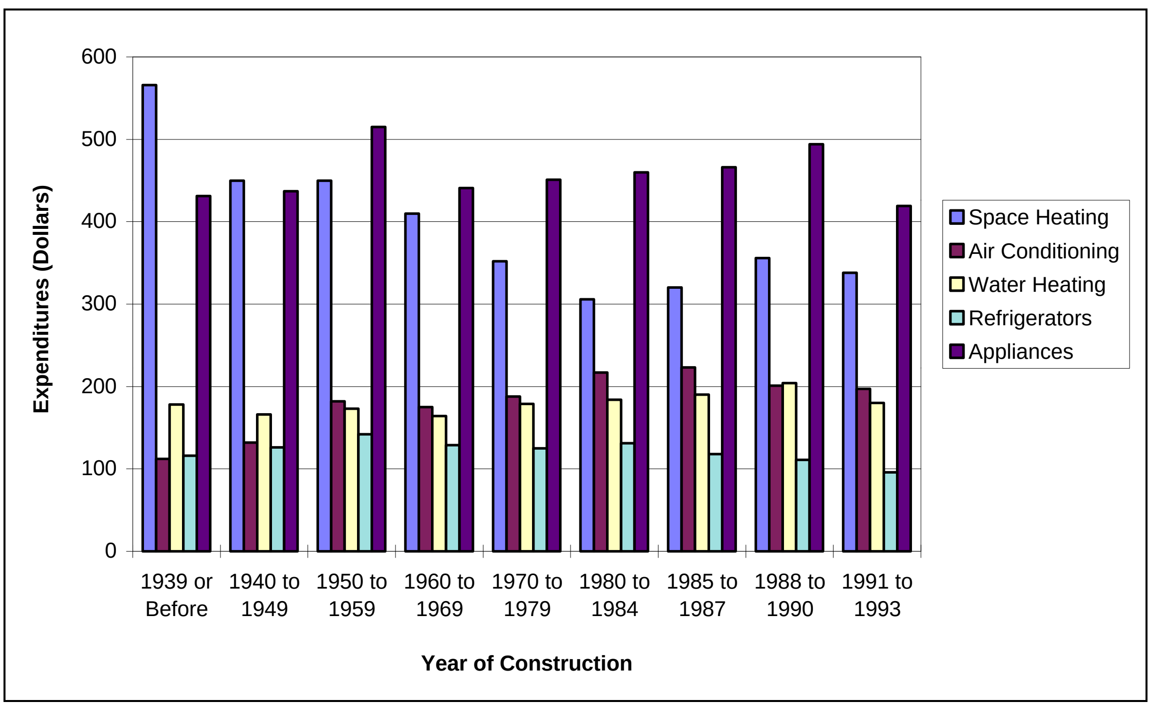
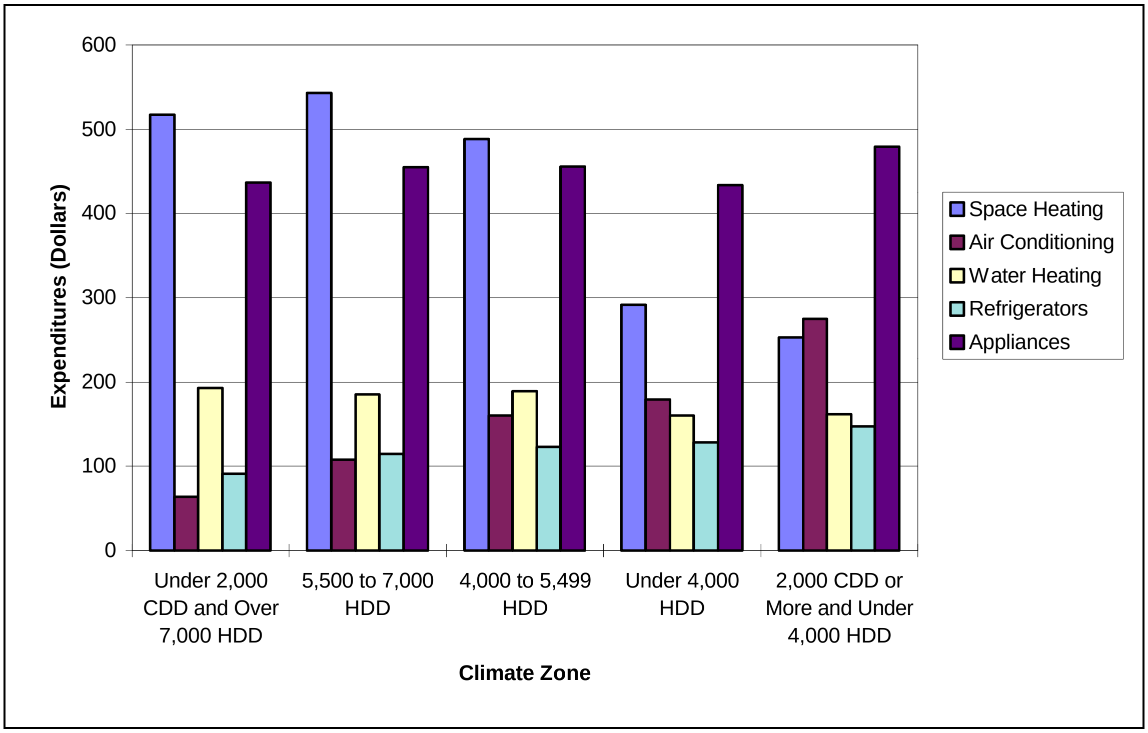


Figure 5-25 shows the expenditures per household by end use in each of the five climate zones defined in the **RECS**. Reference to Figure 5-25 shows that appliance and water heating expenditures are relatively constant, irrespective of climate zone. However, space heating costs are highly dependent upon climatic zone. Space heating expenditures fall as the number of heating degree days (HDD) decreases (heating degree days are a measure of how cold an area is). Conversely, air conditioning and refrigeration expenditures rise as the number of cooling degree days (CDD) increases (cooling degree days are a measure of how hot an area is).

Figure 5-25. Energy Expenditures per Household by End Use and Climate Zone



Figures 5-26 through 5-29 consider average expenditures for all major energy sources in the residential sector on a dollars per square meter (square foot) basis, rather than on a 'per household' basis, as used previously. This allows a more accurate comparison of different parts of the residential sector which accounts for differences in building size, and is useful in comparing building efficiencies.

Figure 5-26 shows how average expenditures vary depending upon the type of structure which is considered. The figure indicates that single family housing expenditures are lower on a per unit area basis than those for multi-family structures, and that both types are less costly than those for mobile homes. This contrasts with the per household data shown in Figure 5-21, which indicates that total household expenditures are actually significantly higher in single family units compared with multi-family units. This is most likely due to the higher median floor area in single family houses. Attached properties also have higher per unit area energy costs than detached structures. This is probably also because detached structures generally have higher floor areas than attached properties. Thus, whilst single family homes are more costly to operate than multi-family homes, they would appear to be more efficient.

Figure 5-26. Average Energy Expenditures for all Major Energy Sources by Type of Unit

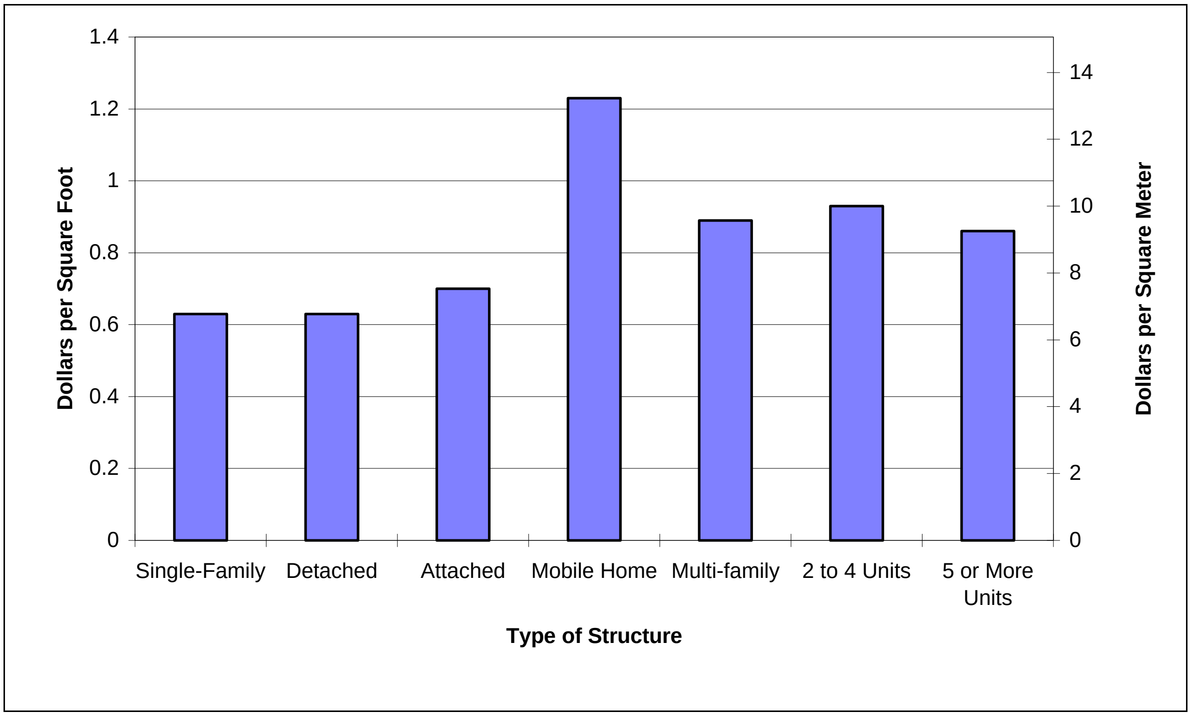


Figure 5-27 shows how average energy expenditures vary across the four census regions, as well as in selected US states. Reference to the figure shows that the west census region has the lowest energy expenditures per square meter (square foot), and the south has the highest. Average expenditures in the south are probably skewed to some extent by the high proportion of mobile homes in this region compared with the other census regions. Data from the **RECS** also indicates that urban areas have higher expenditures than rural areas in all census regions.

In Figure 5-28, the variation in average energy expenditures is shown by year of construction of the structure. The figure suggests that properties constructed more recently have lower average energy expenditures than older units. Figure 5-28 should be compared with Figure 5-24, which indicated that total per household costs are similar irrespective of the age of construction of the property. There are a number of possible reasons for this paradox. Firstly, given that space heating accounts for a relatively large proportion of total energy expenditures, and that we would expect newer homes to be better designed and insulated than older homes, newer buildings should be more efficient. This is discussed in more detail in Section 5.2.4. Secondly, the increasing importance of single-family housing compared with multi-family housing described in Section 5.1, coupled with the trend towards larger single family homes, appears to reduce unit costs, as shown in Figure 5-28. This is probably also the result of newer properties incorporating more energy conservation features than older homes.

Figure 5-27. Average Energy Expenditures for all Major Energy Sources by Location

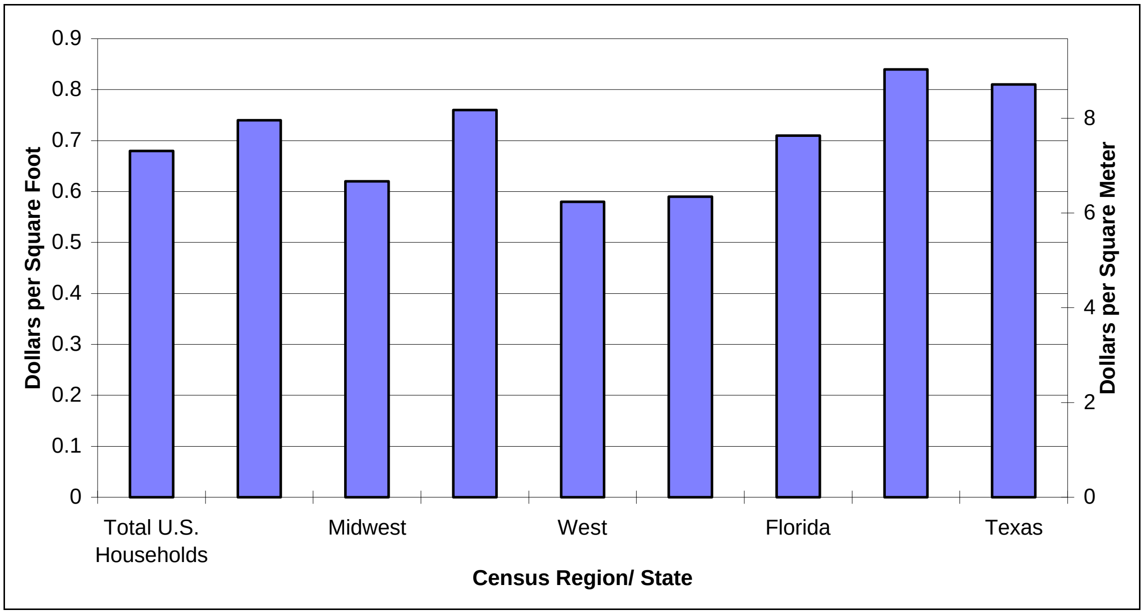


Figure 5-28. Average Energy Expenditures for all Major Energy Sources by Year of Construction

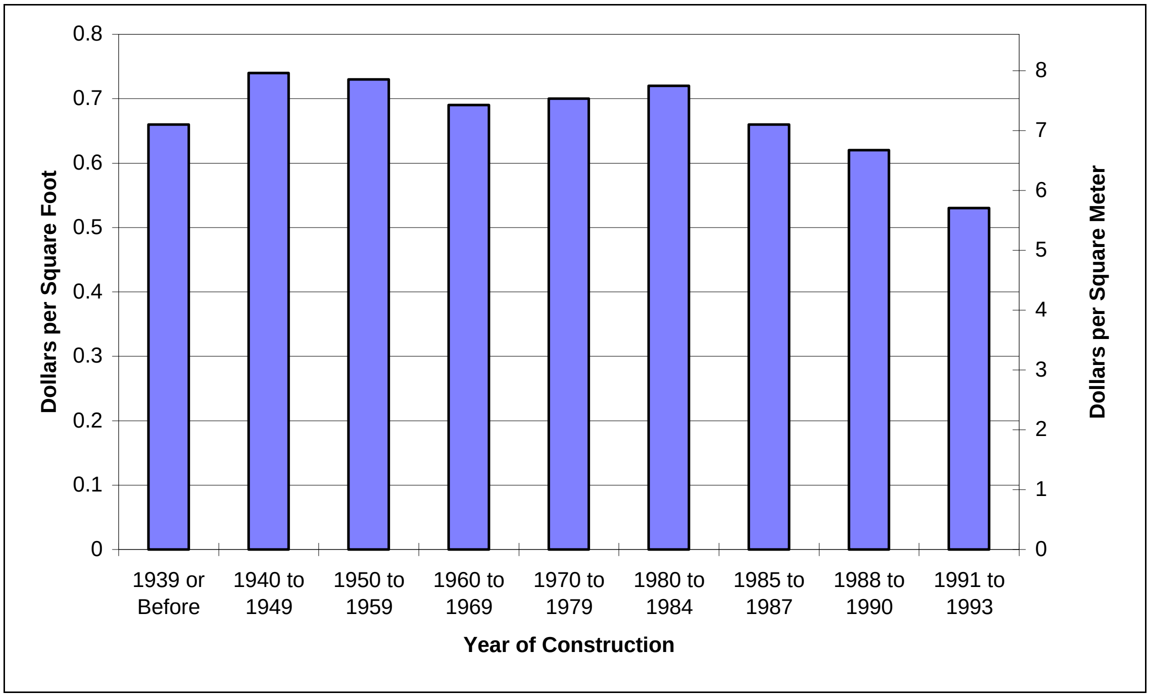
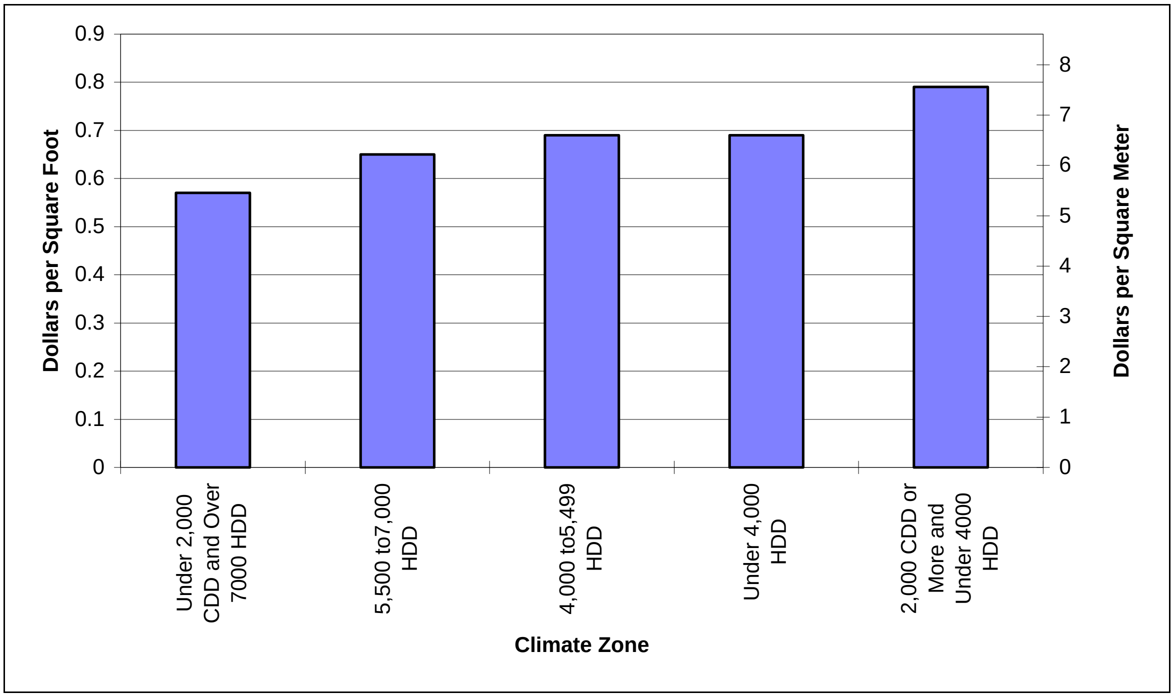


Figure 5-29 shows how average expenditures vary depending upon the climate zone/location of the structure.

Figure 5-29. Average Energy Expenditures for All Major Energy Sources by Climate Zone



5.2.4 Energy Conservation in the Residential Sector

This section addresses some general issues concerning energy conservation in the residential sector. This section examines how prevalent certain conservation features, equipment, and appliances are in the residential sector. In addition, it outlines selected energy efficiency recommendations provided by the Federal Energy Management Program (FEMP). The EIA Report **Housing Characteristics 1993** has been used to generate all of the figures presented in this section.

Figure 5-30 shows the percentage of households which participated in demand side management (DSM) programs in 1993 (demand side management programs are defined by EIA as those programs sponsored by utilities companies to encourage customers to modify their energy usage patterns), and the percentage having set-back clocks or thermostats, by year of construction. The figure indicates that a higher percentage of newer homes participate in DSM programs or have thermostatic devices or set-back clocks compared with older homes.

Figure 5-30. Residential Housing Energy Features: Households Participating in Demand-Side Management Programs/With Set-Back Clocks

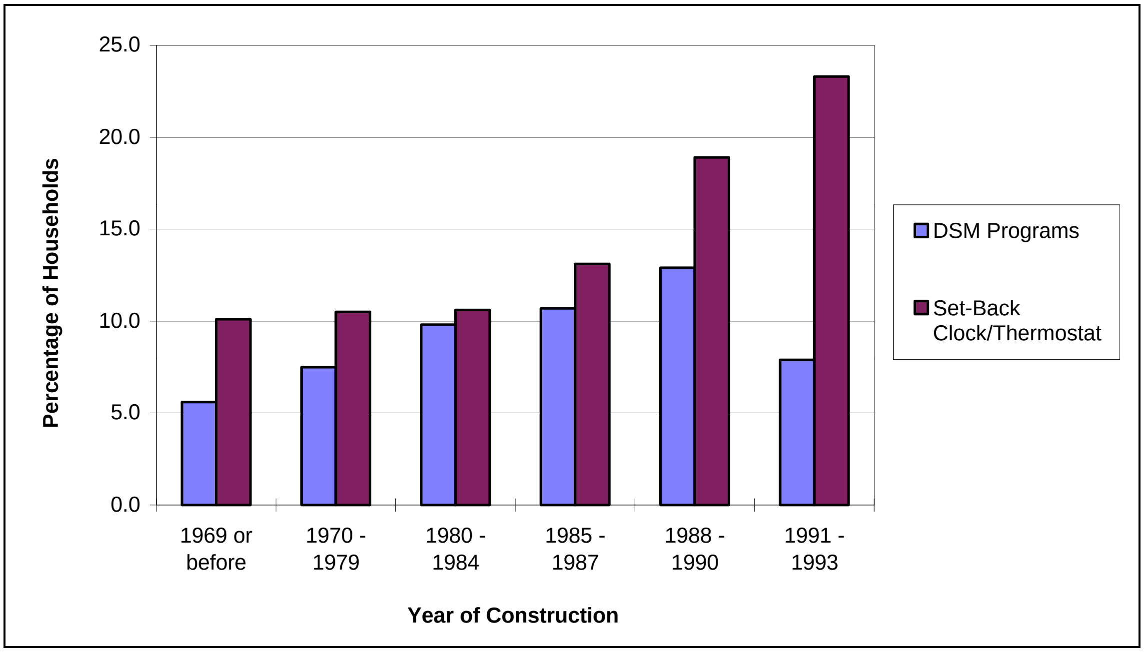


Figure 5-31 shows the percentage of households with single pane and double pane glass by year of construction. As expected, there has been a move toward double pane glass in recent years. However, the figures indicate that over 35 percent of all houses constructed since 1988 still contain single pane glass.

Figure 5-32 shows the different types of insulation present in US homes by year of construction. It is important to recognize that a single home may use more than one type of insulation. Consequently, the sum total across all types of insulation may exceed 100 percent of all homes. Reference to the figure indicates that a relatively high proportion of all homes have roof/ceiling insulation. In addition, wall and hot-water pipe insulation also appears to be present in a similar percentage of homes, irrespective of age category. However, the number of homes reporting having water heater insulation is relatively low at around 25 percent, irrespective of year of construction. The figure suggests that there are still a significant number of households in the US where some form of additional insulation may be cost-effective. More detailed information regarding household conservation features is provided in Table 5-9.

Figure 5-31. Households with Different Types of Glazing

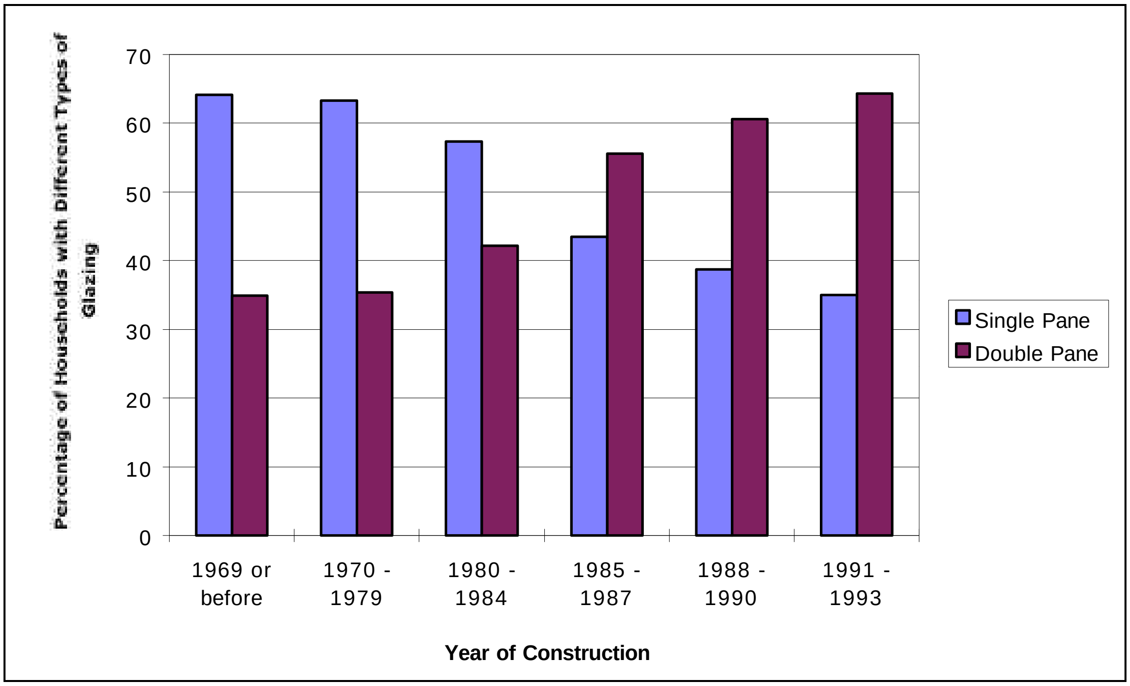


Figure 5-32. Households with Different Types of Insulation

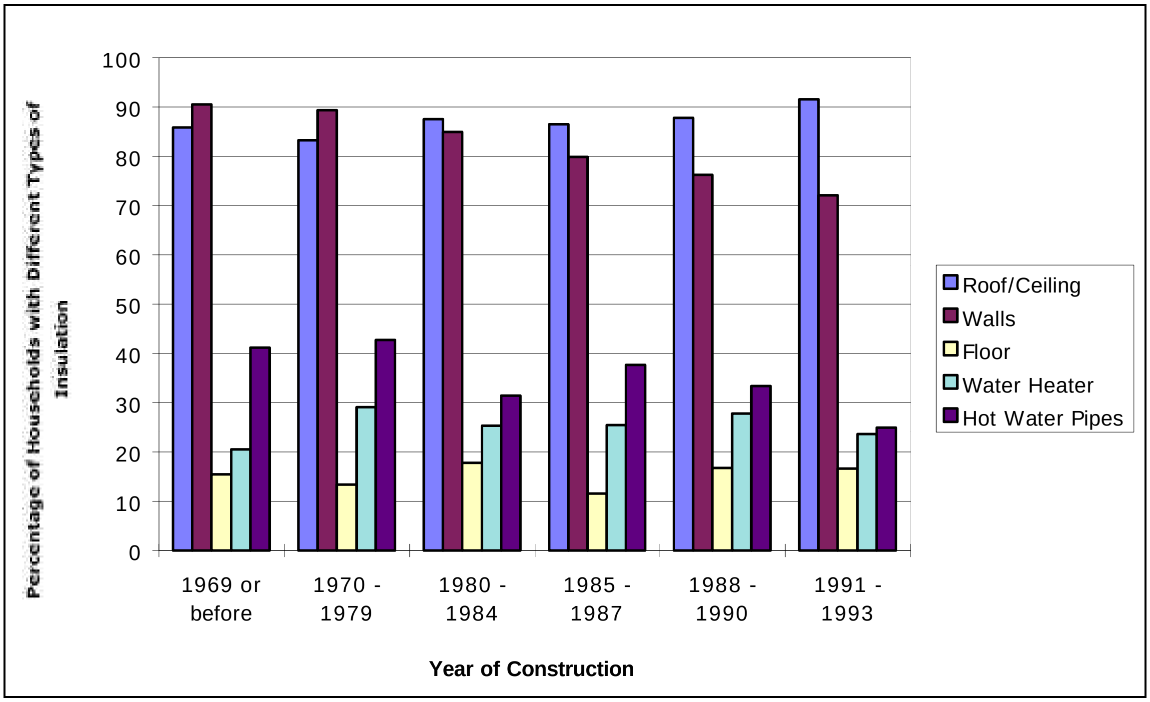


Table 5-9. Residential Housing Conservation Features: 1993

CONSERVATION ITEMS	NUMBER OF HOUSING UNITS BY YEAR OF CONSTRUCTION (MILLIONS)									
	Total Units	**1991 - 1993**	**1988 - 1990**	**1985 - 1987**	**1980 - 1984**	**1970 - 1979**	**1960 - 1969**	**1950 - 1959**	**1940 - 1949**	**1939 or Before**
Total Housing Units	*96.6*	*4.5*	*4.7*	*5.5*	*8.5*	*18.1*	*15.0*	*13.1*	*6.9*	*20.4*
Demand-Side Management Programs										
Were Any Offered by a Utility										
Yes	34.8	1.8	1.9	2.4	3.0	6.1	5.1	5.1	2.4	7.1
No	40.0	1.5	2.0	2.0	3.4	8.2	6.1	5.2	2.9	8.7
Don'tKnow	21.8	1.2	0.8	1.1	2.1	3.9	3.8	2.8	1.6	4.6
Program Participation in Past 12 Months										
No Program Offered	40.0	1.5	2.0	2.0	3.4	8.2	6.1	5.2	2.9	8.7
Don't Know	2.7	0.2	0.1	Q	0.2	0.6	0.3	0.4	0.2	0.7
No	46.4	2.4	2.0	2.8	4.0	8.0	7.8	6.5	3.4	9.5
Yes	7.6	0.4	0.6	0.6	0.8	1.4	0.8	1.0	0.5	1.5
Does the Home Have any of the following:										
Set-Back Clock/Thermostat										
Yes	10.8	1.0	0.9	0.7	0.9	1.9	1.5	1.7	0.4	1.7
No	85.8	3.4	3.8	4.8	7.6	16.2	13.5	11.4	6.5	18.6
Regular Heating System/Furnace Maintenance										
Yes	49.4	2.2	2.5	3.0	4.5	8.6	8.1	6.5	3.3	10.8
No	47.2	2.2	2.2	2.5	4.0	9.6	6.9	6.6	3.7	9.6
Doors and Windows										
Glass in Sliding Doors to the Outside										
Single Pane	12.2	0.6	0.6	1.1	1.7	3.7	2.5	1.3	0.4	0.4
Double Pane	18.3	1.3	1.4	1.5	2.6	4.7	3.7	1.7	0.4	0.9
Untreated	17.5	1.1	1.3	1.5	2.6	4.5	3.6	1.5	0.4	0.9
Low-E Coating	0.8	0.1	0.1	0.1	Q	0.1	Q	Q	Q	Q
Triple Pane	0.4	Q	Q	Q	Q	0.2	Q	Q	Q	Q
No Doors	65.8	2.5	2.7	2.9	4.2	9.5	8.8	10.0	6.1	19.0
Glass in Most Windows										
Single Pane	61.5	1.6	1.8	2.4	4.9	11.5	9.6	9.5	5.3	15.0
Double Pane	34.2	2.9	2.9	3.1	3.6	6.4	5.2	3.5	1.6	5.1
Untreated	32.5	2.6	2.7	2.9	3.5	6.2	5.0	3.2	1.4	4.9
Low-E Coating	1.7	0.2	0.2	0.1	Q	0.2	0.3	0.3	0.1	0.2
Triple Pane	0.9	Q	Q	Q	Q	0.2	Q	Q	Q	0.2
Frames in Most Windows										
Metal	53.3	3.0	3.2	4.0	6.7	12.8	9.9	6.3	2.5	4.7
Nonmetal	43.3	1.5	1.5	1.4	1.7	5.2	5.1	6.8	4.4	15.6
Conservation Measures										
(Single-Family Units and Mobile Homes Only	72.4	3.6	3.9	4.1	6.1	12.4	10.8	11.3	5.6	14.6
Types of Insulation in/around Home										
Roof/Ceiling										
Yes	58.6	3.3	3.4	3.6	5.4	10.3	9.3	8.9	4.4	10.1
No	6.4	Q	Q	0.1	0.2	0.8	0.6	1.3	0.7	2.6
Don'tKnow	7.4	0.2	0.4	0.5	0.6	1.3	1.0	1.2	0.5	1.9
Outside Walls										
Yes	50.7	3.2	3.5	3.5	4.9	9.4	7.8	6.7	3.3	8.4
No	11.4	Q	0.2	0.1	0.3	1.1	1.5	2.7	1.5	4.0
Don'tKnow	10.3	0.3	0.2	0.5	0.9	1.9	1.5	2.0	0.7	2.3
Floor Insulation										
No Basement/Crawlspace	17.8	1.4	1.4	1.6	2.9	3.7	2.9	2.4	0.7	1.0
Basement/Crawlspace	49.0	1.8	1.9	1.9	2.3	6.7	7.3	8.8	4.8	13.6
Heated	20.8	0.9	1.0	0.8	1.2	3.4	3.5	3.2	1.5	5.4
None or PartHeated	28.2	0.8	0.9	1.0	1.1	3.3	3.9	5.6	3.3	8.2
Floor Not Insulated	15.7	0.3	0.3	0.3	0.4	1.3	2.1	3.2	2.1	5.7
Floor Insulated	12.5	0.6	0.5	0.7	0.7	2.1	1.8	2.4	1.2	2.5
Don't Know	5.0	0.2	0.1	0.2	0.3	0.6	0.9	1.1	0.4	1.1

Figure 5-33, Figure 5-34, and Figure 5-35 show the percentage of households with selected appliances and equipment which use either electricity, natural gas, or fuel oil as the energy source. The significant points which arise from these figures are that natural gas is the dominant space heating fuel, followed by electricity, that virtually all air conditioning equipment is electrically operated, and that, with the exception of ovens and ranges, most appliances are electrically operated.

Table 5-10 and Table 5-11 show a series of energy efficiency recommendations for selected residential appliances and equipment. The tables show both the recommended efficiency rating, and the best attainable rating. For further information on this subject, refer to Section 5.1, which lists some additional data sources.

Figure 5-33. Residential Appliances and Equipment: Electric

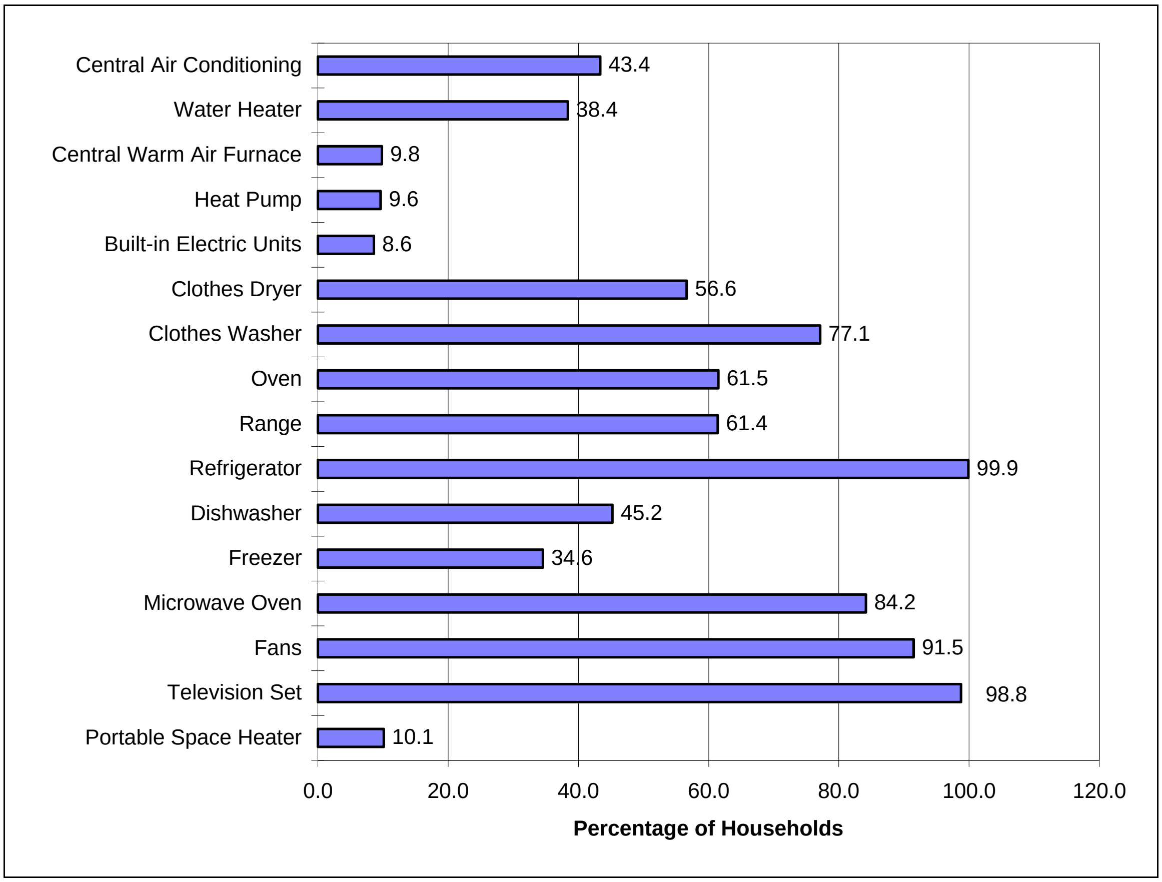


Figure 5-34. Residential Appliances and Equipment: Natural Gas

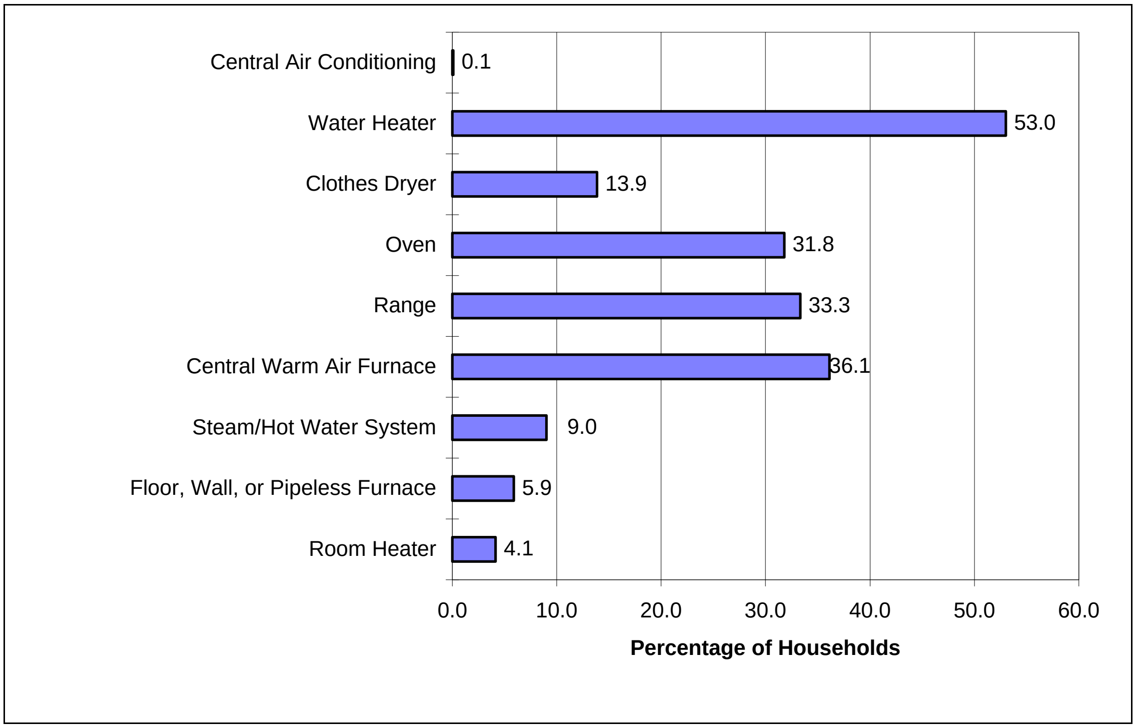


Figure 5-35. Residential Appliances and Equipment: Fuel Oil

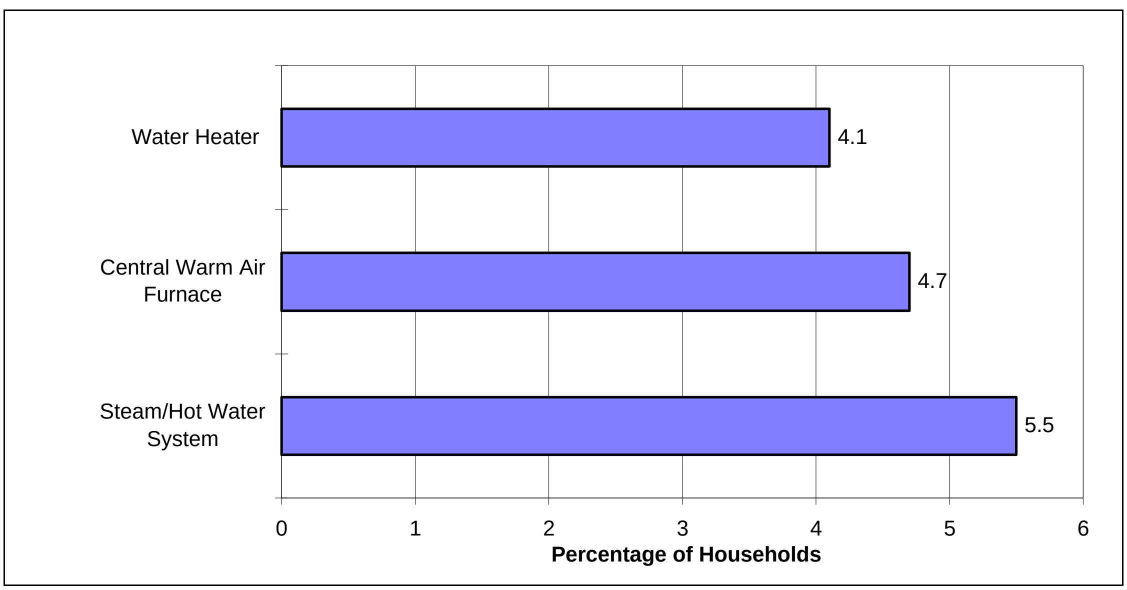


Table 5-10. Energy Efficiency Recommendations for Selected Residential Appliances and Equipment

Product	Recommended Efficiency Rating	Best Available Efficiency Rating
Central Air Conditioner	SEER (Seasonal Energy Efficiency Rating) is greater than or equal to 12.0	SEER = 17.1
Residential Furnace	AFUE (Annual Fuel Utilization Efficiency) is greater than or equal to 90%	AFUE = 97%
Gas Water Heater First Hour Rating (up to 87 gallons/329 liters)	Energy Factor greater than 0.61. Annual Energy use less than 246 therms/259,000 MJ	Energy Factor = 0.72 Annual Energy Use = 208 Therms/219,000 MJ
Electric Water Heater First Hour Rating (up to 87 gallons/329 liters)	Energy Factor greater than or equal to 0.92. Annual Energy use less than or equal to 4773 kwh	Energy Factor = 0.95 Annual Energy Use = 4622 kwh
Room Air Conditioner with Louvres - less than 20,000 Btu/hour(21.1MJ/hour)	EER (Energy Efficiency Ratio) greater than or equal to 10.0	EER = 12.0
Room Air Conditioner with Louvres - greater than or equal to 20,000 Btu/hour	EER greater than or equal to 9.0	EER = 10.0
Room Air Conditioner without Louvres - all cooling capacities	EER greater than or equal to 9.0	EER = 9.6
Dishwasher (built in)	Energy Factor greater than or equal to 0.52 (less than 619 kwh/year)	Energy factor = 0.68 (474 kwh/year)

Table 5-11. Energy Efficiency Recommendations for Refrigerators

Product Type	Total Volume	Recommended	Best Available
	Cubic Feet (Cubic Meters)	kWh/year (Mega Joules/year)	kWh/year (Mega Joules/year)
Single-Door Compact	7.75 or less (0.219 or less)	329 or less (1184.4 or less)	270 (972)
Top-Mount Freezer	12.5-14.4 (0.354-0.408)	526 or less (1893.6 or less)	496 (1785.6)
Top-Mount Freezer	14.5-16.4 (0.410-0.464)	616 or less (2217.6 or less)	514 (1850.4)
Top-Mount Freezer	16.5-18.4 (0.467-0.521)	655 or less (2358.0 or less)	518 (1864.8)
Top-Mount Freezer	18.5-20.4 (0.524-0.577)	655 or less (2358.0 or less)	533 (1918.8)
Top-Mount Freezer	20.5-22.4 (0.580-0.634)	727 or less (2617.2 or less)	555 (1998.0)
Side-by-side Freezer	18.5-20.4 (0.523-0.577)	760 or less (2736.0 or less)	702 (2527.2)
Side-by-side Freezer	20.5-22.4 (0.580-0.634)	760 or less (2736.0 or less)	561 (2019.6)
Side-by-side Freezer	22.5-24.4 (0.637-0.691)	843 or less (3034.8 or less)	750 (2700.0)
Side-by-side Freezer	24.5-26.4 (0.694-0.747)	843 or less (3034.8 or less)	641 (2307.6)

5.3 Summary of Baseline Measures for the Residential Sector

This section summarizes the baseline measures for the residential sector which are presented in Sections 5.2.1, 5.2.2 and 5.2.3. The summary data concentrate upon cost rather than consumption. They are presented in Table 5-12 below.

Table 5-12 shows general information relating to the residential sector, as well as key operations, maintenance, and energy baseline data. The 'General Information' section describes the *total expenditures for new construction, maintenance and repair, and improvements* in the residential sector in 1994, as well as the *average cost of new housing* in the US. The section also provides overall information about the *size of the residential sector*, and selected *key characteristics for single-family homes*, which are the largest component of the sector.

The ‘Operations’ section provides baseline measures for *water and trash costs* for households on an aggregated and ‘per household’ basis. The ‘Maintenance’ section provides information on *maintenance and repairs*, *and improvements* (defined as activities which add value to the property), on a ‘per household’ basis. This information can be compared with the aggregated data presented in the ‘General Information’ section of the table. Finally, the ‘Energy’ section provides information on *energy expenditures*, at an aggregated level for all households, and on a ‘per household’ basis. The baselines focus first upon the *principal energy end-use categorizations* used by the Energy Information Administration (EIA), and second upon expenditures grouped by *primary fuel source*.

It should be noted that the information presented in Table 5-12 represents only the most general of the data presented in Chapters 3 and 5 of this document.

Summary of Abbreviations Used in Table 5-12

VIP	Value of New Construction Put in Place
C50	Current Construction Reports Series C-50 Expenditures for Residential Improvements and Repairs
AHS	American Housing Survey
USGS	United States Geological Survey
EIA	Energy Information Administration

Table 5-12. Summary of Baseline Measures: Residential Sector

DESCRIPTION	YEAR	BASELINE	SOURCE[20]
GENERAL INFORMATION			
Value of New Construction Put in Place	1994	$156,575 million (constant 1992 dollars)	Census VIP Data
Total Maintenance and Repair Expenditures	1994	$39,371 million (constant 1992 dollars)	Census C50 Data
Total Expenditures for Improvements	1994	$66,671 million (constant 1992 dollars)	Census C50 Data
Average Construction Cost - All Housing	1994	$54.54 per square foot/$586.81 per square meter	Statistical Abstract
Total Number of Housing Units	1995	110 million	Census Data
Number of Single-Family (SF) Housing Units	1995	72 million	Census Data
Median Size of SF Unit	1995	1732 square feet/161 square meters	Census Data
Number of New SF Homes Started	1995	1.1 million	Census Data
OPERATIONS			
Total Expenditures for Water and Sanitary Services - All Households	1992	$30 billion	USGS
Median Monthly Cost per Household for Water	1995	$25	AHS
Median Monthly Cost per Household for Trash	1995	$15	AHS
MAINTENANCE			
Median Monthly Cost per Household for Maintenance and Repairs	1995	$25	AHS
Annual Median Expenditures per Household for M&R and Improvements	1995	$940	Census Data

[20] See accompanying text for description of abbreviations used in this table.

Table 5-12. Summary of Baseline Measures: Residential Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
ENERGY			
Total Energy Expenditures for Space Heating - All Households	1993	$39.67 billion	EIA
Total Energy Expenditures for Air Conditioning - All Households	1993	$11.33 billion	EIA
Total Energy Expenditures for Water Heating - All Households	1993	$16.99 billion	EIA
Total Energy Expenditures for Refrigeration - All Households	1993	$11.98 billion	EIA
Total Energy Expenditures for Appliances - All Households	1993	$43.95 billion	EIA
Annual Expenditures per Household for Space Heating	1993	$419	EIA
Annual Expenditures per Household for Air Conditioning	1993	$177	EIA
Annual Expenditures per Household for Water Heating	1993	$177	EIA
Annual Expenditures per Household for Refrigerators	1993	$124	EIA
Annual Expenditures per Household for Appliances	1993	$455	EIA
Median Monthly Cost per Household for Electricity	1995	$69	AHS
Median Monthly Cost per Household for Piped Gas	1995	$42	AHS
Median Monthly Cost per Household for Fuel Oil	1995	$61	AHS
Median Monthly Cost per Household for Bottled Gas	1995	$49	AHS
Median Monthly Cost per Household for Other Fuels	1995	$13	AHS

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6. OM&E Measures for the Commercial/Institutional Sector

6.1 Key Considerations for the Commercial/Institutional Sector

This section of the document addresses the issue of data sources, availability, and constraints in the commercial/institutional sector, and summarizes the key data sources which are used for developing the baseline measures. The section also provides an overview of the commercial/institutional sector.

6.1.1 Data Considerations: Sources, Availability, and Constraints

Preliminary data searches for the commercial/institutional sector indicated there are a variety of organizations carrying out systematic surveys of particular parts of the commercial/institutional sector, but that there are few surveys which cover the entire sector. The most detailed survey of the commercial/institutional sector located by the authors is carried out by the Energy Information Administration (EIA), a part of the US Department of Energy. Information from EIA, and other selected organizations, was examined in detail to determine whether it was suitable for the development of national construction baselines. The principal data sources which are used in this document are described below.

Data from the Energy Information Administration

The EIA carries out the **Commercial Buildings Energy Consumption Survey (CBECS)**, which is a national sample survey that collects data on the consumption of and expenditures for energy in US commercial buildings, along with data on energy-related characteristics of the buildings. The **CBECS** was first conducted in 1979, and has been carried out triennially since 1983. The **1992 CBECS** has been used in this document, principally because at the time of writing, although data for commercial buildings characteristics were available for 1995, energy consumption and expenditures data were not. In the **1992 CBECS**, there were approximately 6,600 sampled buildings. In addition, personal interviews with approximately 5,800 building owners, managers or tenants were conducted. Energy-related characteristics of the buildings were obtained from on-site interviews with the building managers, owners or tenants during the **Commercial Buildings Energy Characteristics Survey**. Data from both the 1992 and 1995 surveys are included in this document. Commercial buildings are defined by EIA as all enclosed, roofed, and walled structures used predominantly for commercial purposes, with floorspace greater than 93 square meters (1,000 square feet). The **CBECS** also covers the institutional sector (e.g., education, religious, and healthcare facilities), though in the survey these are all collectively referred to as commercial buildings.

The EIA produces a number reports from the **CBECS** survey data. These include *Commercial Buildings Characteristics 1992* and *1995*, and *Commercial Buildings Energy Consumption and Expenditures 1992.* EIA also produces the *1996 Renewable Energy Annual*, which includes information relating to municipal solid waste generation.

Data from EIA are available through its Internet site (URL: http://www.eia.doe.gov), or through paper or electronic publications, including the *EIA Energy InfoDisc Volume 2, No.1, 1997*, which provides energy data for all four industry sectors. Energy data provided by EIA are very detailed.

In this document, data from the EIA reports *Commercial Buildings Characteristics 1992*, *Commercial Buildings Characteristics 1995* and *Commercial Buildings Energy Consumption and Expenditures 1992* have been used both to characterize the commercial/institutional sector, and to develop energy cost and consumption baselines for the sector. The highly detailed nature of the data means that there are no data constraints.

Data from the US Bureau of the Census

The US Bureau of the Census (USBC) carries out a number of surveys of the US wholesale, retail, and service industries, and reports periodically upon a variety of related issues. Surveys/reports of particular interest are the **Census of Wholesale Trade**, the **Census of Retail Trade**, and the **Census of Service Industries**. These are considered in more detail below.

The **Census of Wholesale Trade**, which is carried out every five years, considers all establishments with payroll in SIC Division F[21] that sell merchandise to retailers or other wholesalers. Data for 1992 are available at present. The survey includes SIC 50 (durable goods stores, such as motor vehicles and automotive parts, and lumber and construction materials) and SIC 51 (non-durable goods, such as paper, drugs, groceries, beer, and wine). These SIC Codes can be grouped under the 'Mercantile and Service' category which is defined by EIA in the **CBECS**.

The **Census of Retail Trade** is also carried out every five years (data are available for 1992 at present), and considers all establishments in SIC Division G that sell merchandise and related services to the public for personal or household consumption. This excludes non-employees engaged in direct selling (SIC 5936). The survey includes SIC 52 (building materials, hardware, garden supply, and mobile homes dealers), SIC 53 (general merchandise stores), SIC 54 (food stores), SIC 55 (automotive dealers and gasoline service stations), SIC 56 (apparel), SIC 57 (furniture and home furnishings, and equipment stores), and SIC 58 (eating and drinking places). All of these SIC Codes, with the exception of SIC 54 and SIC 58, can be grouped under the 'Mercantile and Service' Category defined by EIA. SIC 54 and SIC 58 correspond to the 'Food Sales' category defined by EIA.

The **Census of Service Industries** is also carried out every five years (data are available for 1992 at present), and considers establishments which provide services to customers, businesses, governments, and other organizations. These include all taxable establishments, and tax-exempt establishments with payroll, in SIC Division I, except for

[21] For further details of the SIC Classifications used in the Economic Census, refer to the US Bureau of the Census.

academic and professional schools (SIC 821-2), labor, political, and religious organizations (SIC 863 and 865-6), and households (SIC 88). The survey includes SIC 70 (hotels, motels etc.), SIC 72 (personal services), SIC 73 (business services); SIC 75 (automobile repair services and garages), SIC 76 (miscellaneous repair services), SIC 78 (motion pictures), SIC 79 (amusement and recreational facilities), SIC 80 (health services), SIC 81 (legal services), SIC 823 (libraries), SIC 83 (social services), SIC 84 (museums, art galleries etc.), SIC 86 (membership organizations), SIC 871 (engineering, architectural and surveying services), SIC 872 (accounting, auditing and bookkeeping); SIC 873 (research, development, and testing services), and SIC 874 (management and public relations services). All of these SIC Codes, can be grouped under either the 'Mercantile and Service', 'Public Assembly', 'Education', 'Health Care', 'Office', 'Lodging', or 'Laboratory' categories defined by EIA.

Data which are collected for these three surveys include the type of business, geographic location, sales, inventory, number of employees, operating expenses, and so forth. Operating expenses data consider the cost of utilities, and the cost of purchased services for the repair of buildings and machinery, as well as a variety of other purchased services, such as legal and accounting services. Selected data from USBC are available through its Internet site (URL: http://www.census.gov), or via electronic or paper publications.

In this document, data from the USBC have been used to provide some general information on operations, maintenance, and energy costs in the commercial/institutional sector. Where specific data constraints have been found, these have been identified in the text.

Data from Whitestone Research

The *Whitestone Building Maintenance and Repair Cost Reference 1997* is the third of a series of annual reports produced by Whitestone Research which presents estimates of 50-year maintenance cost profiles for 24 different building models. Building types include fast food restaurants, motels, auto service garages, offices, supermarkets, movie theaters, and so forth. These cover a good portion of the commercial/institutional sector. The profile for each model includes a building description, a list of major building components, and forecasts of maintenance and repair costs at various levels of aggregation over the service life of the building. These can be adjusted for selected metropolitan areas, and modified to include different building components. The Whitestone Reports are available in paper form from Whitestone Research.

In this document, data from the *Whitestone Building Maintenance and Repair Cost Reference 1997* have been used to provide an overview of maintenance and repair expenditures for typical types of building in the commercial/institutional sector.

Data from the International Facility Management Association

The International Facility Management Association (IFMA) is an association serving the facility management profession, which provides educational and technical services, carries out research, certifies facility management competency, and promotes the profession.

IFMA has carried out a number of benchmarking studies covering both the commercial/institutional and industrial sectors. *Research Report #13*, *Benchmarks II*, printed in 1994, is the result of a 1993 survey of IFMA members, principally in the service sector, which presents benchmarking data derived from 283 survey questionnaires. While the report has a relatively small sample size, it appears to be one of the few reports available which considers operations, maintenance, and energy costs across a significant part of the commercial/institutional sector in any level of detail. Data from IFMA are available through its Internet site (URL: http://www.ifma.org), or through paper or electronic publications.

In this document, data from the IFMA report *Benchmarks II* have been used to generate some general baselines for the commercial/institutional sector.

Data from the Building Owners and Managers Association

The Building Owners and Mangers Association (BOMA) is a trade organization providing technical support to its membership in the building management sector. The *1996 BOMA Experience Exchange Report: Operating a Cost Effective Office Building* (the latest in a series of annual reports) provides published tables of operating income and expense data for over 4000 office buildings located throughout North America for fiscal year 1995. The sample includes 3657 US private sector properties, 213 US government buildings, 175 private properties in Canada, and 430 government buildings in Canada. The BOMA Report provides detailed descriptions of operations, maintenance and energy costs for commercial office buildings in both the US and Canada for both the government and private sector, as well as national cross tabulations, and city specific analyses. Data from BOMA are available through its Internet site (URL: http://www.boma.org), or through paper publications.

In this document, data from the *1996 BOMA Experience Exchange Report: Operating a Cost Effective Building* have been used to develop detailed baselines for commercial office buildings, which represent a significant proportion of all buildings in the commercial/institutional sector.

Data from APPA: The Association of Higher Education Facilities Officers

APPA is an organization with more than 4500 members representing learning institutions across the US and Canada, with universities and colleges representing the largest segment of the membership. APPA promote the effective operation and maintenance of education facilities through education and technical support of facility mangers and others in the profession. The *APPA 1993-94 Comparative Costs and Staffing Report for College and University Facilities* (the second biennial report), provides detailed information on facilities management costs and staffing information. It is based on 516 surveys carried out for the 1993-94 fiscal year. Data are presented which describe operations, maintenance, and energy costs for facilities, sorted by facility funding source, type, geographic location, and size of student population. Data from APPA are available through its Internet site (URL: http://www.appa.org) or through paper publications.

In this document, data from the *APPA 1993-94 Comparative Costs and Staffing Report for College and University Facilities* have been used to develop detailed baselines for educational facilities, which represent an important part of the commercial/institutional sector.

Data from the Institute of Real Estate Management

The Institute of Real Estate Management (IREM) is an organization which educates and certifies real estate professionals, carries out a variety of surveys of apartment buildings, commercial office buildings, and most recently, open and enclosed shopping centers in the US. The *1996 Income/Expense Analysis: Shopping Centers* provides detailed information on the operations, maintenance, and energy costs for open shopping centers and enclosed malls. In 1995, data were collected from over 800 centers, and the report provides national analyses, metropolitan analyses, regional analyses and analyses by center size and age. Data from IREM are available through its Internet site (URL: http://www.irem.org), or through paper publications.

In this document, data from the *1996 Income/Expense Analysis: Shopping Centers* have been used to establish detailed baselines for open shopping centers in the US, which are an important part of the commercial/institutional sector.

Data from Other Sources

A wide variety of other data sources were examined. A brief description of some of these sources is given below:

- The Federal Energy Management Program (FEMP), a part of the US Department of Energy, provides a series of energy efficiency recommendations for selected commercial equipment, some of which are included in this document. These recommendations can be found on the FEMP Internet site (URL: http://www.eren.doe.gov/femp/procurement/begin.html). The FEMP Internet site also provides information about Federal Energy Saver showcase facilities. FEMP is a part of the Energy Efficiency and Renewable Energy Network (EREN), which provides a range of energy-related information, covering such issues as sustainability in building, building efficiency, intelligent building systems, and so forth. A source list of associated organizations is provided on the EREN Internet site (URL: http://www.eren.doe.gov/buildings/energy_savers/sourcelist.html).

- The United States Geological Survey (USGS) provides data on water consumption by the commercial/institutional sector in the US. Data are available on the USGS Internet site (URL: http://www.usgs.gov). Data relevant to the commercial/institutional sector are included in this document.

6.1.2 Overview of the Commercial/Institutional Sector

The overview of the commercial/institutional sector presented in this section expands on the overview presented in Chapter 3 of this document. This section examines the size of the US commercial/institutional sector, grouped by principal building activity, both in terms of number of buildings and total floorspace. It also examines a number of key characteristics of the commercial/institutional sector, such as the age, size, and geographic distribution of facilities. Data are then presented which give an overview of operations, maintenance, and energy costs in the commercial/institutional sector, for all buildings combined. Some of this information will be used later in this document to develop general baseline measures for the commercial/institutional sector. Some of the difficulties which arise from aggregating operations and maintenance costs, and in tracking the rate of change of the size of the commercial/institutional sector are also examined.

6.1.2.1 General Overview

In this section, a variety of figures are presented which show key characteristics of the commercial/institutional sector. Figures 6-1 through 6-3 show the size of the commercial/institutional sector by principal building activity. Figures 6-4 through 6-7 show how the commercial/institutional sector can be categorized by building floorspace/size. Finally, Figures 6-8 through 6-10 examine building characteristics by year of construction of the building.

Data from the 1992 and 1995 *Commercial Buildings Characteristics Reports* have been used to generate Figure 6-1. The figure shows the total number of buildings in the US grouped by principal building activity, as defined by EIA. Reference to Figure 6-1 indicates that of the 4,806,000 buildings in the US in 1992, approximately 26 percent were in the mercantile and service category (which includes automotive sales and services, retail sales, services, shopping centers, and wholesale goods), approximately 16 percent are office buildings, and approximately 16 percent were warehouse and storage buildings (these are considered as part of the industrial sector, but are included in this section, as they are part of the **CBECS**). Comparison between 1992 and 1995 data indicates that the total number of buildings in the commercial/institutional sector fell from 4,806,000 in 1992 to 4,579,000 in 1995. The most significant changes were in the number of warehouses and storage facilities (reduced by 181,000), religious worship buildings (reduced by 97,000), and vacant buildings (reduced by 58,000). The only area where there was a significant increase in the number of buildings was public assembly (increased by 48,000). The mean area of all buildings decreased from 1,310 square meters (14,100 square feet) in 1992 to 1,190 square meters (12,800 square feet) in 1995. Similar changes in mean area per worker were 89 square meters (953 square feet) in 1992 to 71 square meters (766 square feet) in 1995, with mean hours of operation increasing from 58 hours in 1992 to 62 hours in 1995.

Figure 6-2 shows the total building floorspace in each principal building category for all commercial/institutional buildings in the US in 1992 and 1995. Reference to the figure shows that there were 6,308 million square meters (67,876 million square feet) of floorspace in 1992, compared with 5,462 million square meters (58,772 million square feet) in 1995 (a 13.5 percent reduction). Comparison of Figure 6-1 and Figure 6-2 indicates that while the number of educational buildings is not especially high compared with other building categories, in terms of total floorspace, it is one of the largest categories. This suggests that educational establishments are significantly larger than religious, public assembly, or food service establishments. Similarly, office buildings, although smaller in number to mercantile and service buildings, represent a similar amount of total floorspace, most likely because a significant number of office buildings are multi-story. The other important point is that educational, mercantile and service, and office buildings accounted for over 60 percent of total commercial/institutional sector floorspace in the US in 1992 and 1995 (if we exclude warehouse and storage facilities), hence focusing upon these categories for the development of baseline measures captures a large proportion of the sector.

In Figure 6-3, the distribution of building floorspace across the US census regions, by principal building activity is shown for 1992. Reference to the figure shows that there was significantly more commercial/institutional floorspace in the south census region (approximately 35 percent of the total) compared with the other three census regions, with the least amount in the northeast (approximately 20 percent of the total). This was particularly noticeable in the mercantile and service, office, public assembly, and warehouse and storage categories. These trends are also reflected in 1995 data.

Figure 6-4 and Figure 6-5 shows the size distribution of all commercial/institutional buildings (in terms of building floorspace category), by number of buildings and total sector floorspace respectively. Comparison of the two figures indicates that while a large proportion of all buildings have floor areas between 92.9 to 464.5 square meters (1,000 to 5,000 square feet), and a relatively small proportion have areas over 46,451 square meters (500,000 square feet), when total floorspace in each size category is compared, there is a much more even distribution across all building sizes. Thus, while smaller buildings dominate the sector, their relative importance in terms of total floorspace is similar to that of much larger buildings. Similar information is presented in Figure 6-6, which shows how total floorspace in the commercial/institutional sector varied by building size in 1992. Comparison of Figure 6-3 and Figure 6-6 suggests that there are no significantly different trends in building size depending upon census region.

Figure 6-1. Total Number of Buildings by Principal Building Activity: 1992 and 1995

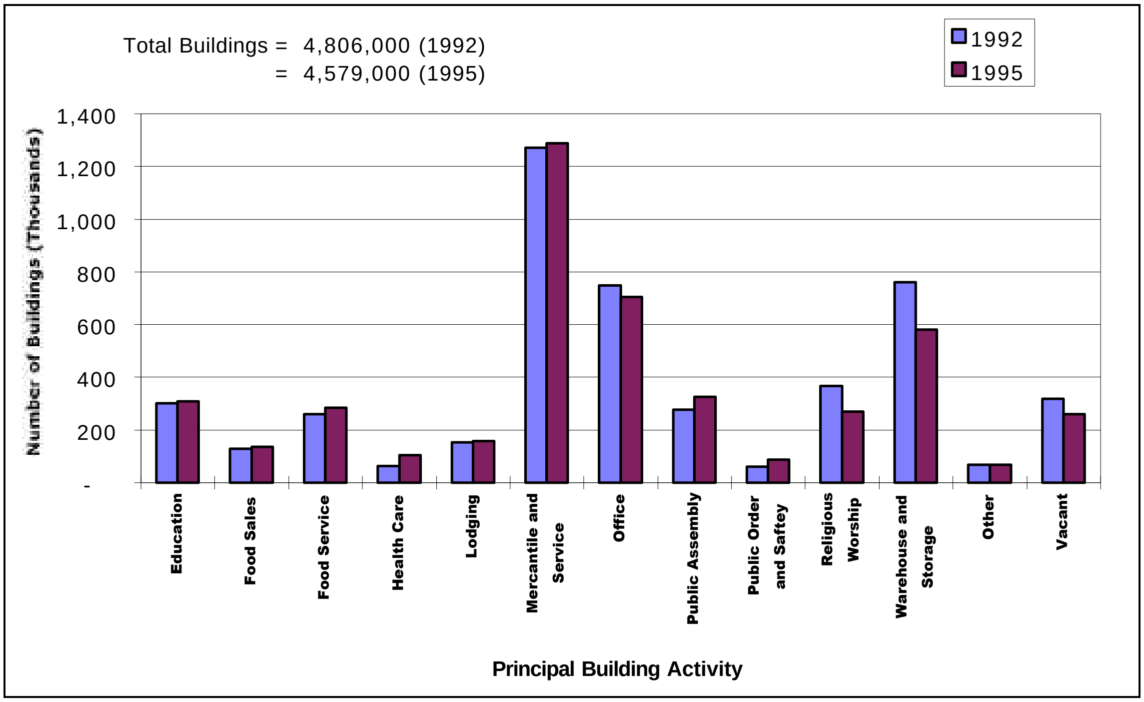


Figure 6-2. Total Floorspace by Principal Building Activity: 1992 and 1995

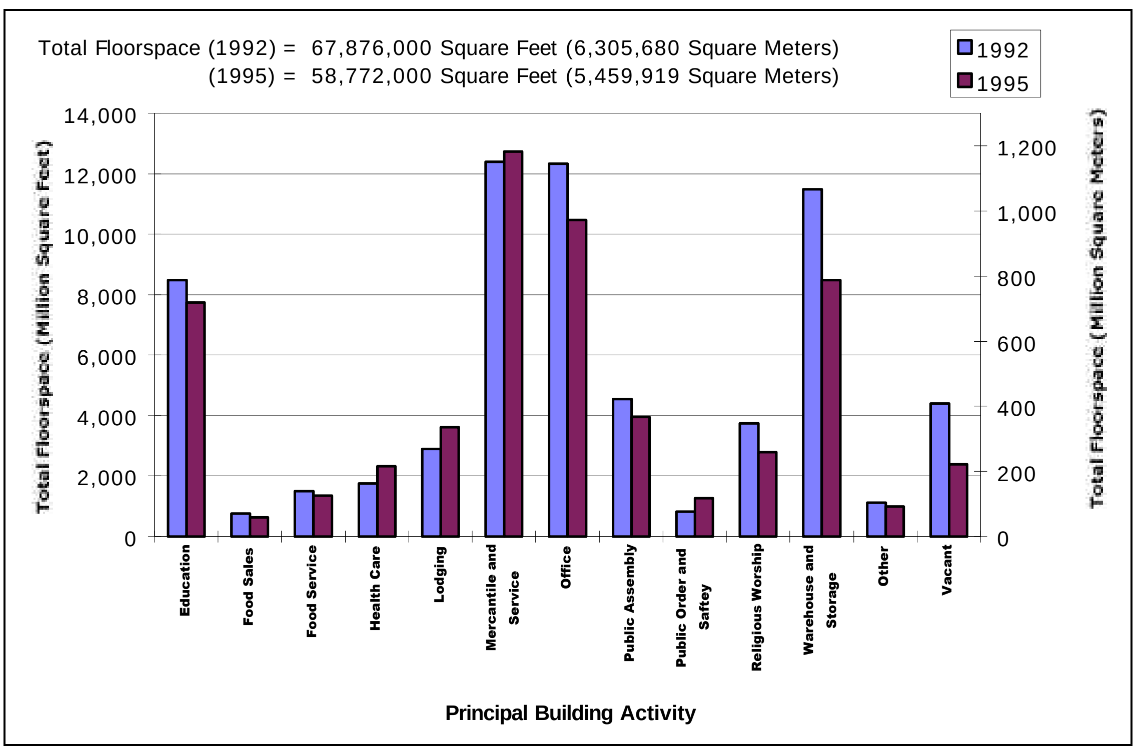
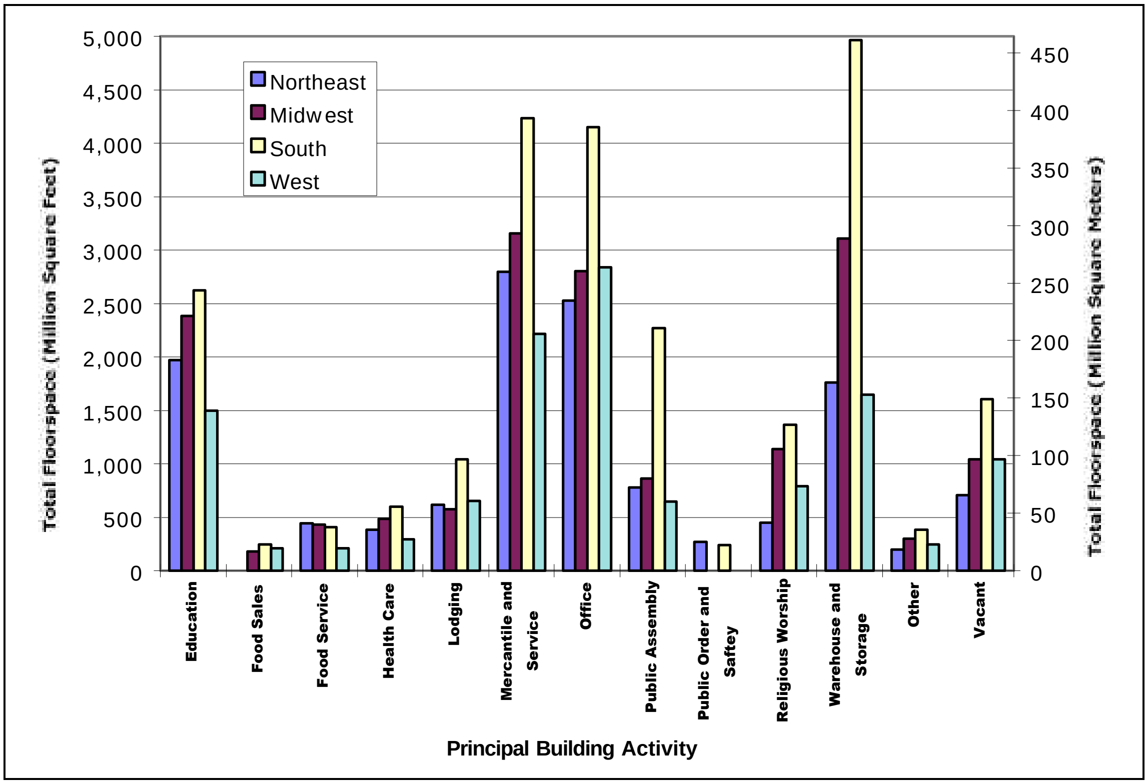


Figure 6-3. Total Floorspace by Principal Building Activity and Census Region: 1992



In Figure 6-7, the number of floors for each size of building is mapped against total floorspace. As expected, there are a greater number of high-rise buildings in the larger floorspace categories. There are no buildings with ten or more floors having total floor areas below 9,290 square meters (100,000 square feet), and no buildings having more than three floors with total floor areas below 464.5 square meters (5,000 square feet).

Figure 6-8 and Figure 6-9 show how the number of buildings and total floorspace vary depending upon the year of construction of the building.

Figure 6-10 shows how total floorspace varies by year of construction and census region. The figure indicates that the relatively high proportion of total floorspace in the south census region has remained consistent over time, thus the geographic distribution of the commercial/institutional sector appears to be relatively stable.

Figure 6-4. Total Number of Buildings by Building Size Category: 1992 and 1995

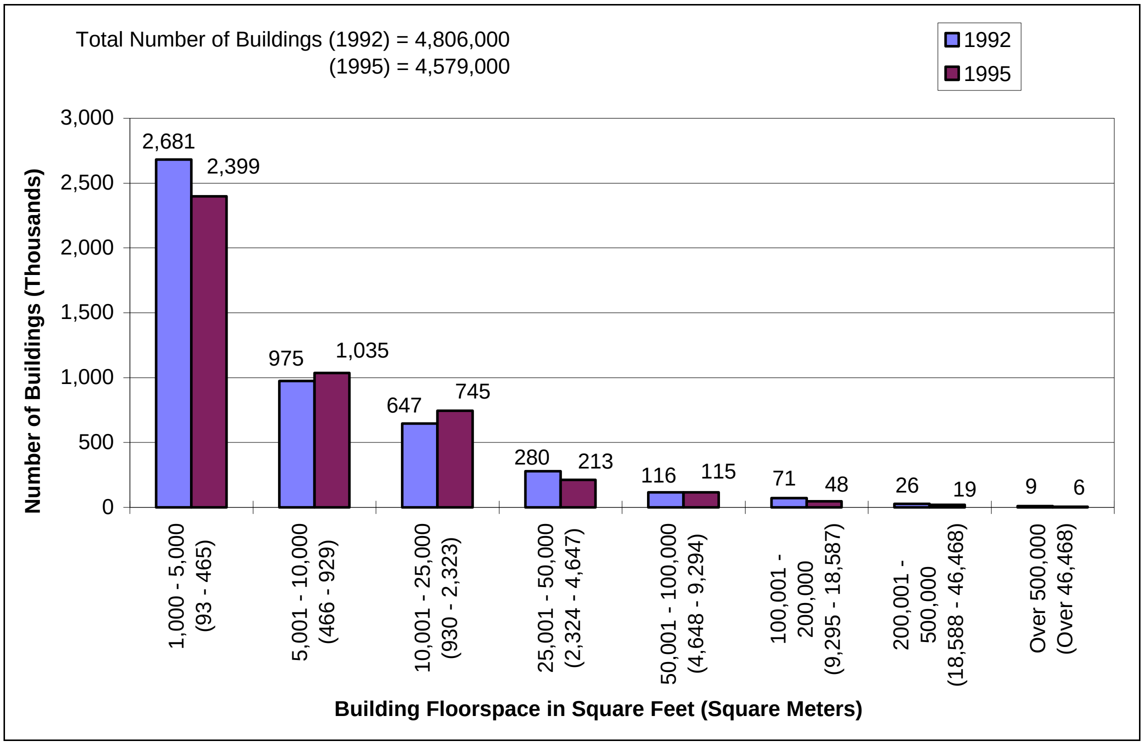


Figure 6-5. Total Floorspace by Building Size Category: 1992 and 1995

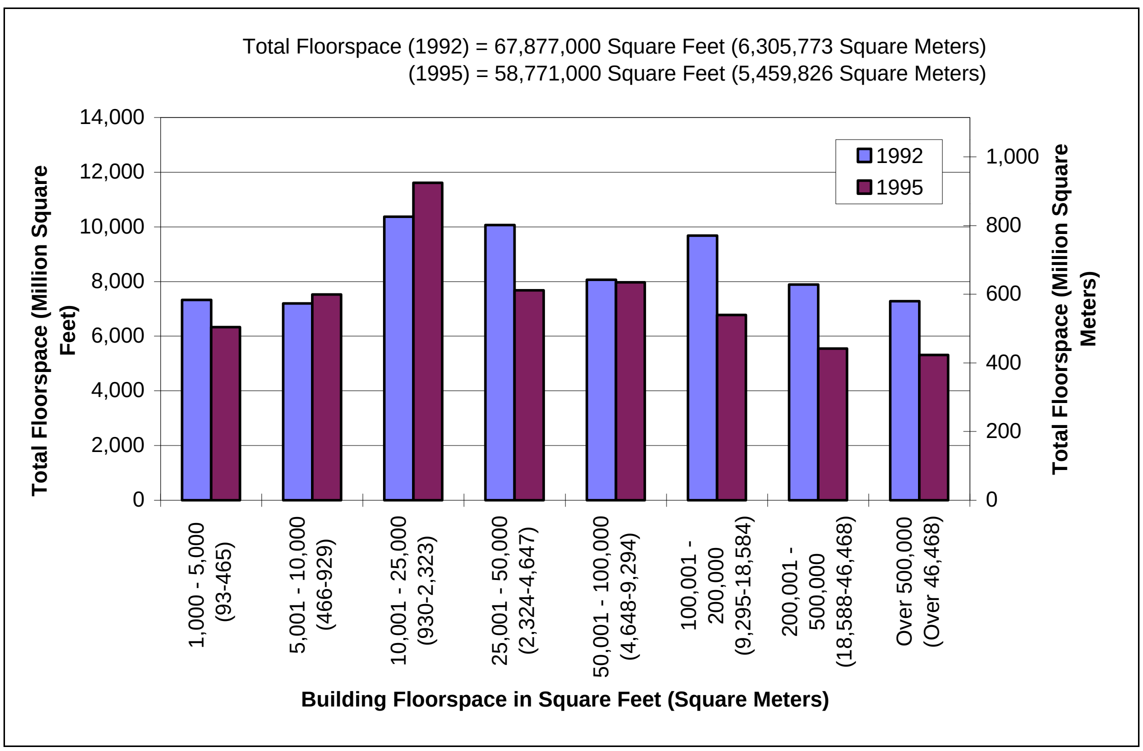


Figure 6-6. Total Floorspace by Building Size Category and Census Region: 1992

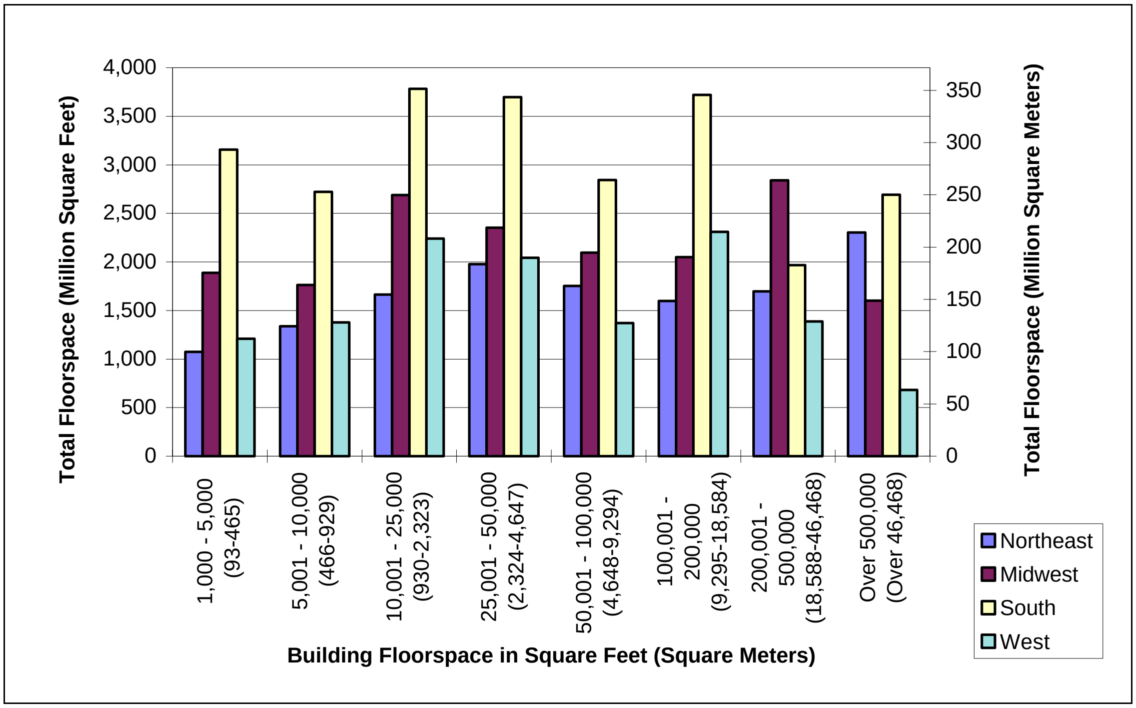


Figure 6-7. Total Floorspace by Building Size Category and Number of Floors: 1992

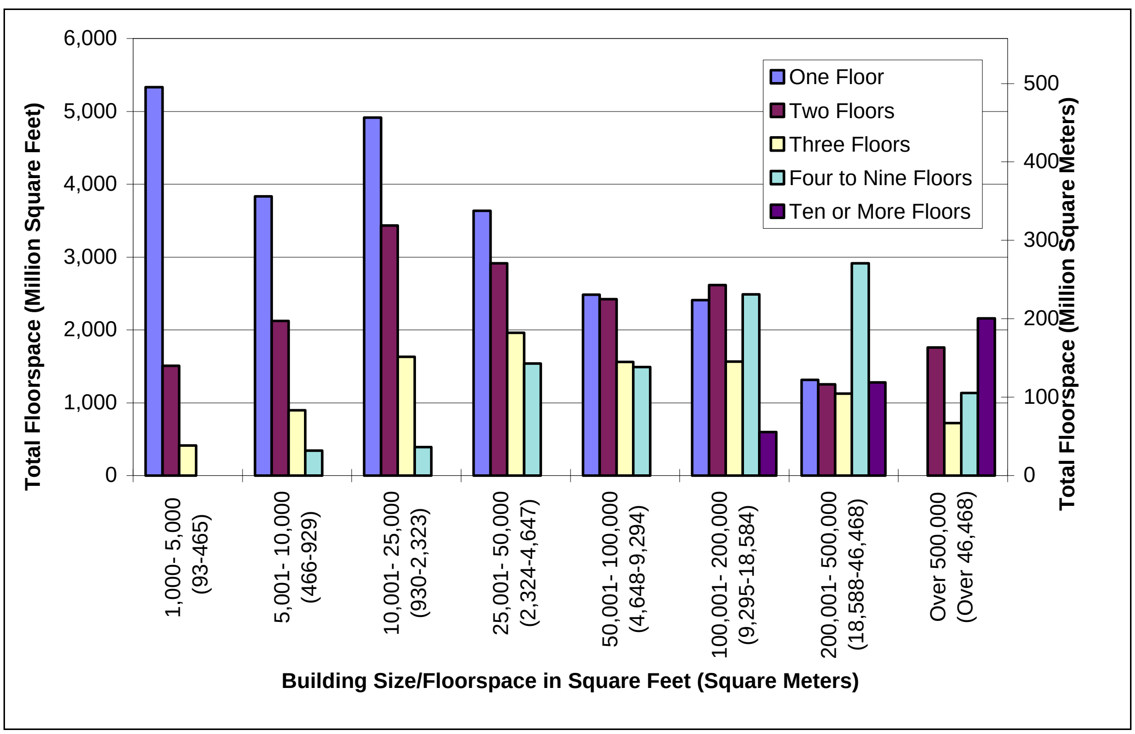


Figure 6-8. Total Number of Buildings by Year of Construction: 1992 and 1995

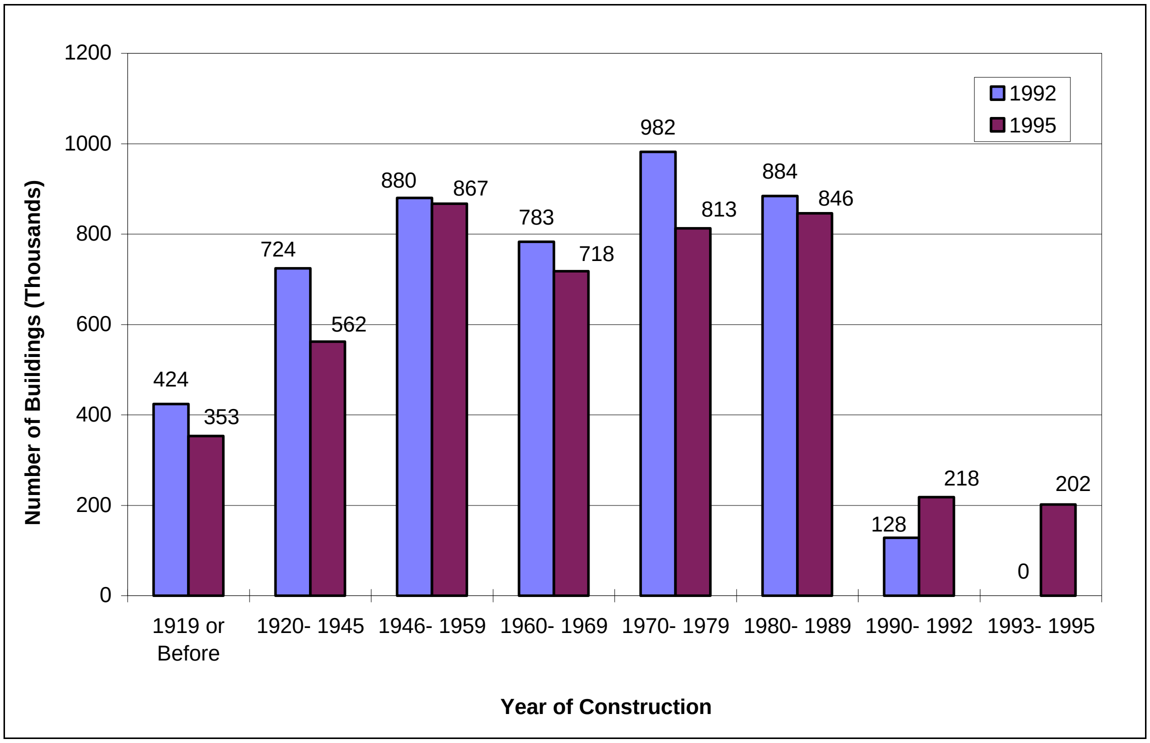


Figure 6-9. Total Floorspace by Year of Construction: 1992 and 1995

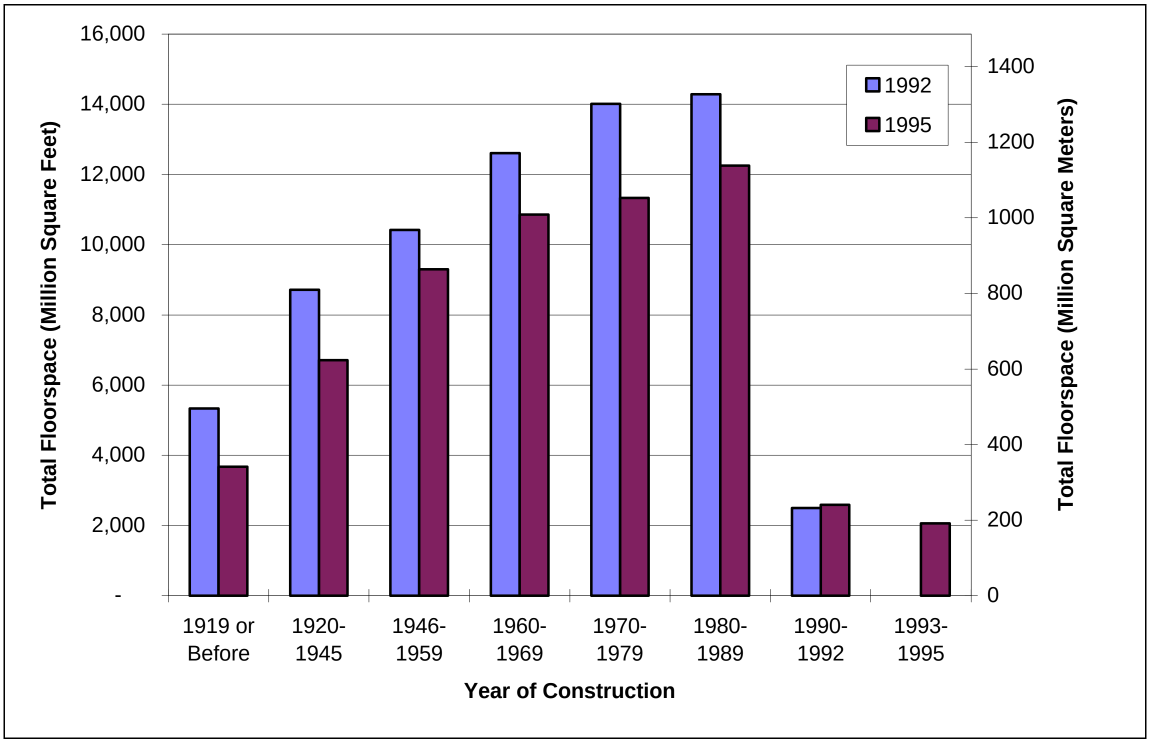
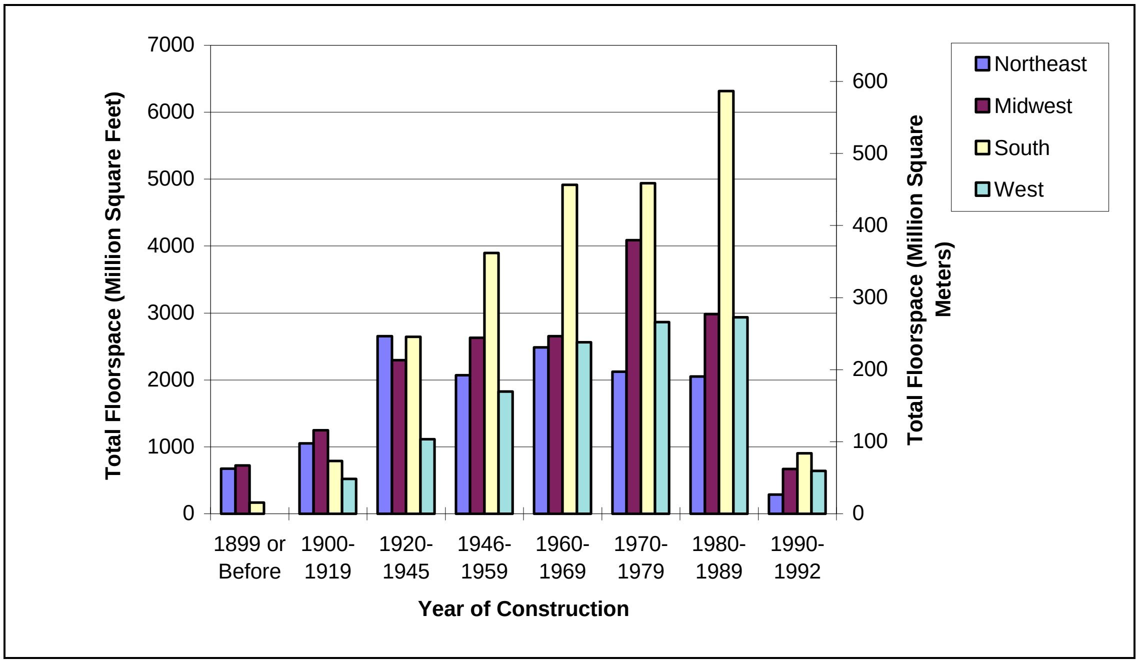


Figure 6-10. Total Floorspace by Year of Construction and Census Region: 1992



6.1.2.2 Operations, and Maintenance and Repair Overview

Data from the **1992 Census of Wholesale Trade, Census of Retail Trade,** and **Census of Service Industries** have been used to produce Table 6-1, which shows selected operating expenses by type and kind of business. These census surveys provide some useful data, but there are some significant limitations to its usage. The major problem is that the combined data from these three surveys do not represent all of the commercial/institutional sector. In particular, it excludes academic and professional schools, labor, political and religious organizations. It also excludes finance, insurance and real estate establishments (SIC Codes 60, 61, 62, 63, 64, 65, and 67), since operating expense data are not provided in the **Census of Finance Insurance and Real Estate**, as well as public administration establishments (SIC Codes 91, 92, 93, 94, 95, 96, and 97), for which no census data exist. The total operating expenses shown in Table 6-1 do not therefore represent true totals for the commercial/institutional sector.

For example, if we look at the total cost for purchased electricity ($33.1 billion), and compare this with the total expenditures from the **CBECS** for electricity ($57.6 billion), we see that there is a factor of 1.74 difference. Similarly, if we compare 'total purchased utilities less water and sewer charges' in Table 6-1 ($41.0 billion) with total expenditures data from **CBECS** presented in Figure 6-14 ($72.6 billion), we see that there is a similar discrepancy. If we assume that we can scale the figures in Table 6-1 by a factor of 1.75 (i.e., we assume that the electricity figures presented in **CBECS** are a good indicator of the 'size' of the commercial/institutional sector), we obtain the estimated totals shown in the bottom line of Table 6-1. Although this is a very crude approximation, it helps us to ballpark some of the figures previously presented in this document. For example, the estimated total for repair services for buildings and structures becomes $20.3 billion. This compares with the calculated total of $24.9 billion calculated from the *Value Put in Place* and the **Census of Construction** data presented in Chapter 3. Similarly, if we compare the estimated total for water sewer and other utilities ($12.2 billion), with the previous estimate of $9.1 billion presented in Section 3.4, we can see that the Table 6-1 estimates appear to be of the right order of magnitude.

Table 6-2 Part A and Part B, which are based upon data from USGS, shows commercial freshwater use in 1990 by water resources region. Reference to the table shows that total withdrawals and deliveries in the commercial sector were 31,378 million liters per day (8,290 million gallons per day), while consumption was approximately 11 percent of this total. Approximately 71 percent of all deliveries were from the public supply, with the remainder from self-supplied ground water sources (11 percent), and surface water sources (18 percent).

Table 6-3, which is based upon data from the *Whitestone Building Maintenance and Repair Cost Reference 1997*, shows average annual maintenance and repair costs per square meter/square foot based upon 50 year maintenance cost profiles for 24 building models in the Washington DC area[22]. The building types are ranked in order of total cost. The total cost comprises two elements. The first element is the cost for major repair and replacement of building components, which varies depending upon the type of building; the second is the cost of in-house maintenance, which is assumed to be constant for all buildings in Washington DC at $16.04 per square meter ($1.49 per square foot). This is based upon an in-house staff of 25 workers per 0.117 million gross square meters (GSM) (1.25 million gross square feet (GSF)) of floorspace. Table 6-3 indicates that the highest maintenance and repair costs are associated with fast food restaurants, and the lowest with warehouses.

[22] See Whitestone Report for details of conversion factors for other metropolitan areas.

Table 6-1. Operating Expenses by Type and Business: 1992 (Millions of Dollars)

SIC Code	SIC Code Description	Part of Commercial Sector	Total Operating Expenses	Annual Payroll	Telephone and Purchased Communications	Total Purchased Utilities	Electricity	Fuels (non-highway)	Water Sewer and Other Utilities	Total Purchased Repair Services	Repair Services - Buildings, Structure and Related Facilities	Repair Services - Machinery, Equipment and Other
50	Durable goods	Mercantile and Service	190,043	88,120	4,551	2,948	1,969	586	392	2,638	773	1,865
51	Nondurable goods	Mercantile and Service	127,769	56,671	1,883	2,925	1,902	724	298	2,868	751	2,118
52	Building materials, hardware, garden supply, and mobile home dealers	Mercantile and Service	27,328	13,188	367	799	560	126	113	568	198	369
53	General Merchandise stores	Mercantile and Service	(S)	29,009	451	2,198	1,909	126	163	831	537	294
54	Food stores	Food Sales	88,777	42,532	507	5,459	4,547	375	537	2,038	620	1,417
55	Automotive dealers and gasoline service stations	Mercantile and Service	80,372	39,213	1,108	2,448	1,814	305	328	1,561	721	840
56	Apparel	Mercantile and Service	38,743	15,115	446	1,159	935	87	136	415	258	157
57	Furniture and home furnishings and equipment stores	Mercantile and Service	33,491	13,616	556	949	719	119	112	418	227	191
58	Eating and drinking places	Food Sales	119,675	53,586	785	7,126	4,878	1,096	1,152	2,835	1,175	1,660
70	Hotels, motels, tourist courts, rooming and boarding houses, camps, trailer parks, and organization and lodging houses	Lodging	57,852	19,674	768	3,495	2,252	497	746	1,630	1,031	598
72	Personal services	Mercantile and Service	43,482	18,843	797	2,022	1,114	518	391	873	366	507
73	Business services	Office	243,594	130,382	4,663	1,739	1,225	314	200	3,275	522	2,753
75	Automotive repair, services, and garages	Mercantile and Service	50,577	18,561	710	1,227	753	225	219	1,245	298	947
76	Miscellaneous repair services	Mercantile and Service	21,742	10,757	373	349	215	78	56	329	91	237
78	Motion pictures	Public Assembly	26,210	8,888	211	396	324	30	42	294	133	161
79	Amusement and recreation services	Public Assembly	52,605	20,631	548	1,821	1,314	216	291	1,220	538	682
80	Health services	Health Care	527,901	264,923	4,643	7,410	4,662	1,517	1,231	5,777	2,118	3,659
81	Legal services	Office	72,366	40,564	1,360	325	263	38	24	550	124	426
823	Libraries	Public Assembly	508	245	4	17	13	3	2	13	8	4
824	Correspondence schools and vocational schools	Education	3,613	1,745	58	51	43	4	4	48	23	26
83	Social services	Health Care	55,289	26,173	601	1,161	678	262	221	722	467	255
84	Museums, art galleries, and botanical and zoological gardens	Public Assembly	2,900	1,253	24	98	71	18	9	53	30	22
86	Membership organizations	Public Assembly	29,355	11,244	(S)	961	547	175	239	581	334	247
871	Engineering, architectural, and surveying services	Office	61,683	33,139	549	(S)	(S)	(S)	(S)	342	101	241
872	Accounting, auditing, and bookkeeping services	Office	29,019	16,210	502	202	144	(S)	20	207	50	157
873	Research, development, and testing services	Laboratory	27,573	12,480	353	307	235	36	36	303	87	217
874	Management and public relations services	Office	57,121	29,176	892	331	(S)	(S)	(S)	436	(S)	296
TOTAL - WHOLESALE, RETAIL + SERVICE INDUSTRY			2,069,588	1,015,938	27,710	47,923	33,086	7,100	6,962	32,070	11,581	20,346
ESTIMATED TOTALS C/I SECTOR (see text)			3,621,779	1,777,892	48,493	83,866	57,600	12,425	12,183	56,123	20,267	35,606

Table 6-2. Commercial Freshwater Use: 1990

Part A: Million Gallons Per Day

	Self-Supplied Withdrawals				Total Use	
	Source					
	Ground Water	Surface Water	Total	Public-Supply Deliveries	Withdrawals and deliveries	Consumptive Use
New England	82	51	133	172	305	36
Mid-Atlantic	94	39	133	937	1,070	101
South Atlantic-Gulf	120	14	134	746	880	121
Grea Lakes	27	81	108	637	746	69
Ohio	58	31	89	411	500	52
Tennessee	56	0.2	56	111	167	16
Upper Mississippi	134	126	260	607	867	83
Lower Mississippi	20	72	92	150	242	29
Souris-Red-Rainy	0.1	0.2	0.3	11	11	1
MissouriBasin	33	6.4	40	270	309	63
Arkansas-White-Red	27	138	165	241	406	53
Texas-Gulf	47	11	57	113	170	14
Rio Grande	19	1.2	20	64	84	44
Upper Colorado	5.6	0.7	6.3	19	25	5.3
Lower Colorado	23	6.3	29	191	220	76
Great Basin	7	9.3	16	89	105	14
Pacific Northwest	49	669	718	202	920	52
California	58	213	271	780	1,050	7.8
Alaska	8.7	9	18	33	51	5
Hawaii	39	0.6	40	62	102	26
Caribbean	0.4	0.3	0.8	57	58	18
Total	908	1,480	2,390	5,900	8,290	885

Part B: Million Liters Per Day

	Self-Supplied Withdrawals				Total Use	
	Source					
	Ground Water	Surface Water	Total	Public-Supply Deliveries	Withdrawals and deliveries	Consumptive Use
New England	310	193	503	651	1,154	136
Mid-Atlantic	356	148	503	3,547	4,050	382
South Atlantic-Gulf	454	53	507	2,824	3,331	458
Grea Lakes	102	307	409	2,411	2,824	261
Ohio	220	117	337	1,556	1,893	197
Tennessee	212	1	212	420	632	61
Upper Mississippi	507	477	984	2,297	3,282	314
Lower Mississippi	76	273	348	568	916	110
Souris-Red-Rainy	0	1	1	42	42	4
MissouriBasin	125	24	151	1,022	1,170	238
Arkansas-White-Red	102	522	625	912	1,537	201
Texas-Gulf	178	42	216	428	643	53
Rio Grande	72	5	76	242	318	167
Upper Colorado	21	3	24	72	95	20
Lower Colorado	87	24	110	723	833	288
Great Basin	26	35	61	337	397	53
Pacific Northwest	185	2,532	2,718	765	3,482	197
California	220	806	1,026	2,952	3,974	30
Alaska	33	34	68	125	193	19
Hawaii	148	2	151	235	386	98
Caribbean	2	1	3	216	220	68
Total	3,437	5,602	9,046	22,332	31,378	3,350

Table 6-3. Summary of Maintenance and Repair Cost Profiles: 1996

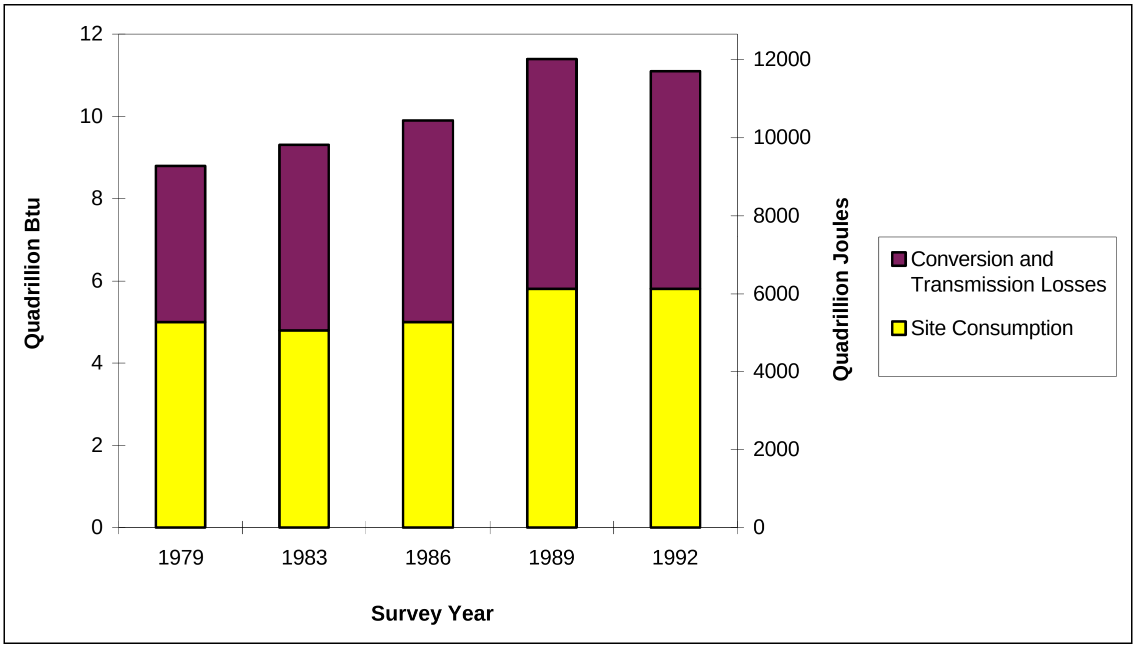
Building Type	Gross Square Feet	Major Repair/ Replacement (Dollars per Square Foot)	Total (Dollars per Square Foot)	Total (Dollars per Square Meter)
Fast Food Resturant	4,000	3.15	4.64	49.93
Motel, 40 Unit	18,000	2.52	4.01	43.15
Apartments, 24 story*	220,000	2.49	3.98	42.82
Public Library	60,000	2.28	3.77	40.57
Restaurant	10,000	2.15	3.64	39.17
Medical Clinic	13,000	2.11	3.60	38.74
General Hospital	125,000	2.00	3.49	37.55
Dormitory, 50 Room	25,000	1.78	3.27	35.19
Movie Theatre	10,000	1.75	3.24	34.86
Auto Service Garage	1,600	1.60	3.08	33.14
County Jail	318,455	1.46	2.95	31.74
Elementary School	47,000	1.41	2.90	31.20
Gymnasium	40,000	1.38	2.87	30.88
Children Center	12,000	1.35	2.84	30.56
Self-Storage warehouse*	24,000	1.24	2.73	29.37
Bowling Center	20,000	1.21	2.70	29.05
Office, 15 story	250,000	1.18	2.67	28.73
Office Park	65,000	1.12	2.61	28.08
Light Manufacturing Plant	45,000	1.09	2.58	27.76
Office, 2 story	83,000	1.07	2.56	27.55
Aircraft Hanger	32,000	0.96	2.45	26.36
Department Store	94,000	0.92	2.41	25.93
Supermarket	96,000	0.89	2.38	25.61
Warehouse*	80,000	0.64	2.13	22.92
*indicates not included as part of Commercial/Industrial sector				

6.1.2.3 Energy Overview

Data from the *1992 Commercial Buildings Energy Consumption Survey* have been used to generate Figures 6-11 through 6-19, which summarize energy consumption and expenditures in the commercial/institutional sector.

Figure 6-11 shows how total energy consumption in the commercial/institutional sector has changed since 1979. Site energy consumption is the amount of energy consumed at the site, while primary energy consumption is equal to the site energy plus energy conversion and transmission losses that occur in the electricity generation process. Reference to Figure 6-11 indicates that the total site energy consumption in the US remained relatively stable between 1989 and 1992, following an annual increase of about one percent between 1979 and 1989, but that primary energy consumption reduced slightly between 1989 and 1992 from 12,000 quadrillion joules (11.4 quadrillion Btu) to 11,700 quadrillion joules (11.1 quadrillion Btu).

Figure 6-11. Total Energy Consumption by Commercial Sector: 1979 to 1992



In Figure 6-12 and Figure 6-13, the consumption of primary energy and site energy are shown by fuel source. Figure 6-12 shows that electricity accounted for 71.1 percent of all primary energy consumption, approximately three times that of natural gas, with fuel oil and district heat making up the remaining 6.4 percent. In contrast, Figure 6-13 shows that electricity and gas accounted for similar amounts of site energy (about 45 percent each).

The total energy expenditures in the commercial/institutional sector shown in Figure 6-14 reflect the cost of energy at the site/building. Between 1989 and 1992, there was no significant difference in total energy expenditures in the sector. The figure shows that electricity costs represent nearly 80 percent of total energy costs to the consumer. This is because, to the consumer, electricity is the most expensive energy source, as a major portion of the cost is associated with energy losses during the generation and transmission of electricity. This is reflected in Figure 6-15, which shows the relative costs of different energy sources in 1992. The cost of electricity generation is comparable to other expenditures for other energy sources, but the site cost is approximately three times greater.

Figure 6-16 shows total energy expenditures in the commercial/institutional sector in 1992 by principal building activity. Reference to the figure shows that office, mercantile and service, and education buildings had the highest expenditures and consumed the greatest amount of energy compared with other types of building. This is to be expected given that these building categories represent the largest amounts of total floorspace in the commercial/institutional sector.

Figure 6-12. Total Primary Energy Consumption by Energy Source: 1992

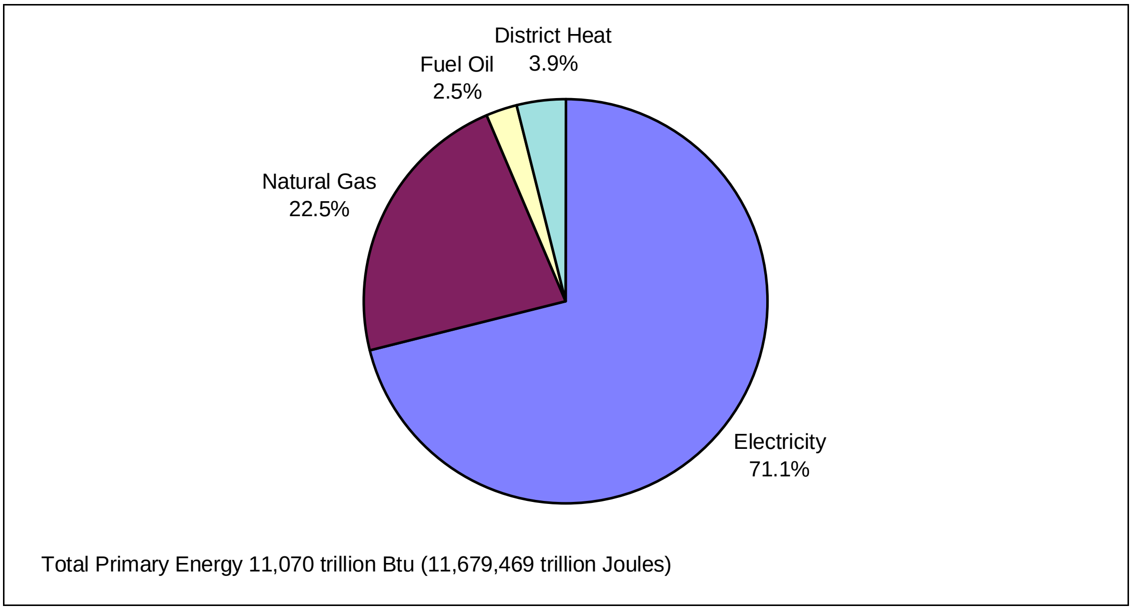


Figure 6-13. Total Site Energy Consumption by Energy Source: 1992

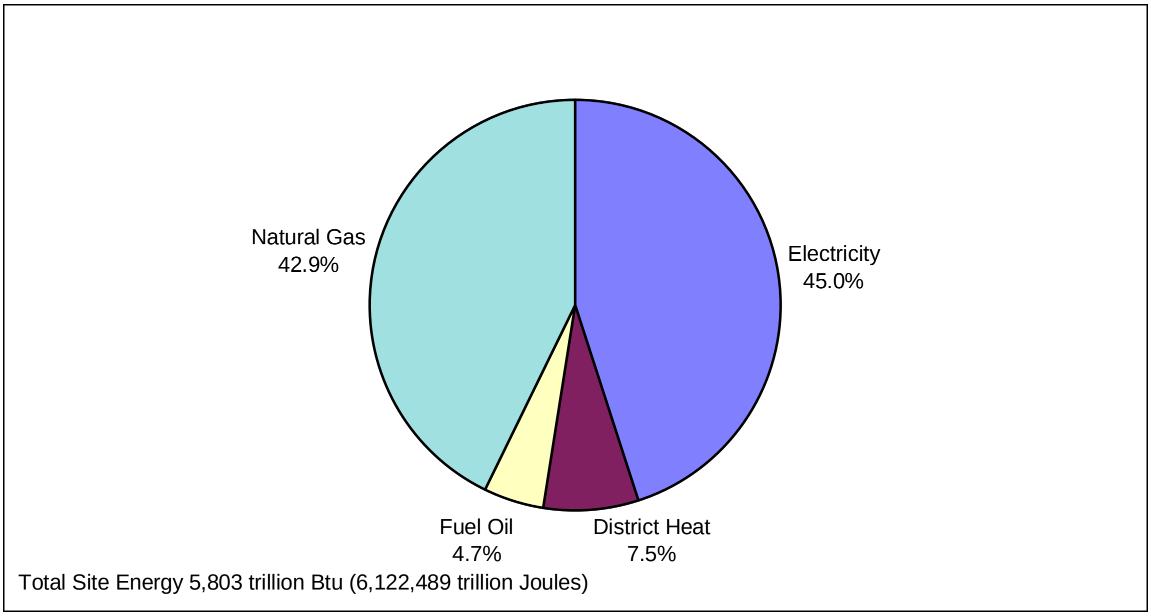


Figure 6-14. Total Energy Expenditures: 1992

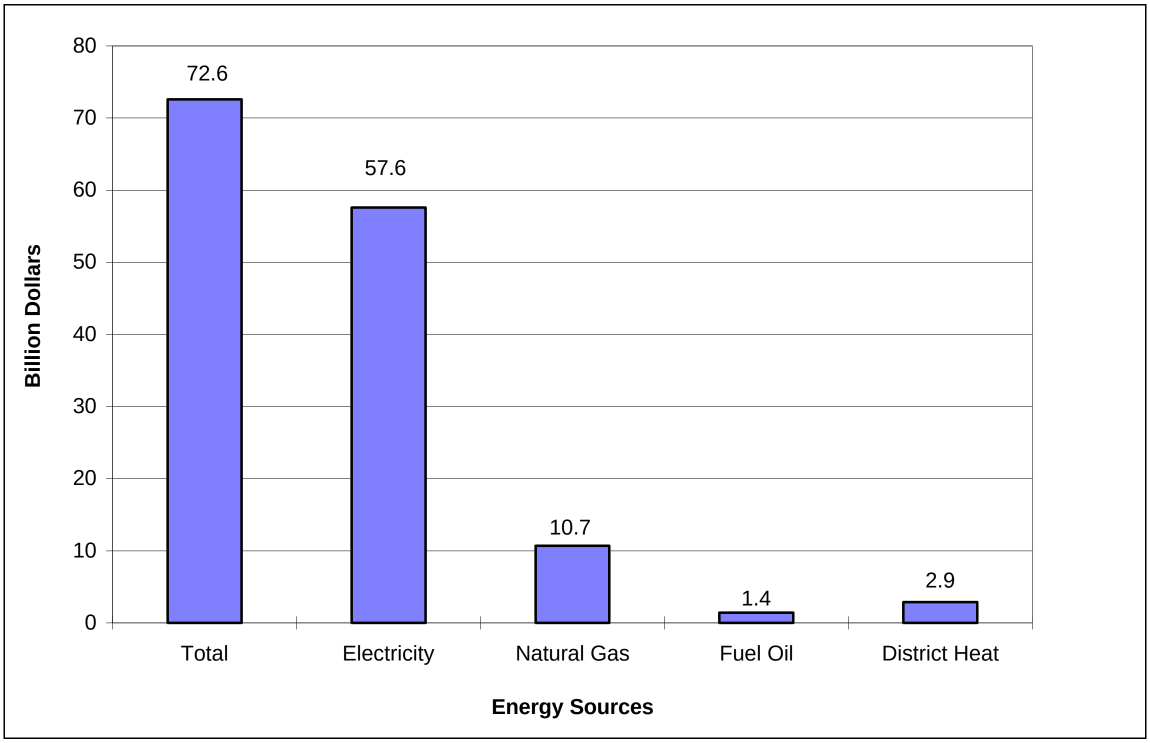


Figure 6-15. Relative Costs of Different Energy Sources: 1992

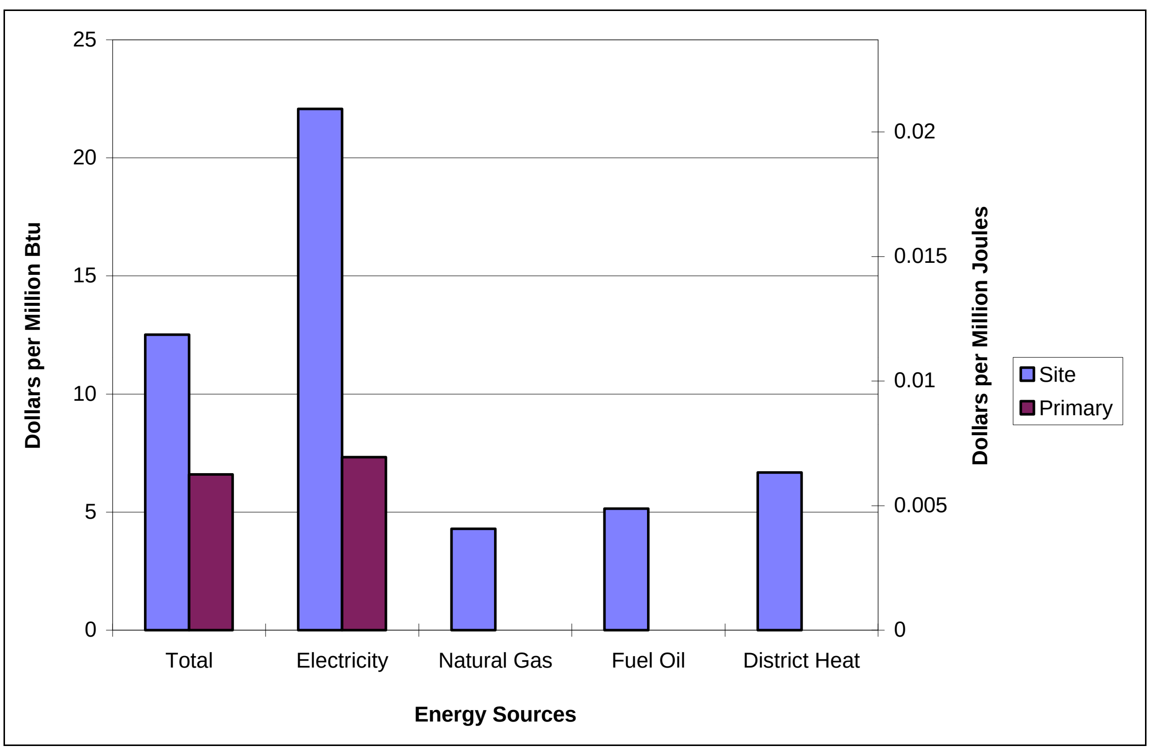
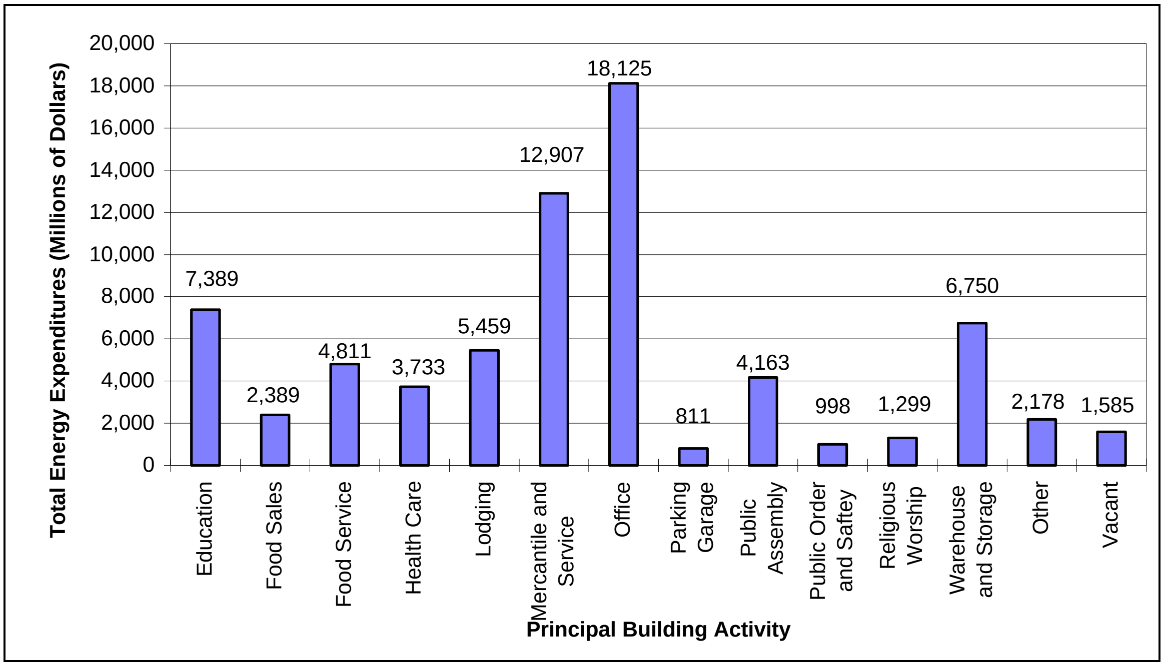


Figure 6-16. Total Energy Expenditures by Principal Building Activity: 1992



It is useful to normalize energy consumption to account for building size, given that size is the most important determinant of total energy consumption. Figure 6-17 shows energy expenditures per unit area by principal building activity and census region. Figure 6-17 indicates that food sales, food service, healthcare, and lodging facilities used energy more intensively, and had higher costs per unit area than other buildings in the commercial/institutional sector. Energy expenditures ranged from between $20.34 per square meter ($1.89 per square foot) for lodging buildings to $34.75 per square meter ($3.23 per square foot) for food service buildings (for all census regions combined). The figure indicates that energy expenditures in the west census region were significantly higher than the other three census regions for food service and lodging facilities. Similar data from **CBECS** indicates that buildings in the mid-west consumed more energy (1,110 MJ per square meter/97,700 Btu per square foot) than was consumed in other census regions (923 MJ per square meter/81,300 Btu per square foot).

Figure 6-18 shows how fuel expenditures per unit area vary by building size. In general, it would appear that larger buildings may be slightly less costly to operate than smaller buildings, on a normalized basis. However, **CBECS** data do not appear to show a clear pattern of energy intensity usage for different building sizes (energy intensity is defined as the energy used per unit area of floorspace). Data from **CBECS** indicate that energy intensity is much more heavily dependent upon weekly hours of operation of the building than building size, as might be expected. Data presented in Figure 6-19 shows a clear correlation between hours of operation and energy expenditures.

Figure 6-17. Sum of Major Fuel Expenditures by Principal Building Activity and Census Region: 1992

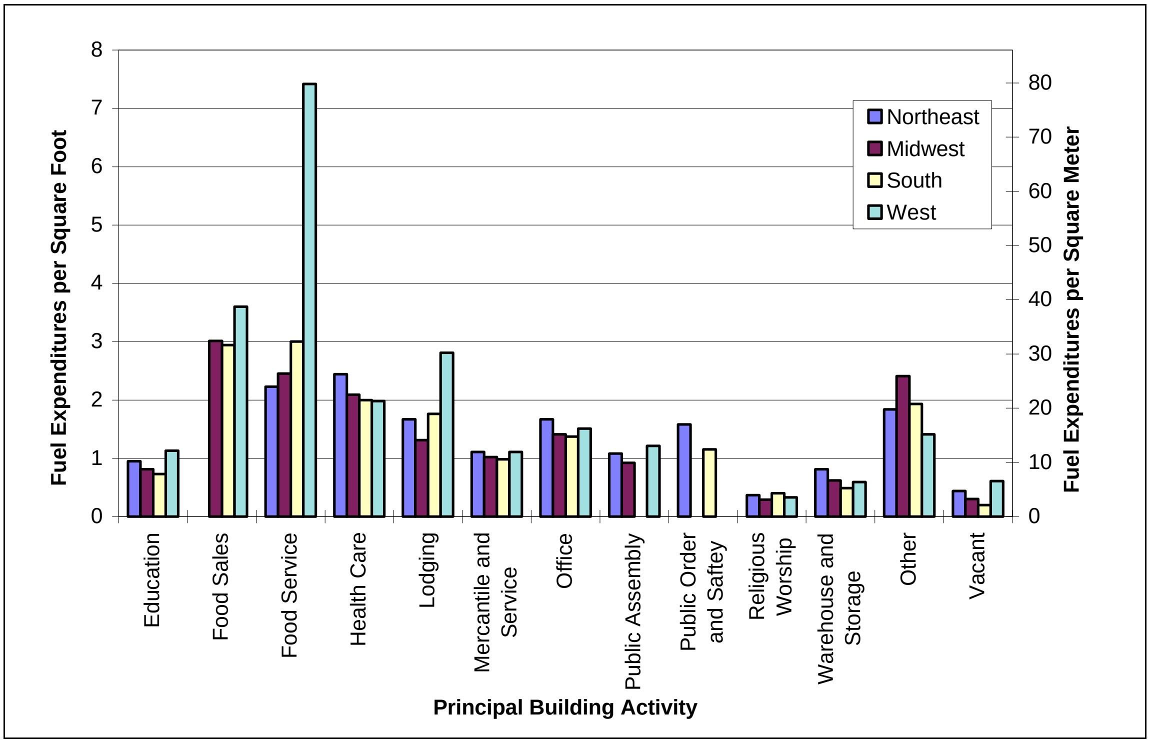


Figure 6-18. Sum of Major Fuel Expenditures by Building Size Category: 1992

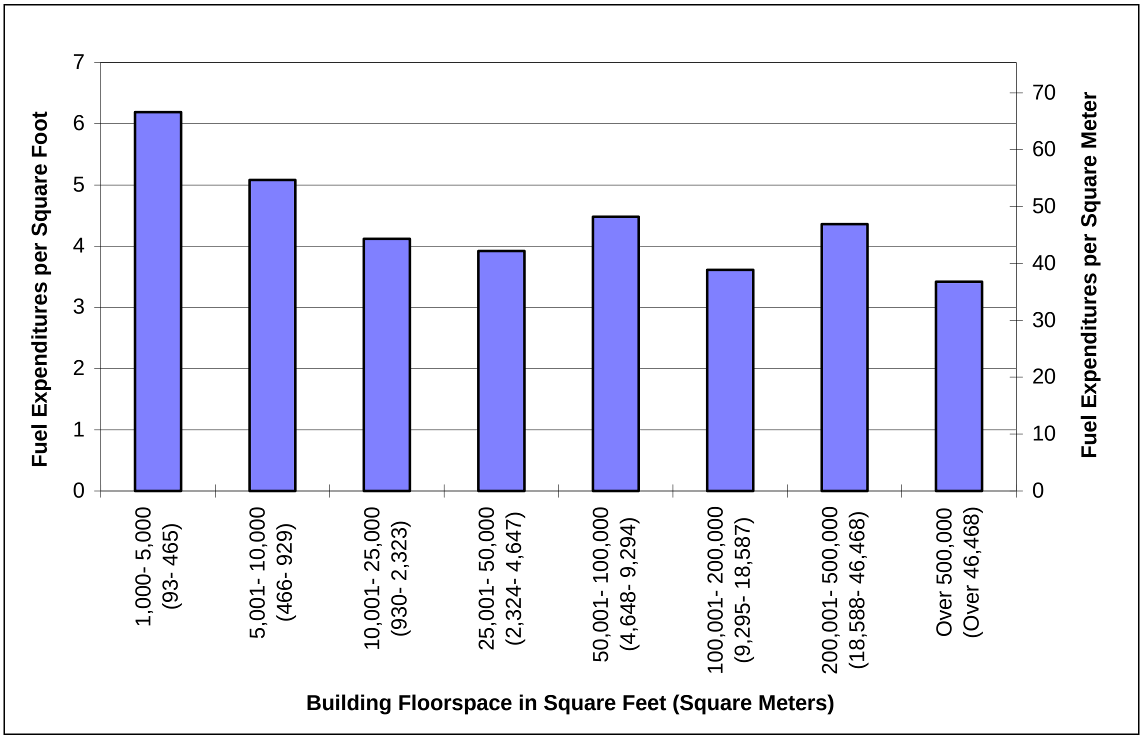
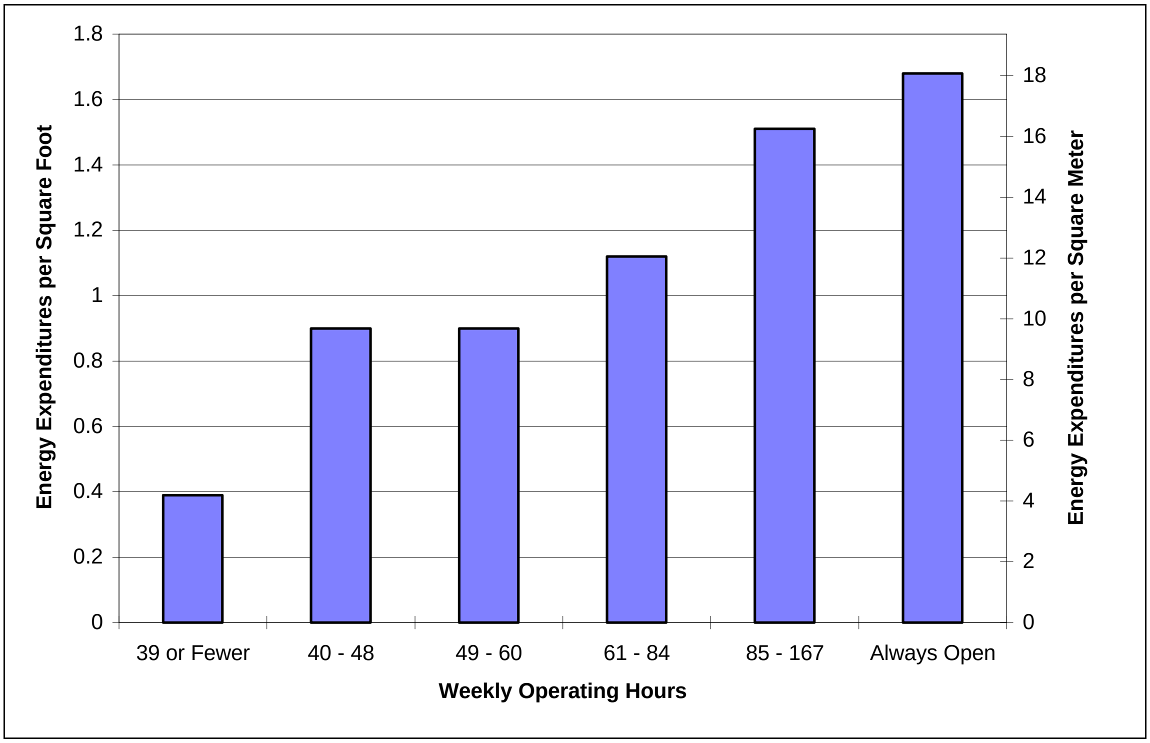


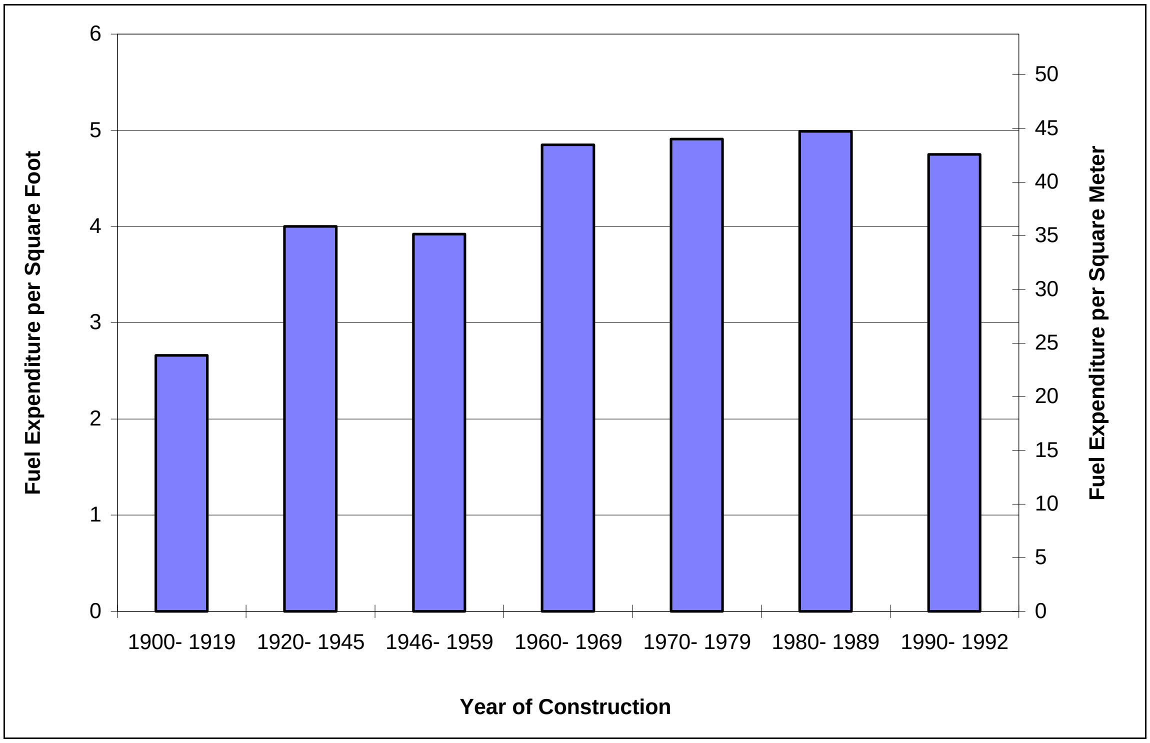
Figure 6-19. Sum of Major Fuel Expenditures by Weekly Hours of Operation: 1992



Finally, Figure 6-20 shows how fuel expenditures per unit area vary with the year of construction of the building. Contrary to what one might expect, expenditures do not appear to be lower in newer buildings compared with older buildings. This corresponds with observations made in **CBECS** that, although site energy consumption for buildings constructed after 1986 was less than that of older buildings, the primary energy consumption of the two groups was about the same when allowing for electricity generation and transmission losses, due in part to increased use of electricity for a variety of energy sources in newer buildings. Buildings constructed after 1986 consumed about 795 MJ per square meter of site energy (70,000 Btu per square foot), while buildings constructed in or before 1986 consumed about 988 MJ per square meter (87,000 Btu per square foot). In addition to newer buildings using more electricity for refrigeration, air conditioning, and office equipment, the number of buildings using electricity for main space heating was six percent higher in newer buildings. Thus the primary energy consumption of newer buildings was virtually identical to that of buildings constructed in or before 1986.

Energy conservation issues are addressed in Section 6.2.5 of this document.

Figure 6-20. Sum of Major Fuel Expenditures by Year of Construction: 1992



6.2 Baseline Measures for the Commercial/Institutional Sector

This section of the document will describe in detail the baseline measures for operations, maintenance, and energy costs in the commercial/institutional sector. In addition, it will also consider energy and water conservation measures for the sector as a whole. The baseline measures are presented as follows:

- Baselines for the *entire commercial/institutional sector*, based upon data presented in section 6.1, and data from the International Facility Management Association
- Baselines for *commercial office buildings*, based upon data from the Building Managers and Owners Association
- Baselines for *education facilities*, based upon data from APPA - the Association of Higher Education Facilities Officers
- Baselines for *shopping centers*, based upon data from the Institute of Real Estate Management

For general definitions of 'operations', 'maintenance', and 'energy', refer to Section 3.4 of this document. For detailed information regarding the components within each of these general definitions, refer to Sections 4.1.1 and 4.1.2.

6.2.1 Baseline Measures for the Entire Commercial/Institutional Sector

Data which are presented in section 6.1 of this document are sufficiently detailed to establish energy baselines for the commercial/institutional sector. However, data that have been presented so far for operations and maintenance costs in the sector are of a highly aggregated nature, and are of limited usefulness for establishing baselines. For this reason, data from the International Facility Management Association (IFMA) are used to establish more detailed baselines for the commercial/institutional sector. When interpreting this data, it must be remembered that the IFMA study is based upon a comparatively small survey sample, and that all of the survey data are from IFMA members, and may not therefore represent 'norms' of industry-wide performance. However, in the absence of more comprehensive research data, it is considered to be reasonable to make use of the IFMA data, at least to establish some general baseline measures.

The IFMA *Research Report 'Benchmarks II'* presents benchmark data for both the commercial/institutional and industrial sectors. In this section of the document, only data relevant to the commercial/institutional sector have been used. IFMA uses the following facility categories in its report:

- financial (includes financial, insurance, real estate, financial services)
- health/hotel (healthcare, hotel, hospitality related)
- utilities (utilities, communications, transportation)*
- wholesale/retail (business services, wholesale, retail)
- other services
- educational
- governmental
- research
- other institutional

*this is considered as part of the public works sector in this document.

These classifications are different to the types of buildings defined by EIA, as shown below:

IFMA Classification	EIA Classification
financial	office
health/hotel	healthcare/lodging
utilities	no comparable classification
wholesale/retail	mercantile and service/ food sales and service
other	no comparable classification
educational	education
governmental	no comparable classification
research	laboratory
other institutional	no comparable classification

Because the classifications used by IFMA and EIA are different, it is not considered to be practical to attempt to adjust IFMA data to match EIA building types. Thus IFMA data are presented in the same format as shown in the Benchmarks II report. IFMA also categorizes facilities by the predominant use of that facility (e.g., customer service, computer center, research, factory plant etc.). However, no data using this form of categorization is used in this document, primarily because the data cannot be mapped back into the building type with the size of the survey sample given.

Table 6-4 Part A and Part B shows the mean gross, rentable, and usable area of the sample facilities according to industry type, in square feet and square meters respectively. Gross area is defined by IFMA as the total of all floor areas of the building. Rentable area is computed by measuring the inside finished surface of the dominant portion of the permanent outer building wall and subtracting all major vertical penetrations. Usable area measures the actual occupiable area of the building, and excludes circulation areas, common areas, meeting areas and so forth from the rentable area calculation. Reference to Table 6-4 shows that the largest proportion of the surveyed buildings were in the financial, utilities, and governmental categories. For those building types where the sample size is below 20, care should be taken in interpreting the data. The data are presented graphically in Figure 6-21.

Table 6-4. IFMA Survey Sample: Gross, Rentable and Usable Floorspace by Industry Type

Part A: Total Mean Square Feet

Industry Type	N	Means		
		Gross Square Feet	Rentable Square Feet	Usable Square Feet
Financial	58	639,864	378,023	300,894
Health/Hotel	8	252,928	221,138	204,166
Utilities	33	419,668	320,518	236,028
Wholesale/Retail	8	372,997	315,732	306,854
Other Services	13	373,554	318,466	279,207
Educational	11	267,085	246,926	171,430
Governmental	25	655,308	562,158	498,355
Research	8	344,668	322,049	255,420

Part B: Total Mean Square Meters

Industry Type	N	Means		
		Gross Square Meters	Rentable Square Meters	Usable Square Meters
Financial	58	59,443	35,118	27,953
Health/Hotel	8	23,497	20,544	18,967
Utilities	33	38,987	29,776	21,927
Wholesale/Retail	8	34,651	29,332	28,507
Other Services	13	34,703	29,585	25,938
Educational	11	24,812	22,939	15,926
Governmental	25	60,878	52,224	46,297
Research	8	32,020	29,918	23,729

Figure 6-21. IFMA Survey Sample: Gross, Rentable, and Usable Floorspace by Industry Type: 1993

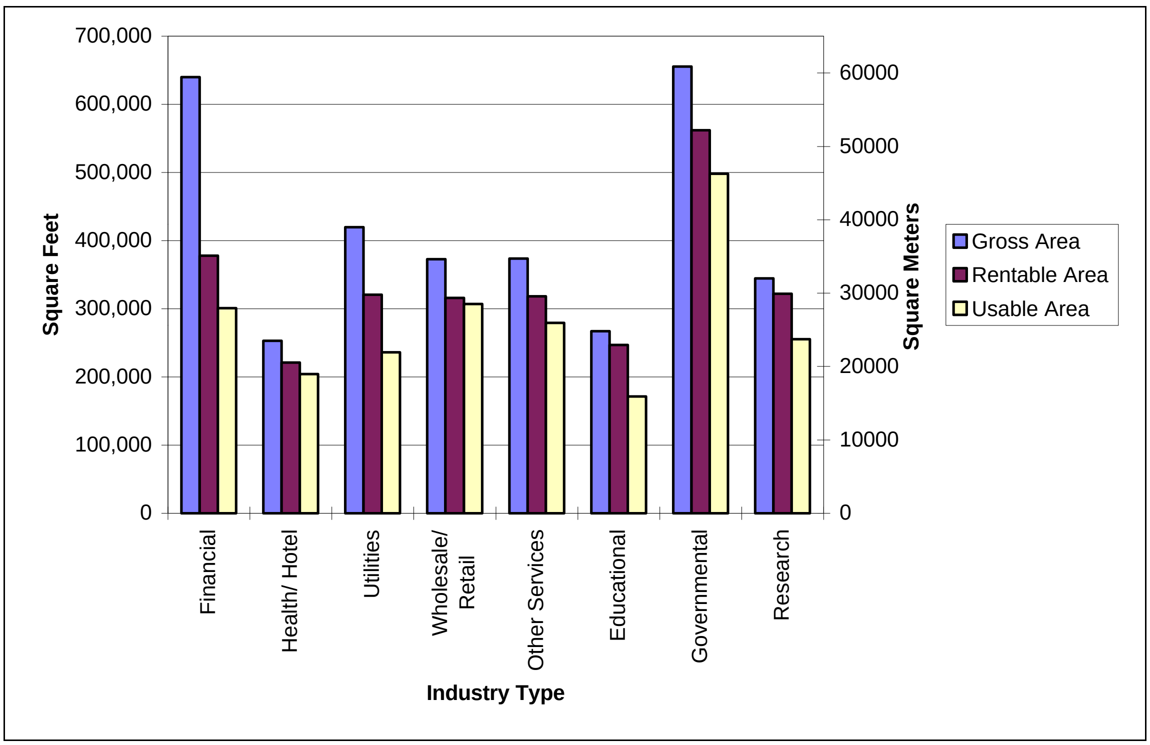


Table 6-5 Part A and Part B shows the mean gross, rentable, and usable area per employee for the sample facilities, according to type of building. The data are also presented graphically in Figure 6-22. The mean gross square feet per employee for the sample was 62 square meters (667 square feet), which compares with 71 square meters (766 square feet) in the EIA **CBECS**. Reference to Figure 6-22 shows that there is a wide variation in building area per employee, with the largest allowance in educational facilities, and the lowest in health/hotel facilities.

Table 6-5. IFMA Survey Sample: Area per Employee

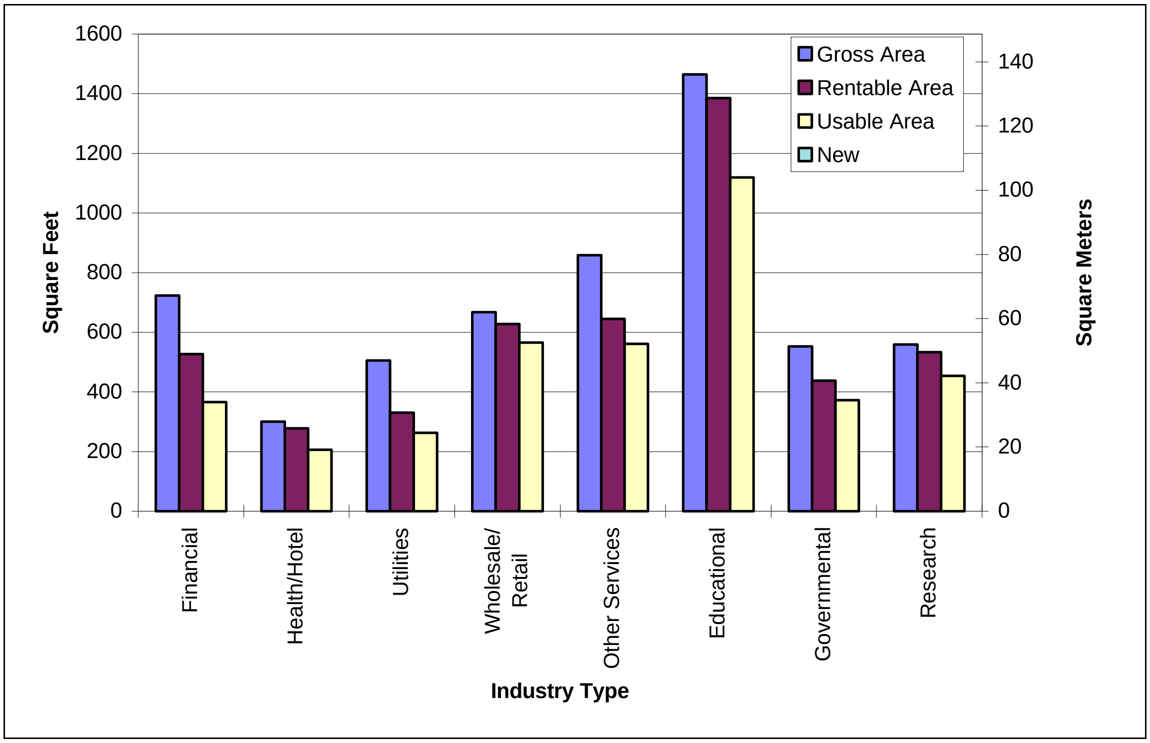
Part A: Square Feet per Employee

Industry Type	N	Means		
		Gross Square Feet	**Rentable Square Feet**	**Usable Square Feet**
Financial	53	723	527	366
Health/Hotel	7	300	278	206
Utilities	31	505	330	263
Wholesale/Retail	7	668	628	565
Other Services	11	858	645	561
Educational	10	1,465	1,385	1,119
Governmental	21	553	438	372
Research	8	559	533	454

Part B: Square Meters per Employee

Industry Type	N	Means		
		Gross Square Meters	**Rentable Square Meters**	**Usable Square Meters**
Financial	53	67	49	34
Health/Hotel	7	28	26	19
Utilities	31	47	31	24
Wholesale/Retail	7	62	58	52
Other Services	11	80	60	52
Educational	10	136	129	104
Governmental	21	51	41	35
Research	8	52	50	42

Figure 6-22. IFMA Survey Sample: Building Floorspace per Employee



In Figures 6-23 through 6-31, a variety of operations, maintenance, and energy costs are compared for each building type on a dollars per year per rentable square foot/square meter basis. These include the following:

Operations

- **Janitorial Costs** - these are the costs associated with the cleaning of offices and other work areas, rest-rooms, cafeteria, and support space
- **Environmental Costs** - these include building concerns, such as ‘sick building syndrome’ and asbestos abatement, which incur consulting fees and monitoring costs, as well as waste removal for standard and hazardous trash, and recycling costs
- **Life Safety Costs** - these include fire and safety equipment
- **Indirect Costs** - these include exterior maintenance costs, such as landscaping and grounds, roadways, and parking facilities
- **Security Costs** - these include building and site security costs

Maintenance

- **Maintenance Costs** - these include items for the upkeep of the building and its components such as HVAC, electrical and plumbing systems, elevators, and painting

Energy

- **Utility Costs** - these include electricity, gas, steam, and water (note that 'water' has previously been categorized under 'operations' in this document)

Figure 6-23 presents janitorial cost data in dollars per rentable square meter ($/RSM) and dollars per rentable square foot ($/RSF). Costs range from $8.72/RSM to $13.67/RSM ($0.81/RSF to $1.27/RSF). Figure 6-24 and Figure 6-25 show environmental cost data. The total costs for research and for other services facilities are high due to high hazardous trash removal costs. With the exception of these two types of facility, the major component of environmental costs is attributable to trash removal. It is interesting to note that IFMA results indicated that at least 10% of surveyed facilities generated income from recycling. Figure 6-26 shows life safety costs by industry type. These are significantly higher in healthcare/lodging, governmental, and research facilities compared with other facilities. In Figure 6-27, indirect costs are shown by industry type. Reference to the figure shows that indirect costs are highest in wholesale/retail facilities. Figure 6-28 shows security costs by industry type. These are generally high compared with other operations cost components.

Maintenance costs are shown in Figure 6-29. These costs vary from between $18.84/RSM ($1.75/RSF) for governmental facilities, to $41.87/RSM ($3.89/RSF) for research facilities. The mean maintenance cost for the commercial/institutional sector is $24.86/RSM ($2.31/RSF). The IFMA report also provides information about the amount spent on maintenance and repair compared with preventive maintenance. The data indicate that more time is spent on preventive maintenance for security and life safety systems compared with electrical, building, structural repair and painting activities. However, overall, almost twice as much is spent on maintenance repair compared with preventive maintenance.

Finally, Figure 6-30 and Figure 6-31 show utility costs by building type. Reference to the figures indicate that the highest utility costs occur in research facilities. Figure 6-31 shows that utility costs are dominated by electricity costs (generally over 50 percent of total utility costs). The average electricity cost was $24.43/RSM ($2.27/RSF). The average cost for oil gas and steam was $3.12/RSM ($0.29/RSF). Water costs range from between $0.97/RSM ($0.09/RSF) for other services facilities to $3.01/RSM ($0.28/RSF) for research facilities. The average water cost was $1.29/RSM ($0.12/RSF). The IFMA report also includes data on utility consumption and cooling consumption. The average monthly utility consumption for a commercial office building was 30.35 kilowatt hours (kWh) per square meter (2.82 kWh per square foot).

Figure 6-23. Janitorial Costs by Industry Type

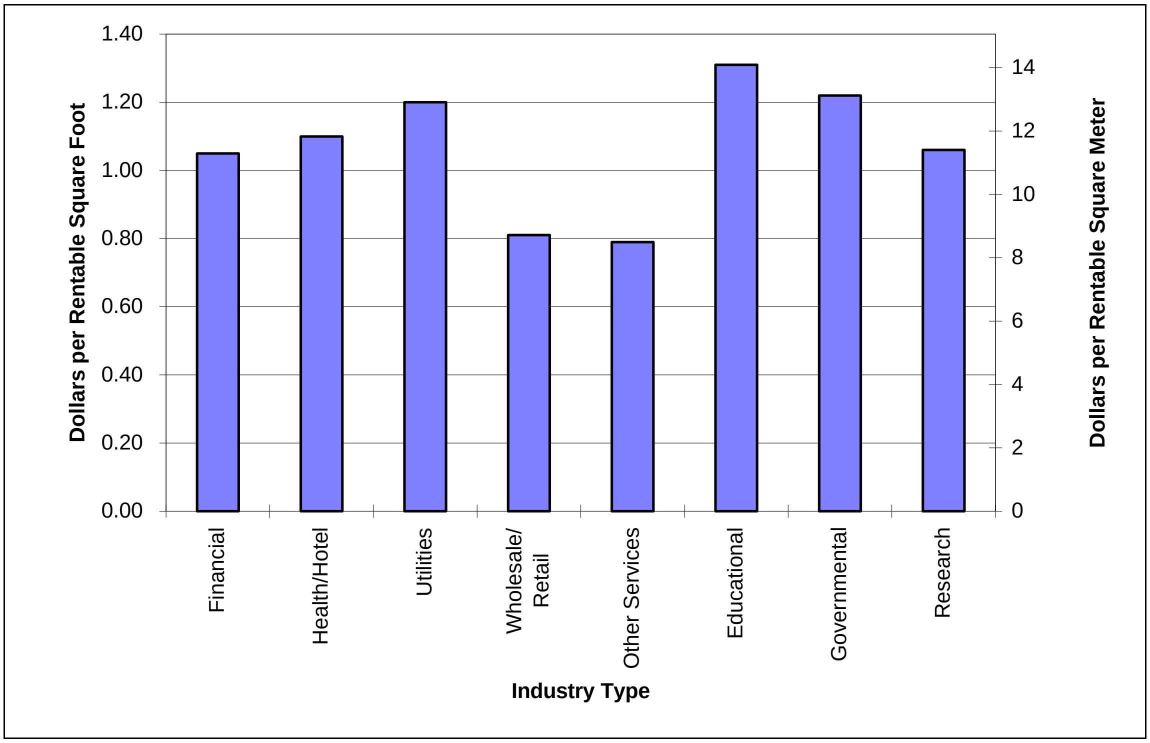


Figure 6-24. Environmental Costs by Industry Type

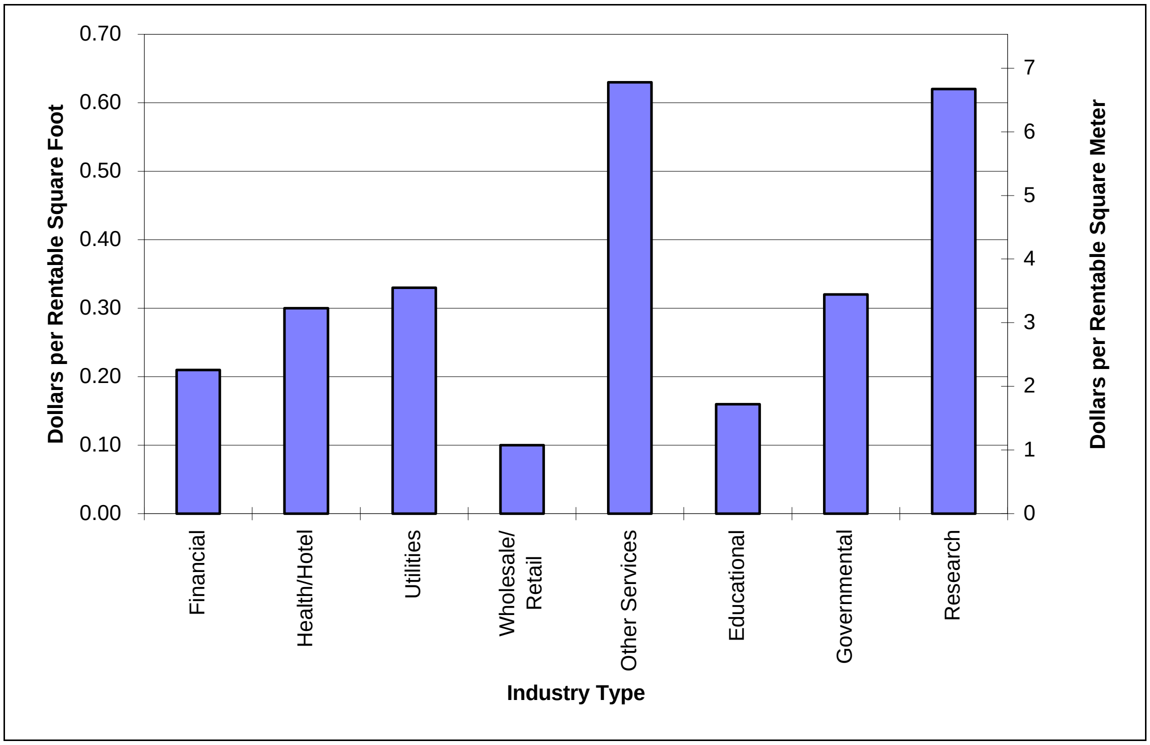


Figure 6-25. Detailed Environmental Costs by Industry Type

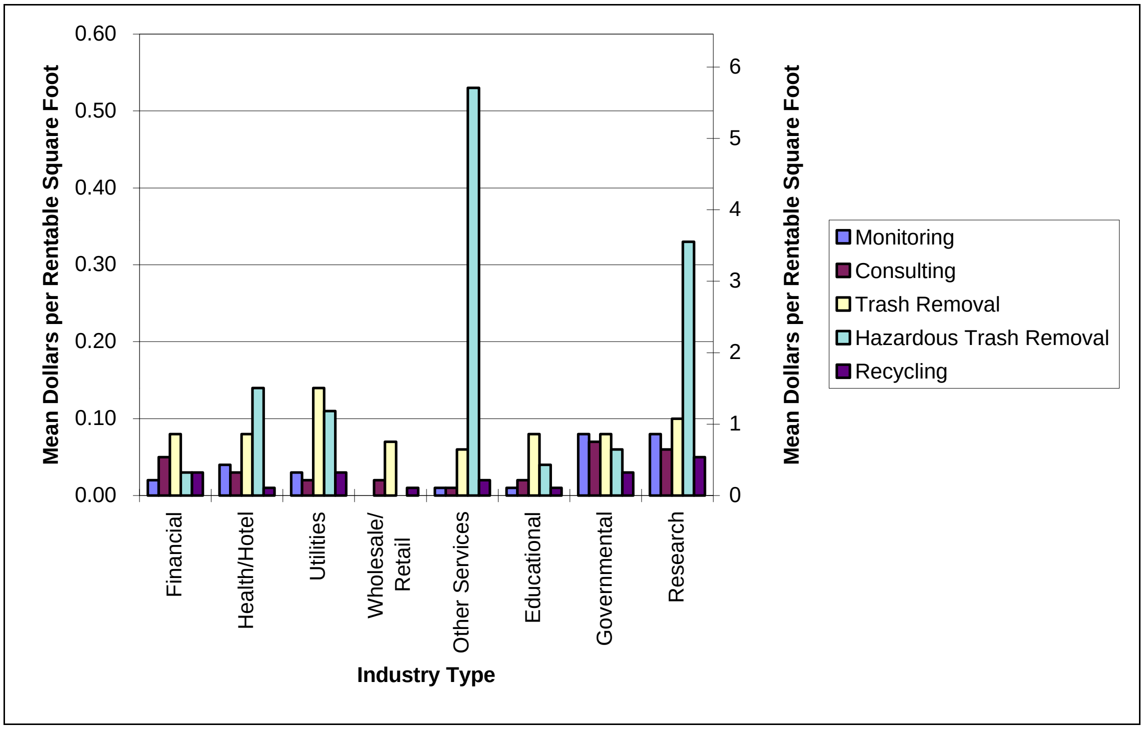


Figure 6-26. Life Safety Costs by Industry Type

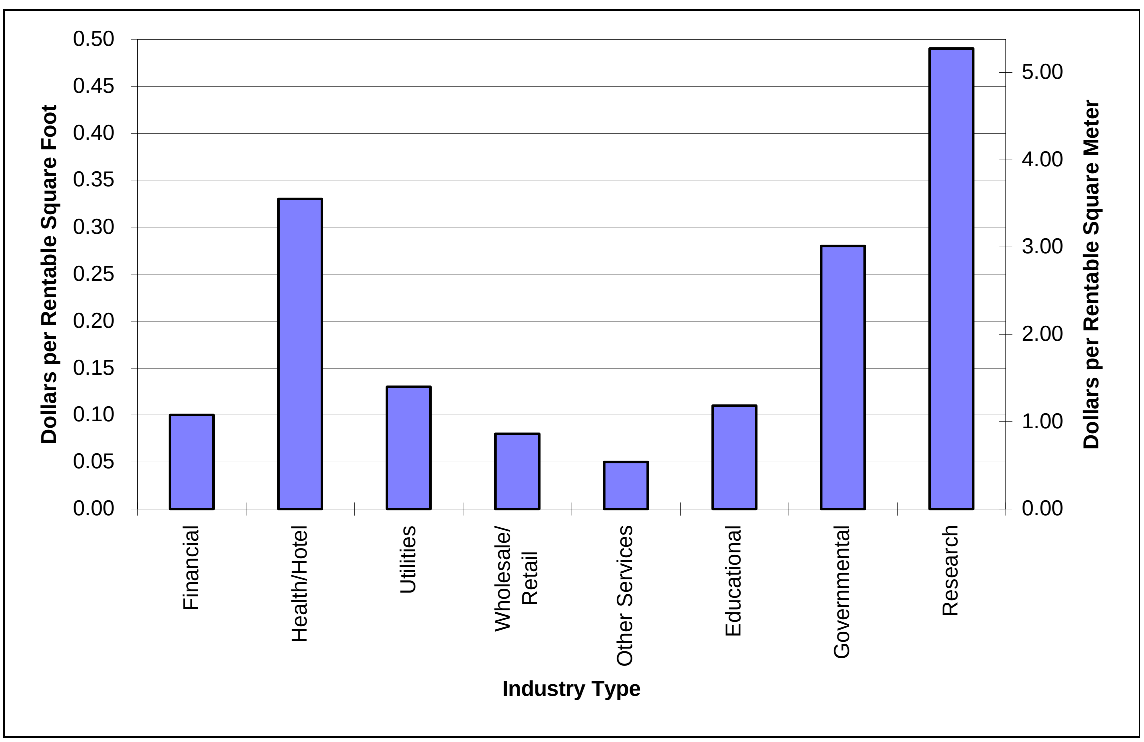


Figure 6-27. Indirect Costs by Industry Type

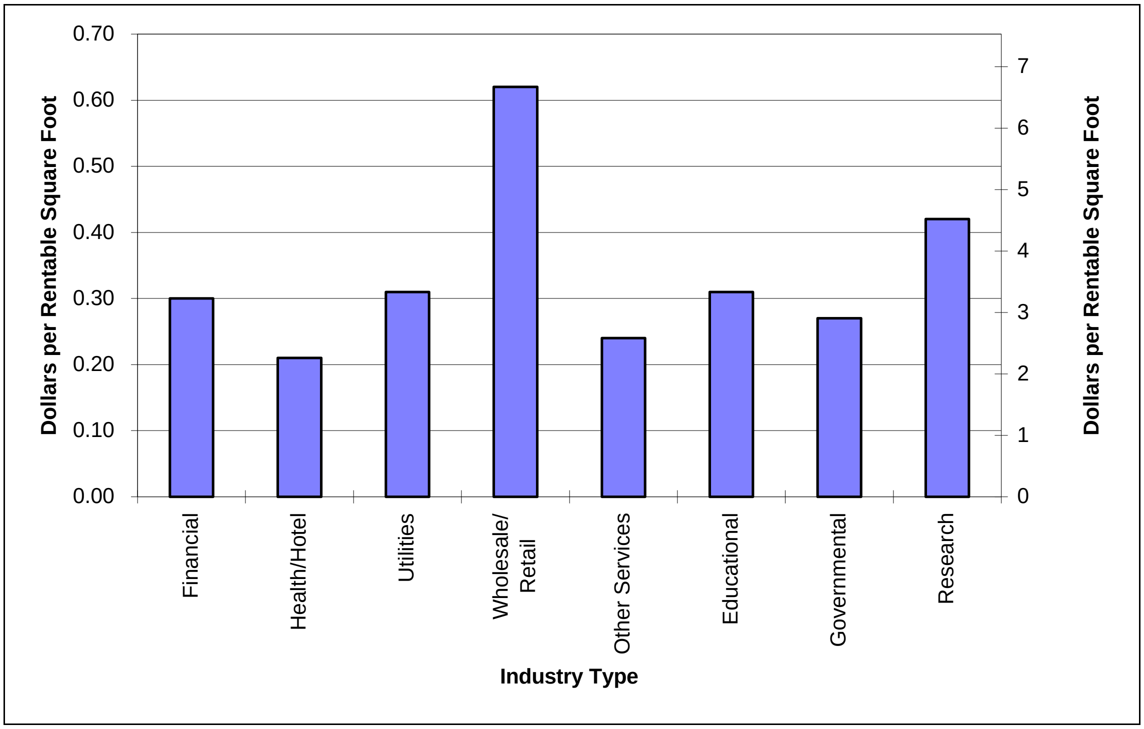


Figure 6-28. Security Costs by Industry Type

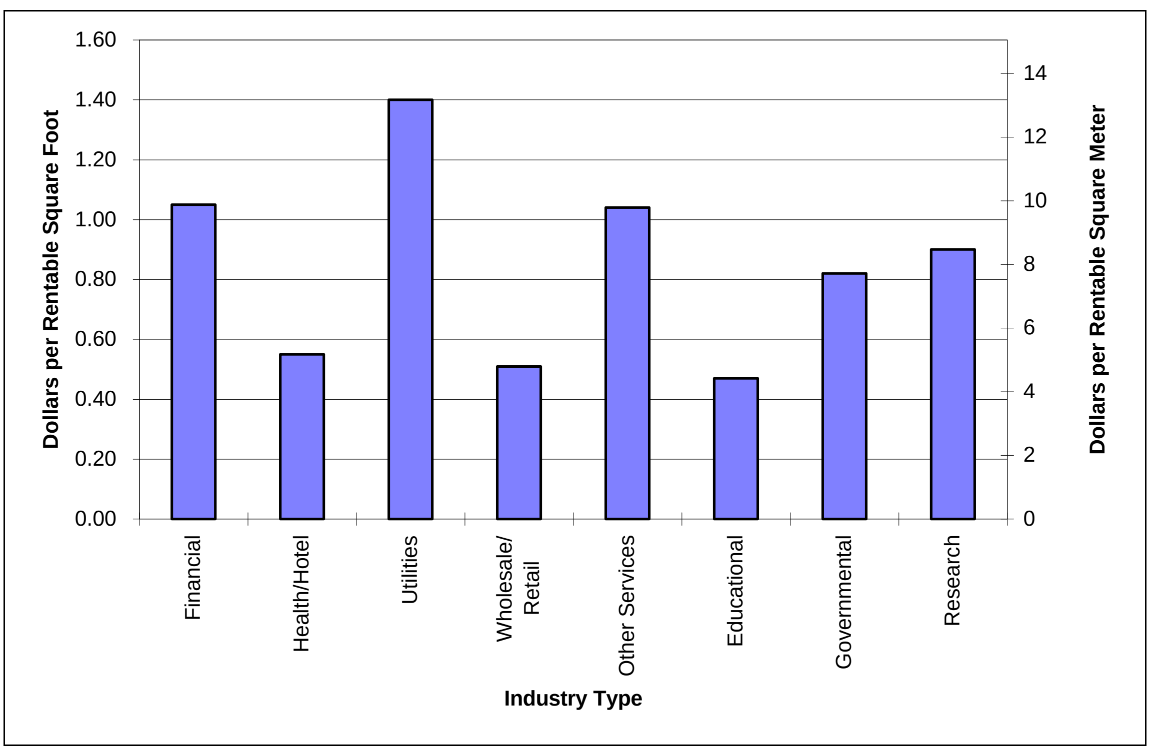


Figure 6-29. Maintenance Costs by Industry Type

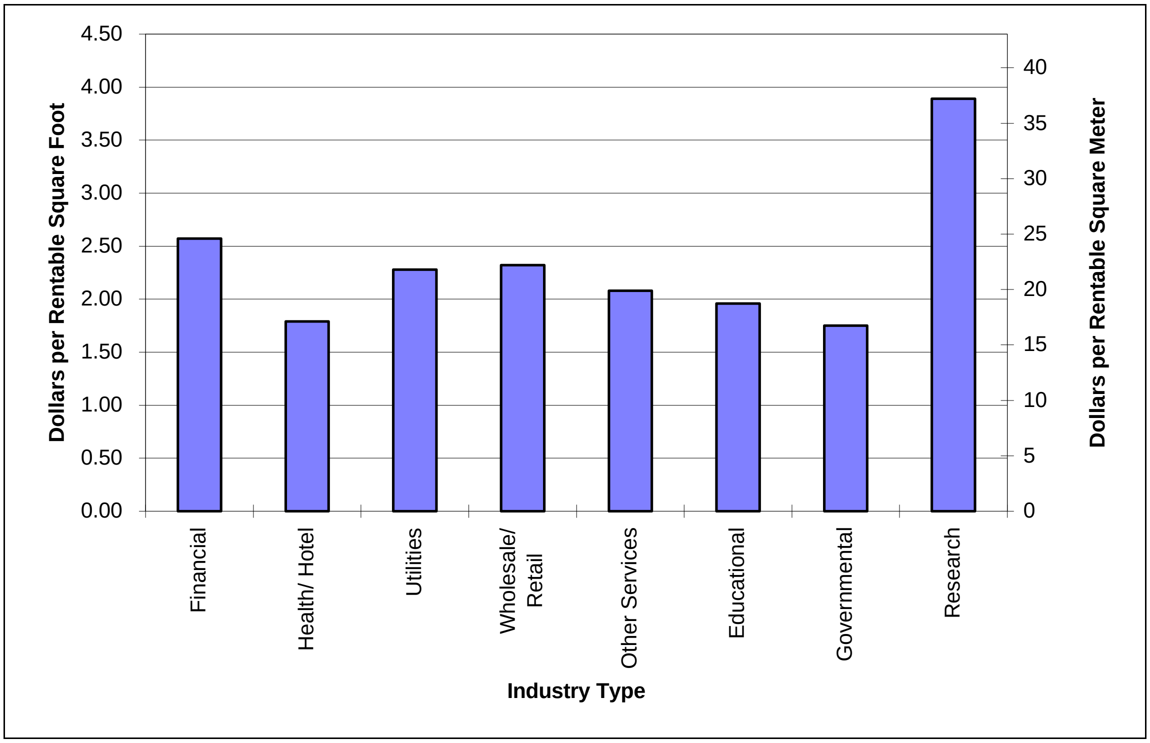


Figure 6-30. Total Utility Costs by Industry Type

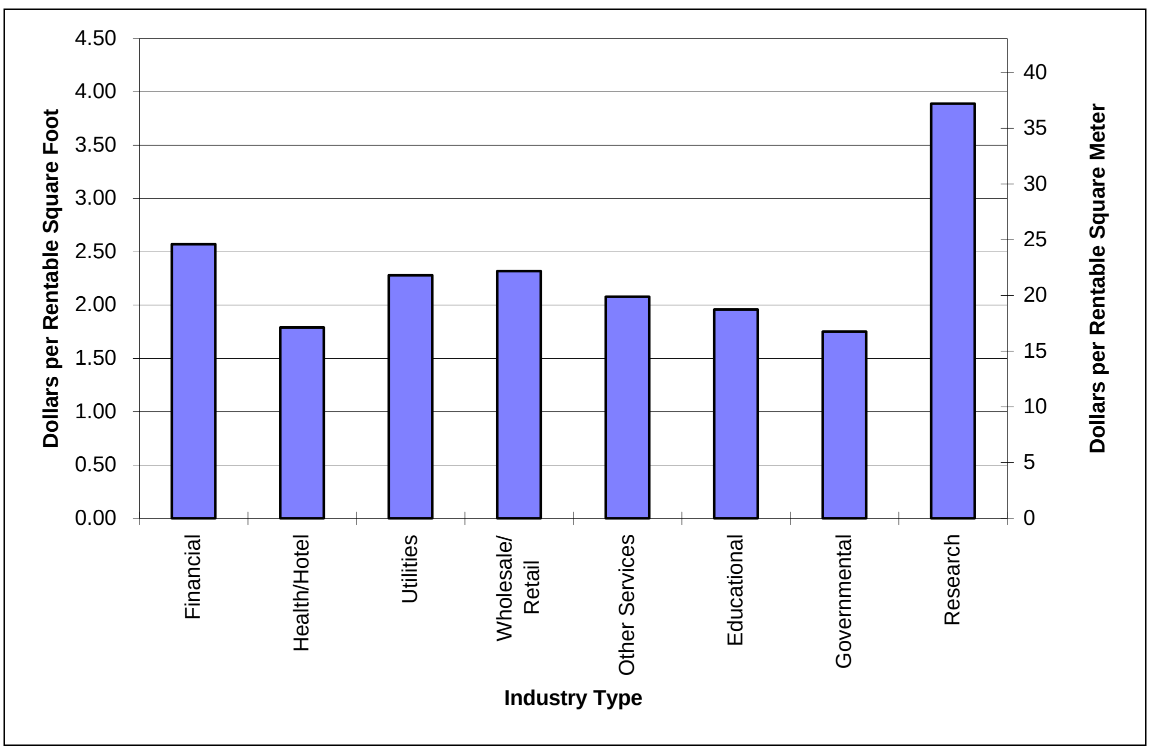
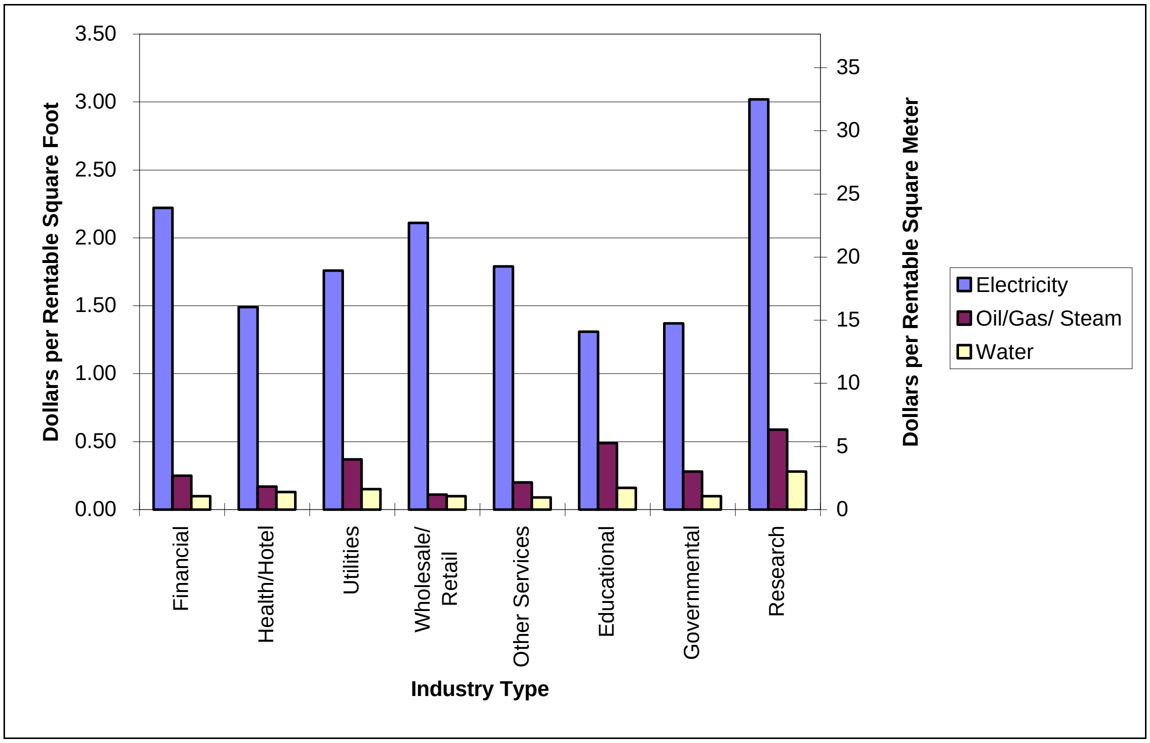


Figure 6-31. Utility Costs by Fuel Type and by Industry Type



The mean values for operations, maintenance and energy costs from the IFMA data can be compared with general commercial/institutional sector census data presented in section 6.1 of this document. However, in order to do this, one needs to convert the aggregated census data into a dollar per rentable square foot/meter basis. In order to do this, one has to make an assessment of what percentage of total gross sector floorspace is rentable floorspace. If we assume that that total gross commercial/institutional sector floorspace in 1993 is 6 billion square meters (65 billion square feet), extrapolating between 1992 and 1995 EIA data, of which 4.8 billion square meters (52 billion square feet) is rentable area (based upon IFMA survey sample data), we can calculate the following mean costs for the commercial/institutional sector:

Description	**Estimated Mean Cost (from Census data)**	**Mean Cost (from IFMA data)**
Total Purchased Utilities	\$17.33/RSM (\$1.61/RSF)	\$24.43/RSM (\$2.27/RSF)
Electricity	\$11.95/RSM (\$1.11/RSF)	\$19.91/RSM (\$1.85/RSF)
Water Sewer and Other	\$2.48/RSM (\$0.23/RSF)	\$1.29/RSM (\$0.12/RSF)
Total Repair Services	\$11.63/RSM (\$1.08/RSF)	\$24.86/RSM (\$2.31/RSF)

This comparison suggests that it is not advisable to extrapolate the IFMA figures to the entire commercial/institutional sector using the mean values for operations, maintenance, and energy costs, and assuming that all floorspace in the sector has similar cost profiles. For this reason, IFMA data has only been used at the building type level to generate baseline measures.

6.2.2 Baseline Measures for Commercial Office Buildings

In this section, data from the Building Owners and Managers Association (BOMA) are used to establish detailed baseline measures for commercial office buildings in 1995. These data are also compared to the IFMA data. This section focuses upon private sector buildings in the US, and omits government buildings. It should be noted that the information presented here is only the most general data which is available in the 1996 *BOMA Experience Exchange Report: Operating a Cost Effective Office Building*, which is highly detailed.

Table 6-6 summarizes expenses for all commercial office buildings sampled in the US private sector, by type of expense category. BOMA groups these expenses into three categories:

- **Operating Expenses**, which include cleaning, repair/maintenance, utilities, roads grounds and security, and administrative costs,
- **Fixed Expenses**, which include taxes, insurance, and
- **Leasing Expenses**

BOMA also extracts data from these categories on total payroll costs (for personnel employed directly for building operations), and total contract costs (for firms or individuals from external sources who are contracted to perform certain tasks). The table shows mean, median, upper, and lower quartile values for selected operations costs in dollars per rentable square foot/meter, and the number of buildings in the survey sample.

Table 6-6. Summary of Office Building Expenses - All Buildings in Private Sector: 1995

	Number of Buildings	Average	Median	Low	High	Average
Expense		Dollars per Square Foot				Dollars per Square Meter
Cleaning	3,023	1.09	0.87	0.72	1.08	11.73
Repair/Maintenance	3,150	1.32	1.01	0.77	1.35	14.20
Utilities	3,023	1.82	1.73	1.39	2.11	19.58
Roads/Grounds/Security	3,143	0.51	0.42	0.28	0.59	5.49
Administrative	3,185	1.03	0.91	0.65	1.18	11.08
Total Operating Exp	2,953	5.76	5.08	4.36	5.94	61.98
Fixed Expenses	3,162	2.73	1.62	1.14	2.34	29.37
Total Operating+Fixed	2,918	8.51	6.79	5.73	8.31	91.57
Leasing Expenses	2,817	1.77	0.82	0.22	2.15	19.05
Total Payroll	2,508	1.02	0.73	0.48	1.05	10.98
Total Contract	1,498	2.29	1.97	1.60	2.45	24.64

A more detailed breakdown of these expenses is shown in Table 6-7, which presents mean data only. Note that the totals in the two tables may not correlate due to differences in sample sizes - for further information refer to the BOMA report. Table 6-6 indicates that the average annual cost for operating a private sector office building is $110.65/RSM ($10.28/RSF) (median is $81.91/RSM ($7.61/RSF)). A comparable cost presented in the IFMA report, referred to as the occupancy cost (which includes the cost of operations plus the cost of providing the fixed asset) for financial buildings is $145.31/RSM ($13.50/RSF). This is higher than the BOMA value, but does include some cost elements, such as depreciation charges, which are not included by BOMA. If we examine total operating expenses (as defined by BOMA), BOMA shows an average value of $62.00/RSM ($5.76/RSF), compared with the IFMA value for cost of operations (which is broadly comparable in scope) of $62.22/RSM ($5.78/RSF).

Figure 6-32, which is based upon data from Table 6-7, shows the comparative magnitude of all operating costs, which, on average, account for approximately 56 percent of total building expenses (fixed expenses account for about 27 percent, and leasing expenses account for about 17 percent of the total building expenses respectively). Utilities costs (which are dominated by electricity costs) are the largest component of these operating costs. Selected operating costs are examined in more detail in Figures 6-33 through 6-35.

Figure 6-33 shows cleaning costs for all buildings in the private sector. The expense categories shown are payroll for in-house janitorial support, contract services for routine and special cleaning (window washing, carpet cleaning etc.), supervision, materials and miscellaneous cleaning expenses, and trash removal. Total annual average cleaning costs (excluding trash removal) amount to $11.73/RSM ($1.09/RSF). This is slightly higher than the janitorial cost of $11.30/RSM ($1.05/RSF) provided by IFMA (see Figure 6-23). The costs for trash removal are also similar, with a value of $0.65/RSM ($0.06/RSF) from the BOMA report, compared with $0.86/RSM ($0.08/RSF) from the IFMA report (see Figure 6-25). Reference to the figure indicates that over 50 percent of all cleaning work is contracted out to external services.

Figure 6-34 shows maintenance and repair costs by type of expense. The annual average cost for all categories was $14.21/RSM ($1.32/RSF). This is significantly lower than the comparable total of $27.66/RSM ($2.57/RSF) presented in the IFMA report (see Figure 6-29). This appears to be the case for all of the BOMA maintenance and repair data, including data from the more detailed tabulations of buildings by age, size, and geographic location. However, BOMA also provides information on 'other repair contracts' which amounts to $6.14/RSM ($0.57/RSF), giving a total of $1.89, which is similar to the IFMA figure.

Comparison between BOMA data and IFMA data for government buildings also shows that the BOMA sample has lower unit maintenance and repair costs than the IFMA sample ($15.71/RSM ($1.46/RSF) compared with $18.84/RSM ($1.75/RSF)), but that this difference is not as large as for office buildings.

In Figure 6-35, a variety of utilities costs for private office buildings are shown. As expected, electricity is the primary cost component, representing $17.01/RSM ($1.58/RSF), with oil, gas, and steam collectively accounting for a further $5.81/RSM ($0.54/RSF), and water/sewer charges of $1.08/RSM ($0.10/RSF). These are broadly comparable with IFMA values of $23.90/RSM ($2.22/RSF), $2.69/RSM ($0.25/RSF), and $1.08/RSM ($0.10/RSF) respectively (see Figure 6-31). Once again, the BOMA figures appear to be consistently lower than the IFMA figures.

Similar comparison of data for roads and grounds maintenance costs show BOMA annual average total of $1.61/RSM ($0.15/RSF) compared with IFMA totals of $3.23/RSM ($0.30/RSF) (see Figure 6-27).

Finally, Figure 6-36 compares operating cost components for identical private buildings between 1991 and 1995. Costs have been converted to constant 1995 dollars using the Monetary Conversion Factor tables in the BOMA report. Reference to the figure indicates that operating costs have only reduced slightly in all categories since 1991.

Table 6-7. Mean Expenses for All Private Sector Office Buildings: 1995

Expense	Number of Buildings	Average Dollars per Square Foot	Average Dollars per Square Meter
Cleaning			
Payroll	472	0.52	5.60
Contract	2,890	0.85	9.15
Supervision/Materials/Misc.	2,514	0.09	0.97
Trash Removal	2,796	0.06	0.65
Repair/maintenance			
Payroll	2,457	0.48	5.16
Elevator	2,768	0.23	2.47
HVAC	2,934	0.19	2.04
Electrical	2,704	0.09	0.97
Structure/ Roof	1,937	0.10	1.08
Plumbing	2,585	0.04	0.43
Fire/Life Safety	2,201	0.05	0.54
Other Maintenance/Support	2,939	0.28	3.01
Utilities			
Electricity	2,866	1.58	17.00
Gas	1,433	0.11	1.18
Fuel Oil	214	0.03	0.32
Purchased Steam	211	0.40	4.30
Purchased Chilled Water	157	0.48	5.16
Coal	7	0.11	1.18
Water/ Sewer	2,765	0.10	1.08
Roads/Grounds/Security			
Total	2,806	0.15	1.61
Payroll	249	0.10	1.08
Contract	2,549	0.12	1.29
Other	1,629	0.06	0.65
Security Total	2,751	0.40	4.30
Payroll	428	0.31	3.34
Contract	2,491	0.31	3.34
Other	1,110	0.06	0.65
Administrative			
Payroll	2,187	0.37	3.98
Management Fees	2,939	0.48	5.16
Professional Fees	2,063	0.08	0.86
General Office Expenses	2,514	0.13	1.40
Other Administrative Expenses	2,119	0.12	1.29
Leasing Expenses			
Advertising/Promotion	1,960	0.08	0.86
Commissions	2,325	0.48	5.16
Professional Fees	1,068	0.09	0.97
Tenant Alterations	2,080	1.55	16.68
Buy-outs	101	0.63	6.78
Other Leasing	931	0.10	1.08
Other Contracts			
Repair/maintenance	1,587	0.57	6.13
Administrative	3,067	0.52	5.60

Figure 6-32. Comparison of Operating Expenses for All Private Sector Office Buildings, Excluding Leasing and Fixed Expenses

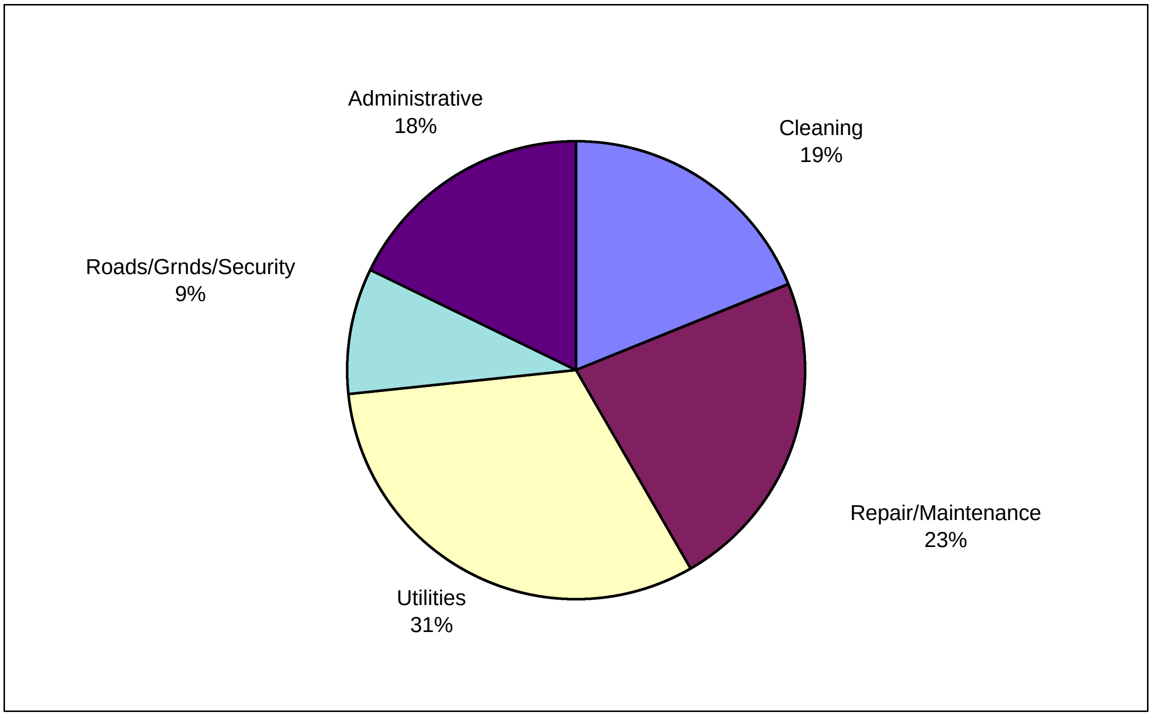


Figure 6-33. Cleaning Expenses for All Private Sector Office Buildings

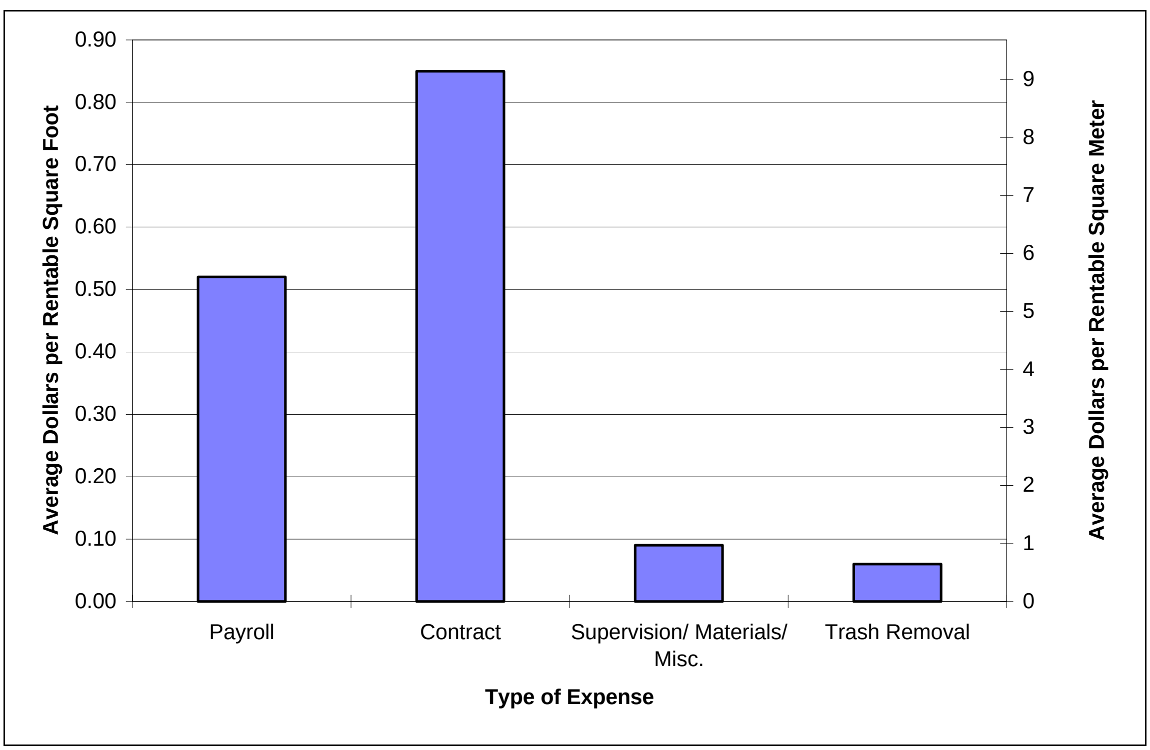


Figure 6-34. Repair/Maintenance Costs for All Private Sector Office Buildings

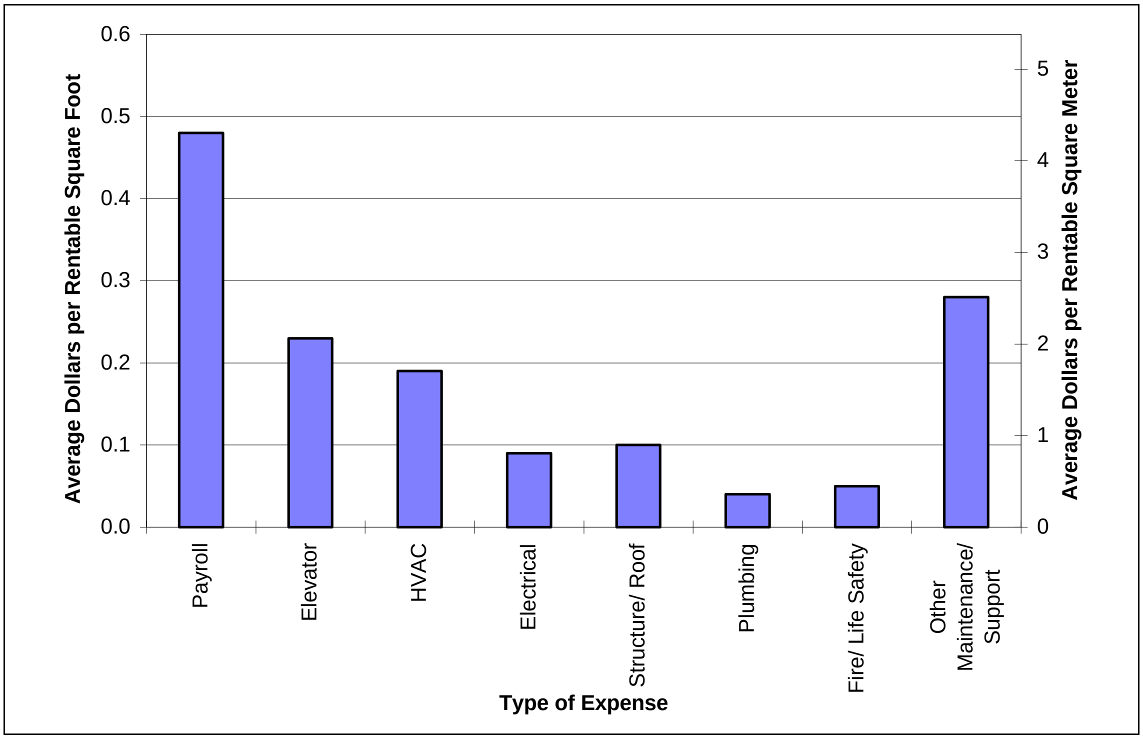


Figure 6-35. Utilities Costs for All Private Sector Office Buildings

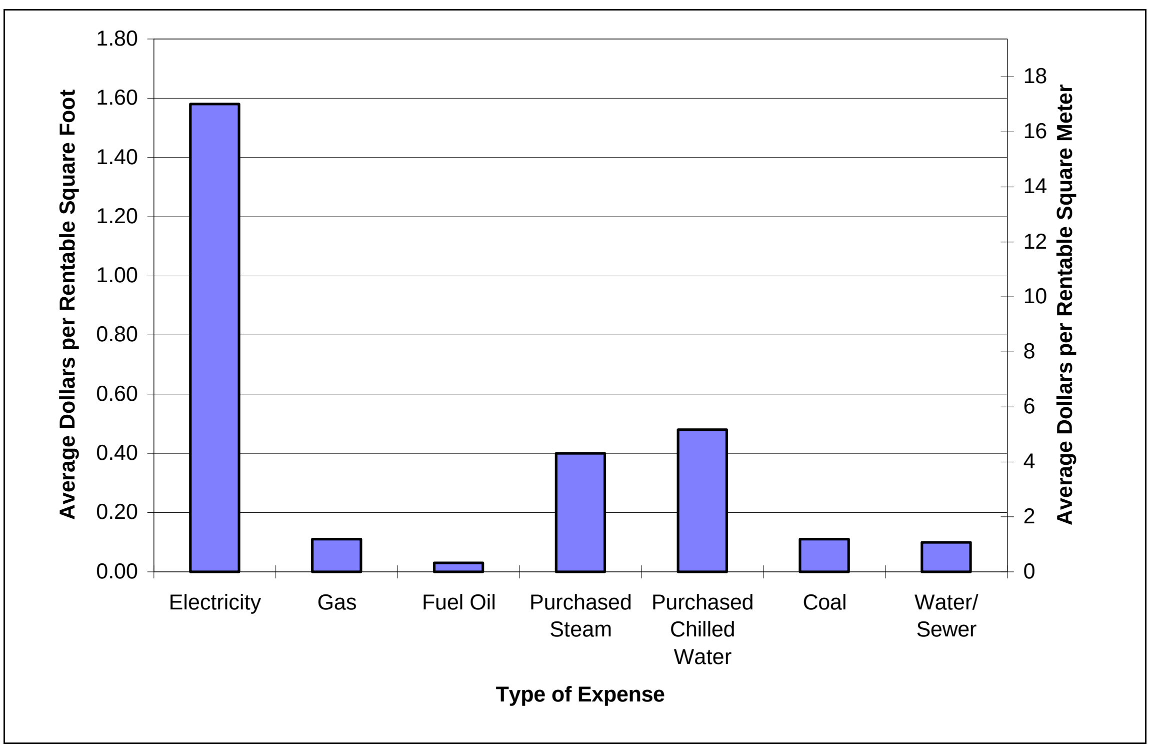
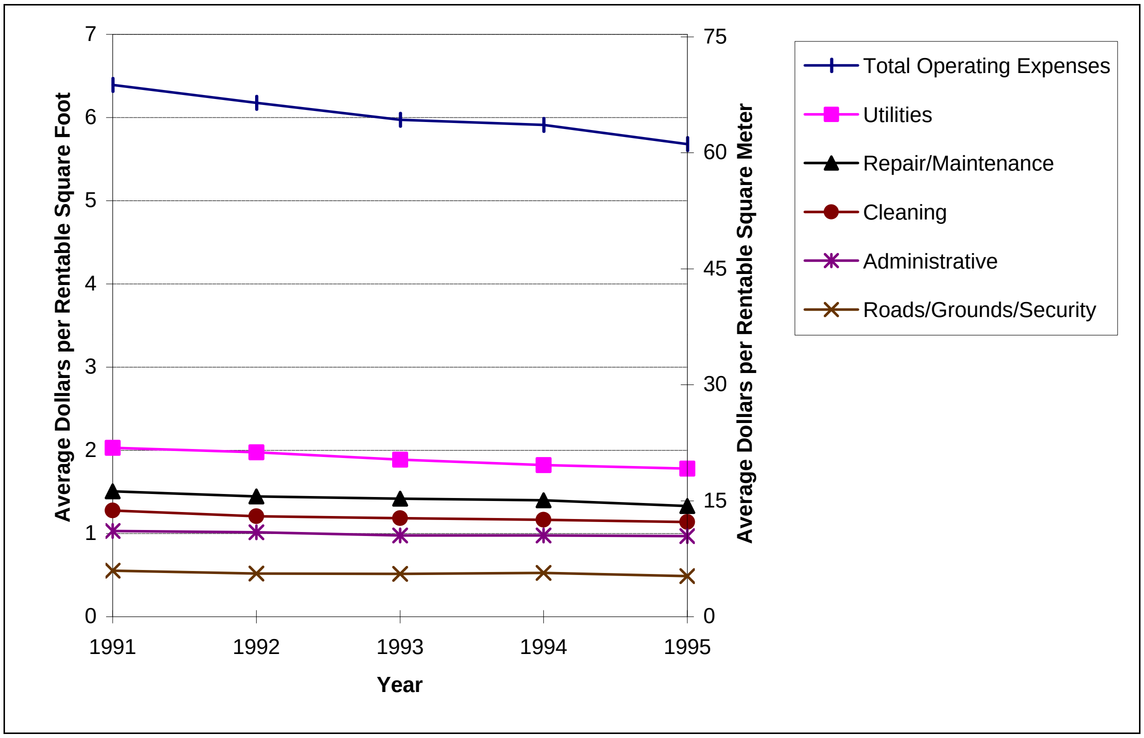


Figure 6-36. Comparison of Operations Costs for Identical Private Sector Office Buildings between 1991 and 1995



6.2.3 Baseline Measures for Educational Facilities

In this section, data from the Association of Higher Education Facilities Officers (APPA), are used to establish baseline measures for educational facilities in fiscal year 1993-94. This data is also compared to the IFMA data presented earlier in this document. It should be noted that data presented here represent only the most general of the data available in the *APPA Comparative Costs and Staffing Report for Colleges and University Facilities.*

Table 6-8 Part A and Part B presents selected aggregated mean operations, maintenance, and energy cost data for college and university facilities grouped by funding source, region (as defined by APPA - refer to page xvii of APPA report for details), and by number of Full-Time Equivalent (FTE) enrollment students at the facility. The following cost components are identified:

- **administration** - includes all administrative costs for the facility including payroll costs, equipment, supplies, communications, computer rental, accounting costs, training costs, etc.
- **work control** - includes all costs necessary for the proper planning, scheduling, and dispatching of maintenance work, including payroll, database maintenance, supervision, cost estimation, etc.
- **engineering/architecture** - includes all design and engineering costs

- **project management** - includes all costs associated with actual estimating, contracting, inspecting, and final approval of new or renovated construction
- **building maintenance** - includes in-house and contracted services for routine repairs, minor corrective maintenance, preventive maintenance and service calls for HVAC, plumbing, electrical, painting, glazing, elevators, etc.
- **custodial maintenance** - includes interior and exterior functions such as window and building cleaning, snow removal, and operating costs such as towels, etc.
- **grounds maintenance** - includes landscaping and grounds maintenance costs for parking areas, irrigation systems, fencing, etc.
- **utilities operations** - includes all costs for heating, cooling, lighting and other utilities for physical plant operations, EXCLUDING cost of fuel and purchased utilities
- **solid waste disposal** - includes all costs associated with refuse removal
- **hazardous waste disposal** - includes all costs associated with hazardous waste removal
- **security** - includes all security expenses such as traffic, parking, and building security

For full details of these definitions refer to pages 361-366 of the APPA report.

Figures 6-37 through 6-42 show selected mean operations costs in dollars per gross square foot/meter. Figure 6-37 compares selected operations costs for all college and university facilities combined. The figure shows that building maintenance, custodial maintenance (cleaning), and utility operations (which exclude the cost of fuels, which for electricity alone is approximately $10.76/GSM ($1.00/GSF) - see Figure 6-39 for details) are the largest cost components, in addition to fuel costs. Some of these costs components can be compared to IFMA data. For example, the APPA mean cost for custodial maintenance of $9.80/GSM ($0.91/GSF) compares with the IFMA janitorial cost for educational facilities of $14.10/RSM ($1.31/RSF) (note different units of floor measurement used in the two reports). Grounds maintenance costs given in APPA are $3.01/GSM ($0.28/GSF), which compares with $3.34/RSM ($0.31/RSF) in the IFMA report. Similarly, waste disposal costs and security costs from APPA data are $0.97/GSM ($0.09/GSF) and $3.77/GSM ($0.35/GSF) compared with $1.29/RSM ($0.12/RSF) and $5.06/RSM ($0.47/RSF) respectively from IFMA data. However, some cost categories cannot be directly compared. For example, the IFMA maintenance and repair category, $21.10/RSM ($1.96/RSF), is probably comparable with the APPA combination of building maintenance plus utilities operations (=$9.69/RSM ($0.90/RSF) plus $6.35/RSM ($0.59/RSF)). In general, it appears that IFMA costs are about 30 percent higher than comparable APPA costs.

Figure 6-38 compares building and custodial maintenance costs for colleges and facilities by the size of the establishment (as measured by the number of FTE students). Reference to the figure indicates that there is no apparent downward trend in unit costs for larger facilities as might be expected. Figure 6-39, which is based upon data presented in Table 6-9 Part A and Part B, shows electricity costs for educational facilities by funding source. The figure indicates that private institutions have approximately 10 percent lower electricity costs per unit area compared with publicly funded facilities. This is probably due to a higher level of co-generation in private facilities. Reference to Table 6-9 also indicates that there are significant regional differences in total electricity costs in the US. The mean electricity cost for all facilities combined is $0.99/GSF, which is approximately 30 percent lower than a comparable figure from IFMA.

Table 6-8. Selected Operations Costs for College and University Facilities by Funding Source, Region, and Number of Students

Part A: Dollars per Square Foot

Carnegie Classification	Administrative Costs	Work Control	Engineering & Architecture	Project Manage-ment	Building Mainten-ance	Custodial Mainten-ance	Grounds Mainten-ance	Utilities Opera-tions	Solid Waste Disposal	Hazardous Waste Disposal	Security
Funding Source											
Private Institutions	0.258	0.087	0.106	0.104	0.989	0.846	0.280	0.698	0.066	0.048	0.355
Public Institutions	0.264	0.076	0.114	0.114	0.851	0.942	0.273	0.554	0.046	0.032	0.353
All Institutions	0.262	0.079	0.112	0.112	0.895	0.912	0.275	0.594	0.052	0.037	0.354
Region											
Eastern	0.314	0.089	0.158	0.170	0.988	1.022	0.260	0.635	0.079	0.031	0.487
Southeastern	0.240	0.071	0.087	0.106	0.953	0.846	0.303	0.548	0.054	0.030	0.406
Midwest	0.238	0.079	0.092	0.058	0.825	1.003	0.244	0.678	0.037	0.029	0.291
Central	0.202	0.062	0.080	0.053	0.695	0.716	0.207	0.536	0.027	0.032	0.246
Rocky Mountain	0.208	0.082	0.090	0.101	0.810	0.807	0.264	0.597	0.032	0.021	0.209
Pacific Coast	0.367	0.084	0.138	0.130	1.117	1.013	0.440	0.509	0.060	0.075	0.351
Number of Students											
0-1,999	0.278	0.100	0.095	0.128	0.946	0.817	0.268	0.753	0.060	0.048	0.271
2,000-4,999	0.289	0.090	0.120	0.155	0.912	0.966	0.300	0.666	0.058	0.025	0.374
5,000-11,999	0.234	0.075	0.151	0.139	0.846	0.991	0.284	0.425	0.051	0.038	0.430
12,000-19,999	0.300	0.055	0.081	0.065	0.897	0.907	0.253	0.897	0.907	0.253	0.564
20,000+	0.162	0.063	0.081	0.055	0.831	0.915	0.218	0.606	0.041	0.031	0.343

Part B: Dollars per Square Meter

Carnegie Classification	Administrative Costs	Work Control	Engineering & Architecture	Project Manage-ment	Building Mainten-ance	Custodial Mainten-ance	Grounds Mainten-ance	Utilities Opera-tions	Solid Waste Disposal	Hazardous Waste Disposal	Security
Funding Source											
Private Institutions	2.776	0.936	1.141	1.119	10.642	9.103	3.013	7.510	0.710	0.516	3.820
Public Institutions	2.841	0.818	1.227	1.227	9.157	10.136	2.937	5.961	0.495	0.344	3.798
All Institutions	2.819	0.850	1.205	1.205	9.630	9.813	2.959	6.391	0.560	0.398	3.809
Region											
Eastern	3.379	0.958	1.700	1.829	10.631	10.997	2.798	6.833	0.850	0.334	5.240
Southeastern	2.582	0.764	0.936	1.141	10.254	9.103	3.260	5.896	0.581	0.323	4.369
Midwest	2.561	0.850	0.990	0.624	8.877	10.792	2.625	7.295	0.398	0.312	3.131
Central	2.174	0.667	0.861	0.570	7.478	7.704	2.227	5.767	0.291	0.344	2.647
Rocky Mountain	2.238	0.882	0.968	1.087	8.716	8.683	2.841	6.424	0.344	0.226	2.249
Pacific Coast	3.949	0.904	1.485	1.399	12.019	10.900	4.734	5.477	0.646	0.807	3.777
Number of Students											
0-1,999	2.991	1.076	1.022	1.377	10.179	8.791	2.884	8.102	0.646	0.516	2.916
2,000-4,999	3.110	0.968	1.291	1.668	9.813	10.394	3.228	7.166	0.624	0.269	4.024
5,000-11,999	2.518	0.807	1.625	1.496	9.103	10.663	3.056	4.573	0.549	0.409	4.627
12,000-19,999	3.228	0.592	0.872	0.699	9.652	9.759	2.722	9.652	9.759	2.722	6.069
20,000+	1.743	0.678	0.872	0.592	8.942	9.845	2.346	6.521	0.441	0.334	3.691

Figure 6-37. Selected Operations Costs for All College and University Facilities

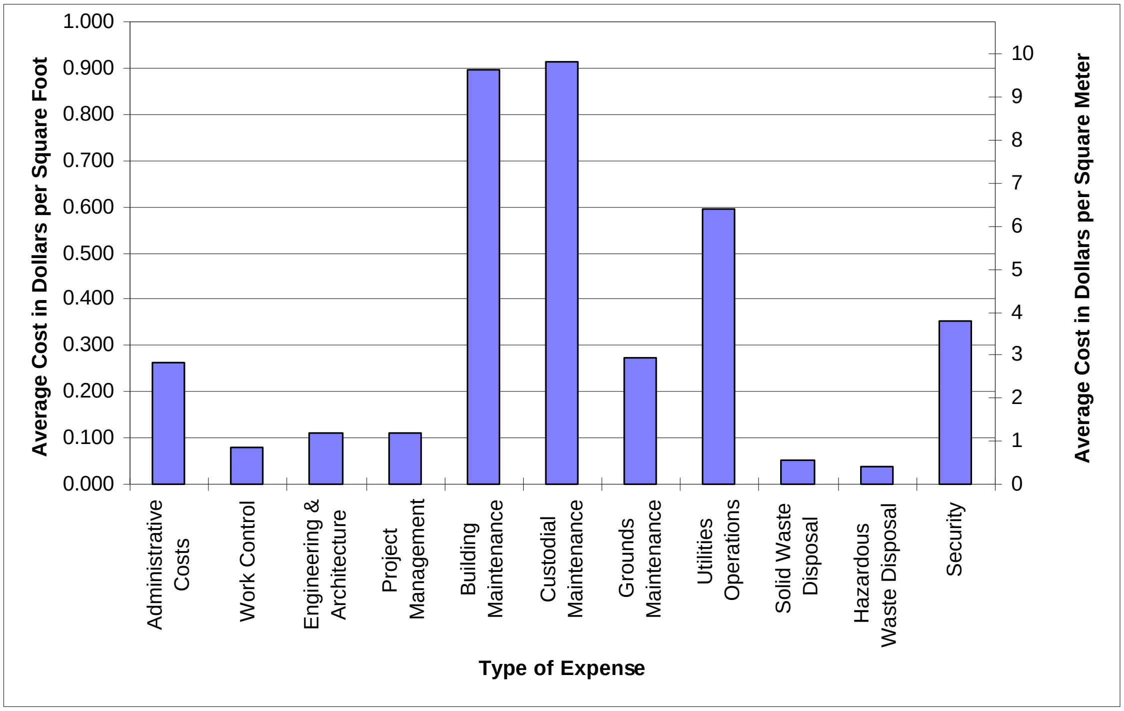


Figure 6-38. Building and Custodial Maintenance Costs for Colleges and Universities by Number of Students: 1993 and 1994

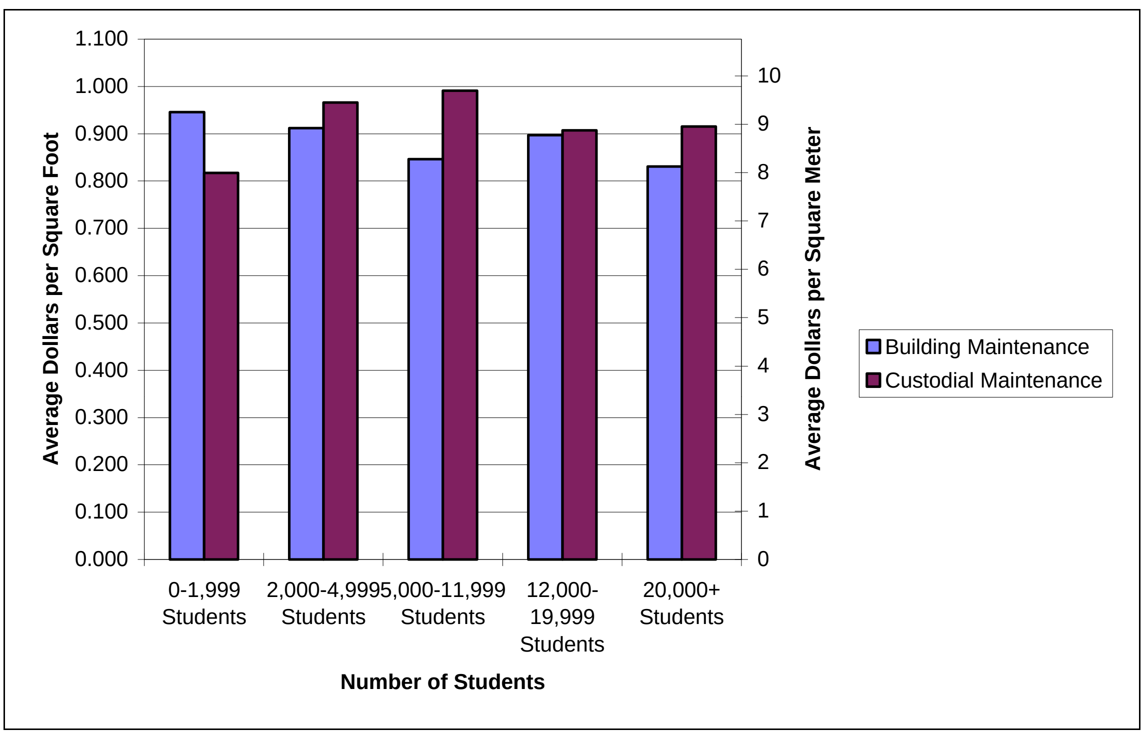


Figure 6-39. Electricity Cost by Funding Source for Colleges and Universities

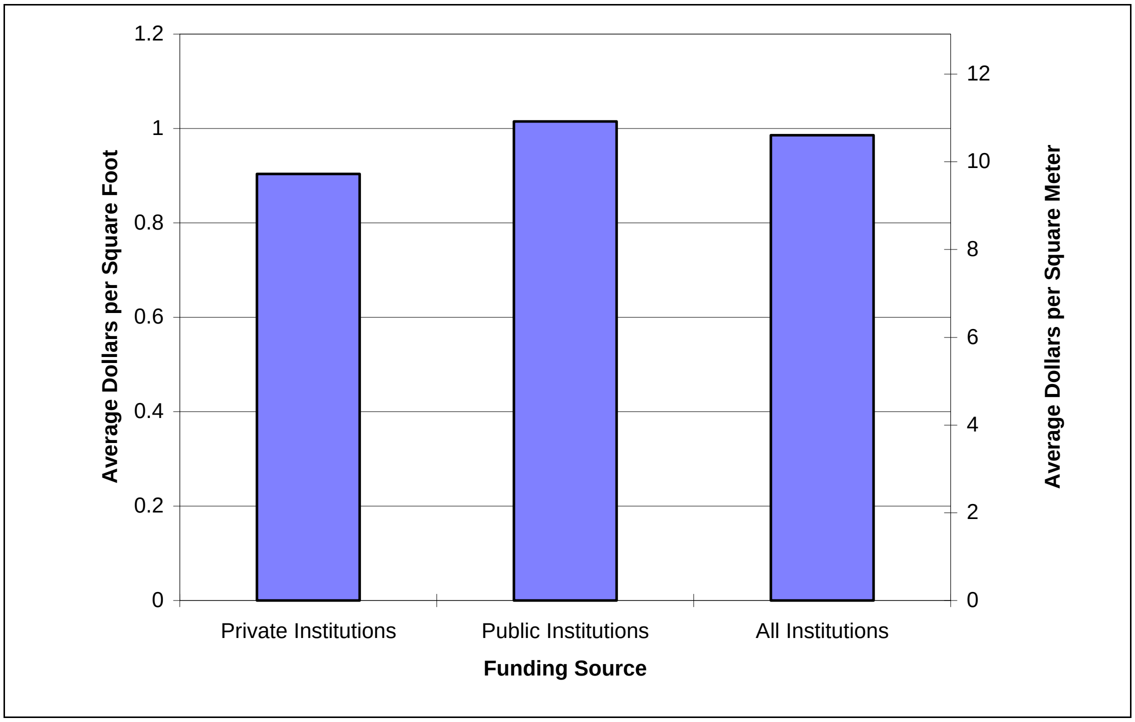


Table 6-9. Mean Electricity Usage by Funding Source, Region, and Number of Students

Part A: English Units

Carnegie Classification	Electricity Purchased (kwh)	Electricity Cost ($)	Cost per kwh	Kwh per Gross Building Square Foot	Cost per Gross Building Square Foot	Kwh per FTE Student	Cogenerated Electricity (kwh)	Cogeneration Cost ($)	Cost per kwh
Funding Source									
Private Institutions	18,652,497	1,039,192	0.069	13.1	0.904	6,725	10,753,227	265,041	0.040
Public Institutions	41,331,277	1,935,262	0.059	17.2	1.015	4,186	36,684,694	1,109,719	0.042
All Institutions	34,227,081	1,649,722	0.062	15.9	0.986	4,983	30,201,827	894,057	0.041
Region									
Eastern	28,457,542	1,733,988	0.077	14.3	1.101	4,718	5,311,438	171,627	0.050
Southeastern	45,832,694	1,927,002	0.056	19.5	1.092	6,372	20,141,742	879,811	0.037
Midwest	40,990,041	1,965,652	0.059	16.6	0.979	5,292	53,108,888	1,304,341	0.037
Central	26,664,401	1,170,056	0.053	16.1	0.853	5,115	37,720,560	901,261	0.043
Rocky Mountain	30,275,123	1,171,497	0.053	13.0	0.689	2,839	58,456,746	3,125,091	0.040
Pacific Coast	29,440,012	1,463,428	0.067	14.0	0.938	3,842	8,432,912	407,471	0.040
Number of Students									
0-1,999	12,833,844	655,258	0.067	14.1	0.945	7,430	7,869,843	228,371	0.061
2,000-4,999	13,576,276	706,228	0.062	15.2	0.942	4,612	6,907,722	186,519	0.045
5,000-11,999	29,752,199	1,641,727	0.061	16.9	1.031	3,711	16,399,549	581,360	0.044
12,000-19,999	53,543,074	2,737,475	0.063	16.3	1.027	3,310	27,318,080	739,973	0.039
20,000+	127,229,064	6,145,515	0.053	19.5	1.034	4,547	66,044,432	2,306,494	0.032

Part B: SI Units

Carnegie Classification	Electricity Purchased (MJ)	Electricity Cost ($)	Cost per MJ	MJ per Gross Building Square Meter	Cost per Gross Building Square Meter	MJ per FTE Student	Cogenerated Electricity (MJ)	Cogeneration Cost ($)	Cost per MJ
Funding Source									
Private Institutions	67,148,989	1,039,192	0.019	507.6	9.730	24,210	38,711,617	265,041	0.111
Public Institutions	148,792,597	1,935,262	0.016	666.5	10.924	15,070	132,064,898	1,109,719	0.012
All Institutions	123,217,492	1,649,722	0.017	616.1	10.612	17,939	108,726,577	894,057	0.011
Region									
Eastern	102,447,151	1,733,988	0.021	554.1	11.853	16,985	19,121,177	171,627	0.014
Southeastern	164,997,698	1,927,002	0.016	755.6	11.755	22,939	72,510,271	879,811	0.010
Midwest	147,564,148	1,965,652	0.016	643.3	10.543	19,051	191,191,997	1,304,341	0.010
Central	95,991,844	1,170,056	0.015	623.9	9.186	18,414	135,794,016	901,261	0.012
Rocky Mountain	108,990,443	1,171,497	0.015	503.8	7.417	10,220	210,444,286	3,125,091	0.011
Pacific Coast	105,984,043	1,463,428	0.019	542.5	10.097	13,831	30,358,483	407,471	0.011
Number of Students									
0-1,999	46,201,838	655,258	0.019	546.4	10.169	26,748	28,331,435	228,371	0.017
2,000-4,999	48,874,594	706,228	0.017	589.0	10.145	16,603	24,867,799	186,519	0.013
5,000-11,999	107,107,916	1,641,727	0.017	654.9	11.097	13,360	59,038,376	581,360	0.012
12,000-19,999	192,755,066	2,737,475	0.018	631.6	11.054	11,916	98,345,088	739,973	0.011
20,000+	458,024,630	6,145,515	0.015	755.6	11.125	16,369	237,759,955	2,306,494	0.009

Figure 6-40, which is based upon data presented in Table 6-10 Part A and Part B, shows gas consumption by funding source for all educational facilities. Reference to the figure indicates that privately funded facilities have higher consumption costs than publicly funded sources. Comparison of Figure 6-39 and Figure 6-40 shows that private and publicly funded facilities have comparable total electricity and gas costs per unit area. Figure 6-41 and Figure 6-42 show how water and sewer costs per acre/square meter vary by funding source and facility size. The data indicate that for all facilities, the average cost is $0.40/square meter ($1,631/acre - approximately $0.04/square foot), which is lower than the IFMA mean cost of $1.72/RSM ($0.16/RSF). However, these two figures may not be directly comparable. The total water cost is split approximately equally between water costs and sewer costs. Publicly funded facilities' costs appear to be higher than those for privately funded facilities, but there does not appear to be any clear relationship between facility size and water/sewer unit costs.

Figure 6-40. Mean Gas Cost by Funding Source for Colleges and Universities

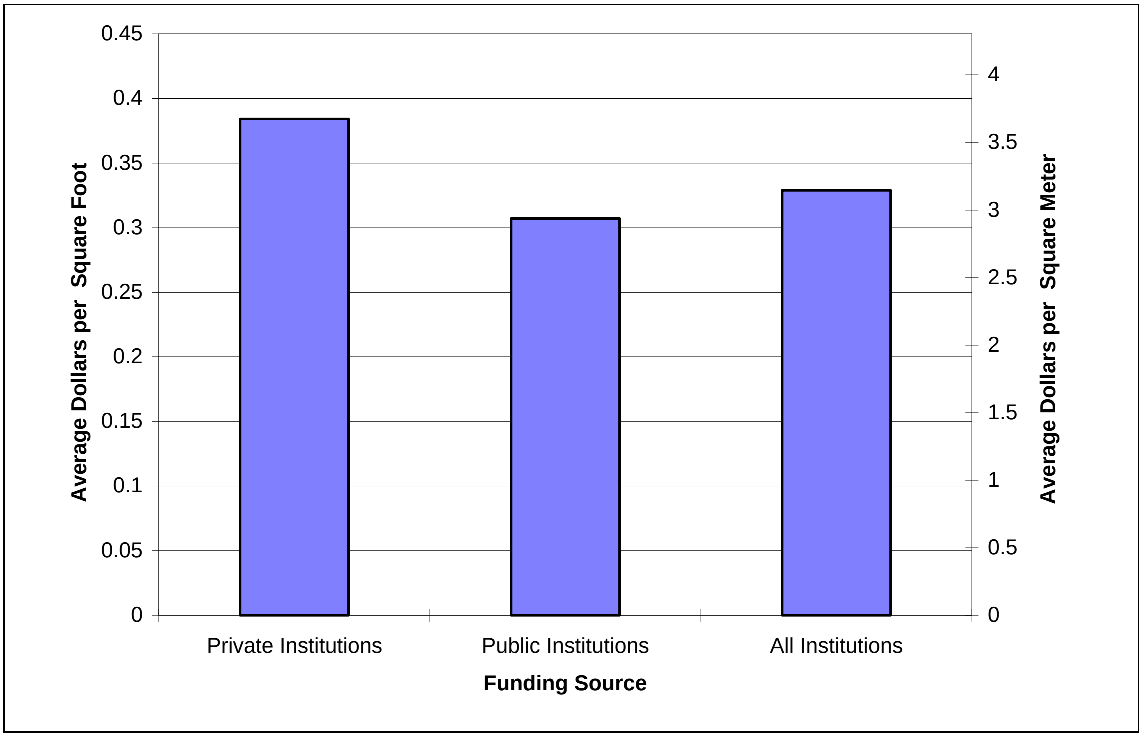


Table 6-10. Mean Gas Consumption by Funding Source, Region and Number of Students

Part A: English Units

Carnegie Classification	Natural Gas (100 cubic feet)	Cost ($)	Cost per 100 cubic feet	Quantity per Gross Building Square Foot	Cost per Gross Building Square Foot	Quantity per FTE student
Funding Source						
Private Institutions	935,743	295,943	0.48	0.80	0.38	357.20
Public Institutions	2,009,531	583,658	0.42	0.73	0.31	201.10
All Institutions	1,682,475	493,579	0.44	0.75	0.33	248.30
Region						
Eastern	1,312,189	451,779	0.53	0.72	0.38	223.50
Southeastern	985,863	335,903	0.51	0.62	0.31	178.00
Midwest	2,544,061	728,268	0.38	0.92	0.34	334.80
Central	1,474,649	381,712	0.35	0.73	0.26	295.80
Rocky Mountain	2,630,722	564,118	0.42	0.89	0.37	206.70
Pacific Coast	1,548,504	498,379	0.43	0.64	0.27	182.00
Number of Students						
0-1,999	531,992	181,362	0.47	0.86	0.40	430.10
2,000-4,999	670,661	224,997	0.46	0.61	0.28	219.20
5,000-11,999	1,147,106	388,974	0.44	0.72	0.32	146.20
12,000-19,999	2,633,960	865,199	0.42	0.67	0.28	159.50
20,000+	6,702,667	1,944,194	0.35	0.98	0.34	228.40

Part B: SI Units

Carnegie Classification	Natural Gas (100 cubic meters)	Cost ($)	Cost per 100 cubic meters	Quantity per Gross Building Square Meter	Cost per Gross Building Square Meter	Quantity per FTE student
Funding Source						
Private Institutions	26,482	295,943	16.92	8.63	145.97	357.20
Public Institutions	56,870	583,658	14.83	7.85	116.50	201.10
All Institutions	47,614	493,579	15.47	8.09	125.16	248.30
Region						
Eastern	37,135	451,779	18.58	7.75	143.91	223.50
Southeastern	27,900	335,903	17.90	6.67	119.44	178.00
Midwest	71,997	728,268	13.24	9.89	130.95	334.80
Central	41,733	381,712	12.36	7.88	97.35	295.80
Rocky Mountain	74,449	564,118	14.76	9.57	141.20	206.70
Pacific Coast	43,823	498,379	15.15	6.89	104.33	182.00
Number of Students						
0-1,999	15,055	181,362	16.56	9.29	153.80	430.10
2,000-4,999	18,980	224,997	16.21	6.55	106.22	219.20
5,000-11,999	32,463	388,974	15.43	7.79	120.22	146.20
12,000-19,999	74,541	865,199	14.66	7.23	105.97	159.50
20,000+	189,685	1,944,194	12.32	10.49	129.30	228.40

Figure 6-41. Water and Sewer Costs by Funding Source for Colleges and Universities

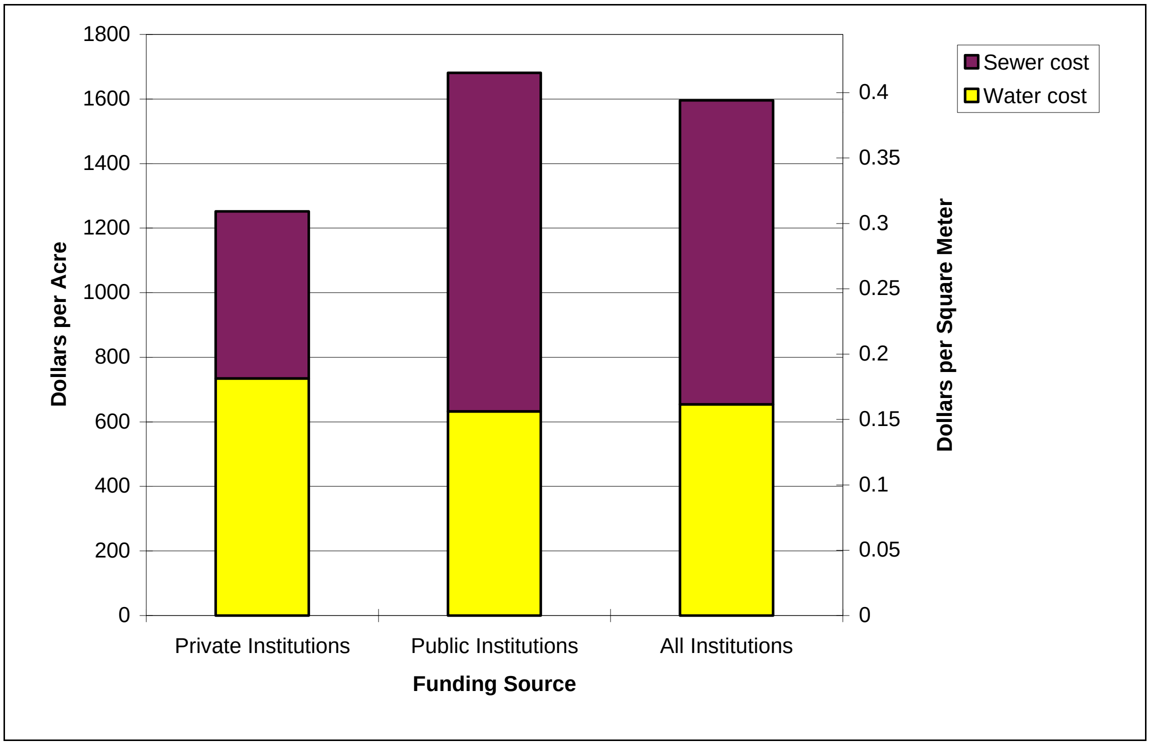


Figure 6-42. Water and Sewer Costs by Number of Students for Colleges and Universities

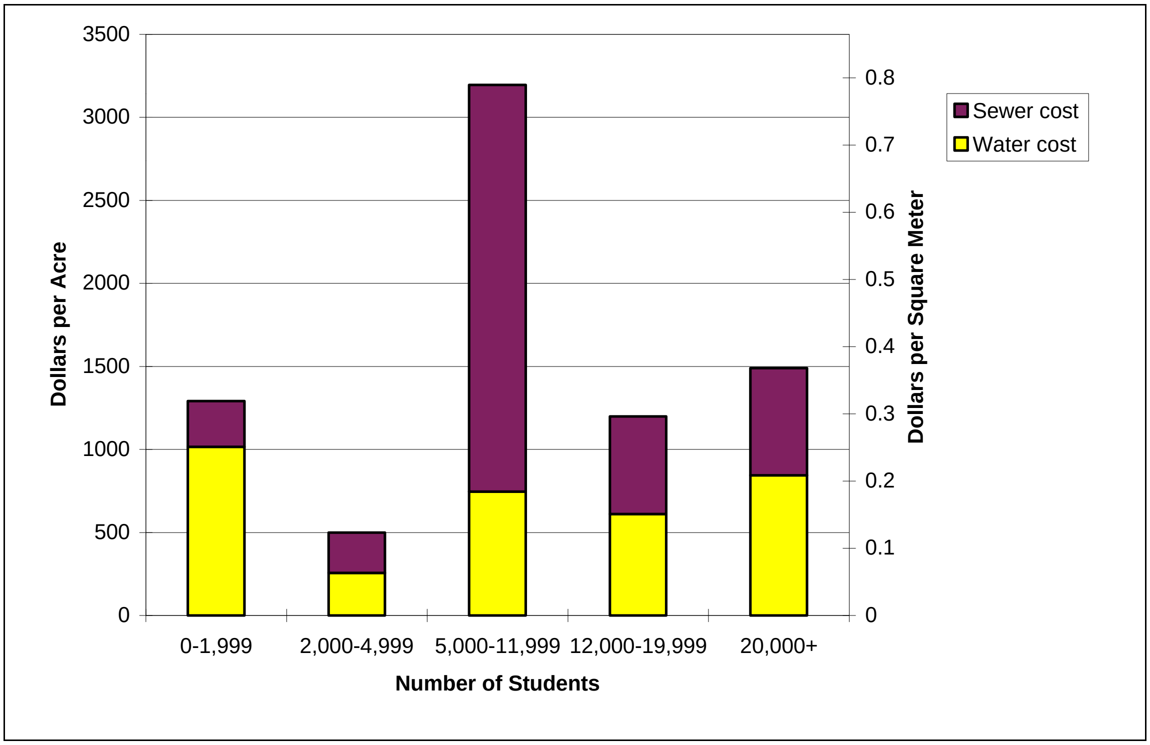


Table 6-11. Water and Sewer Consumption by Funding Source, Geographic Location and Number of Students

Part A: English Units

Carnegie Classification	Water Quantity (kgal)	Water Cost ($)	$ per kgal	Water Cost per Student	Amount per Acre	Sewer Quantity (kgal)	Sewer Cost ($)	$ per kgal	Sewer Cost per Student	Amount per Acre	Combined (kgal)	Combined Cost ($)	$ per kgal	Combined Cost per student	Amount per Acre
Funding Source															
Private Institutions	95,691	140,283	2.97	49	734	68,669	110,517	2.91	21	518	84,414	223,593	4.91	32	549
Public Institutions	215,707	193,721	1.96	32	632	233,664	247,088	2.22	27	1,049	153,068	279,317	4.45	14	
All Institutions	187,388	180,362	2.21	36	654	195,988	213,460	2.38	26	942	127,168	258,165	4.63	21	652
Region															
Eastern	180,254	164,621	2.79	42	645	191,176	201,039	2.84	39	801	188,539	317,255	4.47	19	917
Southeastern	215,596	230,585	1.68	38	534	147,880	251,275	2.04	18	279	111,253	228,498	4.69	38	550
Midwest	293,234	273,817	2.19	77	1,142	217,553	382,824	1.98	18	1,213	118,421	285,097	5.16	15	677
Central	106,465	146,987	2.38	13	489	95,674	102,652	3.24	9	350	74,889	187,279	3.47	15	330
Rocky Mountain	244,864	136,610	1.24	16	606	222,560	152,820	1.11	15	548	120,120	157,101	2.86	14	829
Pacific Coast	116,326	122,249	2.26	15	533	390,895	173,654	2.34	60	3	133,859	323,909	6.43	17	698
Number of Students															
0-1,999	88,632	88,478	3.44	93	1,016	25,144	57,621	2.84	38	275	37,181	84,532	4.93	34	352
2,000-4,999	53,795	48,089	2.27	17	256	53,263	52,480	1.97	18	244	47,873	147,649	5.64	16	390
5,000-11,999	133,068	129,338	1.83	16	745	257,401	197,563	3.36	39	2,450	111,196	312,480	3.43	15	724
12,000-19,999	252,514	319,119	1.38	15	611	230,932	325,790	1.78	14	587	393,268	486,380	5.93	23	1576
20,000+	672,393	663,029	1.23	24	844	514,183	838,028	1.64	18	645	315,846	889,423	3.74	12	706

Part B: SI Units

Carnegie Classification	Water Quantity (1000 liters)	Water Cost ($)	$ per 1000 liters	Water Cost per Student	Amount per Square Meter	Sewer Quantity (1000 liters)	Sewer Cost ($)	$ per 1000 liters	Sewer Cost per Student	Amount per Square Meter	Combined (1000 liters)	Combined Cost ($)	$ per 1000 liters	Combined Cost per student	Amount per Square Meter
Funding Source															
Private Institutions	362,190	140,283	0.785	49	0.181	259,912	110,517	0.769	21	0.128	319,507	223,593	1.297	32	0.136
Public Institutions	816,451	193,721	0.518	32	0.156	884,418	247,088	0.587	27	0.259	579,362	279,317	1.176	14	
All Institutions	709,264	180,362	0.584	36	0.162	741,815	213,460	0.629	26	0.233	481,331	258,165	1.223	21	0.161
Region															
Eastern	682,261	164,621	0.737	42	0.159	723,601	201,039	0.750	39	0.198	713,620	317,255	1.181	19	0.227
Southeastern	816,031	230,585	0.444	38	0.132	559,726	251,275	0.539	18	0.069	421,093	228,498	1.239	38	0.136
Midwest	1,109,891	273,817	0.579	77	0.282	823,438	382,824	0.523	18	0.300	448,223	285,097	1.363	15	0.167
Central	402,970	146,987	0.629	13	0.121	362,126	102,652	0.856	9	0.086	283,455	187,279	0.917	15	0.082
Rocky Mountain	926,810	136,610	0.328	16	0.150	842,390	152,820	0.293	15	0.135	454,654	157,101	0.756	14	0.205
Pacific Coast	440,294	122,249	0.597	15	0.132	1,479,538	173,654	0.618	60	0.001	506,656	323,909	1.699	17	0.172
Number of Students															
0-1,999	335,472	88,478	0.909	93	0.251	95,170	57,621	0.750	38	0.068	140,730	84,532	1.303	34	0.087
2,000-4,999	203,614	48,089	0.600	17	0.063	201,600	52,480	0.520	18	0.060	181,199	147,649	1.49	16	0.096
5,000-11,999	503,662	129,338	0.483	16	0.184	974,263	197,563	0.888	39	0.605	420,877	312,480	0.906	15	0.179
12,000-19,999	955,765	319,119	0.365	15	0.151	874,078	325,790	0.470	14	0.145	1,488,519	486,380	1.567	23	0.389
20,000+	2,545,008	663,029	0.325	24	0.209	1,946,183	838,028	0.433	18	0.159	1,195,477	889,423	0.988	12	0.174

6.2.4 Baseline Measures for Shopping Centers

In this section, data from the Institute of Real Estate Management (IREM) are used to establish baseline measures for shopping centers for 1995. These data will also be compared to the IFMA data presented earlier in this document. It should be noted that the data presented in this section represent only the most general of the data available in the highly detailed IREM report *Income/Expense Analysis: Shopping Centers*.

Table 6-12 shows the size of the survey sample used in the IREM report. It indicates that open shopping centers represent a large proportion of the survey sample, and represent nearly twice the total floor area compared with enclosed shopping centers. For this reason, and for the purposes of brevity, only open shopping centers will be considered in detail in this document. However, Figures 6-43 through 6-45 compare selected operations costs for open shopping centers and enclosed shopping centers (which are further subdivided depending upon whether they have open or enclosed common areas) for the following three major cost categories:

- **Maintenance and Repair** - this includes all costs associated with elevator, escalator, HVAC, electrical, plumbing, painting, building structure, and other cost components.
- **Services** - this includes all costs associated with grounds maintenance, security, trash removal, cleaning, and other cost components.
- **Utilities** - this includes all costs associated with electricity, HVAC fuel, water and sewer services, combined electricity (i.e., where it is not possible to separate HVAC costs into a separate category), and other cost components.

These categories do not include capital expenditures or depreciation charges, income taxes, rent payments, and so forth. The figures are based upon median costs from the survey sample, expressed in dollars per annum per total Average Actual Occupancy (AAO) in square meters and feet, which is a measure of the amount of floorspace occupied in the building.

Table 6-12. IREM Sample Distribution for Shopping Centers: 1995

Item	Open	Enclosed
Number of Centers	819	68
Average Size of Center GLA (square feet)	105,409	594,853
Average Size of Center GLA (square meters)	9,792	55,262
Average Actual Occupancy (square feet)	95,142	566,716
Average Actual Occupancy (square meters)	8,839	52,648

Figure 6-43 shows that that the total median costs for the three categories shown above was \$8.29/(AAO) square meter (\$0.77/square foot) for all open shopping centers. This represents approximately 29 percent of total median operating costs. The remainder of the operating costs comprise items such as insurance and taxes \$11.73/(AAO) square meter (\$1.09/square foot), and other expenses, such as administrative payroll, management fees, and food court charges, which amount to \$8.40/(AAO) square meter (\$0.78/square foot).

Figure 6-43. Comparison of Selected Operations Costs for All Open Shopping Centers

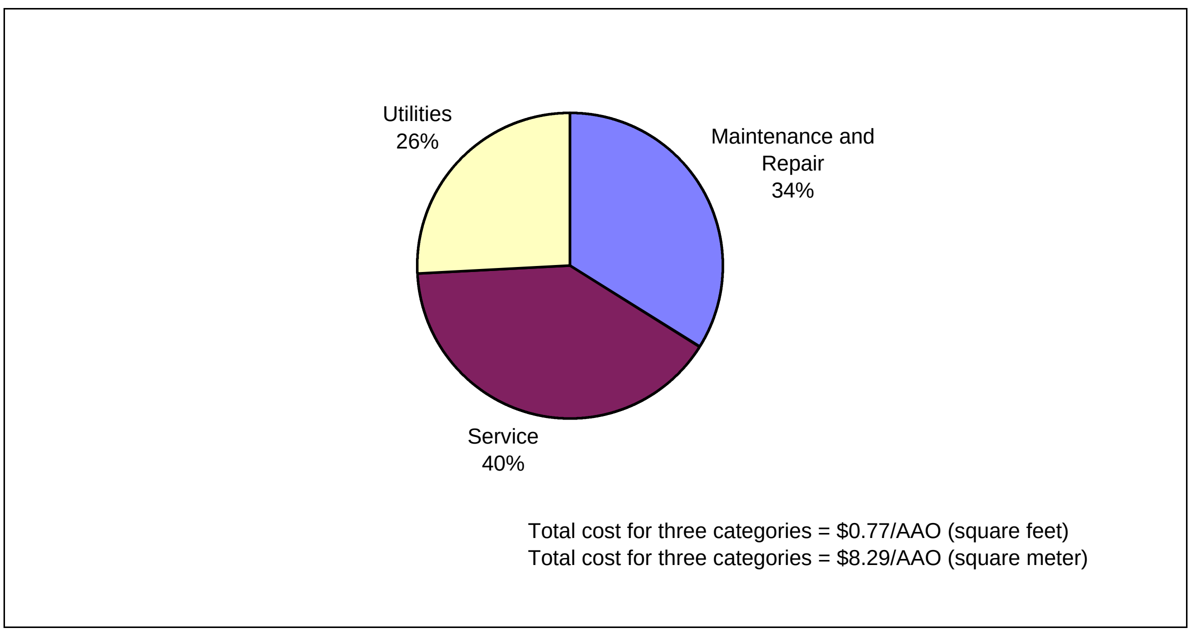


Figure 6-44. Comparison of Selected Operations Costs for All Enclosed Shopping Centers with Enclosed Common Areas

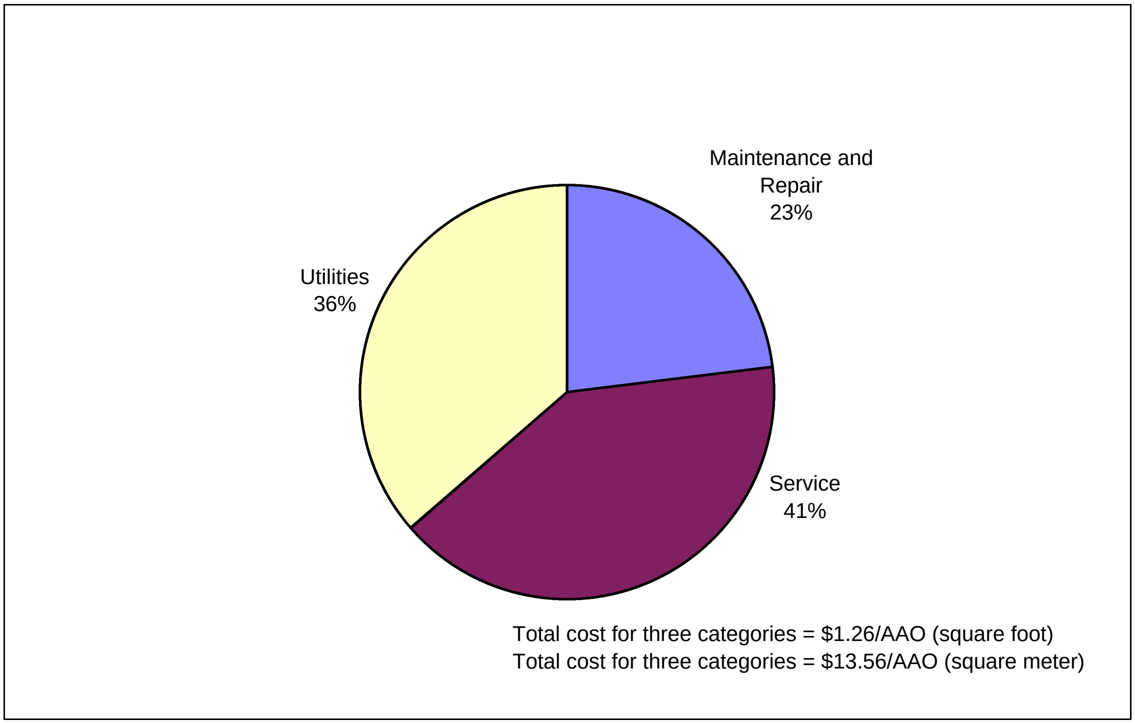
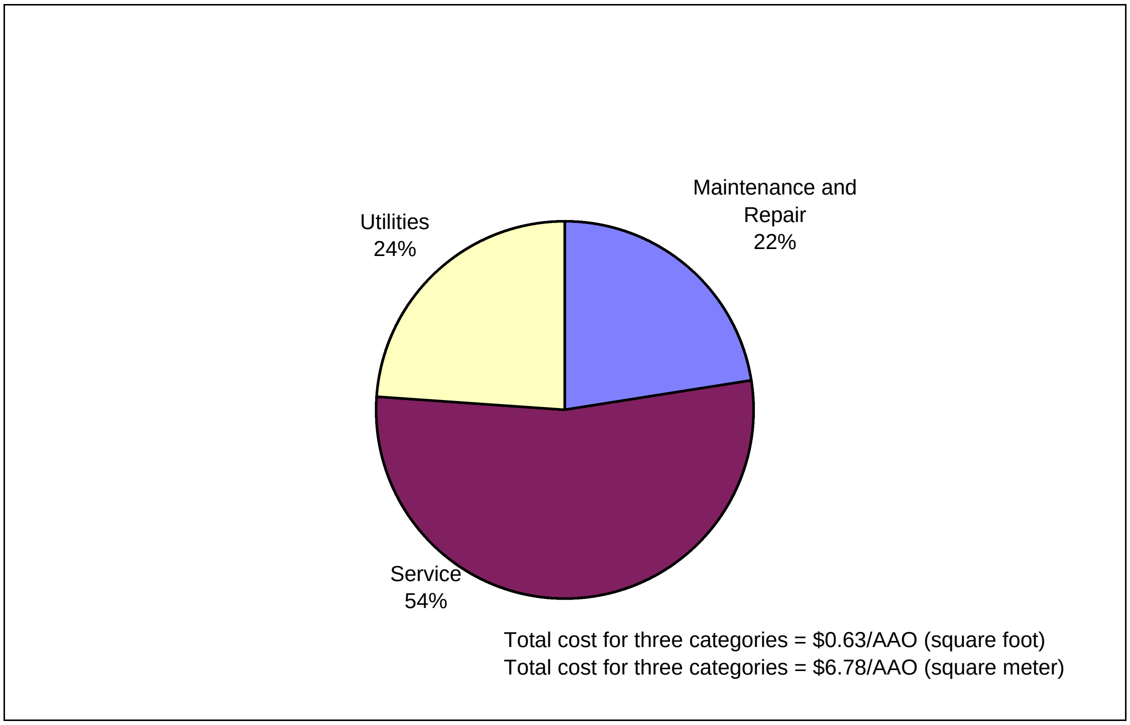


Figure 6-45. Comparison of Selected Operations Costs for Enclosed Shopping Centers with Non-Enclosed Common Areas



In comparison, Figure 6-44 and Figures 6-45 show that the median operating costs for enclosed shopping malls for the three categories shown above vary depending upon whether the shopping center has either open or enclosed common areas. The total median operating expenses for all enclosed shopping combined is $55.43/(AAO) square meter ($5.15/square foot), which is approximately twice that of open shopping centers $28.42/(AAO) square meter ($2.64/square foot).

Table 6-13 shows the range of costs for maintenance and repair, services, and utilities components in more detail. Median and upper and lower quartile figures are presented. Selected operating expenses are also shown graphically in Figures 6-46 through 6-49. Reference to Figure 6-46 shows that taxes, insurance, and other expenses excluding maintenance and repair, services, and utilities account for about 70 percent of total operating costs in open shopping centers. Figure 6-47 examines median services costs in greater detail. Reference to this figure indicates that grounds maintenance costs are the largest component in this category, followed by trash removal and security costs. These are all in the $0.75 - $1.18/(AAO) square meter ($0.07-$0.11/square foot) range, which are generally lower than comparable IFMA data. Figure 6-48 shows median maintenance and repair costs for all open shopping centers. The figure shows that the largest maintenance and repair component is associated with parking lot/sidewalk repairs, striping, sweeping, and surfacing. HVAC maintenance is not shown in this figure, as it is included in a separate category by BOMA. However, HVAC maintenance and repair costs are relatively small at $0.22/(AAO) square meter ($0.02/square foot). Finally, Figure 6-49 shows median utilities costs by type. As expected, electricity costs dominate this category. The range of utilities costs is generally lower than comparable IFMA data, and electricity costs are much lower ($1.29/(AAO) square meter ($0.12/square foot) from BOMA data compared with $2.11 from IFMA data for the wholesale/retail sector). This suggests that IFMA costs may include a component of process-related energy use.

Table 6-13. Operations Expenses: All Open Shopping Centers

			Dollars per total average actual occupancy			
Expense	**Number of Centers**	**Square feet (10,000)**	**In square feet**			**In square meters**
Maintenance and Repair			**Median**	**Low**	**High**	**Median**
Parking Lot/Sidewalk	632	6,434	0.05	0.02	0.13	0.54
Sweeping	673	6,616	0.08	0.05	0.13	0.86
Roof Repair	577	5,648	0.03	0.01	0.06	0.32
Plumbing	478	4,724	0.01	0.00	0.02	0.11
Electrical	647	6,382	0.02	0.01	0.04	0.22
Painting/Decorating	473	4,779	0.02	0.01	0.05	0.22
Other	543	5,477	0.04	0.01	0.09	0.43
Subtotal Maintenance & Repair	804	7,670	0.26	0.16	0.40	2.80
Services						
Outdoor Landscape	775	7,501	0.11	0.06	0.19	1.18
Snow Removal	309	3,361	0.05	0.02	0.12	0.54
Security	378	4,263	0.07	0.02	0.19	0.75
Trash Removal	613	5,938	0.08	0.02	0.16	0.86
Cleaning	434	4,282	0.05	0.02	0.10	0.54
Other	410	4,132	0.02	0.01	0.05	0.22
Subtotal Services	794	7,639	0.31	0.16	0.54	3.34
Utilities						
Electricity	590	5,604	0.11	0.07	0.18	1.18
HVAC Fuel-Electricity	63	599	0.10	0.02	0.19	1.08
Oil	17	169	0.10	0.05	0.19	1.08
Gas	85	972	0.01	0.00	0.03	0.11
Steam	3	72	0.05	0.01	0.05	0.54
Other	10	91	0.03	0.01	0.06	0.32
Water & Sewer	673	6,399	0.08	0.03	0.18	0.86
Combined Electricity	127	1,366	0.12	0.06	0.21	1.29
Other	123	1,382	0.02	0.01	0.04	0.22
Subtotal Utilities	792	7,587	0.20	0.11	0.35	2.15
Total Expenses*	809	7,697	2.64	1.84	3.81	28.41
*Note: Some Expenses such as taxes and insurance excluded from table						

Figure 6-46. Summary of Range of Operations Costs for Open Shopping Centers

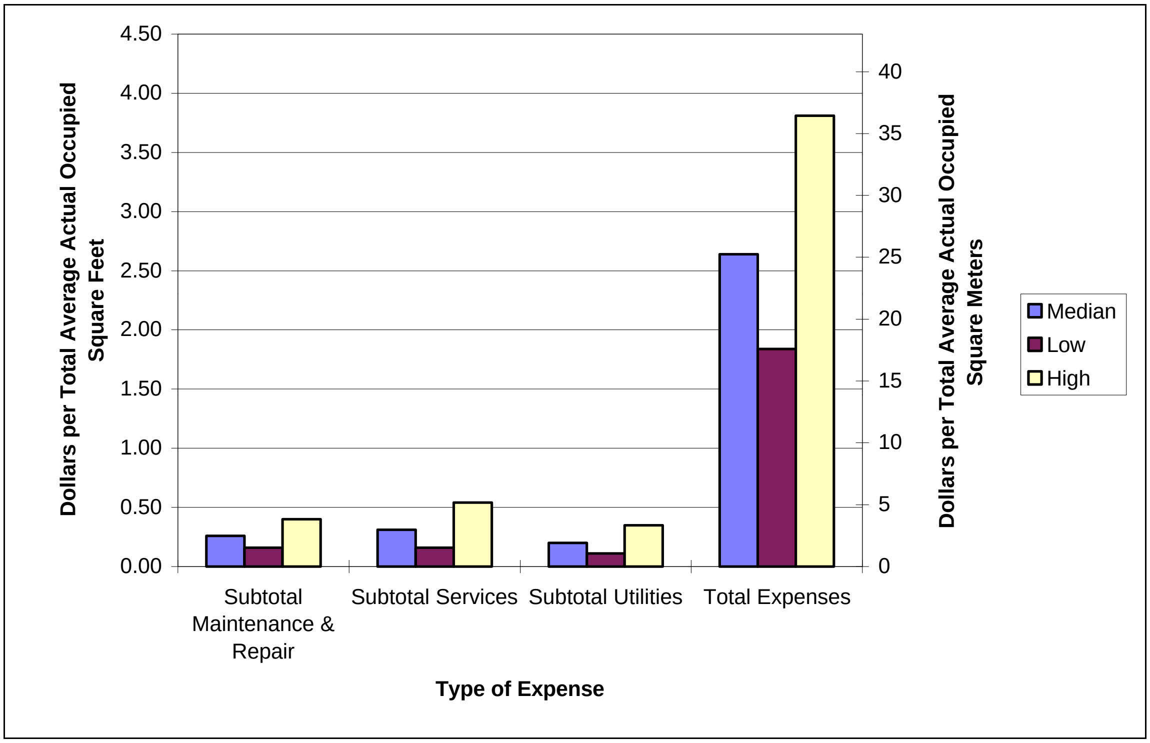


Figure 6-47. Median Services Costs for Open Shopping Centers

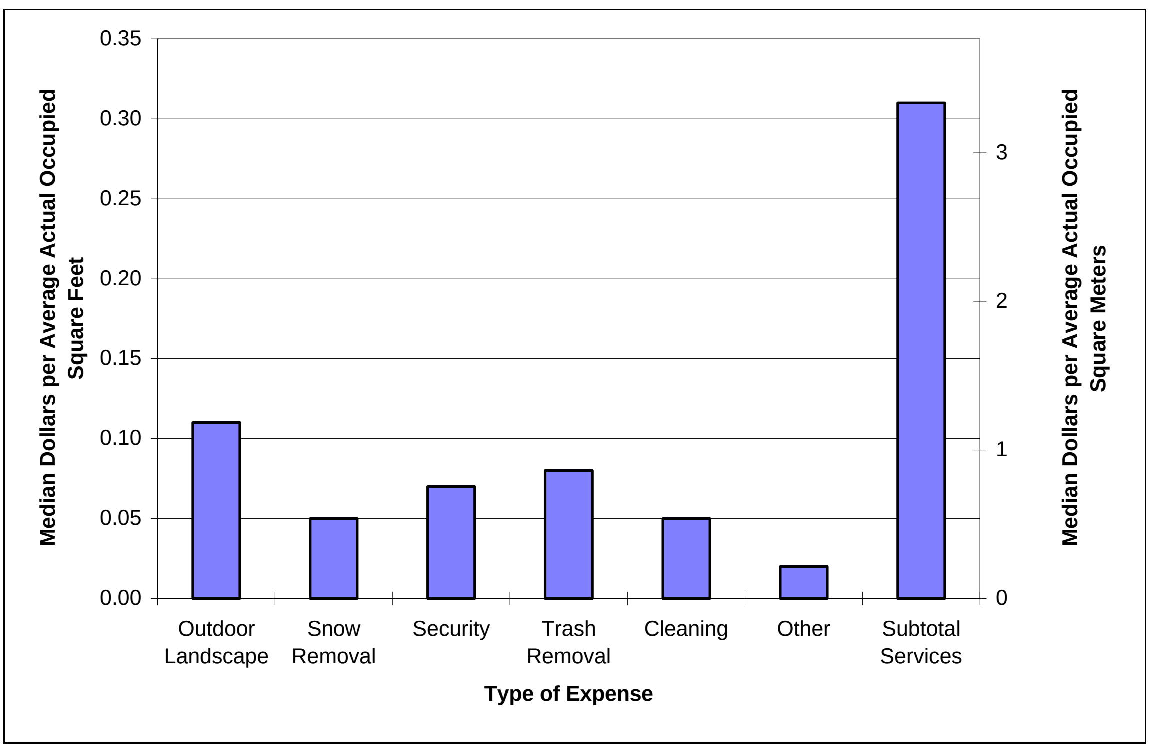


Figure 6-48. Median Maintenance and Repair Costs for Open Shopping Centers

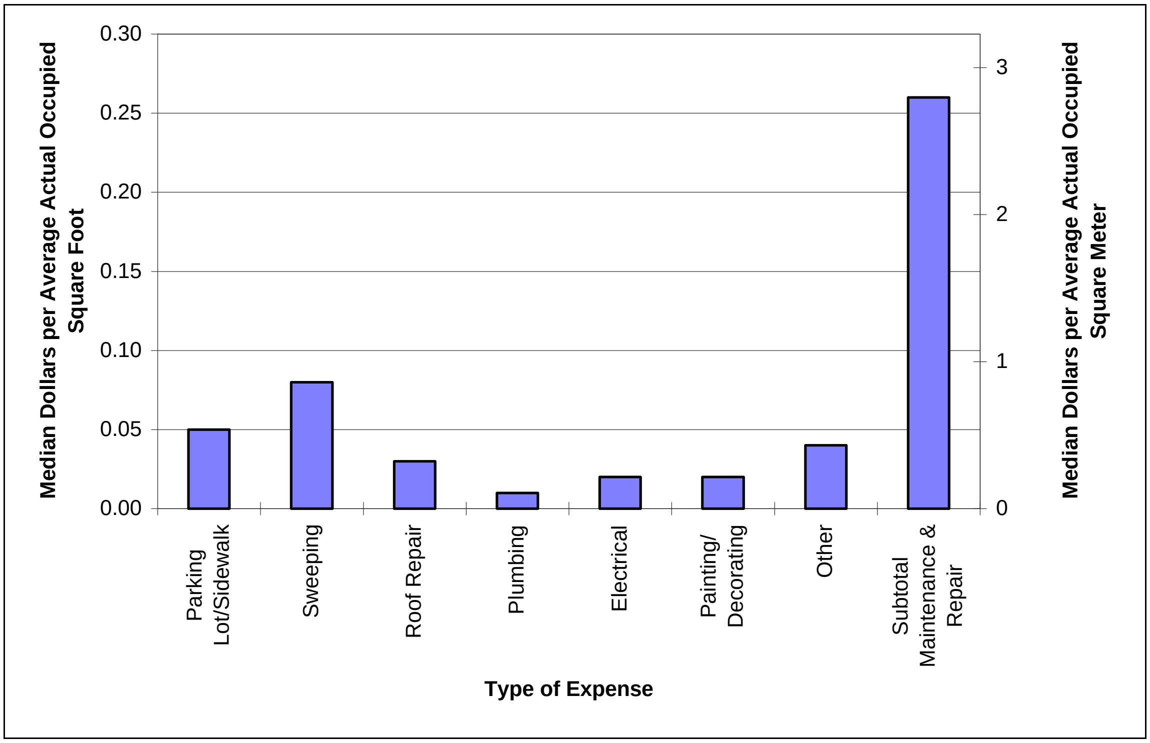
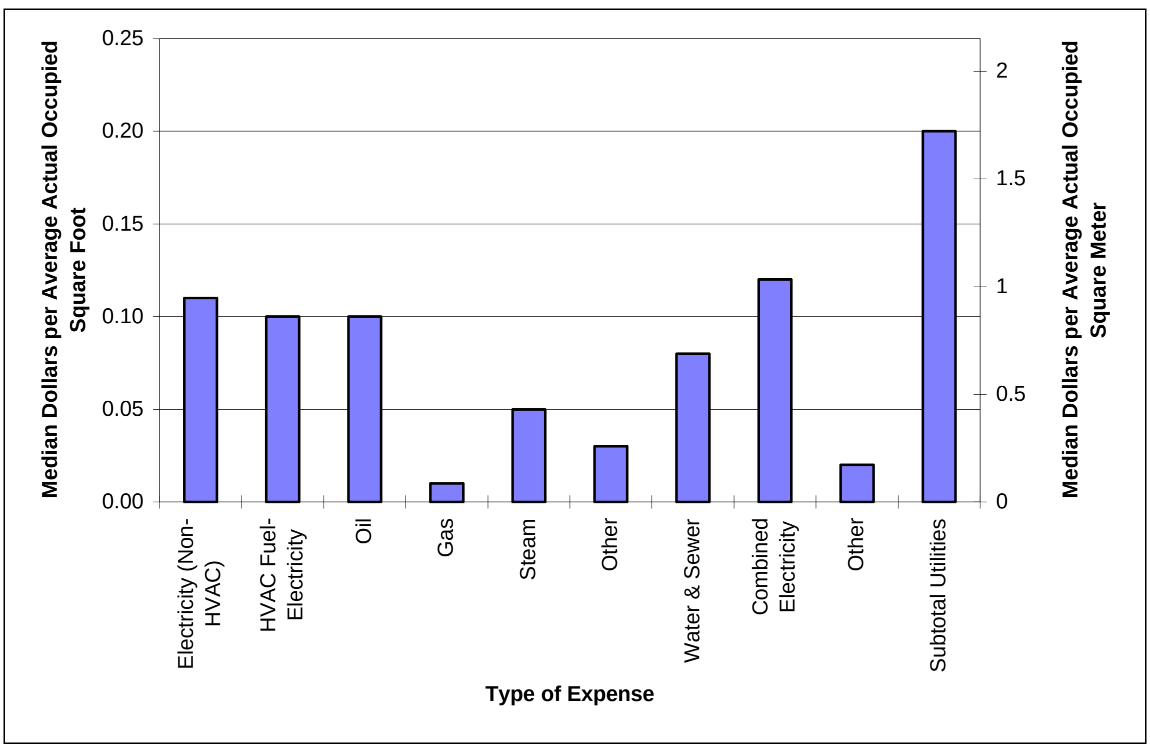


Figure 6-49. Median Utilities Costs for Open Shopping Centers



6.2.5 Energy Conservation in the Commercial/Institutional Sector

This section addresses some general issues concerning energy conservation in the commercial/institutional sector. The section examines how prevalent certain conservation features and equipment are in the sector. It then outlines some water conservation recommendations provided by FEMP. The EIA report *Commercial Buildings Characteristics 1992* has been used to generate all of the figures presented in this section, which show aggregated information for all buildings in the sector. It is important to recognize that portions of a building's total floorspace may be served by more than one type of conservation feature and/or equipment. Consequently, the sum total across all conservation features or equipment (e.g. heating equipment) may exceed 100 percent of the total floorspace.

Figure 6-50 shows the percentage of total floorspace in the commercial/institutional sector using a variety of different types of heating equipment, grouped by building size category. Reference to the figure indicates that a larger proportion of floorspace in smaller buildings was heated by furnaces compared with larger buildings. In addition, there was a high level of usage of individual space heaters across all building sizes (around 30-45 percent of total floorspace, depending upon building size). The figure also indicates that district heat was only used extensively in buildings with floorspaces greater than 18,581 square meters (200,000 square feet).

Figure 6-50. Building Heating Equipment by Building Size Category

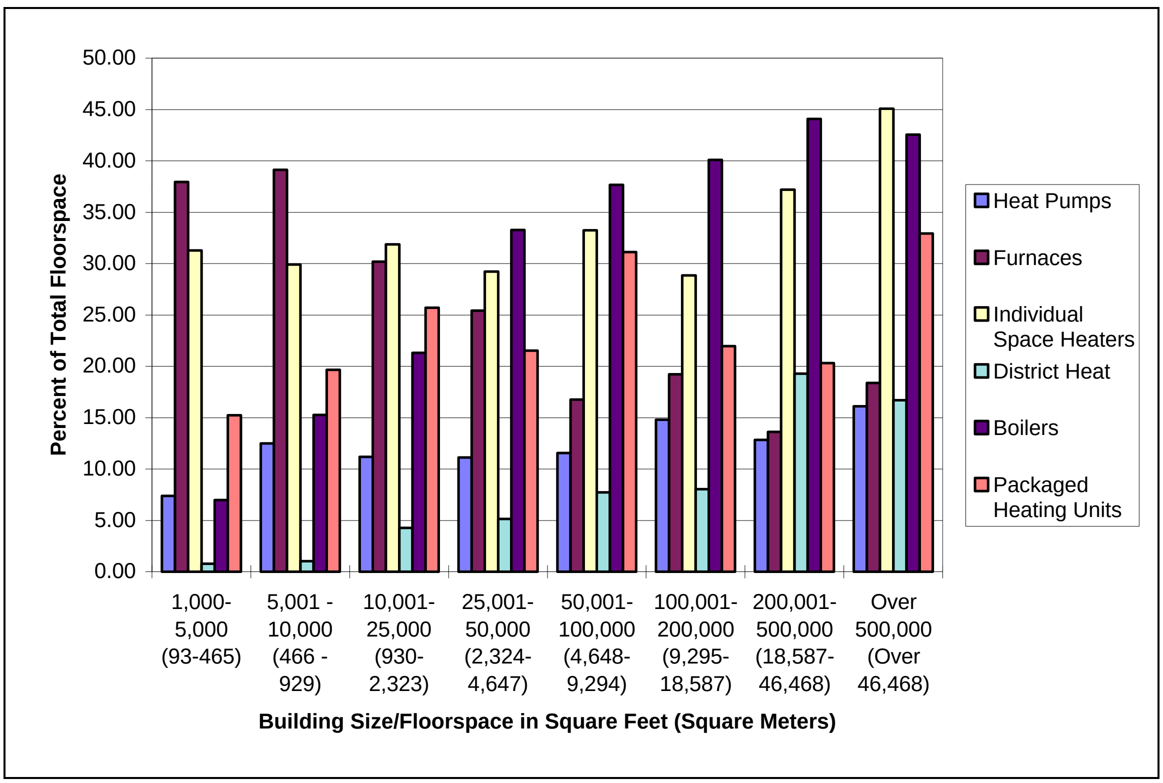


Figure 6-51 shows similar information to that in Figure 6-50, but for cooling equipment. Reference to the figure indicates that use of central residential type air conditioning units decreased as building size increased, but that the number of individual air conditioning units was higher in larger buildings. There was also a high usage of central chiller units in larger buildings, and a relatively high use of packaged air conditioning units irrespective of building size.

Figure 6-51. Building Cooling Equipment by Building Size Category

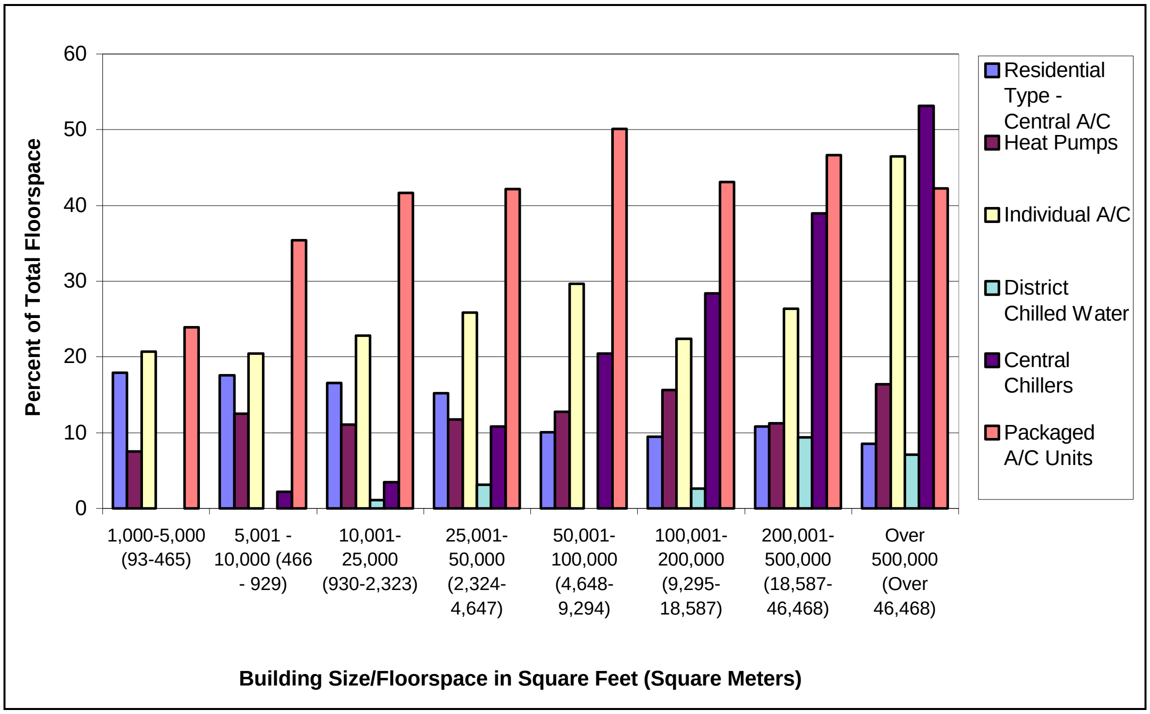


Figure 6-52 also shows similar information to Figure 6-50, but for lighting equipment. As expected, the dominant forms of lighting were standard incandescent (around 50 percent of total floorspace) and standard fluorescent (approximately 90 percent of total floorspace). There was increased usage of compact fluorescent and high intensity discharge (HID) lighting in larger buildings, but this was more noticeable for HID lighting.

Figure 6-53 shows the percentage of total floorspace where some form of energy demand-side management (DSM) system was used. The figure shows building shell, HVAC, lighting, and other DSM categories. The figure indicates that there was a relatively consistent increase in DSM program participation as building size increased, with the highest participation levels in lighting DSM programs. However, it should be noted that even where DSM programs were used most extensively, this still only accounted for around one quarter of total floorspace in the sector.

Figure 6-52. Building Lighting Equipment by Building Size Category

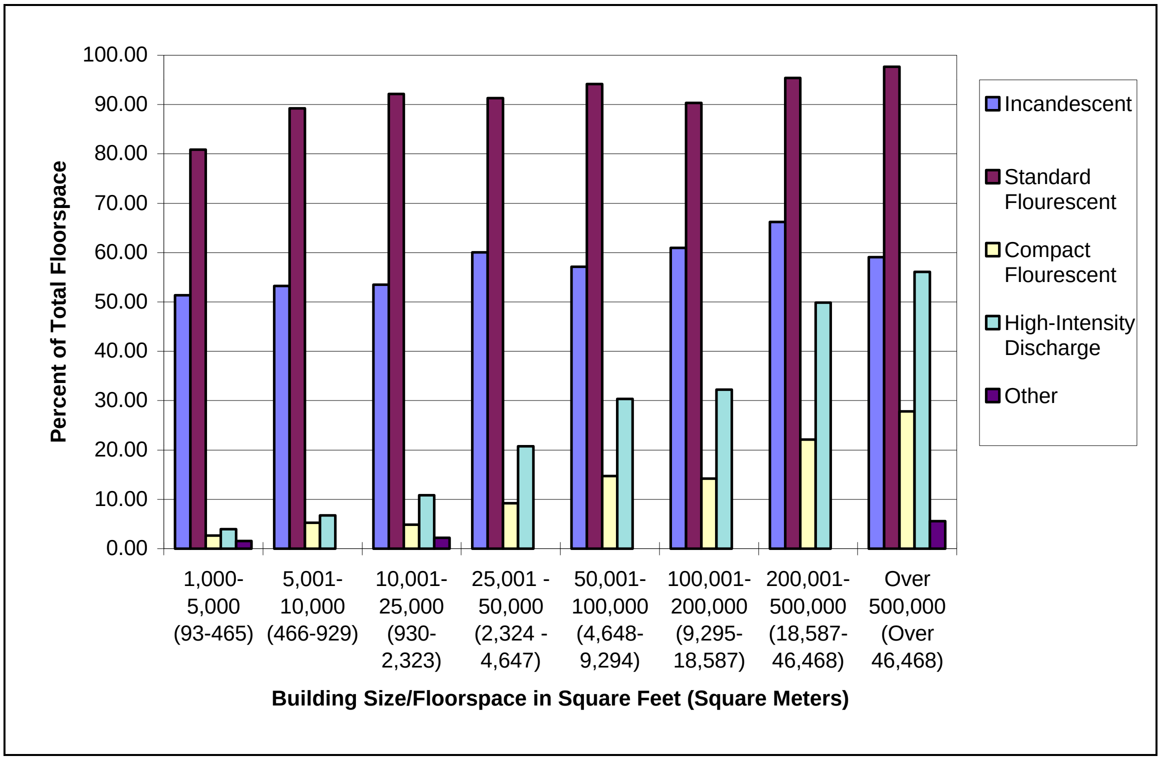


Figure 6-53. Building Demand-Side Management Programs by Building Size Category

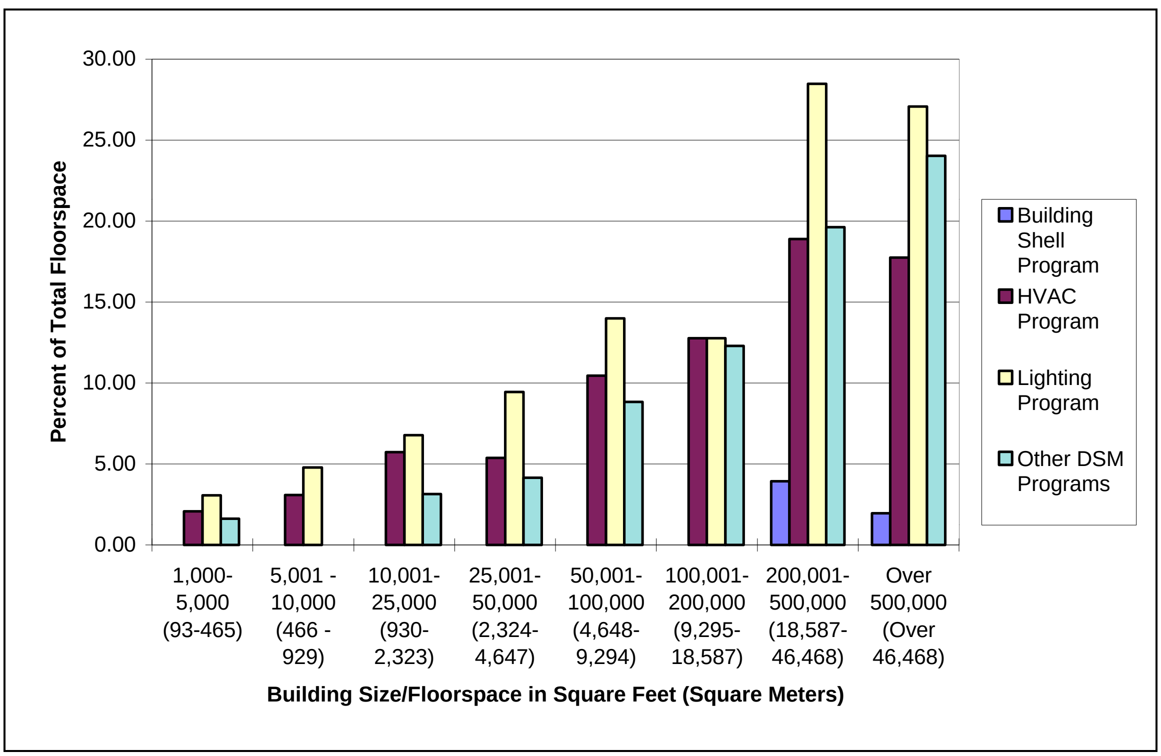
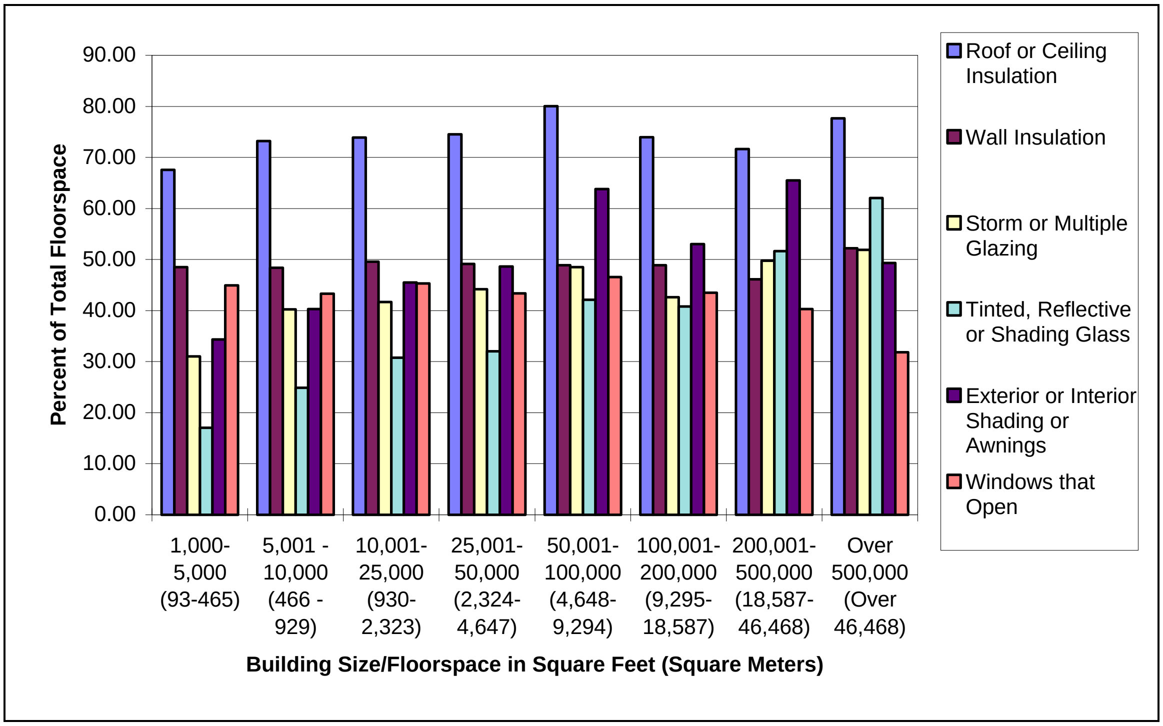


Figure 6-54 shows how the extent of a variety of building shell conservation features varied depending upon building size category. Reference to the figure indicates that use of insulation materials was relatively uniform irrespective of building size. In contrast, multiple glazing and tinted/reflective glazing was more prevalent in larger buildings, which tended to have a smaller percentage of opening windows for a given floor area than smaller buildings.

Figure 6-54. Building Shell Conservation Features by Building Size Category



The trends shown in Figures 6-50 through 6-53 are also reflected in Figure 6-55 and 6-56. In larger buildings, HVAC and lighting conservation features were more prevalent. In particular, there appeared to be an increased use of economizer cycles and time clocks in larger buildings.

Table 6-14 Part A and Part B shows selected water conservation recommendations for a variety of sanitary fixtures common in the commercial/institutional sector in gallons and liters respectively. The table shows both recommended and 'best available' ratings for these fixtures. For further information relating to water and energy conservation information sources, refer to Section 6.1 of this document.

Figure 6-55. Building HVAC Conservation Features by Building Size Category

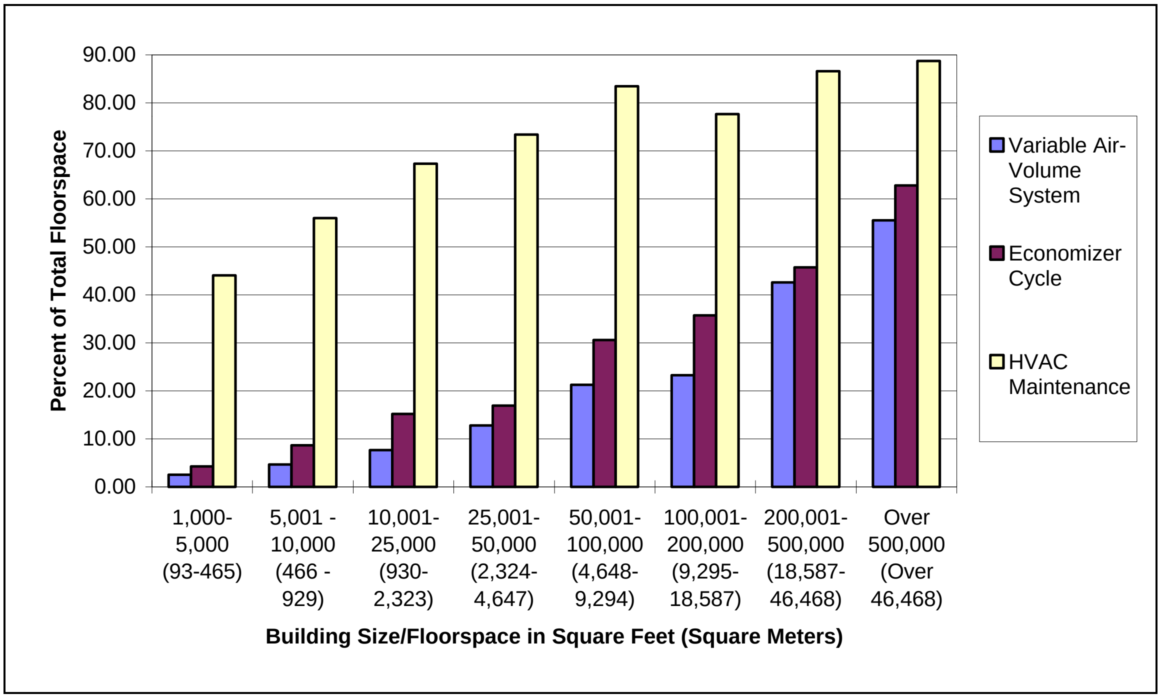


Figure 6-56. Building Lighting Conservation Features by Building Size Category

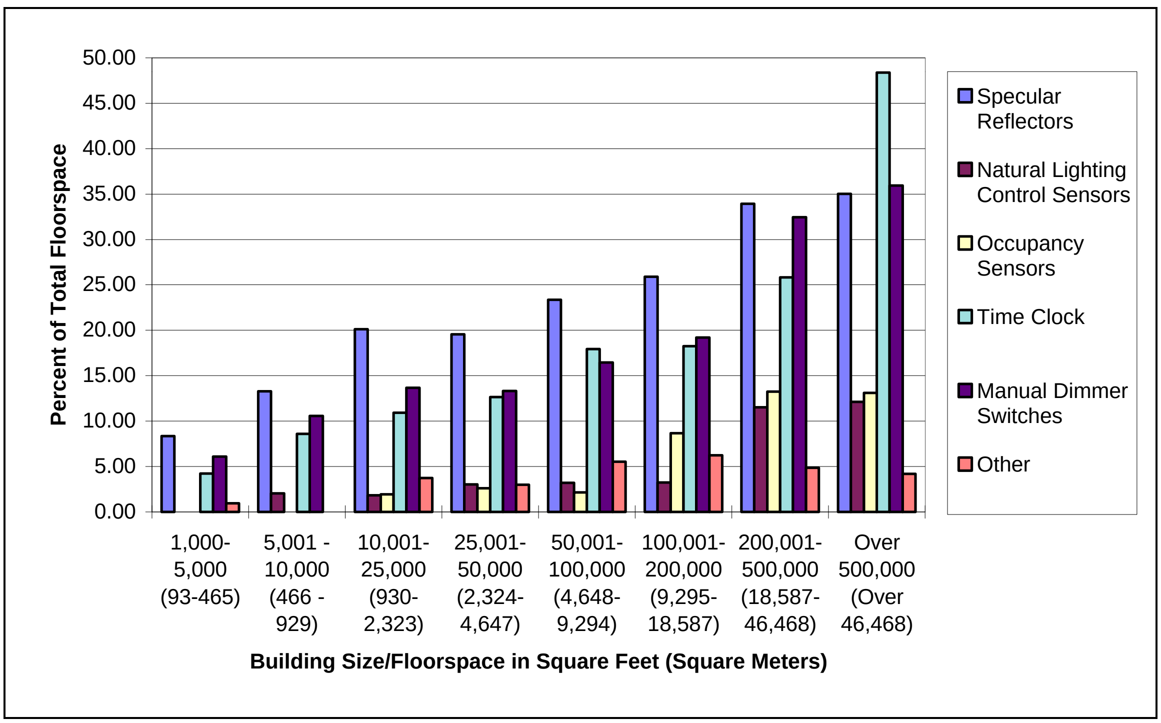


Table 6-14. Water Conservation Recommendations for Selected Fixtures

Part A: Gallon Ratings

Product Type	Recommended Flow Rate	Best Available	Notes
Faucet	2.0 gallons per minute or less	1.5 gallons per minute	Self closing Faucet- 0.25 gallons/ minute
Shower- head	2.2 gallons per minute or less	1.5 gallons per minute	-
Toilet	1.6 gallons per flush or less	1.5 gallons per flush	-
Urinal	1.0 gallons per flush	-	Required by Energy Policy Act October, 1992.

Part B: Liter Ratings

Product Type	Recommended Flow Rate	Best Available	Notes
Faucet	7.6 liters per minute or less	5.7 liters per minute	Self closing Faucet- 0.95 liters/ minute
Shower- head	8.3 liters per minute or less	5.7 liters per minute	-
Toilet	6.1 liters per flush or less	5.7 liters per flush	-
Urinal	3.8 liters per flush	-	Required by Energy Policy Act October, 1992.

6.3 Summary of Baseline Measures for the Commercial/Institutional Sector

This section summarizes the baseline measures for the commercial/institutional sector which are presented in Sections 6.2.1, 6.2.2, 6.2.3, and 6.2.4 of this document. They are presented in Table 6-15 below.

Table 6-15 shows general information relating to the commercial/institutional sector, as well as key operations, maintenance, and energy (OM&E) baseline data for the whole sector. It then shows selected OM&E baseline data for private commercial office buildings, college and university facilities, and open shopping centers. The 'General Information' section describes the *total expenditures for new construction, maintenance and repair, and improvements* in the commercial/institutional sector in 1994. The section also provides overall information about the *size of the commercial/institutional sector*, and the relative proportions of buildings and floorspace in the mercantile and service, office, and education categories, which are the largest components of the commercial/institutional sector[23].

The 'Operations Overview' section provides baseline measures for *water, environmental, life safety, janitorial, indirect, and security costs* for all buildings in the commercial/institutional sector, expressed as a range of mean costs per rentable square foot/square meter. The 'Maintenance Overview' section provides information on *maintenance and repair costs,* both on an aggregated basis for all commercial/institutional facilities, and as a range of mean costs per unit area for all types of building. The 'Energy Overview' section provides information on *total energy expenditures*, at an aggregated level for all buildings, and then for office, service, and education facilities. The baselines focus upon energy expenditures by *primary fuel source*, and present both total dollar values, as well as 'expenditures per unit area' values. *Water costs* per rentable floor area are also included here, as part of the utilities category. These can be compared with the total sector expenditures for water presented in the "Operations Overview" section of the table.

The "Private Office Buildings" section provides OM&E costs per rentable square meter/square foot *for cleaning, roads/grounds/security, maintenance and repair, and utilities*, as well as a metric for *all operating expenses combined*.

The "Education Facilities" section provides OM&E costs per gross square meter/square foot *for custodial maintenance (cleaning), grounds maintenance, solid waste disposal, hazardous waste disposal, security, building maintenance and repair, and utilities.*

The "Shopping Centers" section provides OM&E costs per Annual Average Occupied (AAO) square meter(square foot) for open shopping centers. The baselines are grouped under the sub-headings 'Services/Operations', 'Maintenance and Repair', and 'Utilities'. 'Services/Operations' includes *outdoor landscaping, snow removal, security, trash removal, and cleaning costs.* 'Maintenance and Repair' includes *sweeping of parking lots/sidewalks, parking lot/sidewalk repair, building roof repair, plumbing, electrical, painting and decorating, and other maintenance and repair costs.* 'Utilities' includes the costs for the most prevalent *fuel sources,* as well as *water and sewer costs.*

It should be noted that the information presented in Table 6-15 represents only the most general of the data presented in Chapters 3 and 6 of this document.

Summary of Abbreviations Used in Table 6-15

VIP	Value of New Construction Put in Place
USGS	United States Geological Survey
EIA	Energy Information Administration
IFMA	International Facility Management Association
BOMA	Building Owners and Managers Association
APPA	Association of Higher Education Facilities Officers
IREM	Institute of Real Estate Management

[23] This excludes warehousing and storage, which is considered as part of the industrial sector in this document.

Table 6-15. Summary of Baseline Measures: Commercial/Institutional Sector

DESCRIPTION	YEAR	BASELINE	SOURCE[24]
GENERAL INFORMATION			
Value of New Construction Put in Place	1994	$128,116 million (constant 1992 dollars)	Census VIP Data
Total Maintenance and Repair Expenditures	1994	$26,348 million (constant 1992 dollars)	Census Data
Total Expenditures for Improvements	1994	$71,764 million (constant 1992 dollars)	Census Data
Total Number of Commercial Buildings/Total Floorspace	1992	4,806,000 buildings 6,308 million square meters (67,876 million square feet)	EIA
Mercantile and Service Buildings as % of Total Buildings/Total Floorspace	1992	26% of Total Buildings 18% of Total Floorspace	EIA
Office Buildings as Percent of Total Buildings/Total Floorspace	1992	16% of Total Buildings 18% of Total Floorspace	EIA
Education Buildings as Percent of Total Buildings/Total Floorspace	1992	6% of Total Buildings 12% Total Floorspace	EIA
OPERATIONS - OVERVIEW			
Total Expenditures for Water - All Buildings	1990	$9.08 billion	USGS
Range of Costs for Environmental Services (Trash etc.) - All Buildings	1993	$1.08-$6.78 per rentable square meter ($0.10-$0.63 per rentable square foot)	IFMA
Range of Costs for Life Safety Services - All Buildings	1993	$0.54-$5.27 per rentable square meter ($0.05-$0.49 per rentable square foot)	IFMA
Range of Costs for Janitorial Services - All Buildings	1993	$8.72-$20.12 per rentable square meter ($0.81-$1.87 per rentable square foot)	IFMA
Range of Costs for Indirect Services (Grounds etc.) - All Buildings	1993	$2.26-$6.67 per rentable square meter ($0.21-$0.62 per rentable square foot)	IFMA
Range of Costs for Security Services - All Buildings	1993	$4.73-$15.06 per rentable square meter ($0.44-$1.40 per rentable square foot)	IFMA

[24] See accompanying text for description of abbreviations used in this table.

Table 6-15. Summary of Baseline Measures: Commercial/Institutional Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
MAINTENANCE - OVERVIEW			
Purchased Repair Services for All Buildings and Structures	1992	$20,267 million	Census Data
Purchased Repair Services for All Machinery, Equipment, and Other	1992	$35,606 million	Census Data
Range of Costs for Maintenance and Repair Services - All Buildings	1993	$18.83-$41.86 per rentable square meter ($1.75-$3.89 per rentable square foot)	IFMA
ENERGY - OVERVIEW			
Total Fuel Expenditures - All Buildings	1992	$72,600 million	EIA
Total Electricity Costs - All Buildings	1992	$57,600 million	EIA
Total Natural Gas Costs - All Buildings	1992	$10,700 million	EIA
Total Fuel Oil Costs - All Buildings	1992	$1,400 million	EIA
Total District Heat Costs - All Buildings	1992	$2,900 million	EIA
Range of Costs for All Utilities (including water) - All Buildings	1993	$18.83-$40.35 per rentable square meter ($1.75-$3.75 per rentable square foot)	IFMA
Average Electricity Cost - All Buildings	1993	$24.45 per rentable square meter ($2.27 per rentable square foot)	IFMA
Average Water Cost - All Buildings	1993	$1.29 per rentable square meter ($0.12 per rentable square foot)	IFMA
Total Energy Expenditures- Office Buildings	1992	$18,125 million (25% of sector total)	EIA
Total Fuel Expenditures - Mercantile and Service Buildings	1992	$12,907 million (18% of sector total)	EIA
Total Fuel Expenditures - Education Buildings	1992	$7,389 million (10% of sector total)	EIA

Table 6-15. Summary of Baseline Measures: Commercial/Institutional Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
PRIVATE OFFICE BUILDINGS			
Average Cleaning Cost	1995	$11.73 per rentable square meter ($1.09 per rentable square foot)	BOMA
Average Roads/Grounds/Security Cost	1995	$5.49 per rentable square meter ($0.51 per rentable square foot)	BOMA
Average Administrative Cost	1995	$11.08 per rentable square meter ($1.03 per rentable square foot)	BOMA
Average Maintenance and Repair Cost	1995	$14.20 per rentable square meter ($1.32 per rentable square foot)	BOMA
Average Utilities Cost	1995	$19.58 per rentable square meter ($1.82 per rentable square foot)	BOMA
Average Total Annual Operating Cost	1995	$110.61 per rentable square meter ($10.28 per rentable square foot)	BOMA
EDUCATION FACILITIES			
Average Custodial (Cleaning) Cost	1993	$9.81 per square meter ($0.91 per square foot)	APPA
Average Grounds Cost	1993	$2.96 per square meter ($0.28 per square foot)	APPA
Average Solid Waste Disposal Cost	1993	$0.56 per square meter ($0.05 per square foot)	APPA
Average Hazardous Waste Disposal Cost	1993	$0.398 per square meter ($0.04 per square foot)	APPA
Average Security Cost	199	$3.81 per square meter ($0.354 per square foot)	APPA
Average Building Maintenance Cost	1993	$9.63 per square meter ($0.90 per square foot)	APPA
Average Electricity Cost	1993	$10.61 per square meter ($0.99 per square foot)	APPA
Average Gas Cost	1993	$3.54 per square meter ($0.33 per square foot)	APPA
Average Water and Sewer Cost	1993	$0.43 per square meter ($0.04 per square foot)	APPA

Table 6-15. Summary of Baseline Measures: Commercial/Institutional Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
SHOPPING CENTERS			
Open Shopping Centers			
Services/Operations			
Average Outdoor Landscaping Cost	1995	$1.18 per (AAO) square meter ($0.11/square foot)	IREM
Average Snow Removal Cost	1995	$0.54 per (AAO) square meter ($0.05/square foot)	IREM
Average Security Cost	1995	$0.75 per (AAO) square meter ($0.07/square foot)	IREM
Average Trash Removal Cost	1995	$0.86 per (AAO) square meter ($0.08/square foot)	IREM
Average Cleaning Cost	1995	$0.54 per (AAO) square meter ($0.05/square foot)	IREM
Average Other Cost	1995	$0.22 per (AAO) square meter ($0.02/square foot)	IREM
Maintenance and Repair			
Average Sweeping Cost	1995	$0.86 per (AAO) square meter ($0.08/square foot)	IREM
Average Parking Lot/Sidewalk Cost	1995	$0.54 per (AAO) square meter ($0.05/square foot)	IREM
Average Building Roof Cost	1995	$0.32 per (AAO) square meter ($0.03/square foot)	IREM
Average Plumbing Cost	1995	$0.11 per (AAO) square meter ($0.01/square foot)	IREM
Average Electrical Cost	1995	$0.22 per (AAO) square meter ($0.02/square foot)	IREM
Average Painting/Decorating Cost	1995	$0.22 per (AAO) square meter ($0.02/square foot)	IREM
Utilities			
Average Electricity Cost	1995	$1.18 per (AAO) square meter ($0.11/square foot)	IREM
Average Fuel Oil Cost	1995	$1.08 per (AAO) square meter ($0.10/square foot)	IREM
Average Gas Cost	1995	$0.11 per (AAO) square meter ($0.01/square foot)	IREM
Average Steam Cost	1995	$0.54 per (AAO) square meter ($0.05/square foot)	IREM
Average Water and Sewer Cost	1995	$0.86 per (AAO) square meter ($0.08/square foot)	IREM

7. OM&E Measures for the Industrial Sector

7.1 Key Considerations for the Industrial Sector

This section of the document addresses the issue of data sources, availability, and constraints in the industrial sector, and summarizes the key data sources which are used for developing the baseline measures. The section also provides an overview of the industrial sector.

7.1.1 Data Considerations: Sources, Availability, and Constraints

Preliminary data searches for the industrial sector focused upon organizations such as the Department of Commerce, Department of Energy, and the International Facility Management Association. These searches indicated that the majority of national level data is collected either by the US Bureau of the Census or the Energy Information Administration (EIA), a part of the US Department of Energy. This document focuses upon data from these sources for the development of baseline measures.

Data from the US Bureau of the Census

The US Bureau of the Census (USBC) carries out a number of surveys of the US industrial/manufacturing sector. Surveys/reports of particular interest are the **Census of Manufactures** and the **Annual Survey of Manufactures**.

The **Census of Manufactures** provides detailed information on selected characteristics of the manufacturing sector. The survey is carried out every five years; data are currently available from the 1992 Census. The **1992 Census of Manufactures** includes all establishments with one paid employee or more, primarily engaged in manufacturing. This includes approximately 380,000 establishments. The SIC Manual defines manufacturing as the mechanical or chemical transformation of substance or materials into new products. The assembly of component parts of products is also considered to be manufacturing. The **Census of Manufactures** covers 20 major industry groups with 2 digit SIC Codes 20-39 inclusive. The USBC provides two report series from the Census which are of particular interest. The first is the *General Summary Report*, which provides aggregated industry statistics in one report. These include information on establishment size, number of employees, selected operating costs, and so forth, up to the 4-digit SIC Code level of detail. A second series of reports, the *Industry Reports* comprises 83 separate, more detailed reports. The latter reports provide historical statistics for the industry, selected operating ratios, capital expenditures statistics, purchased services statistics, product statistics, and material statistics for six-digit SIC Codes. This level of detail will not be considered in this document.

The **Annual Survey of Manufactures** presents manufacturing establishments statistical data for years when the **Census of Manufactures** is not carried out. It is a less detailed sample survey of establishments with payroll. Data from the **1995 Annual Survey of**

Manufactures are available at present. Selected data from USBC are available through its Internet site (URL: http://www.census.gov), or via electronic or paper publications.

In this document, data from the USBC have been used to characterize the size and nature of the industrial sector, and to provide some information on operations and maintenance costs. Where specific data constraints have been found, these have been identified in the text.

Data from the Energy Information Administration

The EIA carries out the **Manufacturing Energy Consumption Survey (MECS)**, which is a national sample survey that collects data on energy use in the manufacturing sector. The **MECS** sample size is typically around 20,000 establishments. The **MECS** is a triennial survey; selected data from the latest survey, conducted in 1994 have recently become available.

Data from EIA are available through its Internet site (URL: http://www.eia.doe.gov), or through paper or electronic publications, including the *EIA Energy InfoDisc Volume 2, No.1, 1997*, which provides energy data for all four industry sectors. Energy data provided by EIA are very detailed.

In this document, data from the EIA Report **Manufacturing Consumption of Energy 1991** have been used to develop energy cost and consumption baselines for the industrial sector. The highly detailed nature of the data means that there are no data constraints

Data from the International Facility Management Association

The International Facility Management Association (IFMA) is an association serving the facility management profession, which provides educational and technical services, carries out research, certifies facility management competency, and promotes the profession.

IFMA has carried out a number of benchmarking studies covering both the commercial/institutional and industrial sectors. *Research Report #13, Benchmarks II*, printed in 1994, is the result of a 1993 survey of IFMA members, principally in the service sector, which presents benchmarking data derived from 283 survey questionnaires. While the report has a relatively small sample size, it appears to be one of the few reports available which considers operations, maintenance, and energy costs across a significant part of the industrial sector in any level of detail. Data from IFMA are available through its Internet site (URL: http://www.ifma.org), or through paper or electronic publications.

In this document, data from the IFMA report *Benchmarks II* have been used to generate some general baselines for the industrial sector.

Data from Other Sources

A wide variety of other data sources were examined. A brief description of some of these sources is given below:

- The Office of Industrial Technologies (OIT), a part of the Department of Energy, provides information on selected industries, such as aluminum, chemicals, petroleum and steel, through its *Industries of the Future* strategy, which helps benchmark major manufacturing processes with a view to reducing energy consumption and environmental impacts. This information can be found on the OIT Internet site (URL: http://www.oit.doe.gov).
- The United States Geological Survey (USGS) provides data on water consumption by the commercial sector in the US. These data are available on the USGS Internet site (URL: http://www.usgs.gov). Data relevant to the industrial sector are included in this document.
- The National Association of Manufacturers 1995 report *"Pulsemark: benchmarks for US Productivity"* provides operational and financial measurements and best practices based upon a survey of plant-level operations. Information is available on its Internet site (URL: http://www.nam.org).
- The Office of Naval Research's *Best Manufacturing Practices Program* promotes best manufacturing practices through its *Best Manufacturing Practices Center of Excellence*. Information is available at its Internet site (URL: http://www.bmpcoe.org)

7.1.2 Overview of the Industrial Sector

The overview of the industrial sector presented in this section expands on the overview presented in Chapter 3 of this document. This section examines the total size of the US industrial sector (i.e. SIC Codes 20-39), and a number of key industry characteristics. It also explains some of the difficulties associated with differentiating between process and non-process activities in the development of baseline measures.

Data from the US Bureau of Economic Analysis show that since 1987, all manufacturing industries have accounted for approximately 18 percent of GDP in the US in real terms. Data from the 1987 and 1992 **Census of Manufactures** show that the total number of establishments with payroll has risen slightly from 369,000 in 1987 to 382,000 in 1992. Of these 382,000 establishments, 81,000 were multi-unit companies and 301,000 were single unit companies. Figure 7-1 shows the size distribution of all industrial establishments combined in terms of employee size-classification. Reference to the figure shows that approximately two-thirds of these establishments have less than twenty employees, while only about three percent have greater than 250 employees. This size structure did not change significantly between 1987 and 1992. Single unit companies had a much lower average number of employees (18) compared with multi-unit companies (162). For multi-unit companies, production workers comprised over 60 percent of total employees.

Figure 7-1. Size of Establishments: 1992

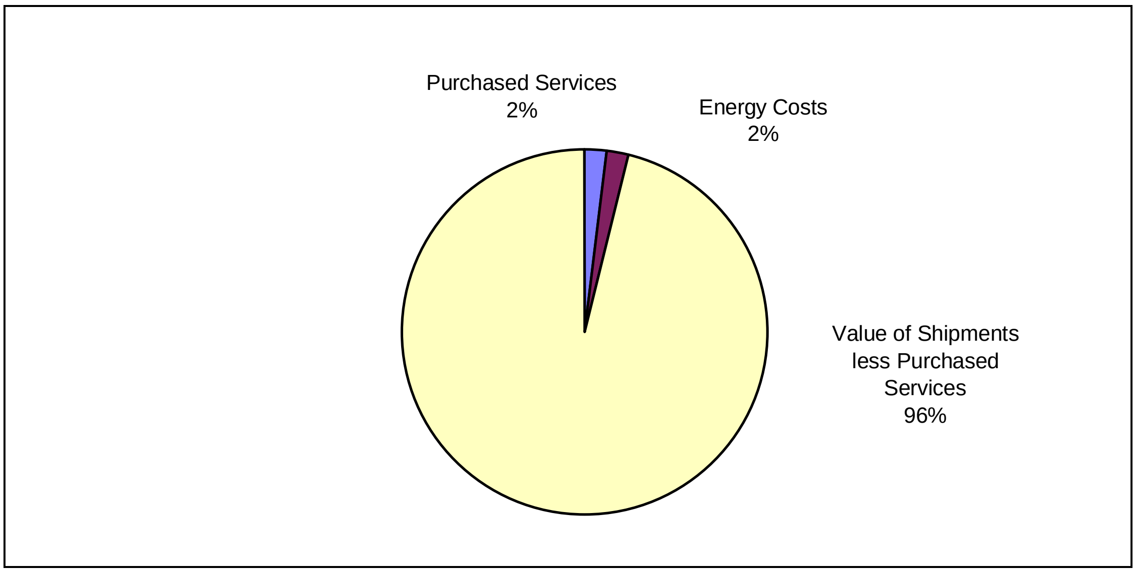
The **Census of Manufactures** provides a large amount of data relevant to value of shipments, value added by manufacturer, payroll costs, materials costs and so forth. These items are all considered to be predominantly process-oriented, and are therefore considered to be beyond the scope of this document. This document focuses upon the non-process costs associated with industrial facilities, which principally include facility management components, such as building maintenance and repair, facility HVAC and lighting costs, and so on. However, it is useful to compare process and non-process cost components, in order to assess the relative importance of introducing process related energy conservation features, compared with building HVAC conservation features, for example.

Figure 7-2 compares "value of shipments less purchased services" costs ($2,945 billion) with purchased services costs, and energy costs for all industrial facilities in 1992. The figure is based upon sample estimates provided in **the Census of Manufactures General Summary,** reference **MS92-S-1**. Purchased services comprise the cost of purchased services for the following:

- Buildings and other structures
- Machinery
- Communications
- Legal services
- Accounting and book-keeping
- Advertising
- Software and other data processing
- Refuse removal, including hazardous waste

These components include both process and non-process elements. Energy costs comprise total expenditures for purchased energy sources (i.e. both process and non-process). The figure shows that purchased services and energy costs are very small in comparison with value of shipments costs (approximately 50 percent of value of shipments costs are raw materials costs, approximately 20 percent are total payroll costs). Thus, although reductions in process and non-process operations, maintenance, and energy costs are important, the leverage upon total industry costs is comparatively small in comparison with the impact of productivity improvements or process efficiencies upon industry output.

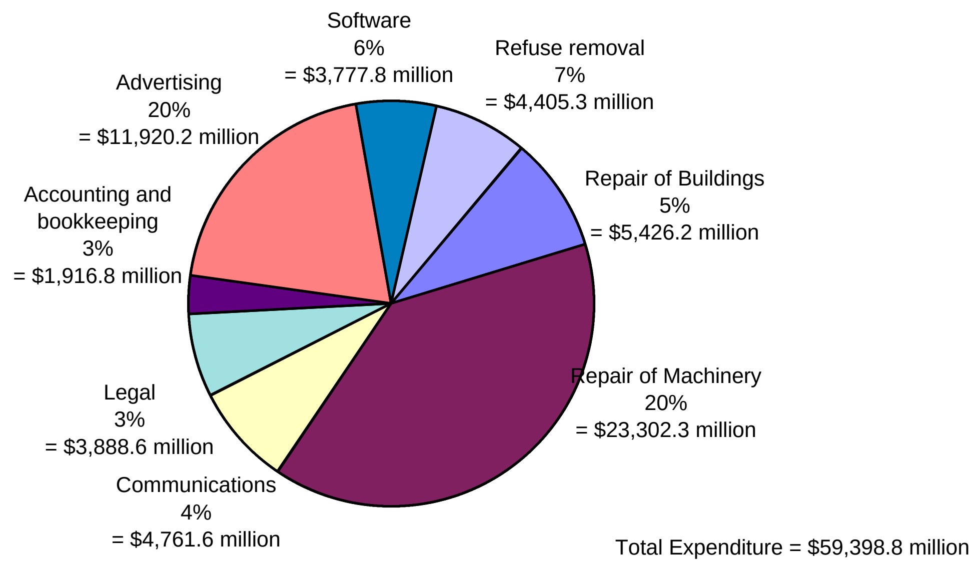
Figure 7-2. Comparison of Value of Shipments, Purchased Services and Energy Costs, All Industries: 1992



The figure for total new capital expenditures in the **1992 Census of Manufactures** ($104 billion) can be compared with *Value Put in Place (VIP)* data presented in Chapter 3 of this document. VIP data suggest that new construction and additions, alterations, and reconstruction, amounted to about $53 billion in 1992. Thus it would appear that about 50% of new capital expenditures in the industrial sector are directly attributable to the construction industry.

In Figure 7-3, purchased services cost components are shown in more detail for all manufacturers. The figure shows that refuse removal accounts for seven percent of purchased services, while repair of building accounts for a further nine percent ($5.4 billion). These operations components will be examined in more detail in Section 7-2 of this document.

Figure 7-3. Costs for Selected Purchased Services (All Manufactures): 1992



The totals for repair of buildings ($5.4 billion), and repair of machinery ($23.3 billion), can be compared with the total value of construction-related maintenance and repair calculated in Chapter 3 of this document ($21.3 billion). This comparison suggests that over half of the machinery maintenance and repair reported in the **1992 Census of Manufactures** is attributable to the construction sector.

7.2 Baseline Measures for the Industrial Sector

This section of the document describes in detail the baseline measures for operations, maintenance, and energy costs in the industrial sector. Section 7.2.1 and Section 7.2.2 make use of Census and EIA data to develop baselines for the whole sector, and for individual SIC Codes, while Section 7.2.3 presents data from IFMA, which examine selected unit operating costs for particular types of industrial buildings.

7.2.1 Baseline Measures for Operations and Maintenance Costs

As has already been mentioned in Chapter 4 of this document, operations and maintenance baselines, exclude process-related cost elements wherever possible. Thus, for example, the repair of machinery is excluded from maintenance and repair when possible, as it is likely to include a large component of maintenance and repair which relates directly to process use or end-product production.

Figure 7-3 showed the relative costs of a variety of purchased services for all SIC Codes combined. In Figures 7-4 through 7-7, the total cost of purchased services, and the cost per employee for the repair of buildings, and for refuse removal, are shown for each major 2-digit SIC Code (for a description of the two-digit SIC Codes see Appendix F).

The SIC Codes for the industrial sector are as follows:

- SIC 20 - Food and Kindred Products
- SIC 21 - Tobacco Products
- SIC 22 - Textile Mill Products
- SIC 23 - Apparel and Other Textile Products
- SIC 24 - Lumber and Wood Products
- SIC 25 - Furniture and Fixtures
- SIC 26 - Paper and Allied Products
- SIC 27 - Printing and Publishing
- SIC 28 - Chemicals and Allied Products
- SIC 29 - Petroleum and Coal Products
- SIC 30 - Rubber and Miscellaneous Plastic Products
- SIC 31 - Leather and Leather Products
- SIC 32 - Stone Clay and Glass Products
- SIC 33 - Primary Metal Products
- SIC 34 - Fabricated Metal Products
- SIC 35 - Industrial Machinery and Equipment
- SIC 36 - Electronic and Other Equipment
- SIC 37 - Transportation Equipment
- SIC 38 - Instruments and Related Products
- SIC 39 - Miscellaneous Manufacturing Industries

Reference to Figure 7-4 shows that there is a wide variation in total building repair costs depending upon SIC Code. In Figure 7-5 costs are normalized on a "per employee" basis to account for the relative size of each SIC sector, and allow more meaningful comparison. The very high repair costs in the petroleum refining/petroleum products industry (SIC 29) are apparent. This is probably due to the high degree of complexity of refinery structures and relatively small size of the workforce. This is also reflected in Figure 7-7, which shows refuse removal and hazardous waste removal per employee. It is worth noting that SIC 29 has one of the 'highest value added per employee' ratios in the industrial sector (the only industry with a higher ratio is SIC 21- tobacco products).

Table 7-1 Part A and Part B, which is based upon data from USGS, shows industrial water consumption in 1990, by water resources region. Reference to the table indicates that public supply deliveries accounted for about 21 percent of total water deliveries to the industrial sector in 1990. The remainder was provided primarily by self supplied surface water withdrawals. Total consumptive use was 3330 million gallons per day (12,604 million liters per day) which was approximately 14 percent of total water deliveries. Since 1980, water consumption in the industrial sector has risen by approximately 30 percent.

Figure 7-4. Total Cost of Purchased Services for the Repair of Buildings by SIC Code: 1992

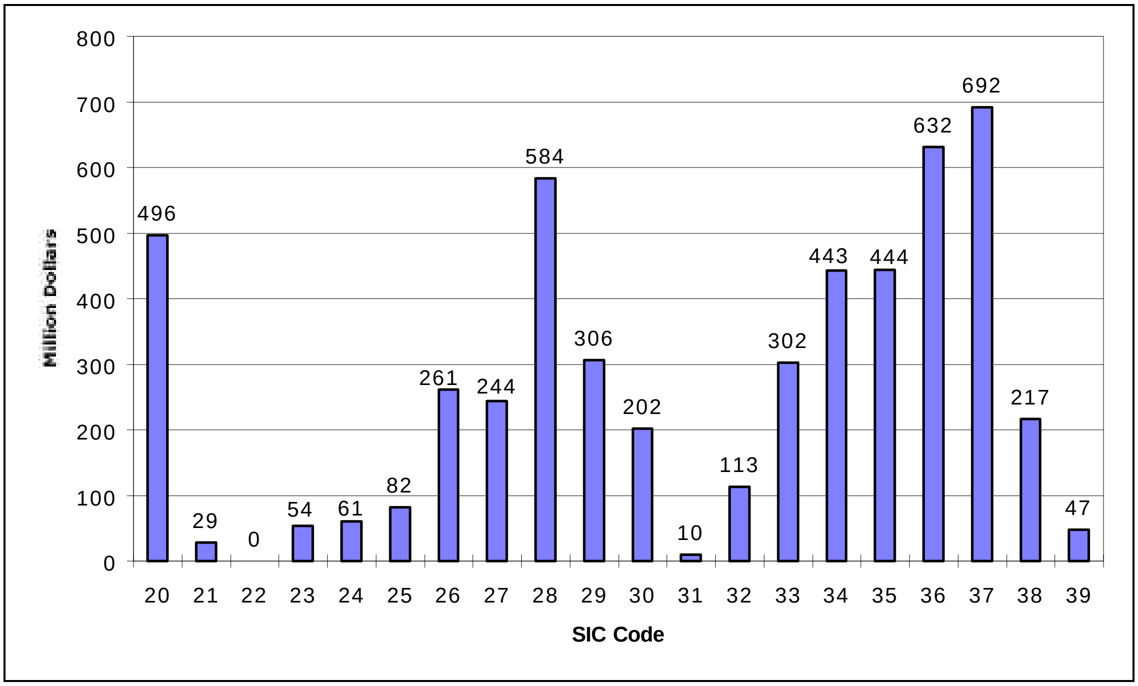


Figure 7-5. Cost of Purchased Services per Employee for the Repair of Buildings by SIC Code: 1992

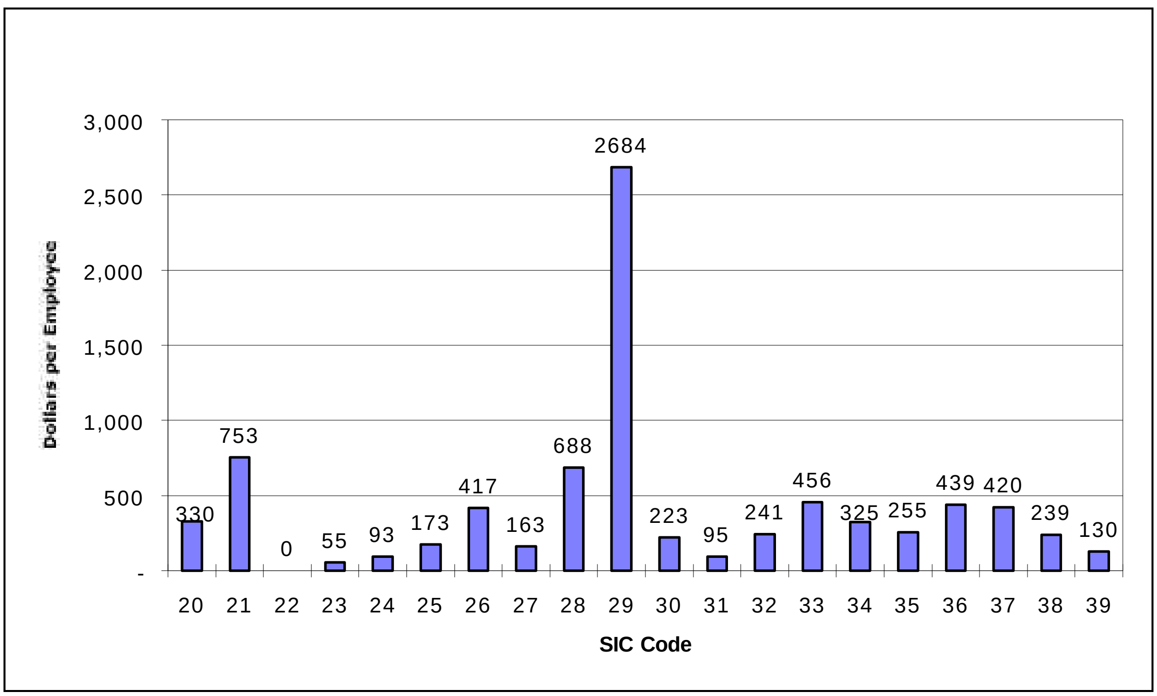


Figure 7-6. Total Cost of Refuse Removal, Including Hazardous Waste, by SIC Code: 1992

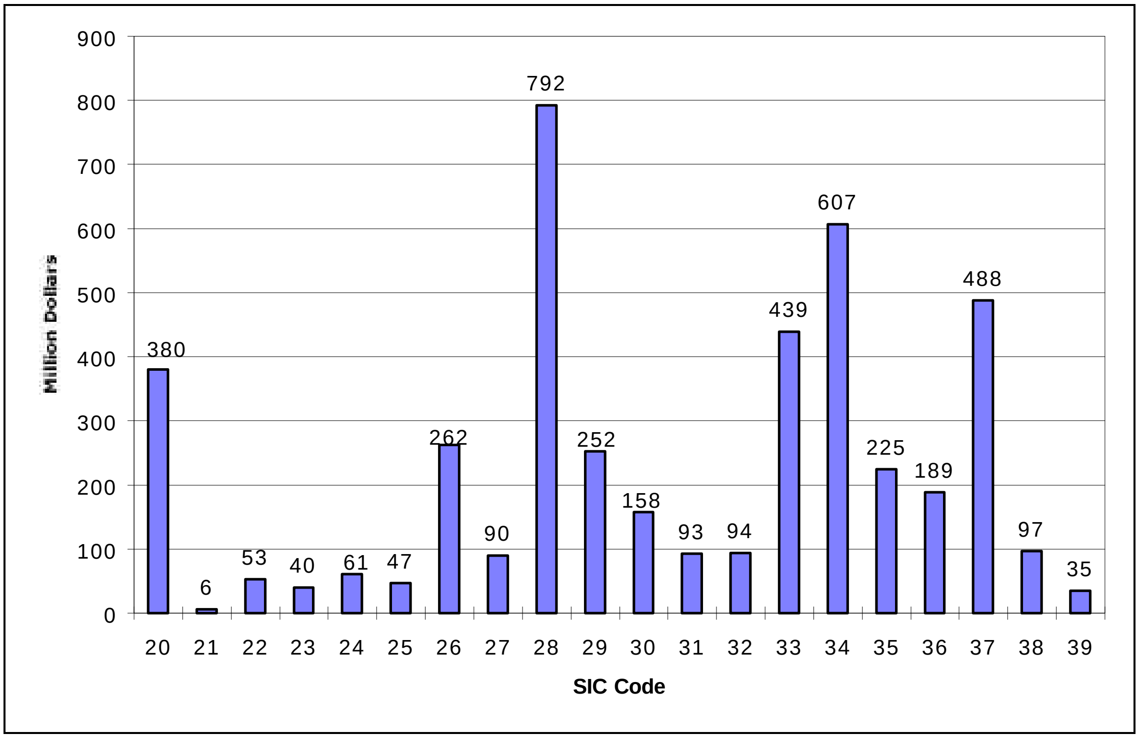


Figure 7-7. Cost of Refuse Removal per Employee, Including Hazardous Waste, by SIC Code: 1992

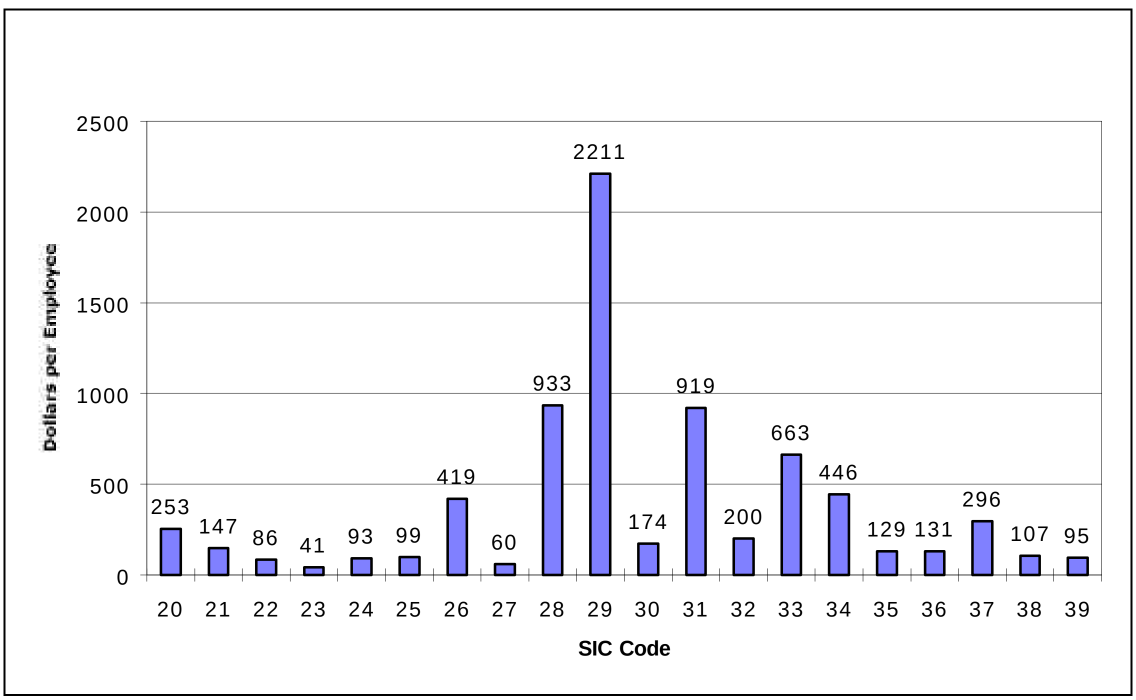


Table 7-1. Industrial Water Use: 1990

Part A: Million Gallons Per Day

	Self Supplied Withdrawals									Total Use		
Region	Ground Water		Surface Water		Total			Reclaimed Waste Water	Public Supply Deliveries	Withdrawals and Deliveries	Consumptive Use	
	Fresh	Saline	Fresh	Saline	Fresh	Saline	Total		Fresh	Fresh	Fresh	Saline
New England	96	0	382	68	479	68	547	0	219	698	71	14
Mid-Atlantic	361	0.2	1,370	1,470	1,730	1,470	3,200	63	672	2,400	256	85
South Atlantic-Gulf	896	0	1,920	94	2,810	94	2,910	0.5	855	3,670	470	2.9
Great Lakes	235	3.7	3,950	0	4,190	3.7	4,190	0	852	5,040	458	0.4
Ohio	532	0	1,840	0	2,370	0	2,370	0	615	2,990	297	0
Tennessee	23	0	1,170	0	1,190	0	1,190	0	94	1,290	163	0
Upper Mississippi	349	0	618	0	967	0	967	0	467	1,430	214	0
Lower Mississippi	501	0.6	2,120	67	2,620	67	2,690	0	70	2,690	286	0.4
Souris-Red-Rainy	1.3	0	47	0	49	0	49	0	3.4	52	9.5	0
Missouri Basin	114	0	57	0	171	0	171	0	112	282	87	0
Arkansas-White-Red	67	0	301	0	368	0	368	1.9	257	625	113	0
Texas-Gulf	141	1.1	600	1,460	741	1,460	2,200	20	143	884	359	803
Rio Grande	11	0	1	0	12	0	12	0.5	19	31	16	0
Upper Colorado	2.9	0	2.5	0	5.4	0	5.4	0	4.4	9.7	4.7	0
Lower Colorado	49	0	124	0	174	0	174	2.3	80	254	227	0
Great Basin	77	2.3	29	0	106	2.3	108	0	21	127	55	1
Pacific Northwest	336	0	691	36	1,030	36	1,060	1.6	175	1,200	125	4.8
California	126	0	4.8	25	130	25	156	0.8	495	625	102	0.3
Alaska	5.2	0	106	0	111	0	111	0	18	129	13	0
Hawaii	20	0.6	23	0	43	0.6	44	0	7.5	51	2.2	0
Caribbean	11	1.2	0	50	11	51	62	0	12	23	6.5	1
Total	3,950	9.7	15,400	3,260	19,300	3,270	22,600	90	5,190	24,500	3,330	913

Part B. Million Liters Per Day

	Self Supplied Withdrawals									Total Use		
Region	Ground Water		Surface Water		Total			Reclaimed Waste Water	Public Supply Deliveries	Withdrawals and Deliveries	Consumptive Use	
	Fresh	Saline	Fresh	Saline	Fresh	Saline	Total		Fresh	Fresh	Fresh	Saline
New England	363	0	1,446	257	1,813	257	2,070	0	829	2,642	269	53
Mid-Atlantic	1,366	1	5,185	5,564	6,548	5,564	12,112	238	2,544	9,084	969	322
South Atlantic-Gulf	3,391	0	7,267	356	10,636	356	11,014	2	3,236	13,891	1,779	11
Great Lakes	889	14	14,951	0	15,859	14	15,859	0	3,225	19,076	1,734	2
Ohio	2,014	0	6,964	0	8,970	0	8,970	0	2,328	11,317	1,124	0
Tennessee	87	0	4,428	0	4,504	0	4,504	0	356	4,883	617	0
Upper Mississippi	1,321	0	2,339	0	3,660	0	3,660	0	1,768	5,413	810	0
Lower Mississippi	1,896	2	8,024	254	9,917	254	10,182	0	265	10,182	1,083	2
Souris-Red-Rainy	5	0	178	0	185	0	185	0	13	197	36	0
Missouri Basin	431	0	216	0	647	0	647	0	424	1,067	329	0
Arkansas-White-Red	254	0	1,139	0	1,393	0	1,393	7	973	2,366	428	0
Texas-Gulf	534	4	2,271	5,526	2,805	5,526	8,327	76	541	3,346	1,359	3,039
Rio Grande	42	0	4	0	45	0	45	2	72	117	61	0
Upper Colorado	11	0	9	0	20	0	20	0	17	37	18	0
Lower Colorado	185	0	469	0	659	0	659	9	303	961	859	0
Great Basin	291	9	110	0	401	9	409	0	79	481	208	4
Pacific Northwest	1,272	0	2,615	136	3,899	136	4,012	6	662	4,542	473	18
California	477	0	18	95	492	95	590	3	1,874	2,366	386	1
Alaska	20	0	401	0	420	0	420	0	68	488	49	0
Hawaii	76	2	87	0	163	2	167	0	28	193	8	0
Caribbean	42	5	0	189	42	193	235	0	45	87	25	4
Total	14,951	37	58,289	12,339	73,051	12,377	85,541	341	19,644	92,733	12,604	3,456

7.2.2 Baseline Measures for Energy Costs

Data from the EIA **1991 MECS** have been used to generate Figures 7-8 through 7-21 in this section. Figure 7-8 through 7-12 examine total energy consumption and expenditures in the industrial sector. Figures 7-13 through 7-21 examine energy end-use in the sector, and focus upon non-process related energy use for the three primary non-process categories, which are facility HVAC, facility lighting, and facility support.

Primary energy consumption is defined as all energy consumed by end users, excluding electricity, but including the energy consumed at electric utilities to generate electricity (i.e., it accounts for any electricity generation and transmission losses). It includes all energy produced off site, all energy produced on-site from non-energy sources (e.g., hydrogen), net electricity, net steam, and net hot water (these are the sum of purchases, transfers in, and onsite production from renewables, minus the quantities sold/transferred off-site), but excludes all energy sources produced onsite as a result of use of another source (e.g. coal coke produced at steel works). The total primary consumption of energy for all purposes in the US industrial sector in 1991 was 21.4 quadrillion kilojoules (20.3

quadrillion Btu), which compares with 21.2 quadrillion kilojoules (20.1 quadrillion Btu) in 1988, and 18.5 quadrillion kilojoules (17.5 quadrillion Btu) in 1985. Figure 7-8 shows the different fuel types which made up this total in 1991. This total primary energy consumption comprised 2.64 quadrillion kilojoules (2.5 quadrillion Btu) of electricity delivered to the manufacturing site, 11.1 quadrillion kilojoules (10.5 quadrillion Btu) of natural gas, coal, fuel oil, and other major energy sources (with 7.9 quadrillion kilojoules (7.5 quadrillion Btu) of this amount being used to produce heat and power on-site, and 3.17 quadrillion kilojoules (3.0 quadrillion Btu) being used for non-fuel purposes), 1.48 quadrillion kilojoules (1.4 quadrillion Btu) of off-site waste, byproducts and other materials (0.53 quadrillion kilojoules/0.5 quadrillion Btu used for non-fuel purposes) and 3.27 quadrillion kilojoules (3.1 quadrillion Btu) of onsite-produced energy for heat, power, and electricity.

Figure 7-8. Total Primary Energy Consumption by Type of Fuel: 1991

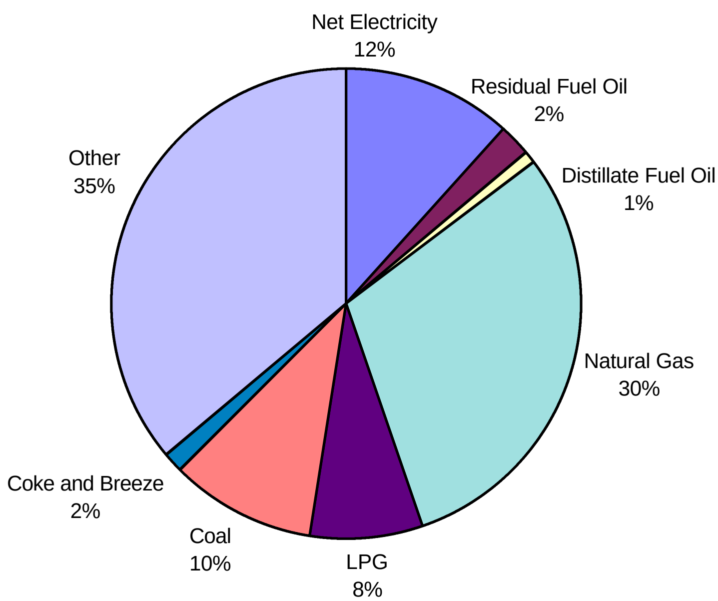
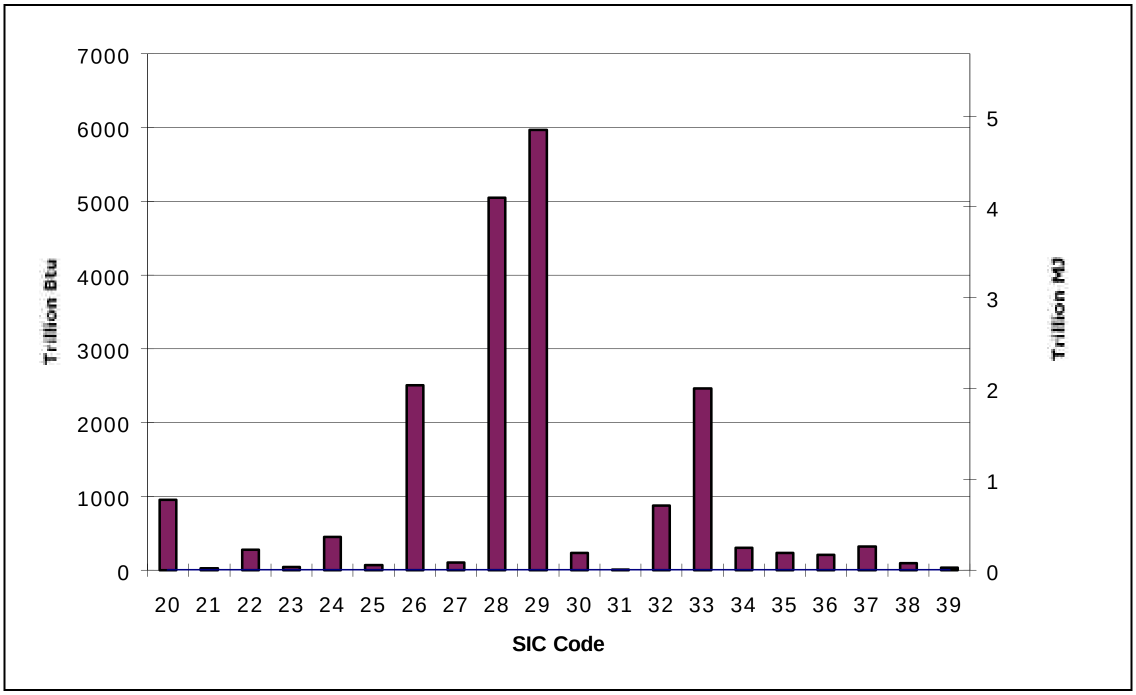


Figure 7- 9 shows how total primary energy consumption is distributed by SIC Code for SIC Codes 20-39. The source data are shown in Table 7-2. Reference to the figure shows that the two largest consumers of energy in 1991 were the petroleum and coal (SIC Code 29), and chemicals and allied products (SIC Code 28) major industry groups. Six industry groups accounted for 88 percent of primary energy consumption. These were food and kindred products, paper and allied products, chemicals and allied products, petroleum and coal products, stone, clay and glass products, and primary metals. About

two-thirds of primary energy consumption was used to produce heat and power and to generate electricity, and about one-third was consumed as raw material input.

Figure 7-9. Total Primary Consumption of Energy for All Purposes in Trillion Btu/ Trillion MJ: 1991



Natural gas was the most heavily consumed energy source in 1991 (30 percent of primary energy consumption). The chemicals sector accounted for 36 percent of all natural gas consumption. Net electricity was the second most heavily used source for primary energy consumption (12 percent), but taking into account site generation, accounted for 29 percent of site energy consumption. Four industry groups consumed 54 percent of primary energy consumption. These were food and kindred products, paper and allied products, chemicals and allied products, and primary metals. Of these, primary metals was the largest consumer. Other energy sources included net steam and other energy used as fuel or raw material input. Petroleum refinery products such as asphalt road oil and solvents accounted for 40 percent of these other energy sources (see **MECS** for rationale for the inclusion of these items).

Figure 7-10 shows the total expenditures for purchased energy sources by SIC Code in 1991. The highest expenditures occurred in the chemical and primary metal industries, which have net electricity usage over twice those of any other industries. The paper and food industries were the third and fourth largest consumers of net electricity respectively, and this is also reflected in their total primary energy consumption expenditures.

Table 7-2. Total Primary Energy Consumption for All Purposes by Fuel Type and Industry Group: 1991

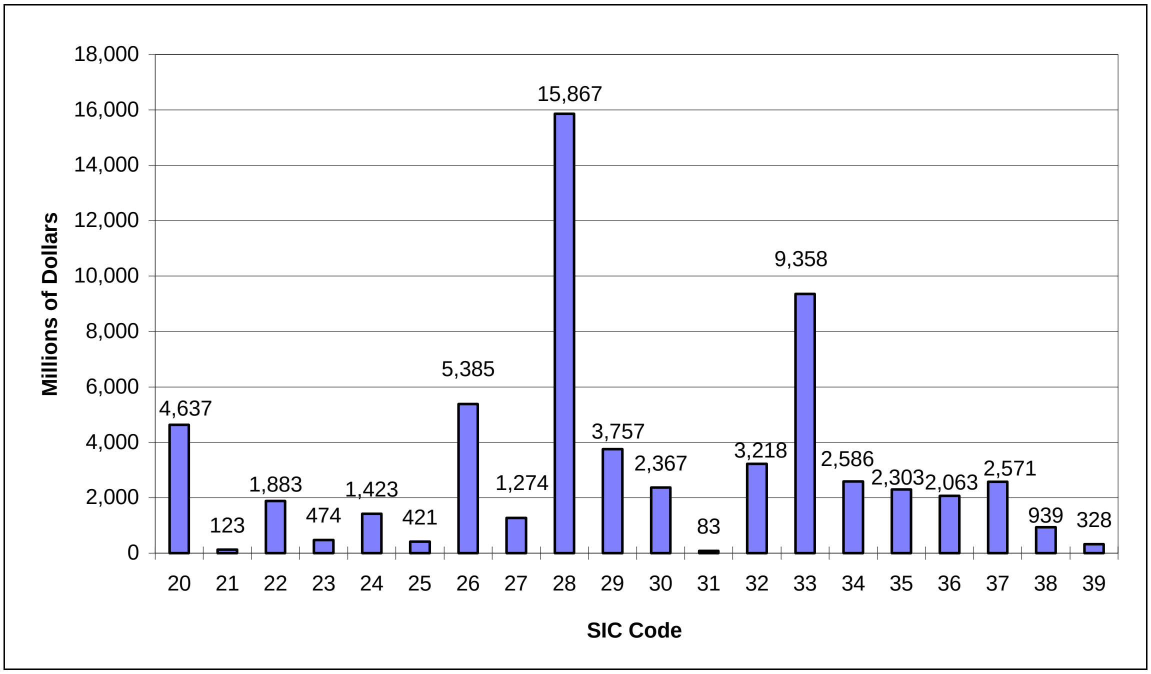
Part A: Trillion Btu

SIC Code	Total	Net Electricity	Residual Fuel Oil	Distillate Fuel Oil	Natural Gas	LPG	Coal	Coke and Breeze	Other
20	956	169	27	17	0	5	154	0	0
21	24	3	1	0	4	0	15	0	0
22	274	101	12	6	108	2	31	0	13
23	44	19	0	1	19	1	2	0	1
24	451	61	2	16	41	4	2		325
25	68	17	1	1	19	1	4	0	26
26	2,506	201	156	9	65	296	0	0	0
27	108	53	0	2	48	1	0	0	4
28	5,051	440	0	14	2,227	0	0	10	526
29	5,967	105	65	21	838	0	0	0	4,864
30	238	116	8	3	96	3	7	0	6
31	12	3	1	1	5	0	0	0	1
32	880	105	9	20	381	0	293	0	0
33	2,467	499	0	11	708	0	853	278	72
34	307	102	3	6	175	4	5	0	0
35	237	101	3	4	109	2	11	1	5
36	212	102	4	2	79	1	0	0	0
37	323	118	12	7	133	2	0	0	17
38	98	42	3	0	26	0	0	0	0
39	32	12	1	0	15	0	1	0	0
All Industries	20,257	2,370	454	146	6,095	1,574	2,006	308	7,304

Part B: Quadrillion Joules

SIC Code	Total	Net Electricity	Residual Fuel Oil	Distillate Fuel Oil	Natural Gas	LPG	Coal	Coke and Breeze	Other
20	1,009	178	28	18	0	5	162	0	0
21	25	3	1	0	4	0	16	0	0
22	289	107	13	6	114	2	33	0	14
23	46	20	0	1	20	1	2	0	1
24	476	64	2	17	43	4	2	0	343
25	72	18	1	1	20	1	4	0	27
26	2,644	212	165	9	69	312	0	0	0
27	114	56	0	2	51	1	0	0	4
28	5,329	464	0	15	2,349	0	0	11	555
29	6,295	111	69	22	884	0	0	0	5,132
30	251	122	8	3	101	3	7	0	6
31	13	3	1	1	5	0	0	0	1
32	928	111	9	21	402	0	309	0	0
33	2,603	526	0	12	747	0	900	293	76
34	324	108	3	6	185	4	5	0	0
35	250	107	3	4	115	2	12	1	5
36	224	108	4	2	83	1	0	0	0
37	341	124	13	7	140	2	0	0	18
38	103	44	3	0	27	0	0	0	0
39	34	13	1	0	16	0	1	0	0
All Industries	21,371	2,500	479	154	6,430	1,661	2,116	325	7,706

Figure 7-10. Total Expenditures for Purchased Energy Sources by SIC Code: 1991



Reference to Figure 7-11, which shows primary energy consumption by size of establishment, indicates that the larger establishments, whilst far fewer in number, accounted for a higher proportion of primary energy consumption compared with smaller establishments. For example, establishments with over 1,000 employees accounted for less than 1 percent of total establishments in the industrial sector, but accounted for approximately 30 percent of total primary energy consumed by the industrial sector. Figure 7-12 shows primary energy consumption on a per-employee basis, by size of establishment. The figure also shows that energy consumption on a per employee basis is greater in larger establishments.

Figures 7-13 through 7-21 compare process and non-process energy inputs based upon inputs of power for heat, power, and electrical generation. This energy measure includes all energy sources used to produce heat and power, and to generate electricity whether produced off-site or on-site. It also includes net electricity, steam, or hot water, but excludes all energy sources used as raw material or for other non-fuel uses.

Figure 7-11. Total Primary Consumption of Energy by Size of Establishment: 1991

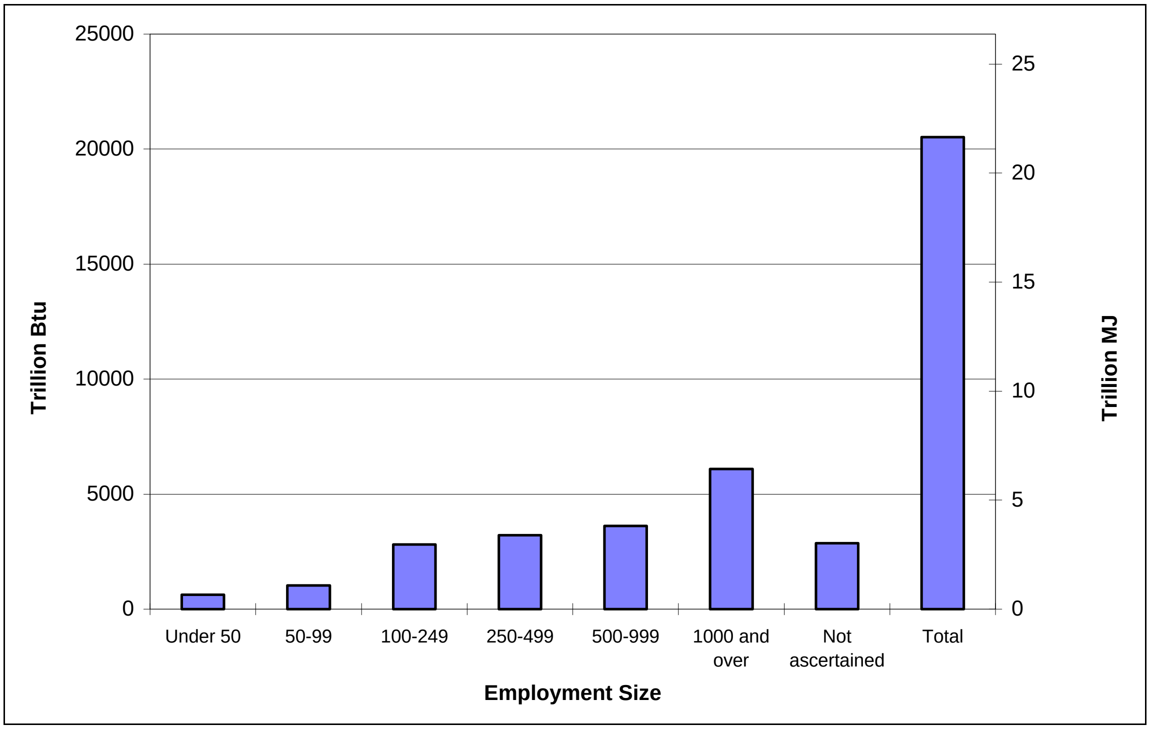
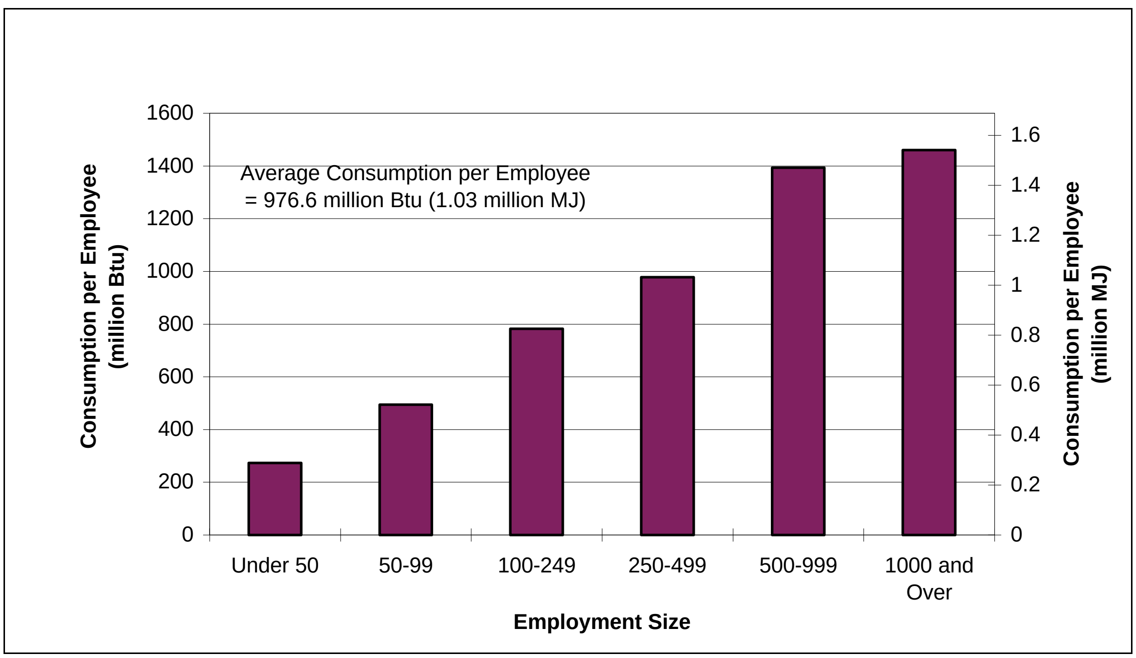


Figure 7-12. Consumption per Employee by Employment Size: 1991



Total input of energy for heat, power, and electrical generation in 1991 was 15.8 quadrillion kilojoules (15.0 quadrillion Btu), compared with 16.4 quadrillion kilojoules (15.5 quadrillion Btu) in 1988, and 14.3 quadrillion kilojoules (13.6 quadrillion Btu) in 1985. Figure 7-13 shows the total inputs of energy for heat, power, and electrical generation by fuel type and end use (i.e. total inputs for both process use, and non-process- see Chapter 4 of this document and **MECS** for full definitions). It should be noted that the figure does not show boiler fuel end-use, which accounted for approximately one third of end use consumption. Reference to the figure shows that natural gas was the dominant energy source followed by other fuels (blast furnace gases, waste gas, petroleum coke, pulping liquor, wood byproducts, and waste oil materials), and net electricity. Energy produced off-site made up 72 percent of total inputs; fuels produce on-site made up the remaining 28 percent. The major consumers of energy for heat, power, and electrical generation are the same as those for primary energy consumption. The major consumers of byproduct energy were the blast furnace, petroleum refining, and pulp and paper industries, which primarily used byproduct energy for boiler fuel.

Figure 7-14 compares total process and non-process uses of energy for electricity and natural gas (this document focuses upon these two fuel types, as byproduct energy is not associated with non-process uses such as facility HVAC, which are of interest here). Reference to this figure shows that natural gas non-process uses accounted for 13 percent of total gas and electricity consumption, and net electricity non-process uses accounted for 7 percent. Thus 80 percent of gas and net electricity consumption for heat power and electrical generation was attributed to process-related uses. When all energy sources are considered, direct non-process uses accounted for only 12 percent of total energy consumption for heat, power, and electrical generation in 1991.

Figure 7-15 and Figure 7-16 show how process and non-process inputs of net electricity and gas varied by end use. Reference to the two figures indicates that the largest non-process end-uses of net electricity and natural gas were facility HVAC, facility lighting and facility support (e.g., computing).

Figure 7-17 shows how non-process inputs of net electricity and natural gas are distributed between the three largest non-process categories defined in the **MECS** (i.e., facility HVAC, facility lighting, and facility support). Facility HVAC inputs accounted for about three percent of all process and non-process energy inputs, lighting accounted for about one percent, and facility support accounted for less than half of one percent. Thus non-process facility costs are very small compared with process costs.

Figure 7-13. Total Inputs of Energy for Heat Power and Electrical Generation by Type of Fuel and Primary End Use: 1991

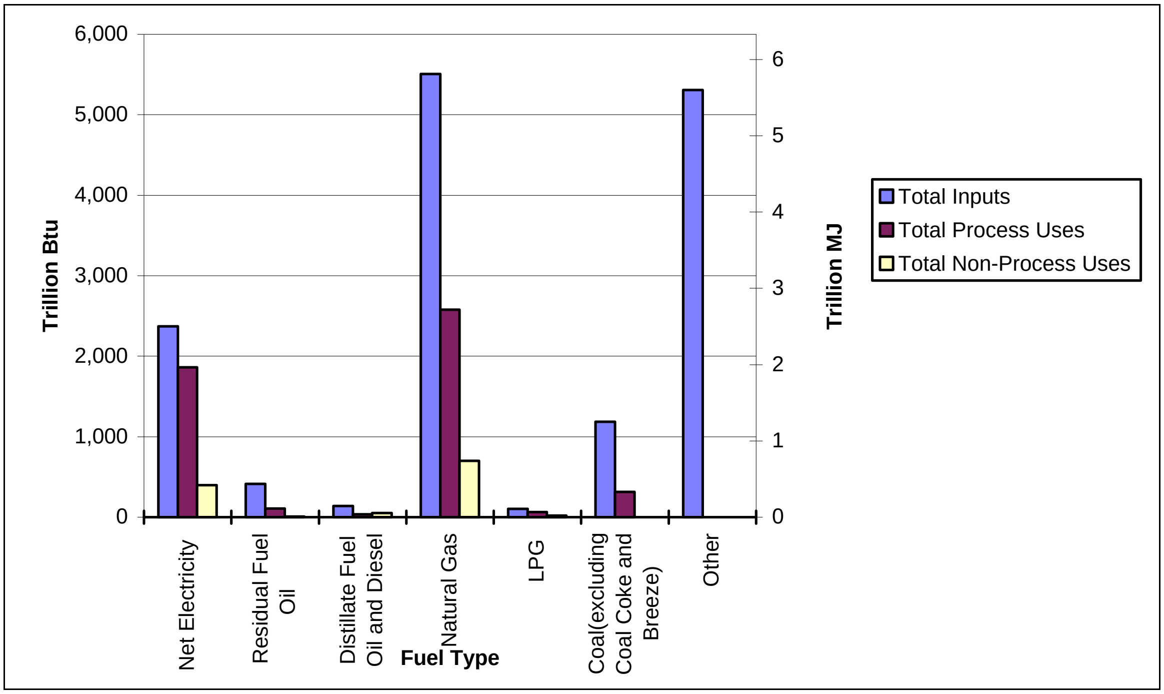


Figure 7-14. Comparison of Process and Non-Process Uses of Energy for Heat Power and Electrical Generation for Electricity and Natural Gas: 1991

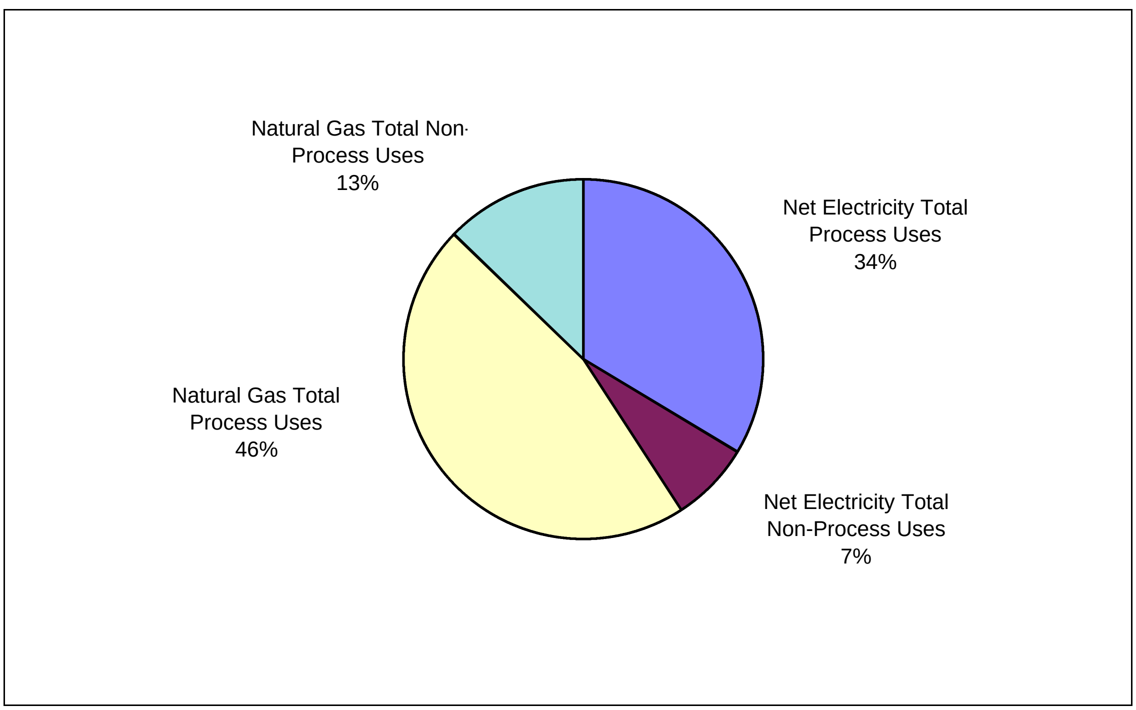
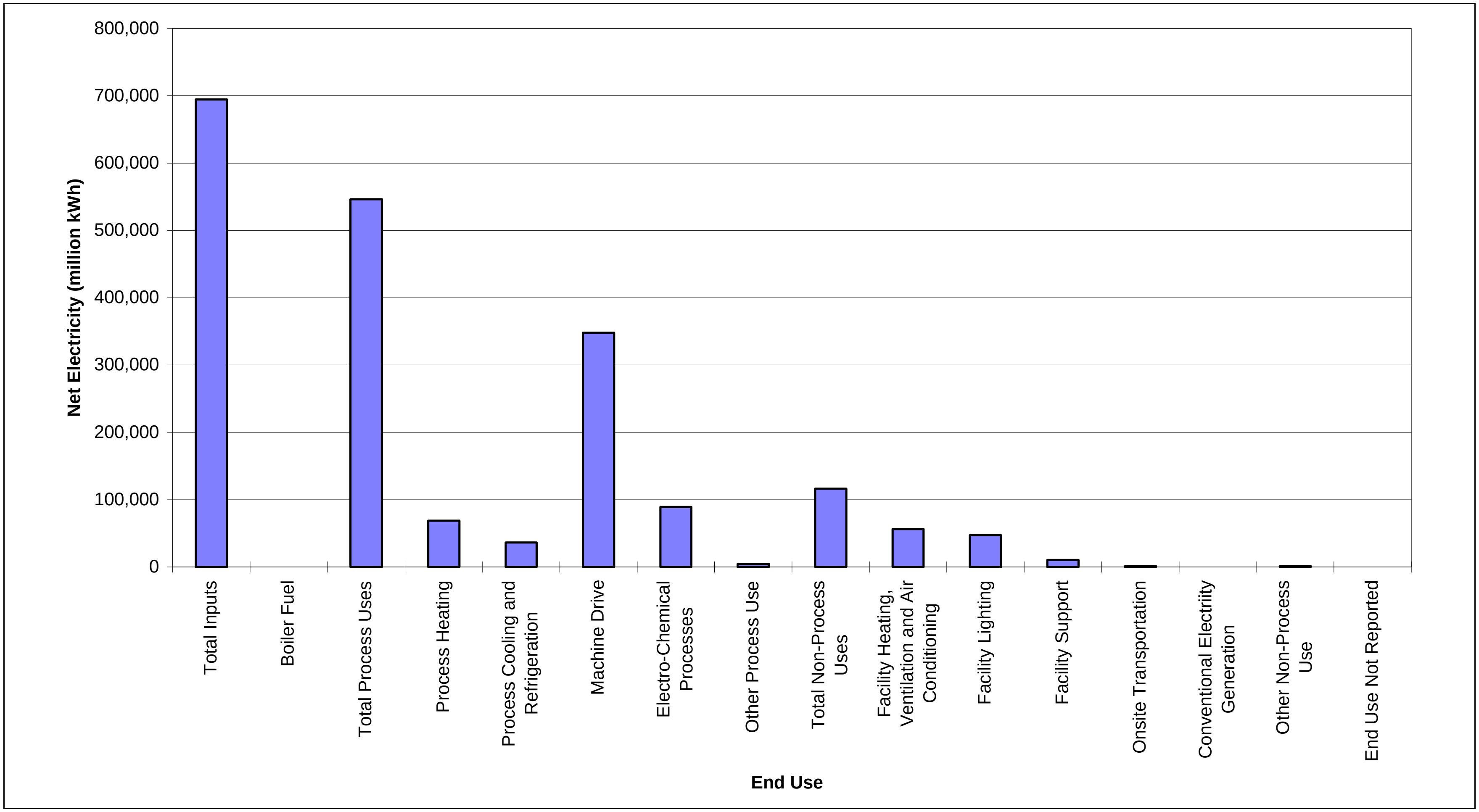


Figure 7-15. Total Inputs of Net Electricity for Heat Power and Electricity Generation by End Use: 1991



Note: Boiler Fuel Data Withheld by EIA

Figure 7-16. Total Inputs of Natural Gas for Heat Power and Electrical Generation by End Use: 1991

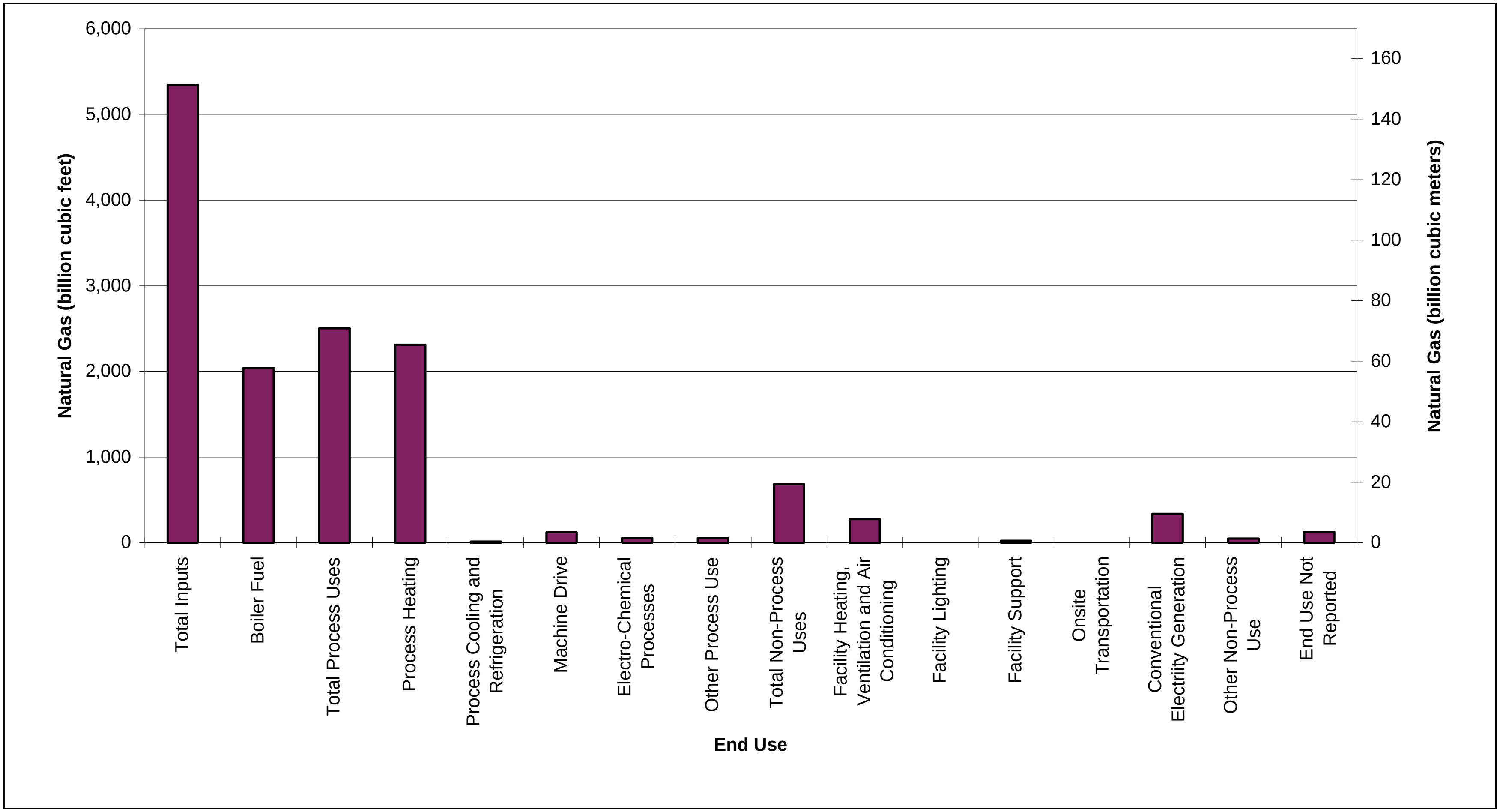


Figure 7-17. Non-Process Inputs of Electricity and Natural Gas by End Use: 1991

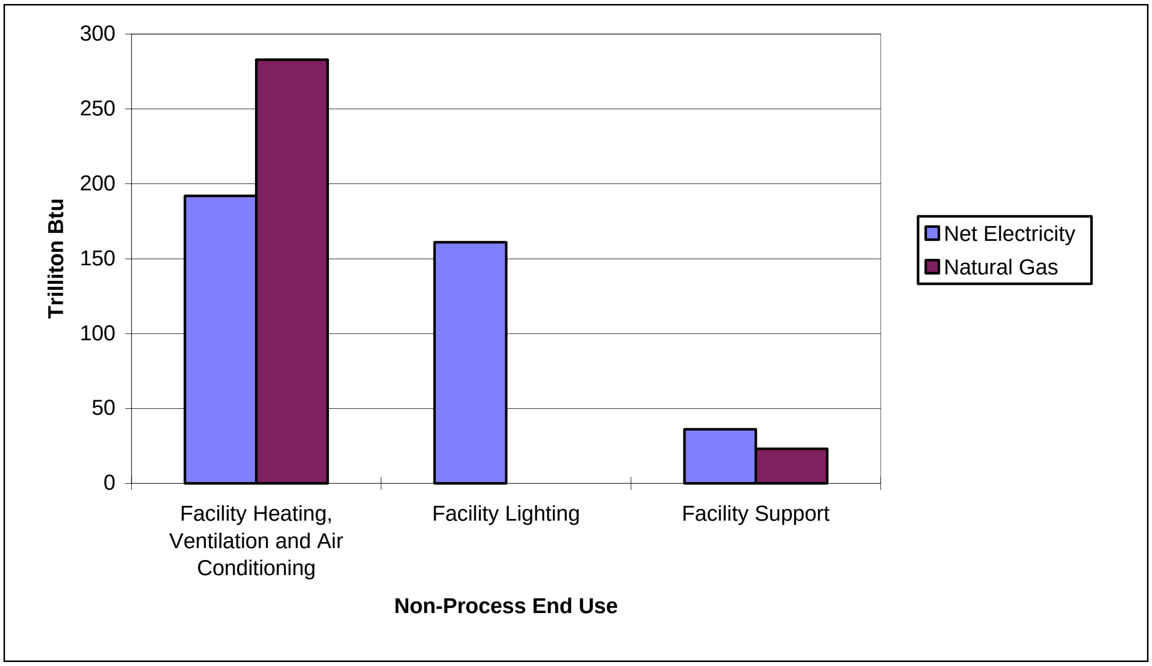


Figure 7-18 and Figure 7-19 compare inputs of net electricity and natural gas for heat power and electrical generation by SIC Code. Reference to these two figures indicates that many industries only use a small percentage of the energy they consume for non-process end-uses, as expected. It should be noted that the figures are not truly indicative of the scale of the difference between total process and non-process energy inputs, as they do not include boiler fuel, which is a major component of process-related energy consumption. However, in those industries where assembly-type manufacturing takes place in large, environmentally controlled buildings, non-process consumption can be more significant. Examples of this are the furniture and fixtures industry (SIC 25), where 32 percent of energy consumption is non-process related, the transportation equipment industry (SIC 37), where 25 percent is non-process related, and the office equipment industry (SIC 36), where 43 percent is non-process related. The source data are shown in Table 7-3 Part A and Part B.

Figure 7-20 and Figure 7-21 show how total inputs of net electricity and natural gas for primary non-process end-uses vary by SIC Code. Reference to Figure 7-20 indicates that net electricity inputs for HVAC and lighting are of similar magnitude in most industries, and are generally much higher than facility support costs. In comparison, Figure 7-21 shows that the majority of natural gas consumption is attributable to HVAC use only.

Figure 7-18. Total Net Electricity Inputs for Heat Power and Electrical Generation by SIC Code and End Use: 1991

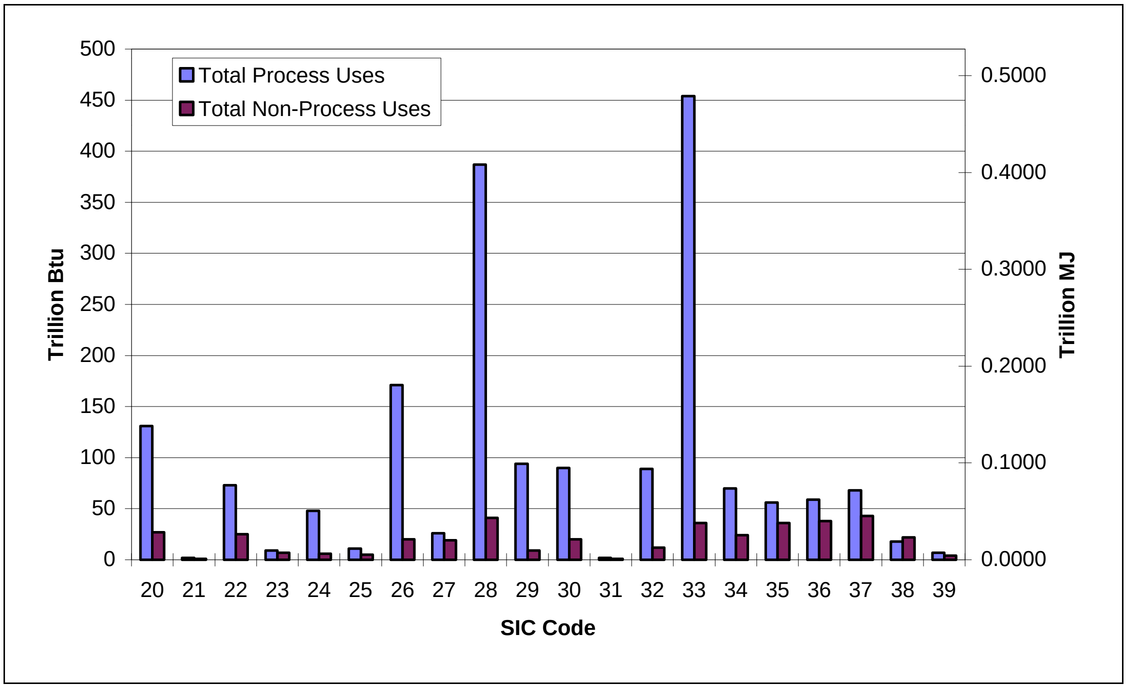


Figure 7-19. Total Natural Gas Inputs for Heat and Power and Electrical Generation by SIC Code and End Use: 1991

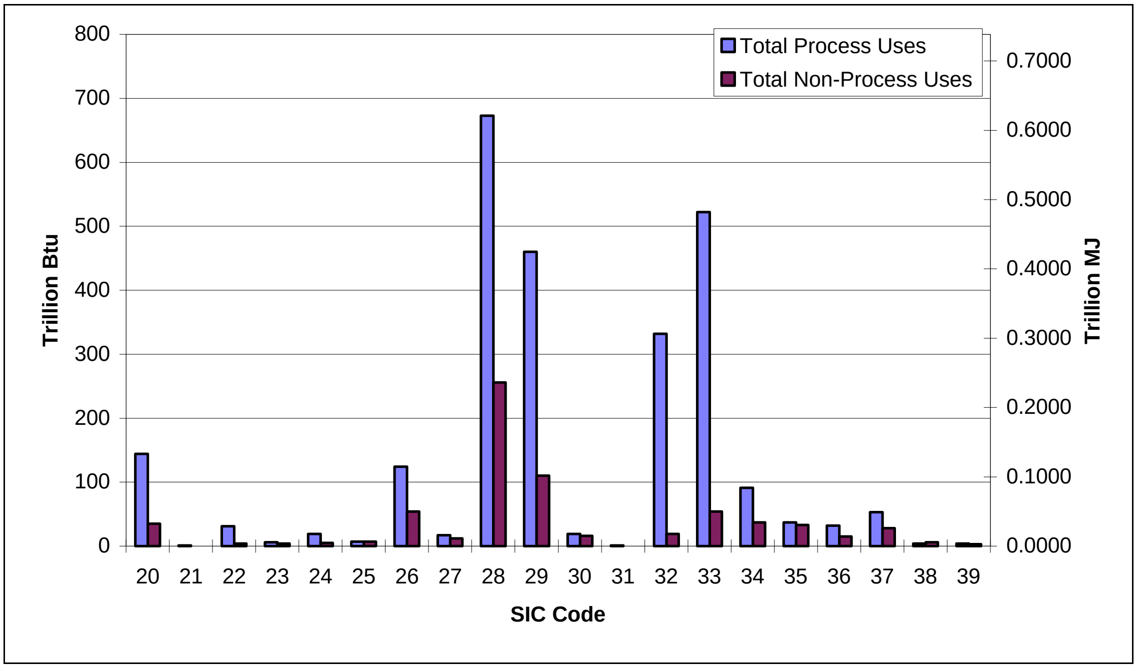


Table 7-3. Total Net Electricity and Natural Gas Inputs for Heat, Power and Electrical Generation by SIC Code and Selected End Use: 1991

Part A: Trillion Btu

SIC Code	Net Electricity					Natural Gas			
	Total Process Uses	Total Non-Process Uses	Facility Heating, Ventilation and Air Conditioning	Facility Lighting	Facility Support	Total Process Uses	Total Non-Process Uses	Facility Heating, Ventilation and Air Conditioning	Facility Support
20	131	27	12	12	3	144	35	20	2
21	2	1	0	0	0	1	0	0	0
22	73	25	14	9	1	31	4	4	0
23	9	7	4	3	0	6	4	4	0
24	48	6	2	3	1	19	5	5	0
25	11	5	2	2	0	7	7	7	0
26	171	20	9	9	2	124	54	0	0
27	26	19	10	7	2	17	12	11	1
28	387	41	21	15	4	673	256	0	4
29	94	9	4	4	1	460	110	10	2
30	90	20	9	9	2	19	16	15	0
31	2	1	0	0	0	1	0	0	0
32	89	12	6	5	1	332	19	17	1
33	454	36	16	16	3	522	54	44	6
34	70	24	10	11	2	91	37	34	2
35	56	36	17	15	4	37	33	31	0
36	59	38	21	13	4	32	15	15	1
37	68	43	20	18	4	53	28	25	2
38	18	22	11	8	2	4	6	6	0
39	7	4	2	2	5	4	3	0	0

Part B: Quadrillion Joules

SIC Code	Net Electricity					Natural Gas			
	Total Process Uses	Total Non-Process Uses	Facility Heating, Ventilation and Air Conditioning	Facility Lighting	Facility Support	Total Process Uses	Total Non-Process Uses	Facility Heating, Ventilation and Air Conditioning	Facility Support
20	138	28	13	13	3	152	37	21	2
21	2	1	0	0	0	1	0	0	0
22	77	26	15	9	1	33	4	4	0
23	9	7	4	3	0	6	4	4	0
24	51	6	2	3	1	20	5	5	0
25	12	5	2	2	0	7	7	7	0
26	180	21	9	9	2	131	57	0	0
27	27	20	11	7	2	18	13	12	1
28	408	43	22	16	4	710	270	0	4
29	99	9	4	4	1	485	116	11	2
30	95	21	9	9	2	20	17	16	0
31	2	1	0	0	0	1	0	0	0
32	94	13	6	5	1	350	20	18	1
33	479	38	17	17	3	551	57	46	6
34	74	25	11	12	2	96	39	36	2
35	59	38	18	16	4	39	35	33	0
36	62	40	22	14	4	34	16	16	1
37	72	45	21	19	4	56	30	26	2
38	19	23	12	8	2	4	6	6	0
39	7	4	2	2	5	4	3	0	0

Figure 7-20. Total Net Electricity Inputs for Facility HVAC, Lighting and Facility Support: 1991

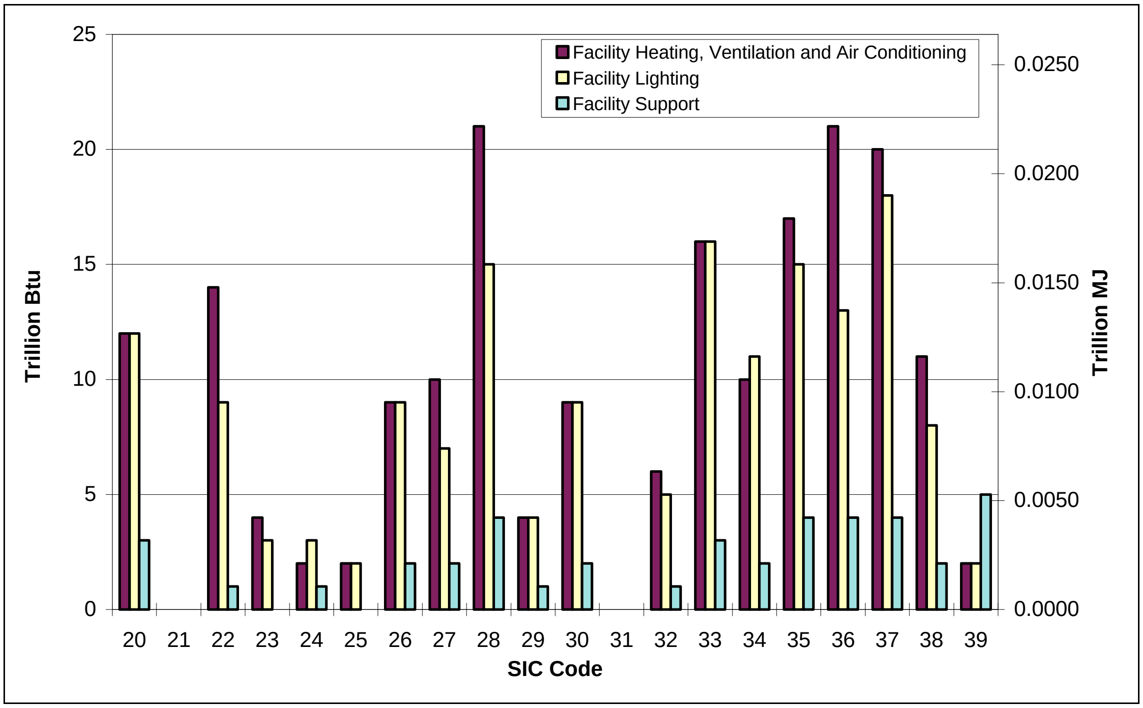
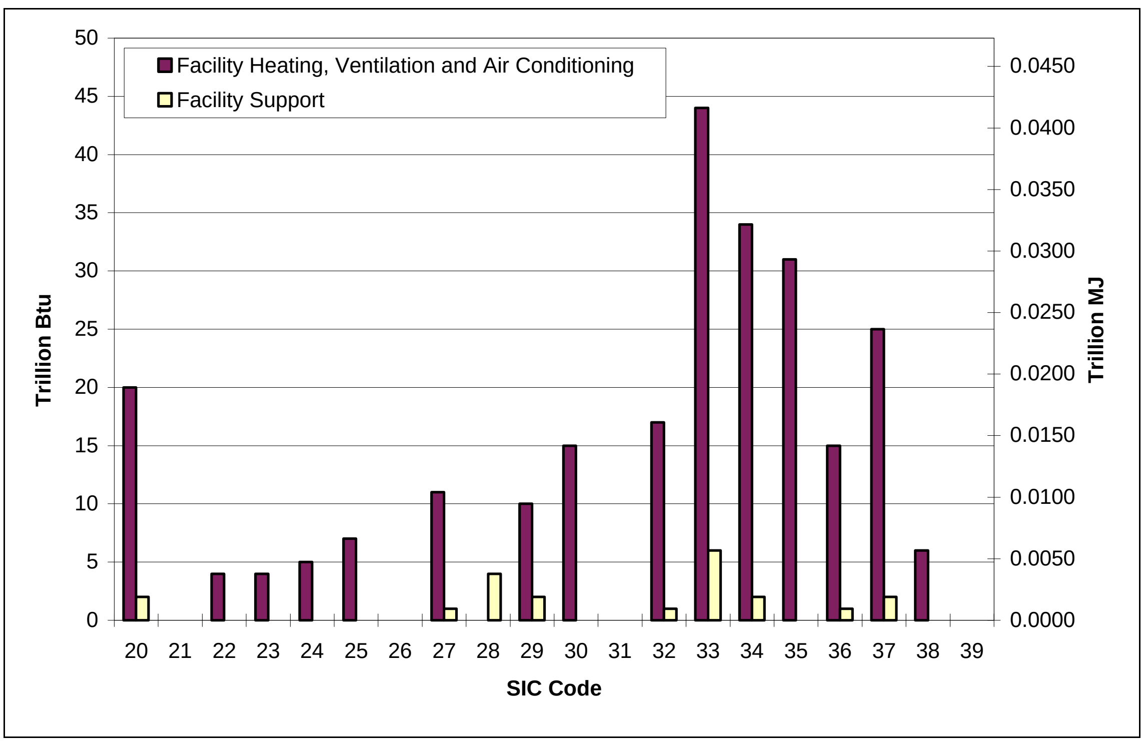


Figure 7-21. Total Natural Gas Inputs for Facility HVAC and Facility Support: 1991



7.2.3 Baseline Measures for Operations, Maintenance, and Energy Costs Using Data from the International Facility Management Association (IFMA)

Data which are presented in Section 7.2 of this document are sufficiently detailed to establish energy baselines for the industrial sector. However, data that has been presented so far for operations and maintenance costs in the sector are of a highly aggregated nature, and are of limited usefulness for establishing baselines. For this reason, data from the International Facility Management Association (IFMA) are used to establish more detailed baselines for the industrial sector. When interpreting these data, it must be remembered that the IFMA study is based upon a comparatively small survey sample, and that all of the survey data are from IFMA members, and may not therefore represent 'norms' of industry-wide performance. However, in the absence of more comprehensive research data, it is considered to be reasonable to make use of the IFMA data, at least to establish some general baseline measures.

The IFMA Research Report "*Benchmarks* II" provides benchmark data for both the commercial/institutional and industrial sectors. In this section of the document, only data relevant to the industrial sector have been used. IFMA uses the following facility categories in its report:

- Chemicals (chemicals, pharmaceuticals)
- Computers (computers, telecommunications, electronics)
- Consumer products (consumer products, food and related)
- Energy/mining (energy-related, mining)[25]
- Motor vehicles (motor vehicles, aircraft, industrial equipment)
- Other manufacturing

These classifications can be compared with the SIC Codes, as shown below:

IFMA Classification	SIC Classification
Chemicals	28 - Chemicals and Allied Products
Computers	35 - Industrial and Commercial Machinery and Computer Equipment
Consumer Products	No Comparable Classification (primarily SIC 20, 21, 22, 23)
Motor Vehicles	37 - Transportation Equipment
Other	39 - Miscellaneous Manufacturing Establishments

[25] Although mining is not included in this document, energy production/power generation is considered as part of the public works sector in this document (See Chapter 8).

Because these classifications are different, it is not considered to be practical to attempt to adjust IFMA data to match SIC Codes. Thus IFMA data are presented in the same format as shown in the *Benchmarks* II report. However, where possible, comparisons are made between IFMA data and Census data. IFMA also categorizes facilities by the predominant use of that facility (e.g., customer service, computer center, research, factory plant, etc.). However, no data using this form of categorization are used in this document, primarily because the data cannot be mapped back into the building type with the size of the survey sample given.

Table 7-4 shows the mean gross, rentable, and usable area of the sample facilities according to industry type, in square feet and square meters respectively. Gross area is defined by IFMA as the total of all floor areas of the building. Rentable area is computed by measuring the inside finished surface of the dominant portion of the permanent outer building wall and subtracting all major vertical penetrations. Usable area measures the actual occupiable area of the building, and excludes circulation areas, common areas, meeting areas and so forth from the rentable area calculation. Reference to Table 7-4 shows that the largest proportion of the surveyed buildings were in the computing category. For those building types where the sample size is below 20, care should be taken in interpreting the data. The data are presented graphically in Figure 7-22.

Table 7-5 shows the mean gross, rentable, and usable area per employee for the sample facilities, according to type of building. The mean gross square feet per employee for the sample was 45 square meters (479 square feet).

Table 7-4. IFMA Survey Sample: Gross, Rentable and Useable Floorspace by Industry Type: 1993

		Means			Means		
Industry Type	N	Gross Sq.Ft.	Rentable Sq.Ft.	Usable Sq.Ft.	Gross Sq. Meters	Rentable Sq. Meters	Usable Sq. Meters
Chemicals	9	628,658	455,242	437,537	58402	42292	40647
Computers	37	902,541	849,186	700,227	83846	78889	65051
Consumer Products	18	350,294	338,766	290,659	32542	31471	27002
Energy/Mining	16	787,187	647,820	503,843	73130	60182	46807
Motor Vehicles	11	1,550,082	1,376,382	1,166,022	144003	127866	108323
Other Manufacturing	22	689,711	642,967	598,959	64074	59732	55643

Figure 7-22. IFMA Survey Sample: Gross, Rentable and Useable Floorspace by Industry Type: 1993

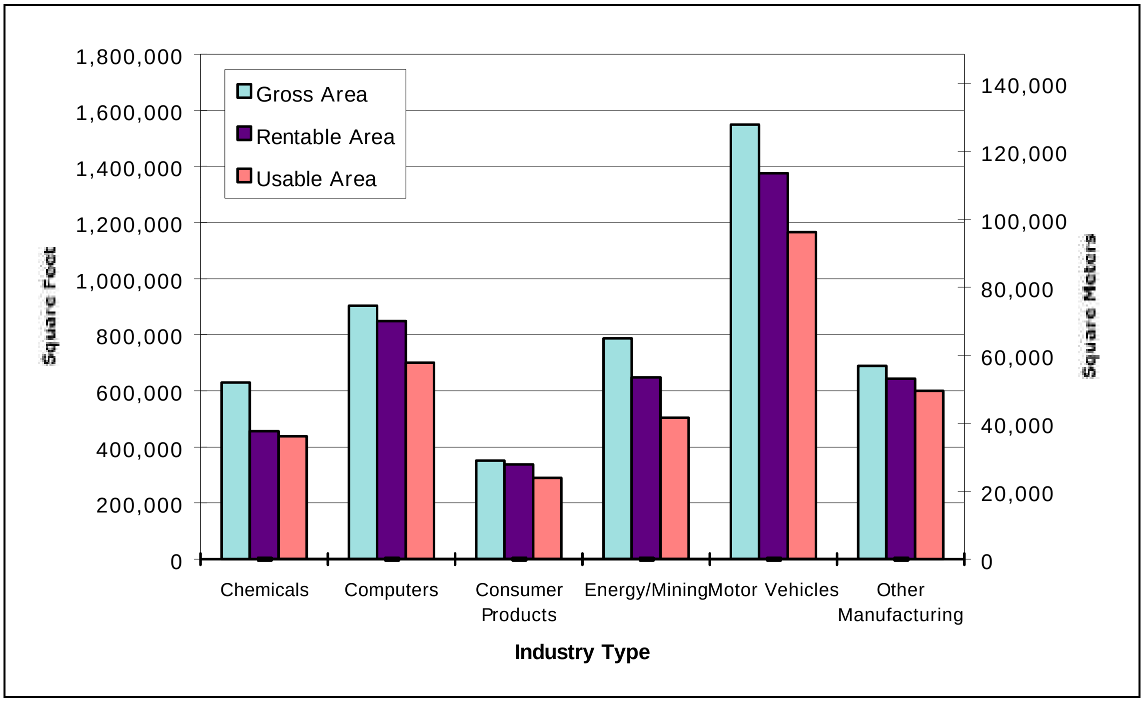


Table 7-5. IFMA Survey Sample: Gross, Rentable and Useable Floorspace per Employee by Industry Type and Facility Use

		Means			Means		
Industry Type	N	Gross Sq.Ft.	Rentable Sq.Ft.	Usable Sq.Ft.	Gross Sq. Meters	Rentable Sq. Meters	Usable Sq. Meters
Chemicals	8	433	349	341	40	32	32
Computers	36	434	424	324	40	39	30
Consumer Products	16	379	356	289	35	33	27
Energy/Mining	14	533	493	359	50	46	33
Motor Vehicles	10	495	468	380	46	43	35
Other Manufacturing	21	607	549	473	56	51	44

In Figures 7-23 through 7-31, a variety of operations, maintenance, and energy costs are compared for each building type on a dollars per year per rentable square foot/square meter basis. These include the following:

Operations

- **Janitorial Costs** - these are the costs associated with the cleaning of offices and other work areas, rest-rooms, cafeteria, and support space
- **Environmental Costs** - these include building concerns, such as 'sick building syndrome' and asbestos abatement, which incur consulting fees and monitoring costs, as well as waste removal for standard and hazardous trash, and recycling costs
- **Life Safety Costs** - these include fire and safety equipment
- **Indirect Costs** - these include exterior maintenance costs, such as landscaping and grounds, roadways, and parking facilities
- **Security Costs** - these include building and site security costs

Maintenance

- **Maintenance Costs** - these include items for the upkeep of the building and its components such as HVAC, electrical and plumbing systems, elevators and painting

Energy

- **Utility Costs** - these include electricity, gas, steam, and water (note that 'water' has previously been categorized under 'operations' in this document)

Figure 7-23 presents janitorial cost data in dollars per rentable square foot ($/RSF) and dollars per rentable square meter ($/RSM). Costs range from $9.36/RSM ($0.87/RSF) for "other manufacturing establishments" to $14.75/RSM ($1.37/RSF) in chemicals establishments. Figure 7-24 and Figure 7-25 show environmental cost data. The highest costs occur in the motor vehicles category, primarily due to a high component of hazardous trash removal. Non-hazardous trash removal costs are relatively consistent across all facility types, with a mean cost of $1.29/RSM ($0.12/RSF). Figure 7-26 shows life safety costs by industry type. These are highest in the motor vehicles sector ($2.80/RSM/$0.26/RSF). In Figure 7-27, indirect costs are shown by industry type. Reference to the figure shows that these are highest in chemical facilities. Figure 7-28 shows security costs. These are relatively consistent across all industry types, at around $11.84/RSM ($1.10/RSF), with the exception of energy/mining, where security costs are lower at $7.53/RSM ($0.70/RSF).

Figure 7-23. Janitorial Costs by Industry Type

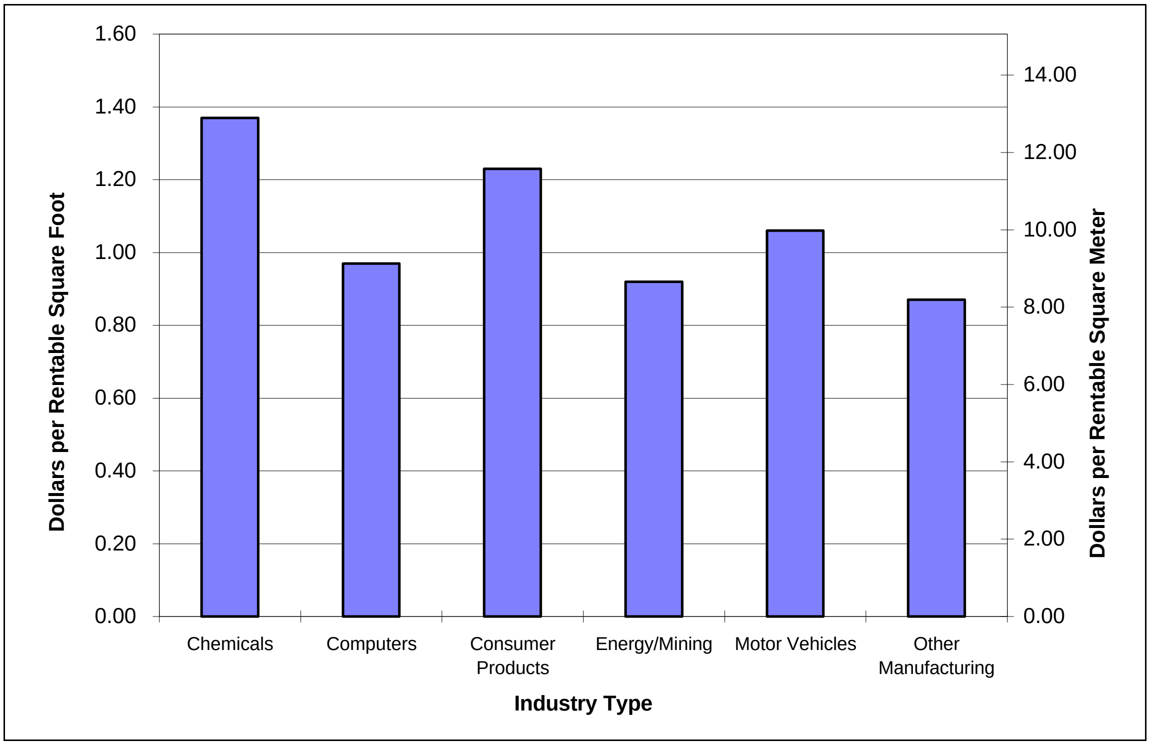


Figure 7-24. Environmental Costs by Industry Type

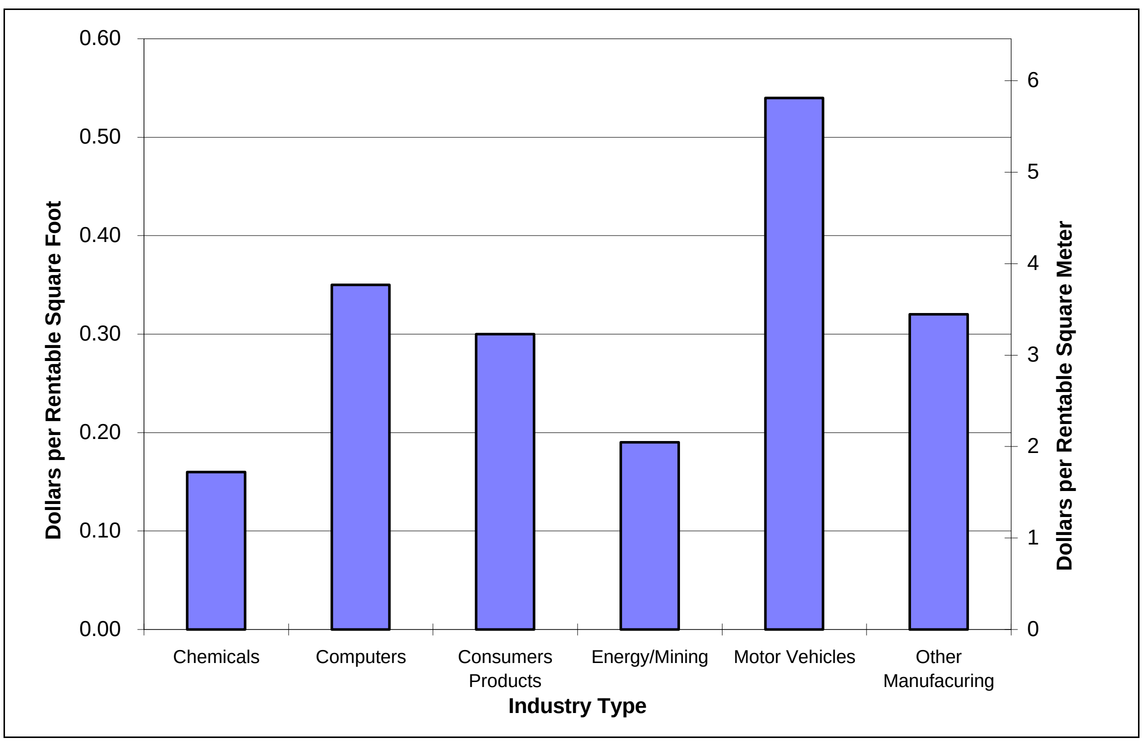


Figure 7-25. Detailed Environmental Costs by Industry Type

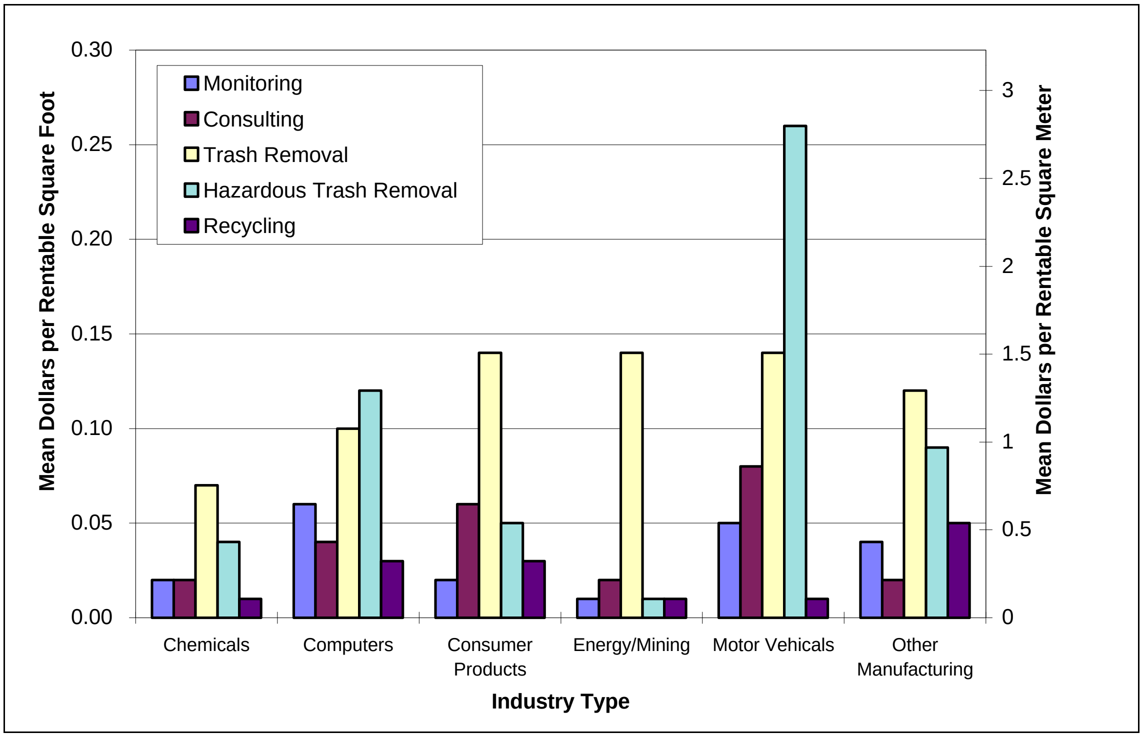


Figure 7-26. Life Safety Costs by Industry Type

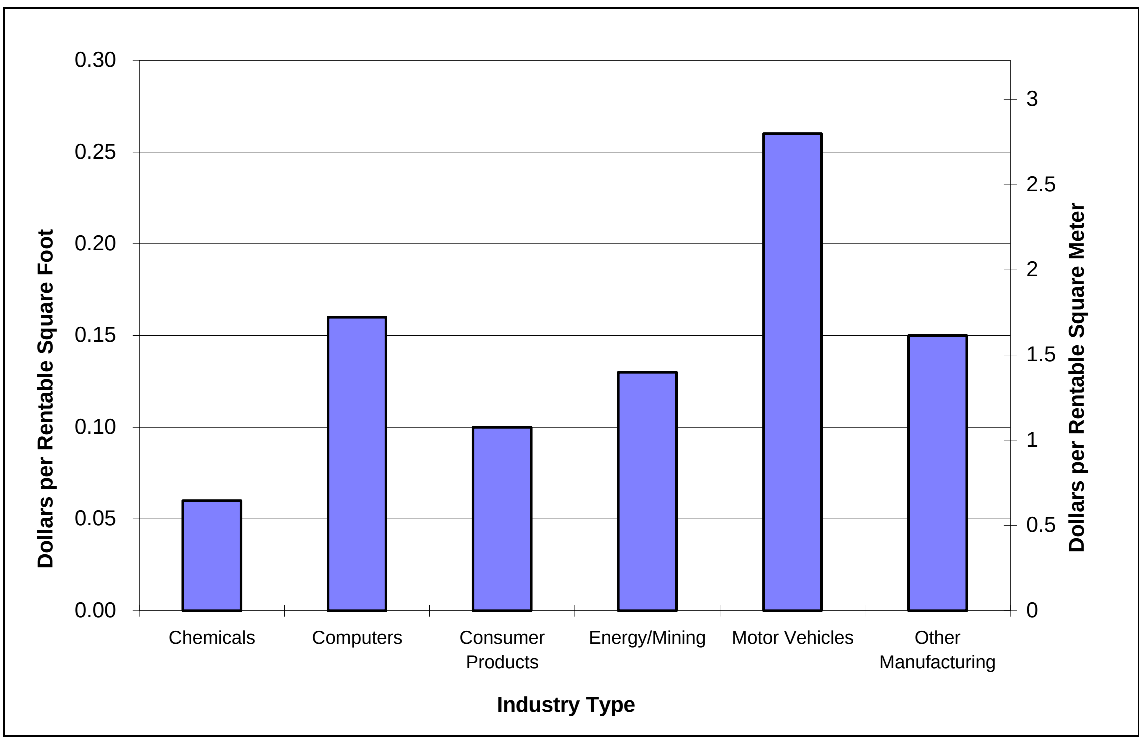


Figure 7-27. Indirect Costs by Industry Type

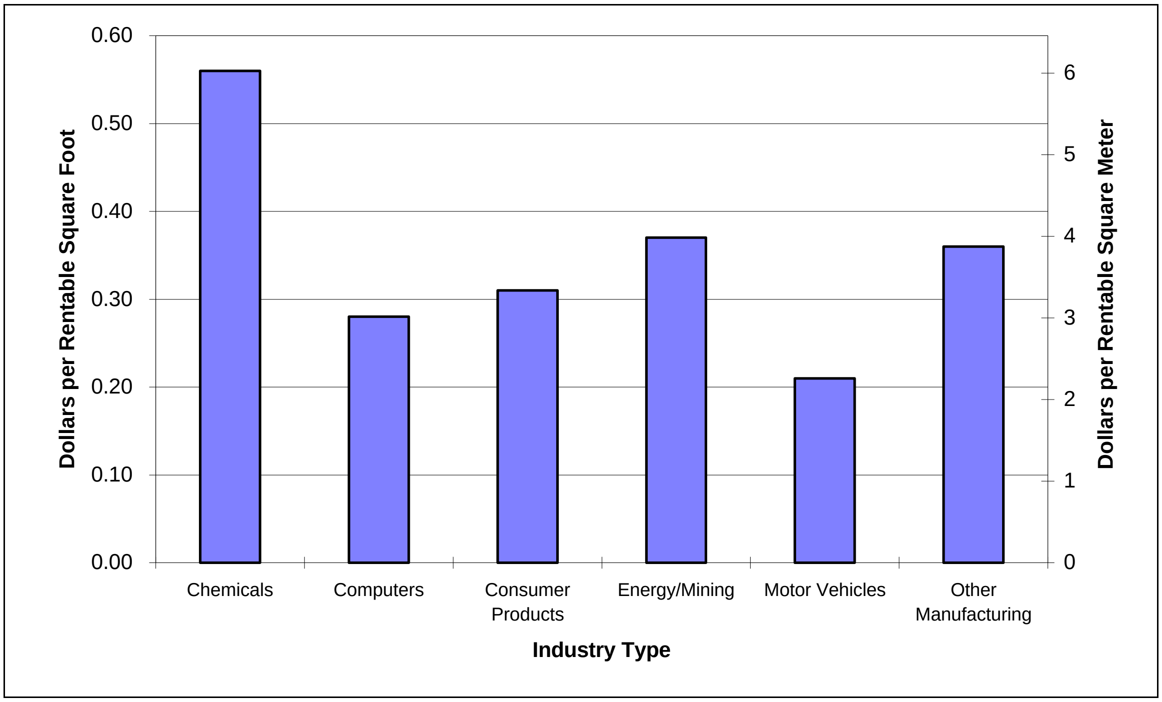
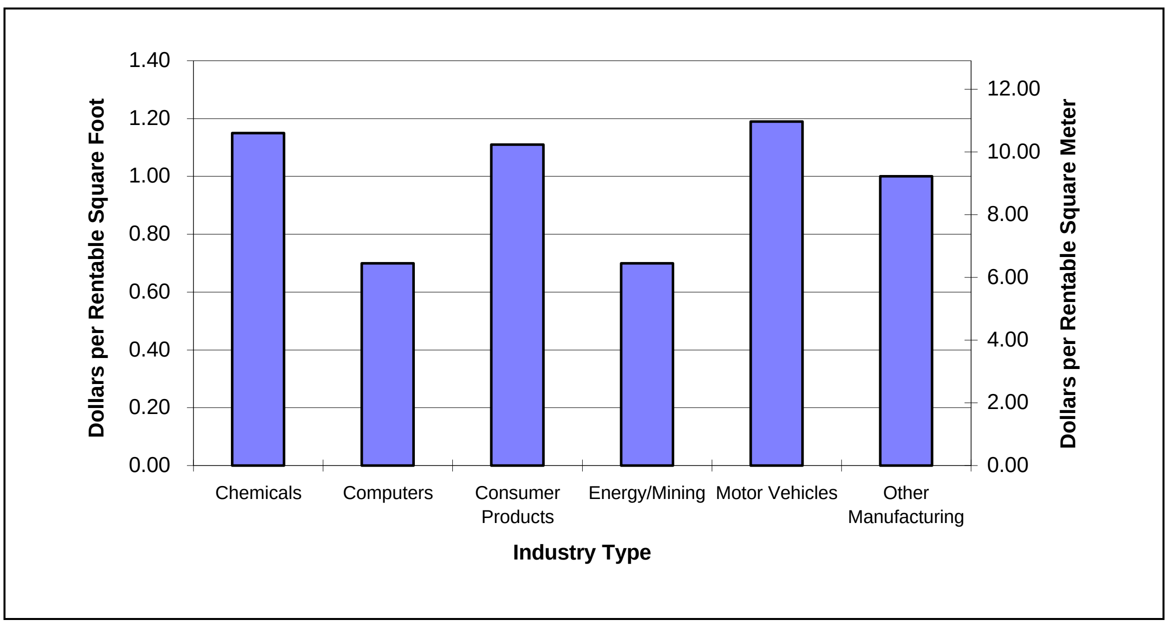


Figure 7-28. Security Costs by Industry Type



In Figure 7-29, maintenance costs are also shown to be relatively consistent across the industrial sector, ranging from $25.19/RSM to $31.00/RSM ($2.34/RSF to $2.88/RSF), with a mean cost of $28.95/RSM ($2.69/RSF). The IFMA report also provides information about the amount spent on maintenance and repair compared with preventive maintenance. The data indicate that more time is spent on preventive maintenance for security and life safety systems compared with electrical, building, structural repair and painting activities. However, overall, almost twice as much is spent on maintenance repair compared with preventive maintenance.

Finally, Figure 7-30 and Figure 7-31 show utility costs by building type. Again, total utility costs are similar across the sector, ranging from $25.19/RSM to $31.00/RSM ($2.34/RSF to $2.88/RSF), with a mean value of $28.85/RSM ($2.68/RSF). Reference to Figure 7-31 indicates that utility costs are dominated by electricity costs (generally over 75 percent of total utility costs). Electricity costs are highest in the computer sector. The mean electricity cost is $23.79/RSM ($2.21/RSF), the mean cost for oil, gas, and steam is $3.44/RSM ($0.32/RSF), and the mean water cost is $1.61/RSM ($0.15/RSF).

Figure 7-29. Maintenance Costs by Industry Type

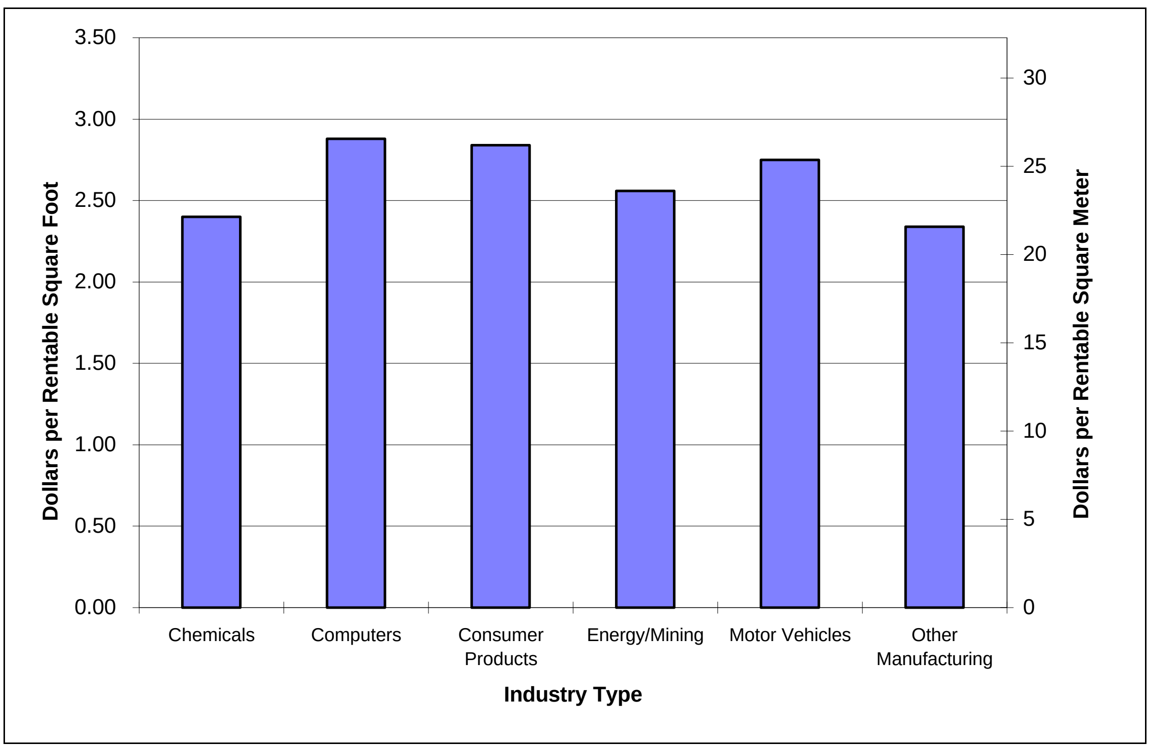


Figure 7-30. Total Utility Costs by Industry Type

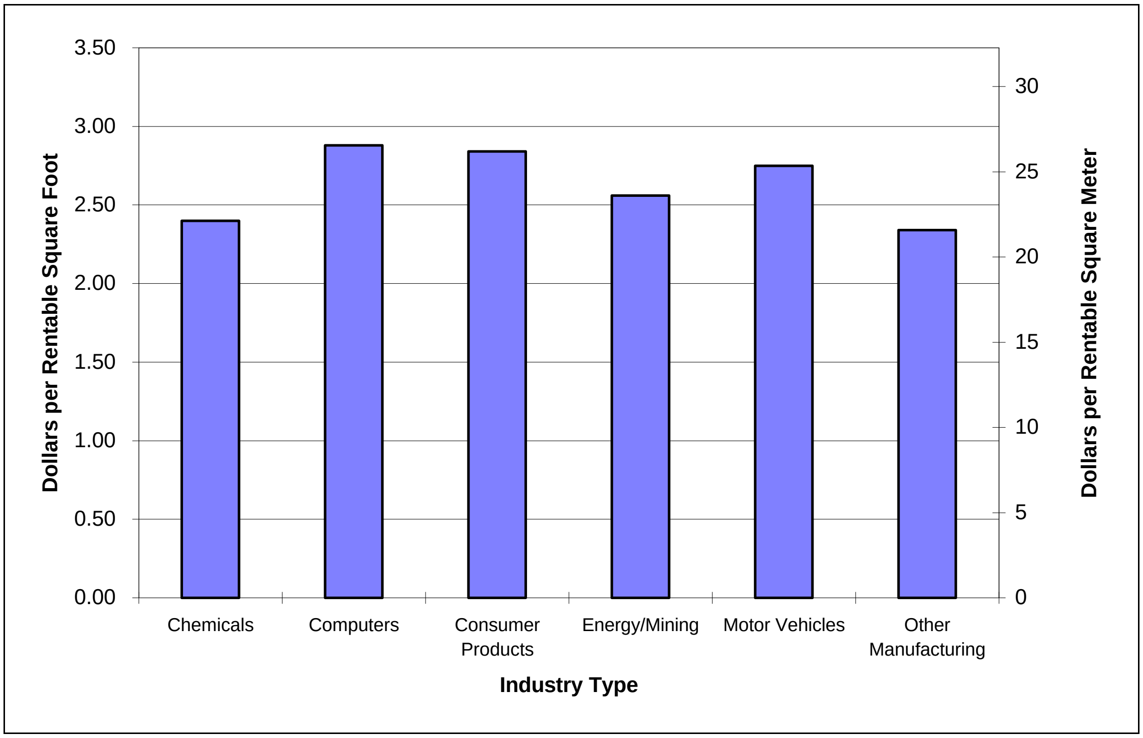
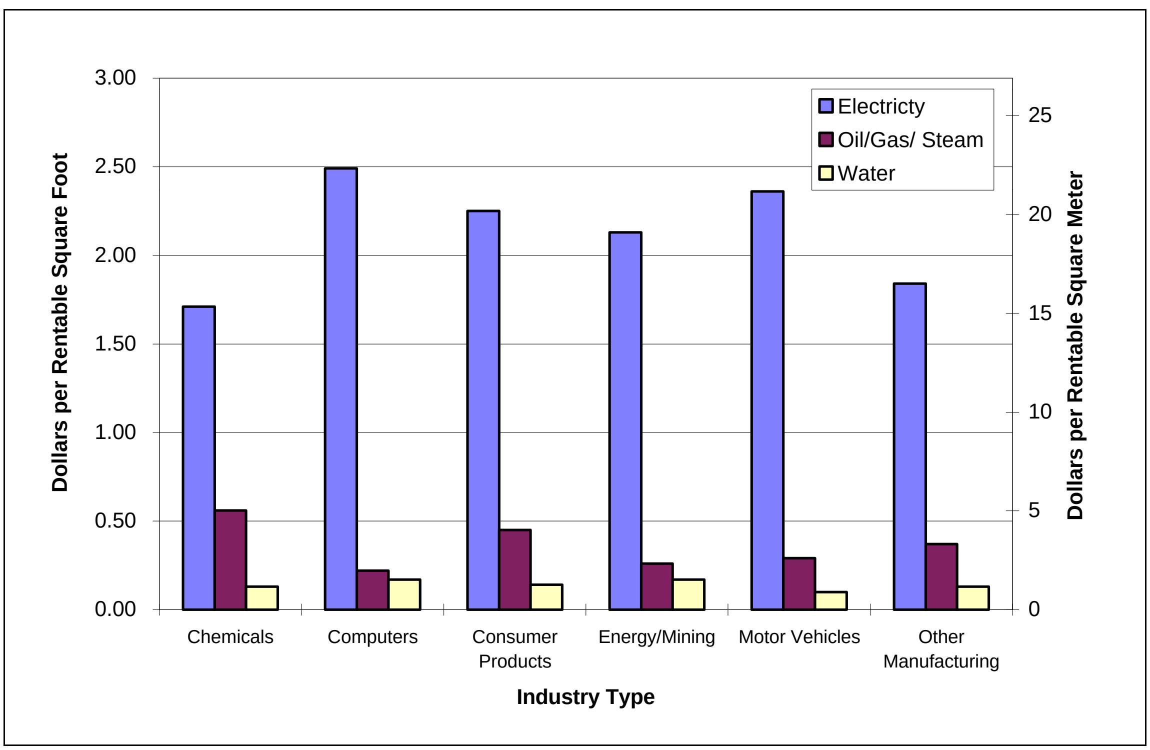


Figure 7-31. Utility Costs by Fuel Type and by Industry Type



Some of the IFMA data for operations, maintenance, and energy costs can be compared with general industrial sector Census data presented in Section 7-1 of this document. However, in order to do this, given that census data are only available regarding number of establishments and not total floorspace, one has to estimate the cost per establishment from IFMA data, based upon the sample data.

The problem in doing this is that the IFMA data are probably not representative of the entire manufacturing sector, given that many establishments have under twenty employees, which were unlikely to be included in the IFMA sample. Therefore, if we were to examine just one part of the industrial sector, which is likely to be characterized by larger establishments, such as the chemicals and allied products industry (SIC 28), a comparison between IFMA data and census data would be more valid.

SIC 28 comprised 12004 establishments in 1992, of which 5004 had more than 20 employees. The mean rentable area of the IFMA sample chemical facilities was 42,2943 square meters (455,242 square feet). We can therefore calculate the following mean costs for the industrial sector:

Description	**Estimated Mean Cost (based upon Census Data)**	**Mean Cost (from IFMA data)**
Purchased Fuels & Electric Energy	\$20.64/RSM[26]	\$25.83/RSM
	\$1.92/RSF	\$2.40/RSF
Total Repair Services	\$7.10/RSM	\$25.83/RSM
(buildings, and machinery)	\$0.66/RSF	\$2.40/RSF
Refuse Removal (inc. hazardous)	\$1.51/RSM	\$1.18/RSM
	\$0.14/RSF	\$0.11/RSF

This comparison suggests that the IFMA figures are of the right order of magnitude for this part of the sector (SIC 28). However, it is not considered to be advisable to extend IFMA "mean" OM&E values from all categories to the entire industrial sector, given that the mean RSF/establishment figures from the IFMA sample may not be representative of the true industry "mean". For this reason, IFMA data should only be used at the building type specific level, as presented in this document, to generate baseline measures.

7.2.4 Energy Conservation in the Industrial Sector

This section addresses some general issues concerning energy conservation in the industrial sector. This section examines fuel switching capability within the industrial sector, and looks at the level of participation in energy management programs. It also describes a variety of useful sources of information relating to energy conservation in the sector.

[26] Calculated as follows: \$10,476.2 million/(42,293 m^2 area x 12,004 establishments)=\$20.64/RSM
\$10,476.2 million/(455,242 ft^2 area x 12,004 establishments)=\$1.92/RSF

The **1991 MECS** provides detailed information on the ability of manufacturers to switch between different types of fuel, in order to adapt to changes in economic conditions or fuel supply interruptions, and thus reduce their fuel expenditures. This varies from one industry to another, depending on the technologies and circumstances involved. For example, many boilers may be able to use either natural gas or residual fuel oil, but few can switch between natural gas and electricity. In 1991, manufacturers could switch 2.8 quadrillion Btu of all fuels, which represented 28 percent of total consumption. In 1991, manufacturers reported being able to replace 40 percent of switchable natural gas consumption with distillate fuel oil or 34 percent with residual fuel oil. However, the switching potential for electricity is much more limited. Only two percent of manufacturing electricity consumed in 1991 could have been replaced by alternatives. While 45 percent of coal consumption was switchable, because coal was cheaper than any competing fuel, there was little incentive to switch. For more detail on this subject refer to the **MECS**.

The **MECS** also provides information on participation levels in various demand side management (DSM) programs and other energy management programs. The greatest benefits achieved through energy efficiency programs would be through improvement of direct process operations, as these are a much greater consumer of energy compared with non-process operations (only 12 percent of total energy consumed). From 1989 through 1991, the level of participation in direct process operation DSM programs, expressed as a percentage of total input energy use was as follows: installing or retrofitting motors to achieve better efficiency (36 percent), improving the efficiency of process heating (34 percent) and improving the efficiency of process cooling (15 percent).

To improve the energy efficiency of direct non-process operations, manufacturing establishments also participated in other DSM programs. From 1989 through 1991, their participation, expressed in terms of total input energy used by participating establishments was as follows: improving the efficiency of facility lighting (36 percent), and installing equipment to improve facility HVAC systems (23 percent). These data are shown in Table 7-6. The MECS also provides information about the level of usage of computer control systems for the building environments, which, for brevity are not included here.

A variety of other sources of information have been identified which provide very detailed information about manufacturing processes, and ways of improving process efficiencies, for certain parts of the industrial sector. Although this is beyond the scope of this document, given that the focus is upon non-process related activities, details of some of the data sources are given below.

The Office of Industrial Technologies (OIT) provides detailed information about the aluminum, chemicals, forest products, glass, metalcasting, petroleum, and steel industries, which use more than 80 percent of the energy consumed by the US manufacturing sector. A series of “technology roadmaps” are being developed which include performance goals for each of those industries.

Table 7-6. Participation in Selected Demand Side Management Programs

Part A: Energy Input Attributable to Program in Trillion Btu

SIC CODE	Participation in One or More of the Following Types of Programs	Energy Input Attributable to Energy Program				
		Census Region				
		All US	Northeast	Midwest	South	West
20-39	**TOTAL ENERGY INPUTS**	**15,027**	**1,635**	**3,833**	**7,507**	**2,052**
	Energy Audits	7,083	665	2,085	3,543	791
	Direct Electricity Load Control	5,086	664	1,459	2,536	427
	Special Rate Schedule	6,517	813	1,708	3,225	772
	Standby Generation Program	1,133	102	426	521	84
	Equipment Rebate(s)	783	201	216	77	289
	Equipment Installation or Retrofit for the Primary Purpose of Improving Energy Efficiency Affecting:					
	Steam Production	4,757	375	1,403	2,389	599
	Direct/Indirect Process Heating	5,146	552	1,453	2,458	682
	Direct Process Cooling/Refrigeration	2,212	167	579	1,193	272
	Direct Machine Drive	5,354	570	1,465	2,575	744
	Facility Heating, Ventilation, and Air Conditioning	3,424	388	1,325	1,330	381
	Facility Lighting	5,405	828	1,788	2,068	721
	Equipment Installation/Retrofit for the Primary Purpose of Using a Different Energy Source	1,693	213	541	681	258
	Other	376	47	105	178	45

Part B: Energy Input Attributable to Program in Quadrillion Joules

SIC CODE	Participation in One or More of the Following Types of Programs	Energy Input Attributable to Energy Program				
		Census Region				
		All US	Northeast	Midwest	South	West
20-39	**TOTAL ENERGY INPUTS**	**15,853**	**1,725**	**4,044**	**7,920**	**2,165**
	Energy Audits	7,473	702	2,200	3,738	835
	Direct Electricity Load Control	5,366	701	1,539	2,675	450
	Special Rate Schedule	6,875	858	1,802	3,402	814
	Standby Generation Program	1,195	108	449	550	89
	Equipment Rebate(s)	826	212	228	81	305
	Equipment Installation or Retrofit for the Primary Purpose of Improving Energy Efficiency Affecting:					
	Steam Production	5,019	396	1,480	2,520	632
	Direct/Indirect Process Heating	5,429	582	1,533	2,593	720
	Direct Process Cooling/Refrigeration	2,334	176	611	1,259	287
	Direct Machine Drive	5,648	601	1,546	2,717	785
	Facility Heating, Ventilation, and Air Conditioning	3,612	409	1,398	1,403	402
	Facility Lighting	5,702	874	1,886	2,182	761
	Equipment Installation/Retrofit for the Primary Purpose of Using a Different Energy Source	1,786	225	571	718	272
	Other	397	50	111	188	47

Table 7-7 and Table 7-8 are extracted from the *1997 Report of the Aluminum Technology Workshop* sponsored by OIT and the Aluminum Association. Aluminum industry energy expenditures represent about nine percent of total sales, which is the highest in the manufacturing sector (industry average is approximately two percent of sales). Table 7-7 shows performance targets established for the aluminum industry, while Table 7-8 shows targets for the primary products sector of the aluminum industry (this considers the products of molten aluminum). As can be seen, these targets are very detailed. Other data sources are shown in Section 7.1.

Table 7-7. Performance Targets for the Aluminum Industry

Cost and Productivity Targets

1. Reduce the costs associated with metal production by 25 %
2. Reduce the cost ratio of aluminum to steel to less than 3-1 for auto applications
3. Increase capital productivity of the aluminum industry
4. Reduce product costs and product lead times through process re-engineering

Market Targets

5. Increase aluminum use in auto markets by 40% in five years
6. Increase aluminum use in non-auto transportation markets
7. Increase aluminum use in infrastructure markets by 50%
8. Increase aluminum use in building and construction markets

Environmental Targets

9. Recycle and treat all types of aluminum wastes
10. Increase recyclability of aluminum scrap
11. Achieve 80% wrought recycling of autos by 2004

Energy Targets

12. Increase the efficiency of the Hall-Heroult cell process to over 97%
13. Reduce overall energy intensity of aluminum production

Health and Safety Targets

14. Increase the health and safety of workers

Workforce Targets

15. Increase the level of training and knowledge of the existing aluminum workforce
16. Increase the number of qualified scientists and engineers available to the aluminum industry

Source: *1997 Report of the Aluminum Technology Workshop* - The Office of Industrial Technologies/Department of Energy

Table 7-8. Performance Targets for the Aluminum Industry Primary Products Sector

DETAILED PERFORMANCE TARGETS
1. Improve the efficiency of the Hall-Heroult Cell: Achieve an average efficiency of 97% on an annual basis (currently between 93 and 96%) Reduce the energy intensity of aluminum production to 13kWh/kg (5.9 kWh/lb) using retrofit technology (currently estimated to be 15.2kWh/kg/6.9kWh/lb) in near to mid term Reduce the energy intensity of aluminum production to 11kWh/kg (5kWh/lb) in the long term Reduce capital cost of aluminum production to $2500 per annual metric ton of capacity Cost-effectively minimize the generation of perfluorcarbons (PFCs) 2. Improve Bayer process productivity by approximately 20% 3. Reduce/eliminate carbon dioxide emissions during smelting 4. Enhance aluminum recycling technologies: Increase education on existing technologies Minimize or eliminate formation/landfilling of dross and salt cake 5. Improve metal quality: Adapt to using alternative sources of carbon Reduce impurities in recycled alumina 6. Reduce the cost of aluminum reduction by 25% using alternative technologies 7. Develop new uses for wastes and byproducts from aluminum processes

Source: *1997 Report of the Aluminum Technology Workshop* - The Office of Industrial Technologies/Department of Energy

7.3 Summary of Baseline Measures for the Industrial Sector

This section summarizes the baseline measures for the industrial sector which are presented in Sections 7.2.1, 7.2.2 and 7.2.3 of this document. The summary data concentrate upon cost rather than consumption, and are presented in Table 7-9 below.

Table 7-9 shows general information relating to the industrial sector, as well as key operations, maintenance, and energy baseline data. The 'General Information' section describes the *total expenditures for new construction, maintenance and repair, and improvements* in the industrial sector in 1994. The section also shows the *number of industrial establishments* in 1992.

The 'Operations' section provides baseline measures for *water consumption* (cost data are not available) at an aggregated level, and for *refuse removal* for all industrial SIC Codes 20 through 39, both at an aggregated level, and for each individual SIC Code. The

‘Maintenance’ section provides information on *maintenance and repairs for buildings and structures, and for machinery.* Baselines for *repair of buildings* are shown for each SIC Code 20 through 39. Finally, the ‘Energy’ section provides information on *total energy expenditures for all fuel sources*, at an aggregated level for all SIC Codes, and then for each individual SIC Code. The energy baselines presented in the table include both process and non-process energy components. These data are presented because all other energy data provided in this document consider energy consumption measures, rather than expenditure measures, as this is the only information available from EIA.

Summary of Abbreviations Used in Table 7-9

VIP	Value of New Construction Put in Place
USGS	United States Geological Survey
EIA	Energy Information Administration

Table 7-9. Summary of Baseline Measures: Industrial Sector

DESCRIPTION	YEAR	BASELINE	SOURCE[27]
GENERAL INFORMATION			
Value of New Construction Put in Place	1994	$28,161 million (constant 1992 dollars)	Census VIP Data
Total Maintenance and Repair Expenditures	1994	$22,521 million (constant 1992 dollars)	Census Data
Total Expenditures for Improvements	1994	$22,861 million (constant 1992 dollars)	Census Data
Total Number of Establishments (SIC 20-39)	1992	382,000	Statistical Abstract
OPERATIONS			
Total Fresh Water Deliveries	1990	92,733 million liters per day (24,500 million gallons per day)	USGS
Total Fresh Water Consumption	1990	12,604 million liters per day (3,330 million gallons per day)	USGS
Total Cost for Refuse Removal	1992	$4,405 million	Census Data
Cost of Refuse Removal - SIC 20	1992	$379.9 million	Census Data
Cost of Refuse Removal - SIC 21	1992	$5.6 million	Census Data
Cost of Refuse Removal - SIC 22	1992	$52.7 million	Census Data
Cost of Refuse Removal - SIC 23	1992	$40.2 million	Census Data
Cost of Refuse Removal - SIC 24	1992	$61.1 million	Census Data
Cost of Refuse Removal - SIC 25	1992	$46.6 million	Census Data
Cost of Refuse Removal - SIC 26	1992	$262.2 million	Census Data
Cost of Refuse Removal - SIC 27	1992	$89.6 million	Census Data
Cost of Refuse Removal - SIC 28	1992	$792.3 million	Census Data
Cost of Refuse Removal - SIC 29	1992	$252.1 million	Census Data

[27] See accompanying text for description of abbreviations used in this table.

Table 7-9. Summary of Baseline Measures: Industrial Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
Cost of Refuse Removal - SIC 30	1992	$157.7 million	Census Data
Cost of Refuse Removal - SIC 31	1992	$92.8 million	Census Data
Cost of Refuse Removal - SIC 32	1992	$93.8 million	Census Data
Cost of Refuse Removal - SIC 33	1992	$439.0 million	Census Data
Cost of Refuse Removal - SIC 34	1992	$607.1 million	Census Data
Cost of Refuse Removal - SIC 35	1992	$224.7 million	Census Data
Cost of Refuse Removal - SIC 36	1992	$188.9 million	Census Data
Cost of Refuse Removal - SIC 37	1992	$488.1 million	Census Data
Cost of Refuse Removal - SIC 38	1992	$97.1 million	Census Data
Cost of Refuse Removal - SIC 39	1992	$34.6 million	Census Data
MAINTENANCE			
Total Cost for Repair of Buildings and Structures	1992	$5,426 million	Census Data
Total Cost for Repair of Machinery	1992	$23,302 million	Census Data
Cost for Repair of Buildings - SIC 20	1992	$496.1 million	Census Data
Cost for Repair of Buildings - SIC 21	1992	$28.6 million	Census Data
Cost for Repair of Buildings - SIC 22	1992	not available	Census Data
Cost for Repair of Buildings - SIC 23	1992	$53.9 million	Census Data
Cost for Repair of Buildings - SIC 24	1992	$60.9 million	Census Data
Cost for Repair of Buildings - SIC 25	1992	$81.7 million	Census Data
Cost for Repair of Buildings - SIC 26	1992	$261.3 million	Census Data

Table 7-9. Summary of Baseline Measures: Industrial Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
Cost for Repair of Buildings - SIC 27	1992	$243.7 million	Census Data
Cost for Repair of Buildings - SIC 28	1992	$583.7 million	Census Data
Cost for Repair of Buildings - SIC 29	1992	$306.0 million	Census Data
Cost for Repair of Buildings - SIC 30	1992	$201.9 million	Census Data
Cost for Repair of Buildings - SIC 31	1992	$9.6 million	Census Data
Cost for Repair of Buildings - SIC 32	1992	$113.1 million	Census Data
Cost for Repair of Buildings - SIC 33	1992	$302.2 million	Census Data
Cost for Repair of Buildings - SIC 34	1992	$442.6 million	Census Data
Cost for Repair of Buildings - SIC 35	1992	$444.0 million	Census Data
Cost for Repair of Buildings - SIC 36	1992	$631.6 million	Census Data
Cost for Repair of Buildings - SIC 37	1992	$691.8 million	Census Data
Cost for Repair of Buildings - SIC 38	1992	$216.8 million	Census Data
Cost for Repair of Buildings - SIC 39	1992	$47.4 million	Census Data
ENERGY			
Total Expenditures for Purchased Energy Sources	1991	$61,059 million	EIA
Cost of Purchased Energy Sources - SIC 20	1991	$4,637 million	EIA
Cost of Purchased Energy Sources - SIC 21	1991	$123 million	EIA

Table 7-9. Summary of Baseline Measures: Industrial Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
Cost of Purchased Energy Sources - SIC 22	1991	$1,883 million	EIA
Cost of Purchased Energy Sources - SIC 23	1991	$474 million	EIA
Cost of Purchased Energy Sources - SIC 24	1991	$ 1,423 million	EIA
Cost of Purchased Energy Sources - SIC 25	1991	$421 million	EIA
Cost of Purchased Energy Sources - SIC 26	1991	$5,385 million	EIA
Cost of Purchased Energy Sources - SIC 27	1991	$1,274 million	EIA
Cost of Purchased Energy Sources - SIC 28	1991	$1,5867 million	EIA
Cost of Purchased Energy Sources - SIC 29	1991	$3,757 million	EIA
Cost of Purchased Energy Sources - SIC 30	1991	$2,367 million	EIA
Cost of Purchased Energy Sources - SIC 31	1991	$83 million	EIA
Cost of Purchased Energy Sources - SIC 32	1991	$3,218 million	EIA
Cost of Purchased Energy Sources - SIC 33	1991	$9,358 million	EIA
Cost of Purchased Energy Sources - SIC 34	1991	$2,586 million	EIA
Cost of Purchased Energy Sources - SIC 35	1991	$2,303 million	EIA
Cost of Purchased Energy Sources - SIC 36	1991	$2,063 million	EIA
Cost of Purchased Energy Sources - SIC 37	1991	$2,571 million	EIA
Cost of Purchased Energy Sources - SIC 38	1991	$939 million	EIA
Cost of Purchased Energy Sources - SIC 39	1991	$328 million	EIA

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8. OM&E Measures for the Public Works Sector

8.1 Key Considerations for the Public Works Sector

This section of the document addresses the issue of data sources, availability and constraints in the public works sector, and summarizes the key data sources that are used for developing the baseline measures. The section also provides a general overview of the public works sector, as well as a brief overview of each of the sub-sectors. To re-cap, the public works sub-sectors are as follows:

- Transportation (road, rail, transit, air, and water)
- Communications (masts, structures, and cabling services)
- Power Utilities (power generation and distribution)
- Water (storage, supply, treatment, and flood control)
- Solid Waste
- Pipelines (except natural gas)

For the reasons already given in Section 4.1.1 of this document, the communications and solid waste sub-sectors will not be discussed further.

8.1.1 Data Considerations: Sources, Availability, and Constraints

Preliminary data searches for the public works sector indicated that there were a number of organizations that produce reports about some of the sub-sectors identified within Chapter 4 of this document. There do not appear to be any authoritative sources examining the public works sector in its entirety. For this reason, the primary data sources for each sub-sector are considered separately below.

8.1.1.1 Primary Data Sources: Transportation Sub-Sector

Data from the US Bureau of the Census

The US Bureau of the Census (USBC) carries out the **Census of Construction** and produces the *Current Construction Reports Series C30* publication *Value of Construction Put in Place,* both of which are described in detail in Chapter 3 of this document. It also produces data concerning government investment in transportation. These data are available through the USBC Internet site, or via paper or electronic publications. For this sub-sector, data from USBC have been used to quantify transportation investments and construction expenditures.

Data from the Bureau of Transportation Statistics

The Bureau of Transportation Statistics (BTS) provides a wide range of information about the transportation sector through the **National Transportation Data Archives**, the **National Transportation Library**, and the **Transportation Studies** databases.

Documents which are of particular interest are the *Transportation Statistics Annual Report 1995*, *1996*, and *1997*, which provide general information about the sector, and the report *Federal, State and Local Transportation Financial Statistics: Fiscal Years 1982-1994*, which provides data on government expenditures for transportation. These reports are available on the BTS Internet site (URL: http://www.bts.gov).

Data from the Statistical Abstract of the United States: 1996 and 1997

Some information from the *Statistical Abstract* has been used to quantify freight and passenger volumes with the public works sector, and to provide a general overview of selected operating expenses for railroads. Specific data sources are identified in the text as appropriate.

Data from the Federal Highway Administration

The Federal Highway Administration (FHWA) publishes the annual report *Highway Statistics,* which provides very detailed information about highway finances and highway extent, characteristics, and performance. This is also referred to as the "Yellowbook". The 1994 report has been used in this document, although 1995 data have recently become available. The report is available on the Bureau of Transportation Statistics Internet site (URL: http://www.bts.gov/ohim/1994/index.html) or via paper publications. In this document, data from *Highway Statistics 1994* have been used to characterize the size and nature of the US highway system, and to provide detailed data on highway performance and expenditures.

Data from the Association of American Railroads

The Association of American Railroads (AAR) provides statistics for the US national railroad system. Data are available via the AAR Internet site (URL: http://www.aar.org), and have been used in this document to characterize the sector, and provide information on Class I railroad operating expenses.

Data from the Federal Transit Administration

The Federal Transit Administration (FTA) provides access to a wide range of detailed information about transit systems through the **National Transit Library**, and **National Transit Database**. Documents of particular interest include *FTA Budget Brief*, and *Transit Agency Operating Expenses* for 1995, 1996, 1997, and 1998, and the FTA report *Characteristics of Urban Transportation Systems-Revised Edition September 1992*. Data are available through the FTA Internet site (URL: http://www.fta.dot.gov). In this document, data from the FTA have been used to characterize the extent of the transit sector, and to provide general information on transit operations costs.

Data from the Federal Aviation Administration

The Federal Aviation Administration (FAA) publication *FAA Statistical Handbook of Aviation 1997* provides information on the size of the aviation sector. The report is available at the BTS internet site.

Data from the Maritime Administration

The Maritime Administration *Report to Congress on the Status of Public Ports of the United States, 1994-1995*, provides information on the number of ports in the US and selected operating expenditures. The report is available through the Maritime Administration Internet site (URL: http://marad.dot.gov).

Data from the US Army Corps of Engineers

The US Army Corps of Engineers (USACE) provides information on domestic waterborne commerce in its report *Commerce of the United States, Calendar Year 1995*. The Civil Works Division of the USACE provides information on the scope of its Civil Works activities (see the information paper at the USACE Internet site: http://www.usace.army.mil/inet/functions/cw/prog-man/cwmprog.htm). These include navigation activities, which are considered in this sub-sector, and flood control and other activities, which are considered in the "water" sub-sector.

The USACE provides data on dredging activities through its *Water Resources Support Center/Navigation Data Center*. For details refer to its Internet site (URL:http://www.wrc-ndc.usace.army.mil).

Data from Other Sources

A wide range of other transportation related data sources were examined, some of which are described below:

- US Department of Transportation Surface Transportation Board (STB) *Financial data for Class I Railroads*[28] *1996*, available from STB Internet Site (URL: http://www.stb.dot.gov/infoex1.htm#Finance).

- American Public Works Association- provides a range of data and publications relating to all public works sub-sectors, including transportation, and a variety of publications relating to public works facility and grounds management. (URL: http://www.pubworks.org).

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[28] Class I railroads are defined as any railroad having an annual operating revenue of at least $255.9 million (as of January 1997, there were 9 Class I railroads in the US).

- US Department of Energy Transportation Technologies (URL: http://www.ott.doe.gov) provides information relating to energy conservation in the transportation sector. However, given that this is primarily attributable to vehicle or vessel operations, rather than infrastructure related energy consumption, this will not be considered further in this document.

8.1.1.2 Primary Data Sources: Power Utilities Sub-Sector

Data from the Energy Information Administration

The EIA publishes the *Annual Energy Review*, which provides a range of information relevant to power generation, distribution, and consumption in the US. Data from the *Annual Energy Review 1996*, which are available through the EIA Internet Site (URL: http://www.eia.doe.gov) have been used to characterize the electric power industry by net generation and consumption by sector.

Data from the US Bureau of the Census

The USBC carries out the **Census of Transportation, Communication, and Utilities** every five years - data are currently available for 1992. The Census covers SIC Codes 40, 41, 42, 44, 45, 46, 47, 48, and 49. This includes electric, gas and sanitary services (SIC 49), which are relevant to the power utilities sub-sector. Data from the Census have been used to characterize the size of the industry, and provide aggregated data on maintenance and repair expenditures.

Data from the Energy Information Administration

The EIA publication *Natural Gas Monthly April 1997*, provides details of interstate natural gas pipeline capacity and planned additions for 1995-2000. The EIA also produces detailed information regarding operations costs for domestic oil and gas fields in the US (see *Costs and Indices for Domestic Oil and Gas Field Equipment and Production Operation, 1993 through 1996*), but this is not included here, as it is beyond the scope of this document.

Data from the United States Geological Survey (USGS)

The USGS provides data on water consumption for the generation of thermoelectric and hydroelectric power. Data are available on the USGS Internet site (URL: http://www.usgs.gov), and are used to establish baseline measures for the electric utility industry in this document.

8.1.1.3 Primary Data Sources: Water Sub-Sector

Data from the US Army Corps of Engineers (USACE)

The USACE provides information on domestic waterborne commerce in its report *Waterborne Commerce of the United States, Calendar Year 1995*. The Civil Works Division of the USACE provides information on the scope of its Civil Works activities (see the information paper at the USACE Internet site: http://www.usace.army.mil/inet/functions/cw/prog-man/cwmprog.htm). These include navigation activities, which are considered in the transportation sub-sector, and flood control and other activities, which are considered in this sub-sector.

The USACE also provides information on the FY1998 budget for USACE Civil Works Program, which includes information on the comparative magnitude of operations expenditures by the Corps.

Data from the United States Geological Survey (USGS)

The USGS provides data on wastewater treatment in the US. Data are available at the USGS Internet site, and are used to establish baseline measures in this document.

8.1.1.4 Primary Data Sources: Pipelines Sub-Sector

Data from the US Bureau of the Census

The USBC carries out the **Census of Transportation, Communications and Utilities** every five years - data are currently available for 1992. The Census covers SIC Codes 40, 41, 42, 44, 45, 46, 47, 48, and 49. This includes pipelines, except natural gas (SIC 46) which is relevant to the pipelines sub-sector. Data from the Census provide aggregated maintenance and repair data for petroleum and other types of pipelines in the US.

8.1.2 Overview of the Transportation Sub-Sector - Introduction

This section first examines the transportation sub-sector as a whole, before moving on to examine the principal components of the sub-sector in more detail (i.e. highways, rail, transit, air, and water). The general overview examines government investment in transportation, construction expenditures, and the volume of freight and passenger traffic attributable to the different modes of transportation. The more detailed descriptions of each of these transportation modes consider the extent of the infrastructure associated with each mode, and key operational characteristics.

8.1.2.1 General Overview of the Transportation Sub-Sector

Transportation plays a pivotal role in the US economy, both by providing mobility for the movement of passengers and freight, and as an intermediate good that is consumed at every stage to create a final product. The Bureau of Transportation Statistics (BTS) estimates that transportation services in 1993 accounted for about 11 percent of Gross Domestic Product, but that even this may be an underestimate[29].

Consumer expenditures for transportation, of which the largest element is personal vehicle operation, upkeep, and purchase, is the second largest component of total consumer spending (second only to housing). However, it will not be considered further here, as it is beyond the scope of this document.

Government agencies play a significant role in providing transportation infrastructure and services, and are also significant purchasers of transportation equipment and services. Table 8-1 which is based upon data from the *1997 Transportation Statistics Annual Report* shows how government investment in infrastructure and equipment has changed between 1983 and 1993. The table shows investment by type of government and mode of transport, and compares total investment for all government with investment in construction. Reference to the table indicates that in 1993, all levels of government invested heavily in highways, but that the proportions were quite different, with state government putting 92 percent of their transportation investment into highways, local governments 47 percent, and federal government 32 percent. For all government combined, the states made 75 percent of total government investment in highways. In 1993, local governments invested more in airports and urban transit combined than they did in highways, and were responsible for over 70 percent of government investment in these two modes that year. Investment in highways, transit and airports is heavily slanted toward construction. Almost 90 percent of public investment in highways for 1993 was for construction. The only mode experiencing a loss of investment in real terms between 1983 and 1993 was water transportation and terminals, due to a decrease in construction. Equipment investment, however, increased 67 percent in real terms.

Table 8-1. Government Transportation Investment by Mode : 1983 and 1993

Investment in Billions of Constant 1992 Dollars, After Transfers										
	All Government		**Federal**		**State**		**Local**		**Construction Outlays All Government**	
Mode	*1983*	*1993*	*1983*	*1993*	*1983*	*1993*	*1983*	*1993*	*1983*	*1993*
Transportation Total	34.1	51.3	1.4	2.1	19.9	30.6	13.4	18.7	28.6	43.0
Highways	25.2	37.5	0.3	0.7	18.3	28.1	7.2	8.8	22.1	33.2
Airports	2.3	6.3	0.4	1.0	0.3	0.8	1.8	4.5	1.7	4.6
Parking Facilities	-	0.4	-	-	-	-	-	0.4	-	0.3
Water Transportation and Terminals	1.9	1.2	0.8	0.6	0.3	0.2	0.7	0.4	1.6	0.7
Transit	4.8	6.1	-	-	1.2	1.4	3.8	4.7	3.0	4.2

[29] See Transportation Statistics Annual Report 1995 pp. 33 for details.

Table 8-2 summarizes transportation construction expenditures by transportation mode for 1987 and by year for highways, streets, and related facilities, the transportation mode with the largest construction expenditures. Part A, which is based upon the **Census of Construction 1987** and *Value Put in Place Series*, examines expenditures by SIC 1611, 1622 and 1629 for each of the transportation modes in 1987. Reference to Table 8-2, Part B shows how expenditures for highways and streets, which is the largest component of transportation construction, have varied between 1989 and 1996. The Value of New Construction Put in Place for highways, streets, and related facilities has risen by about 10 percent over this time in real terms. The second largest component of new construction in the transportation sector is for buildings and other construction, which would include new airport or rail terminals, and so forth. The data presented in Table 8-2 Part A are shown graphically in Figure 8-1.

Table 8-2. Transportation Construction Expenditures

Part A. Transportation Construction Expenditures by Mode: 1987

Transportation Construction, 1987 (Thousands of Dollars)				
	Highway and Street Construction (SIC 1611)	**Construction of Bridges, Tunnels, and Elevated Highways (SIC 1622)**	**Heavy Construction Not Elsewhere Classified (SIC 1629)**	**Total**
Establishments	10,986	1,159	14,532	26,677
Employees	284,380	47,494	297,618	629,492
Value of Construction	34,161,427	5,480,936	25,632,969	65,275,332
Highways, Streets, and Related Facilities	28,123,431	387,161	923,313	29,433,905
Airport Runways	123,809	-	-	123,809
Bridges, Tunnels, and Elevated Highways	1,152,276	4,476,501	532,104	6,160,881
Marine Construction	88,785	29,291	1,379,611	1,497,687
Harbor and Port Facilities		53,509	431,507	485,016
Mass Transit	54,092	-	780,781	834,873
Pipelines (Except Water)	-	-	249,086	249,086
Buildings and Other Construction	4,169,034	534,474	21,336,567	26,040,075

Part B. Value of New Construction put in Place for Highways Streets and Related Facilities in Constant 1992 Dollars: 1989 to 1996

	Value of New Construction put in Place in Millions of Constant 1992 Dollars							
Year	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Highways and Streets	30,407	31,777	30,300	33,132	34,164	36,151	33,500	33,297

Table 8-3 Part A and Part B which is based upon data from the *Statistical Abstract of the United States: 1996*, shows how the total volume of freight and passenger traffic using each transportation mode has changed between 1980 and 1993. Reference to the table indicates that there has been a 25 percent increase in total freight traffic over this period. The largest increase has been in truck freight (461 billion ton-kilometers/316 billion ton-

miles, an increase of 57 percent), with a smaller increase in railroad freight (366 billion ton-kilometers/251 billion ton-miles, an increase of 27 percent) There has been a reduction in freight carried on the Great Lakes and by oil pipelines. The highest growth in freight movement has occurred in domestic airways, but this still only represents less than 0.5 percent of total freight movement in the US.

For passenger traffic, there has been a 45 percent growth in the number of passenger miles/kilometers traveled between 1980 and 1993. Approximately 77 percent of this growth is attributable to private automobile usage, and the majority of the remainder is attributable to a 69 percent increase in air traffic passenger miles. Bus usage has declined by 15 percent. Whilst railroad use has risen by 27 percent, it still only accounts for less than one percent of total passenger miles traveled.

Figure 8-2 and Figure 8-3 show the distribution of total inter-city freight and passenger traffic in 1993 respectively. Reference to Figure 8-2 indicates that highways and railroads are the major transportation modes for freight movement in the US. Figure 8-3 indicates that highways and domestic airways represent the bulk of all passenger miles traveled in the US. In comparison, bus and railroad passenger miles traveled are very small. These figures serve to emphasize the importance of highways to the US economy.

Figure 8-1. Government Transportation Investment by Mode: 1987

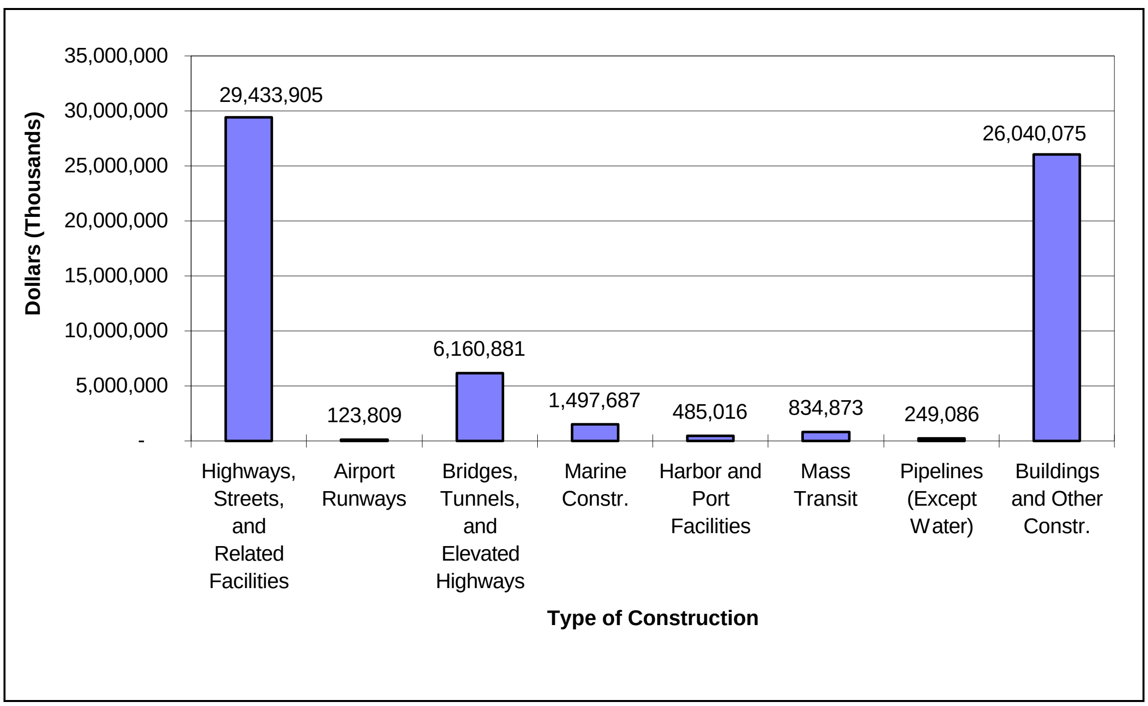


Table 8-3. Volume of Domestic Intercity Freight and Passenger Traffic: 1980 to 1993

Part A: Billion Ton-Miles/Billion Passenger-Miles

VOLUME OF DOMESTIC INTERCITY FREIGHT AND PASSENGER TRAFFIC					
Transport Mode	**YEAR**				
	1980	**1985**	**1990**	**1992**	**1993**
Freight Traffic (billion ton-miles)					
Total	*2,487*	*2,458*	*2,895*	*3,009*	*3,105*
Railroads	932	895	1,091	1,138	1,183
Truck:					
ICC Truck	242	250	311	342	365
Non-ICC Truck	313	360	424	473	506
Total Truck	555	610	735	815	871
Water:					
Rivers/canals	311	306	390	397	393
Great Lakes	96	76	85	77	74
Oil Pipelines	588	564	584	571	572
Domestic Airways	5	7	10	11	12
Passenger Traffic (billion passenger-miles)					
Total	*1,467*	*1,635*	*1,993*	*2,079*	*2,126*
Private Automobile	1,210	1,310	1,598	1,675	1,718
Air- Public Carrier	219	290	359	367	370
Bus	27	24	23	24	23
Railroads	11	11	13	14	14

Part B: Billion Metric Ton-Kilometers/Billion Passenger Kilometers

VOLUME OF DOMESTIC INTERCITY FREIGHT AND PASSENGER TRAFFIC					
Transport Mode	**YEAR**				
	1980	**1985**	**1990**	**1992**	**1993**
Freight Traffic (billion ton-kilometers)					
Total	*3,629*	*3,586*	*4,224*	*4,390*	*4,530*
Railroads	1,360	1,306	1,592	1,660	1,726
Truck:					
ICC Truck	353	365	454	499	533
Non-ICC Truck	457	525	619	690	738
Total Truck	810	890	1,072	1,189	1,271
Water:					
Rivers/canals	454	446	569	579	573
Great Lakes	140	111	124	112	108
Oil Pipelines	858	823	852	833	835
Domestic Airways	7	10	15	16	18
Passenger Traffic (billion passenger-kilometers)					
Total	*2,360*	*2,631*	*3,207*	*3,345*	*3,421*
Private Automobile	1,947	2,108	2,571	2,695	2,764
Air- Public Carrier	352	467	578	591	595
Bus	43	39	37	39	37
Railroads	18	18	21	23	23

Figure 8-2. Proportional Distribution of Freight Traffic by Mode: 1993

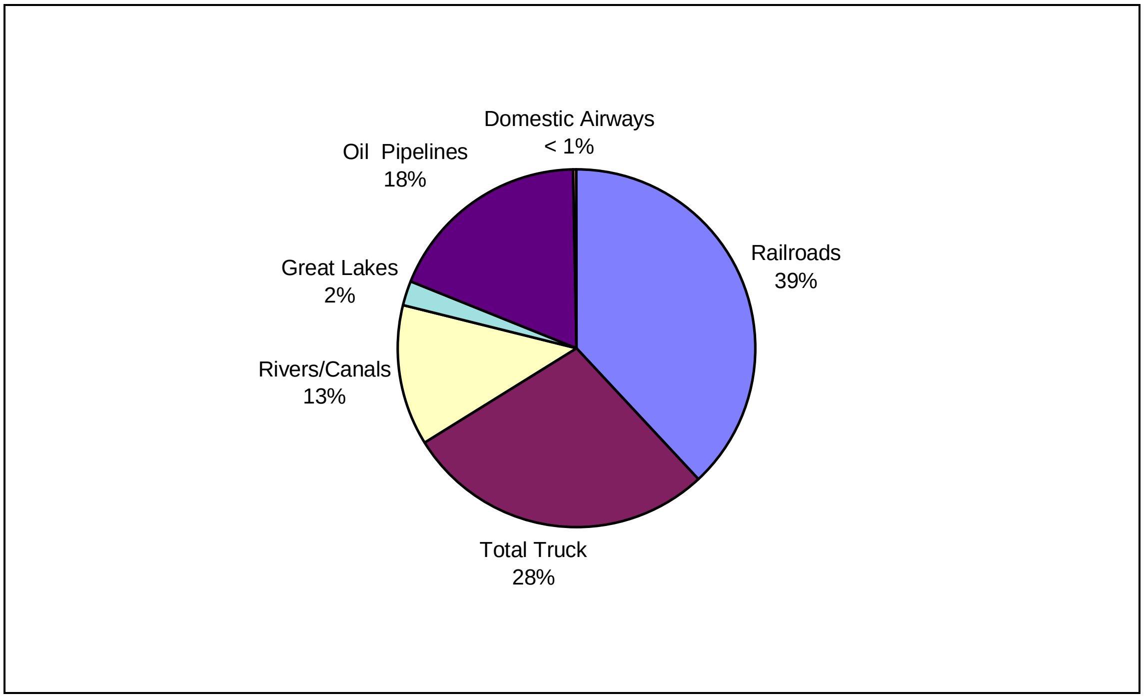
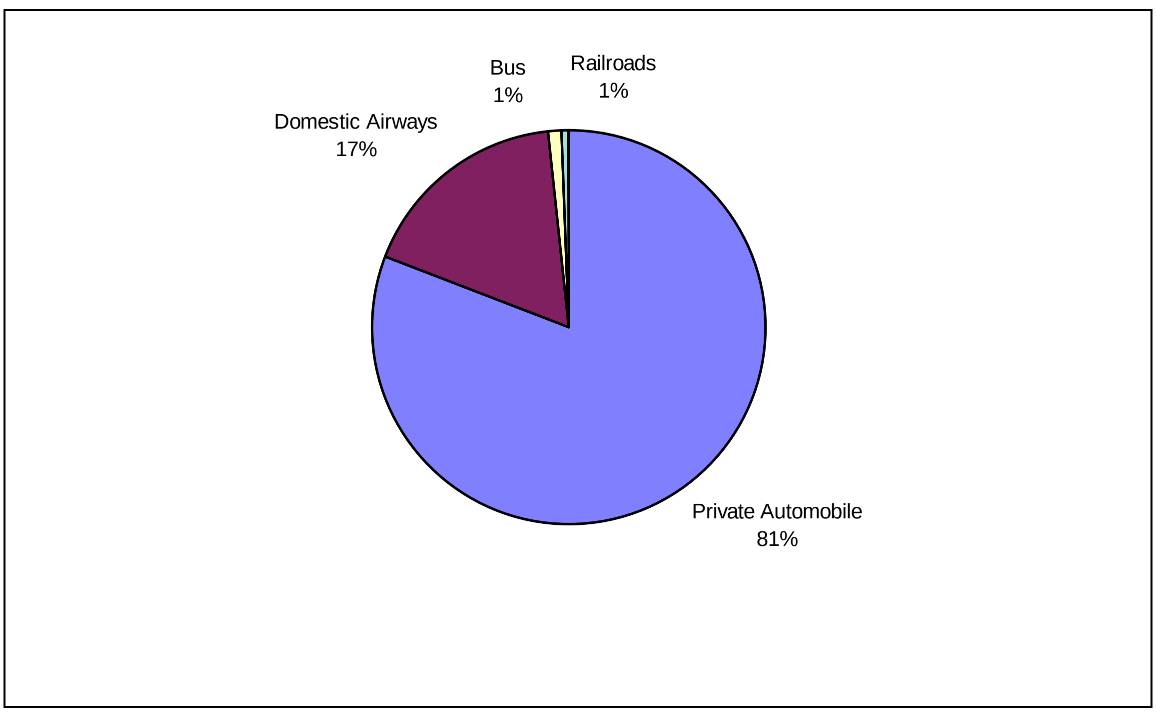


Figure 8-3. Proportional Distribution of Passenger Traffic by Mode: 1993



8.1.2.2 General Overview of Highway Transportation

The most widely used form of transportation in the US is the highway. It includes the highway infrastructure, composed of roads, streets and bridges, traffic control devices and additional facilities, as well as vehicles and drivers, and other highways-related services. This section will deal only with highway infrastructure, as issues relating to operations, maintenance, and energy costs of vehicles and their users are considered beyond the scope of this document.

The highway network comprises 6.3 million kilometers (3.9 million miles) of public roads, which are operated primarily by state and local governments. The total size of the US highway system has been relatively stable for many years (in 1980, total mileage was 6.43 million kilometers (3.995 million miles), in 1994, it had fallen slightly to 6.29 million kilometers (3.906 million miles)). The US also has a substantial private road mileage, but data to describe its extent and variety are lacking. The public road network is classified according to the traffic functions the roads are intended to serve. The functional types identified in this section are as follows:

- Interstates, Freeways, and Expressways
- Arterials
- Collectors, and
- Local Roads

Figure 8-4. Total Highway Mileage by Functional Type: 1993

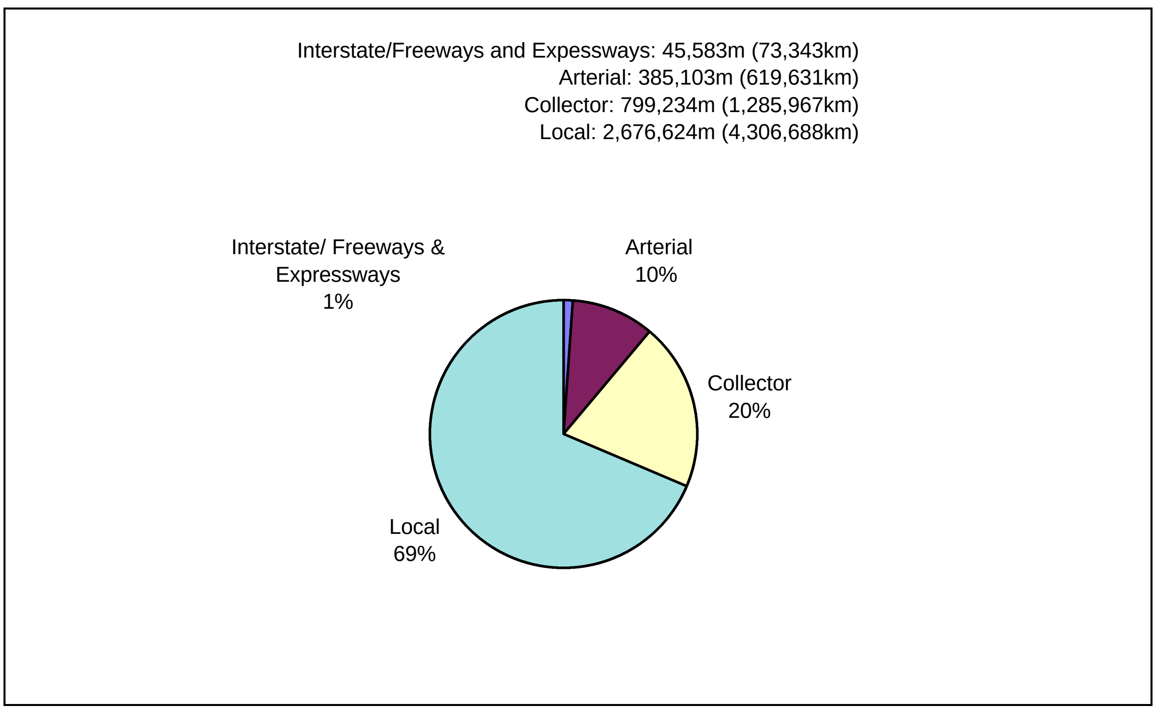
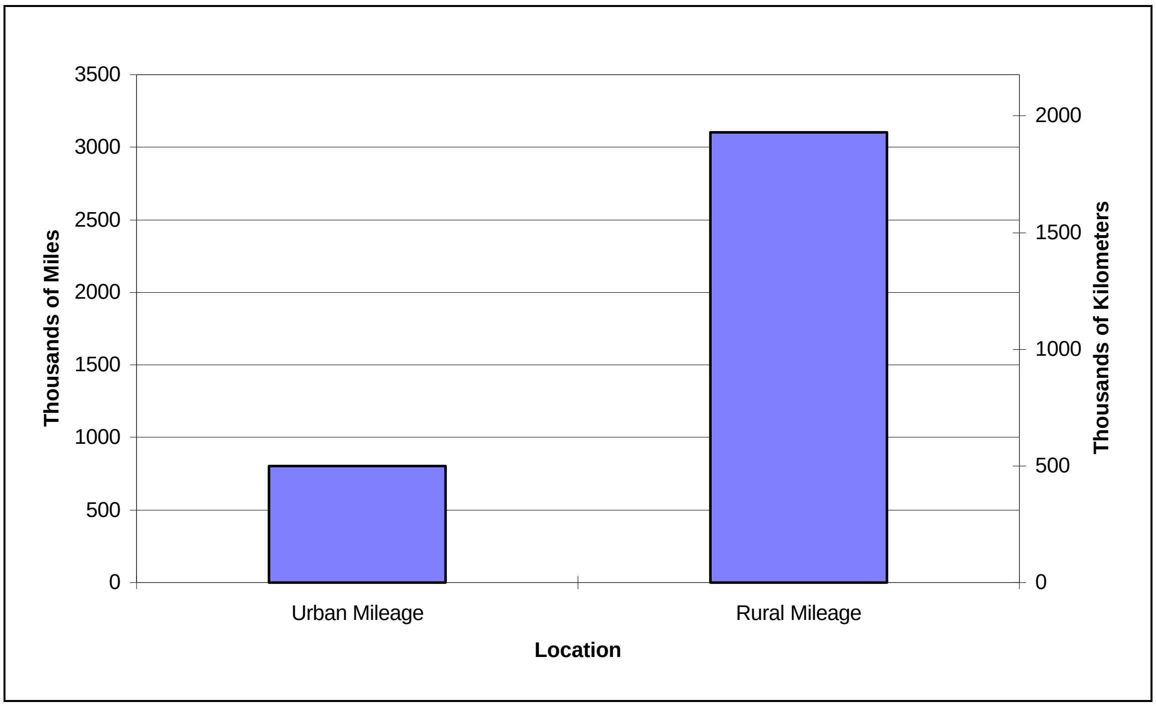


Figure 8-4, which is based upon data from the *1996 Statistical Abstract,* shows the relative proportions of each of these functional types of roads. Local roads represent the largest proportion of the highway network. Figure 8-5, which is also based upon data from the *1996 Statistical Abstract*, shows how total highway mileage is distributed between urban and rural areas. Reference to the figure indicates that rural roads account for about 80 percent of total mileage. However, if these figures are compared with vehicle usage, in terms of vehicles miles of travel, a different pattern emerges. Urban vehicle miles account for about 60 percent of total vehicle miles. In addition, only about 13 percent of total annual vehicle miles take place on local roads; approximately 71 percent take place on arterials and Interstates, with about one-third of this total on Interstates alone.

Figure 8-5. Total Highway Mileage by Geographic Location: 1993



While the federal government plays an important role in funding and managing US highways, state and local governments control almost all of the roads and bridges in the US. This is shown graphically in Figure 8-6, which shows how total highway mileage was distributed by jurisdiction in 1993. A more detailed breakdown of highway mileage by jurisdiction in 1994, for urban highway mileage, and for rural highway mileage, is shown in Figure 8-7 and Figure 8-8 respectively, which are based upon data from *Highway Statistics, 1994.* Reference to Figure 8-7 shows that 70 percent of total urban mileage was under local control, 11 percent was under state control, 19 percent was not classified by system, and less than one percent was under federal control. A very similar picture merges for rural highway mileage jurisdiction, as shown in Figure 8-8.

Figure 8-6. Total Highway Mileage by Jurisdiction: 1993

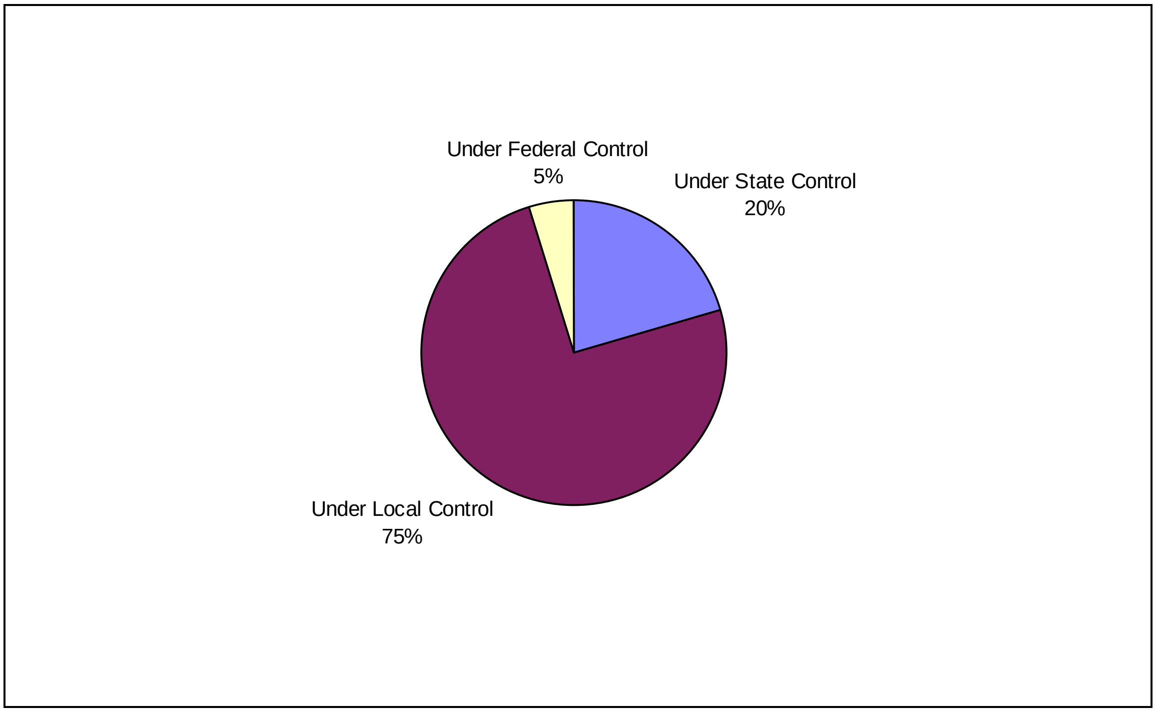


Figure 8-7. Urban Highway Mileage by Jurisdiction: 1994

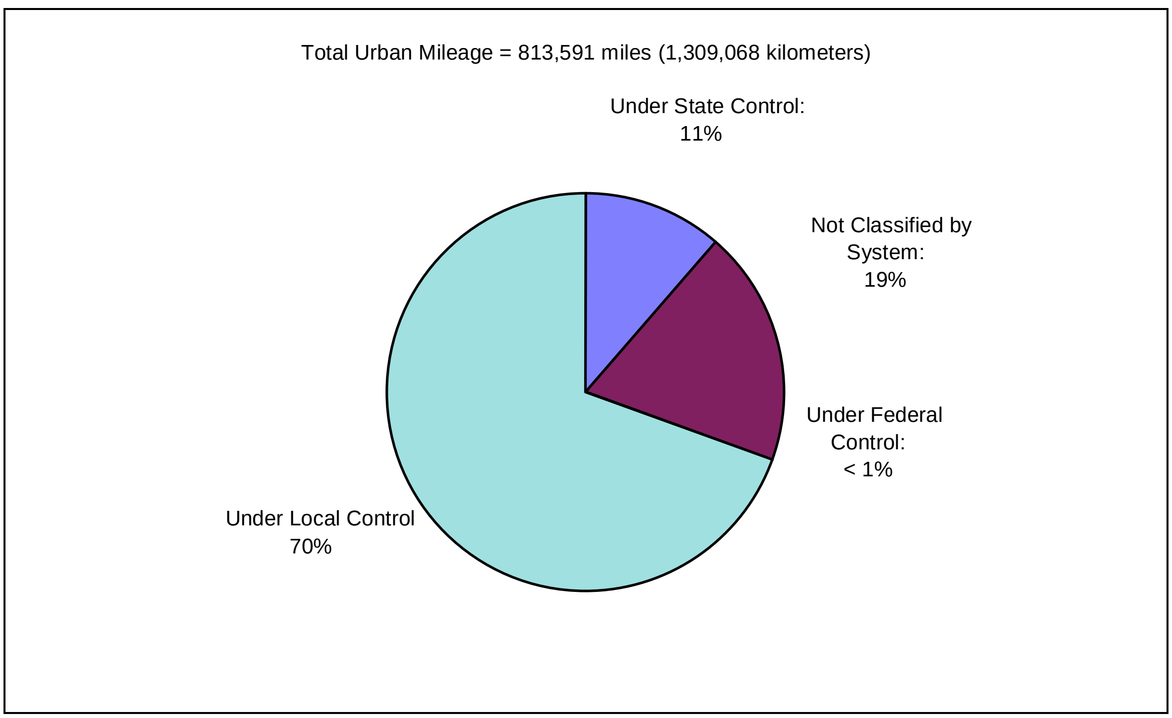


Figure 8-8. Rural Highway Mileage by Jurisdiction: 1994

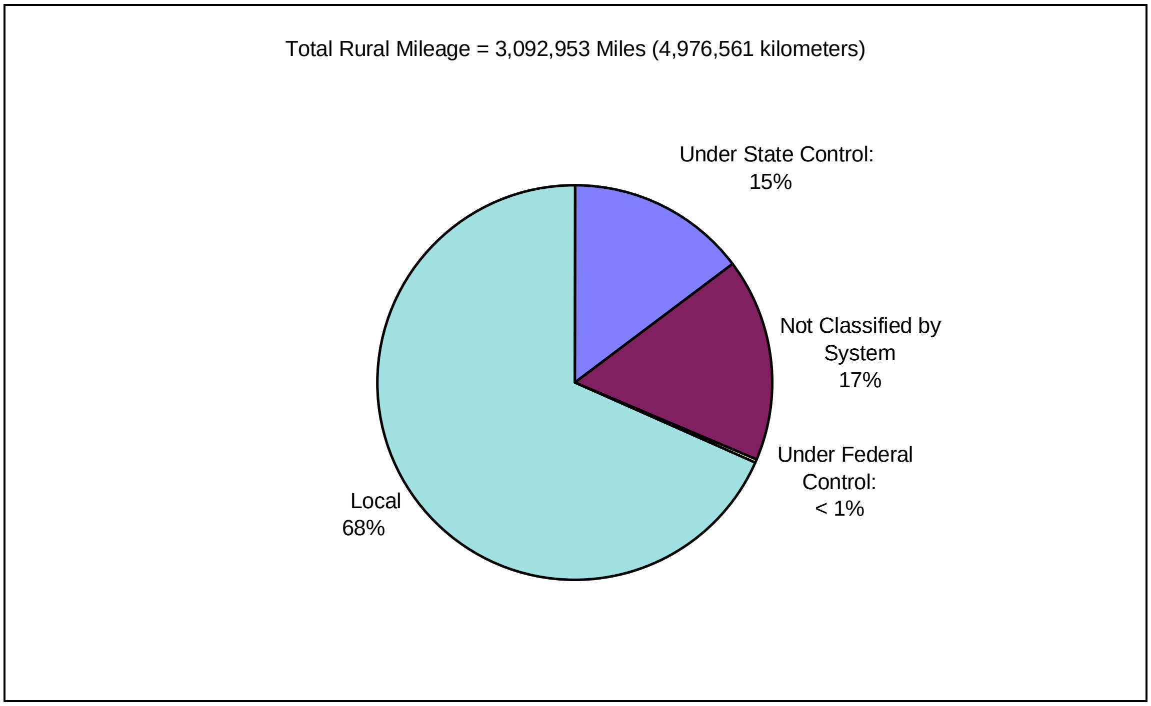


Figure 8-9 and Figure 8-10 show road mileage by functional type for state and locally administered roads in rural areas. The source data from *Highway Statistics, 1994* (which is compiled from reports by State Authorities) are shown in Table 8-4 Part A and Part B.

Comparison of the two figures shows that state authorities control a much higher mileage of Interstates and arterial compared with local authorities, which control no Interstates. Both authorities control similar total mileages of collector roads. However, local authorities control over ten times the mileage of local roads compared with state authorities.

Figure 8-11 and Figure 8-12 show similar information for urban highway mileage. Once again, state authorities have control for more Interstates and arterial than local authorities, who predominantly control local roads.

In Figure 8-13 and Figure 8-14, which are also based upon data from *Highway Statistics, 1994*, the number of bridges greater than or equal to 6.1 meters (20 feet) is shown by functional type for rural and urban areas respectively. Of the 577,481 bridges in the US with spans greater than or equal to 6.1 meters (20 feet), approximately 80 percent are in rural areas; with 45 percent of these on local roads, and 33 percent of the remainder on collectors. In comparison, urban bridges are more evenly distributed between the different types of functional system.

Figure 8-9. State Highway Administered Roads in Rural Areas - Mileage by Functional Type: 1994

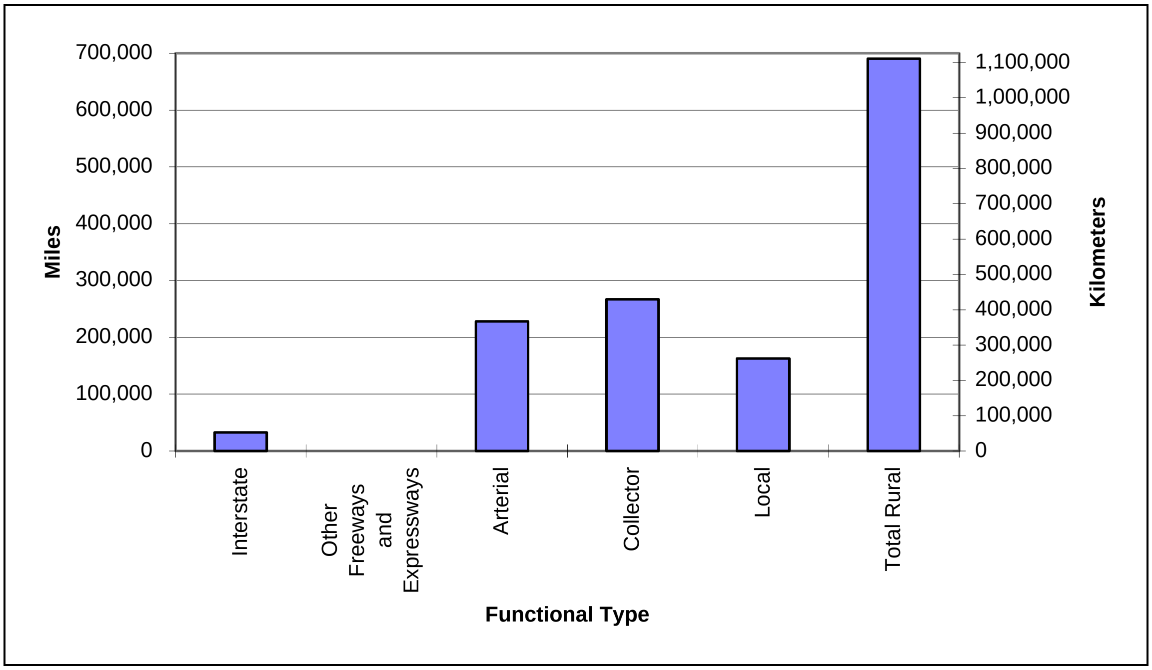


Figure 8-10. Locally Administered Roads in Rural Areas - Mileage by Functional Type: 1994

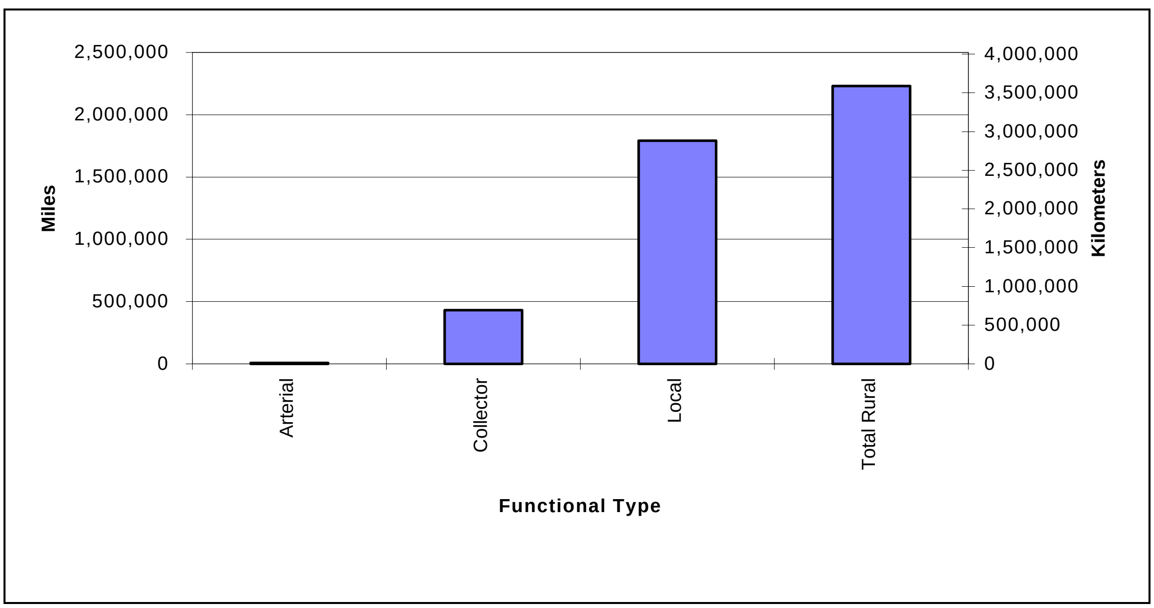


Table 8-4. Highway Mileage by Functional System, Jurisdiction, and Location: 1994

Part A: Miles

	URBAN				
JURISDICTION	Interstate	Other Freeways and Expressways	Principal Arterial	Minor Arterial	Total Arterial
State	13,126	8,532	36,431	24,489	60,920
Local	-	400	16,576	63,244	79,820
Federal	-	63	83	119	202
	Major Collector	Minor Collector	Total Collector	Local	**Total Urban**
State	10,394		10,394	17,042	**110,014**
Local	75,644		75,644	546,231	**702,095**
Federal	60		60	1,157	**1,482**
	RURAL				
	Interstate	Other Freeways and Expressways	Principal Arterial	Minor Arterial	Total Arterial
State	32,457	-	96,308	131,525	227,833
Local	-	-	514	5,156	5,670
Federal	-	-	173	1,490	1,663
	Major Collector	Minor Collector	Total Collector	Local	**Total Rural**
State	198,614	68,568	267,182	162,899	**690,371**
Local	227,709	203,398	431,107	1,792,176	**2,228,953**
Federal	4,788	10,059	14,847	157,119	**173,629**

Part B: Kilometers

	URBAN				
JURISDICTION	Interstate	Other Freeways and Expressways	Principal Arterial	Minor Arterial	Total Arterial
State	21,124	13,731	58,630	39,411	98,041
Local	-	644	26,676	101,781	128,458
Federal	-	101	134	192	325
	Major Collector	Minor Collector	Total Collector	Local	**Total Urban**
State	16,728		16,728	27,426	**177,050**
Local	121,737		121,737	879,074	**1,129,912**
Federal	97		97	1,862	**2,385**
	RURAL				
	Interstate	Other Freeways and Expressways	Principal Arterial	Minor Arterial	Total Arterial
State	52,234	-	154,993	211,669	366,662
Local	-	-	827	8,298	9,125
Federal	-	-	278	2,398	2,676
	Major Collector	Minor Collector	Total Collector	Local	**Total Rural**
State	319,638	110,349	429,988	262,161	**1,111,044**
Local	366,462	327,337	693,799	2,884,228	**3,587,152**
Federal	7,706	16,188	23,894	252,859	**279,429**

Figure 8-11. State Highway Administered Roads in Urban Areas - Mileage by Functional Type: 1994

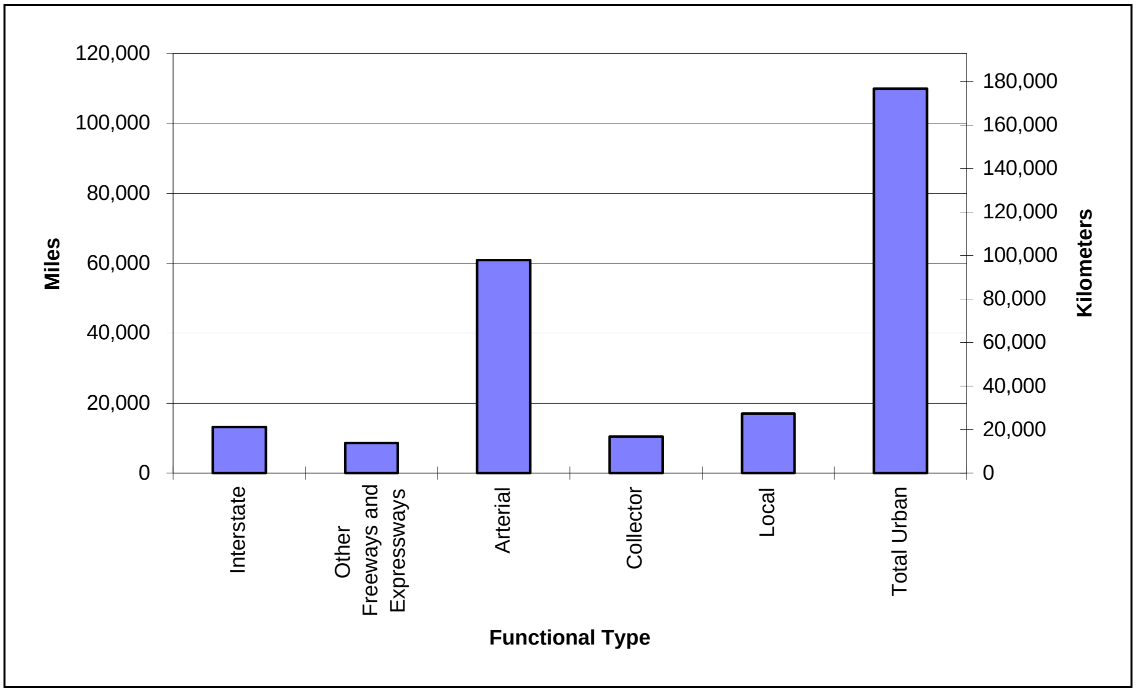


Figure 8-12. Locally Administered Roads in Urban Areas - Mileage by Functional Type: 1994

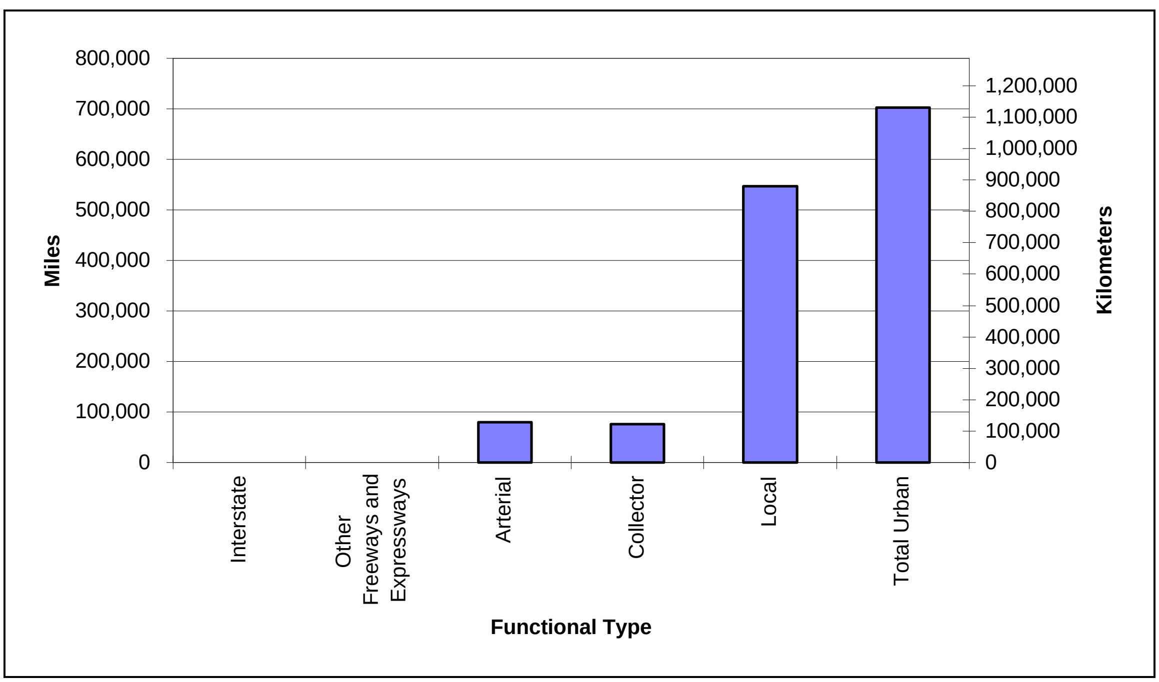


Figure 8-13. Number of Rural Bridges Greater Than or Equal to 20 Feet: 1994

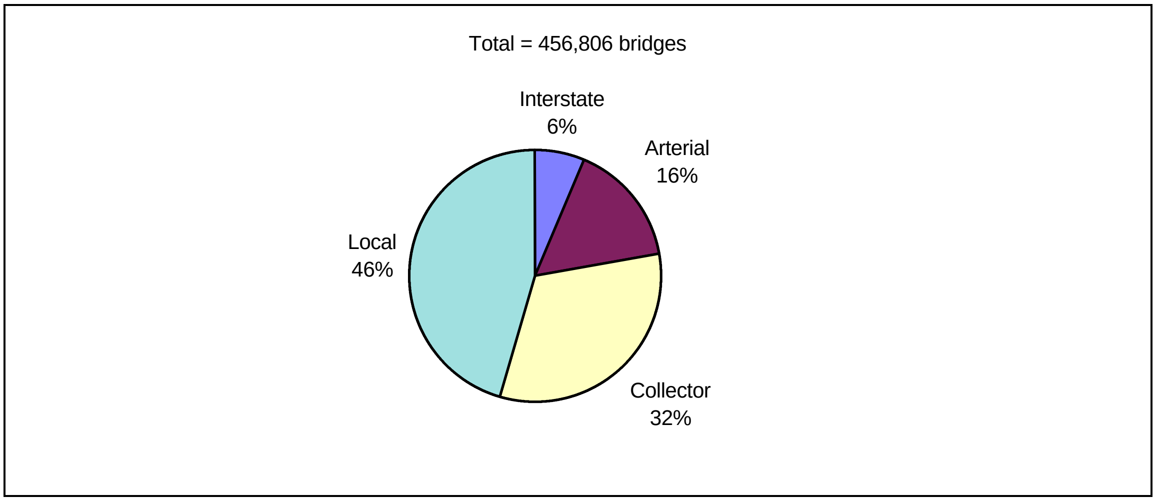
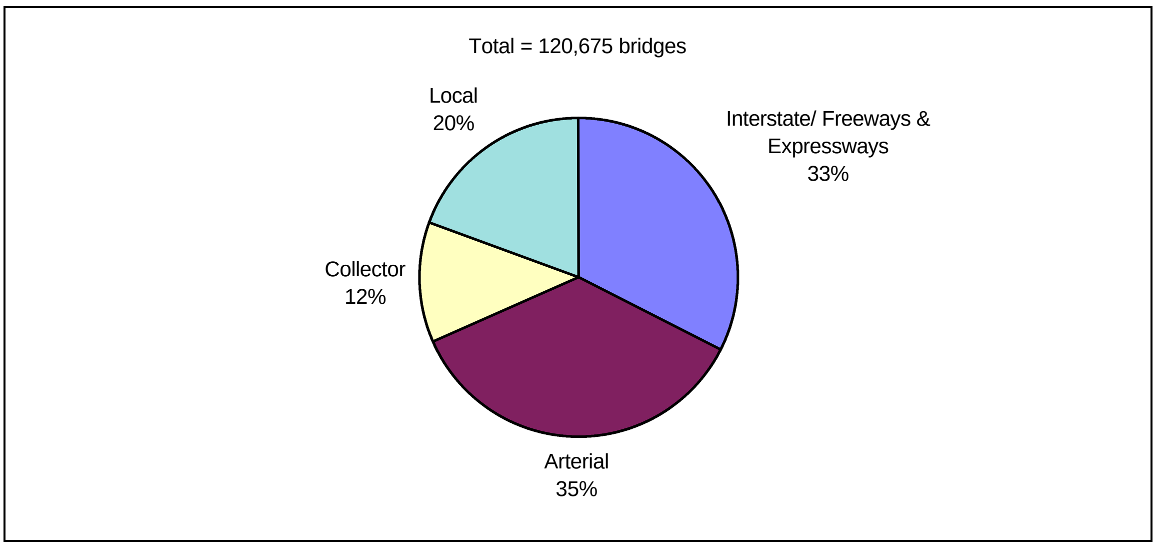


Figure 8-14. Number of Urban Bridges Greater Than or Equal to 20 Feet: 1994



Figures 8-15 through 8-18 show how pavement type and condition varied for rural and urban areas in 1995. Reference to Figure 8-15, which shows rural pavement type, shows that approximately 90 percent of all rural roads were surfaced (an increase of approximately 10 percent over the previous ten years), but that of this total, approximately one-third had a gravel or stone surfacing. Flexible pavements dominated the higher service level categories, with rigid pavements representing only 3.4 percent of total paved rural mileage. Figure 8-16 which shows urban pavement type, indicates that less than 20 percent of urban roads had gravel, stone or unpaved surfaces, and that the majority of roads had an intermediate or high service level surfacing. There was a higher proportion of rigid pavements in urban areas compared with rural areas.

Figure 8-15. Rural Pavement Type: 1994

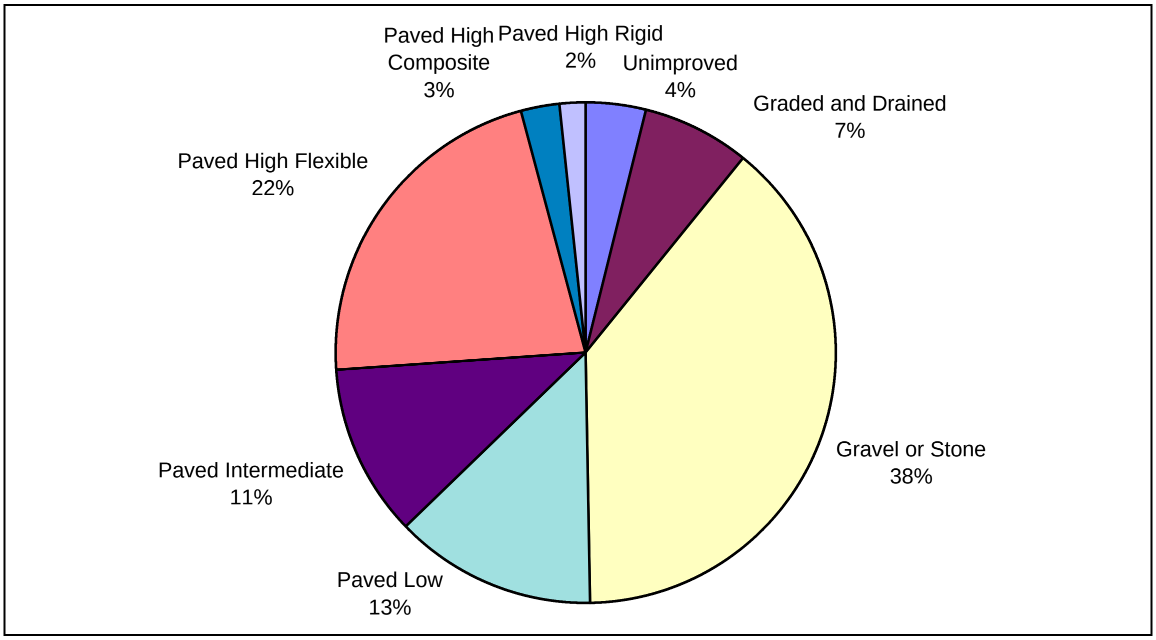
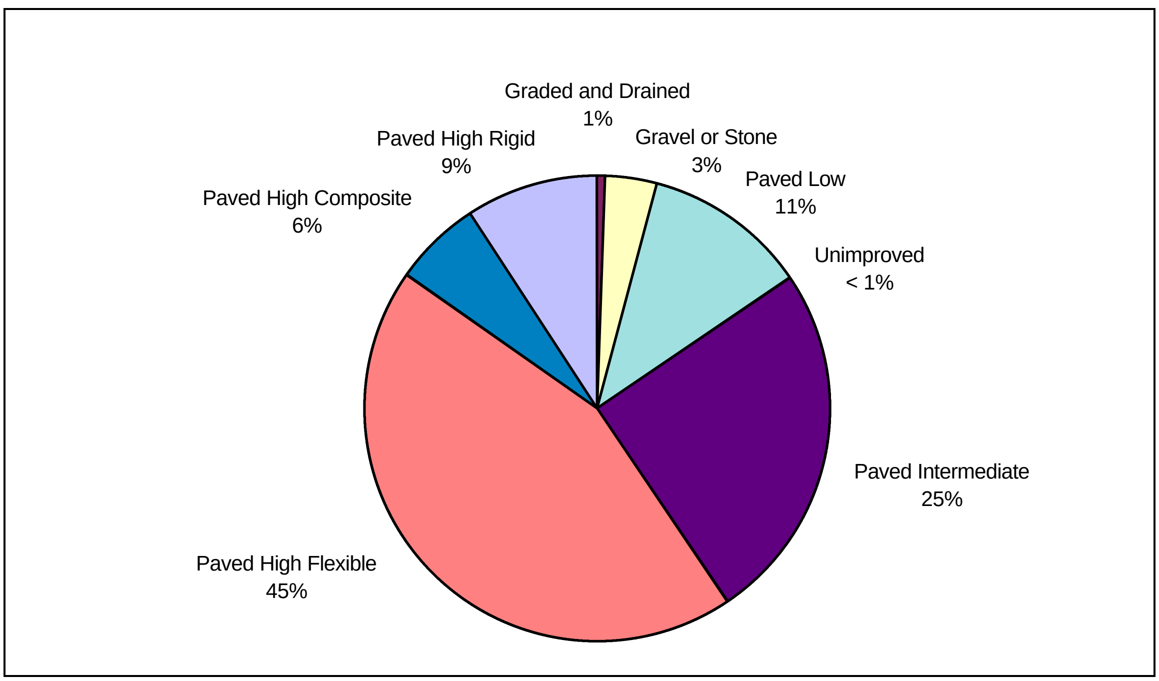


Figure 8-16. Urban Pavement Type: 1994



Highway pavement condition has been shown to have an effect upon vehicle operating costs, and is thus an important factor when assessing highway performance. Data from the publication *Characteristics of Urban Transportation System, Chapter 4, Table 4-9* indicate that the operating cost factor for a vehicle may vary by as much as 50 percent depending upon the condition of the pavement along which it is traveling.

An extract from the *Transportation Statistics Annual Report 1995*, indicates that:

"to maintain current highway conditions and performance, the FHWA estimates that over 161,000 kilometers (100,000 miles) of highway and 11,000 bridges require some degree of capital investment. In recent years, pavement conditions have been improving, congestion has been worsening slightly, and bridge conditions have stabilized".

The *1996 Annual Report* expands upon this, noting that:

"between 1983 and 1991, highway pavement conditions improved as measured by the Present Serviceability Rating. For example, the percentage of urban Interstates in poor or mediocre condition dropped from 32.9 percent in 1983 to 23.2 percent in 1991. The corresponding drop for rural Interstates is 27.1 to 23.2 percent."

And also that:

"*bridge conditions have improved over the past few years. The number of deficient bridges on Interstates, arterials, and collectors have all decreased between 1990 and 1994. Approximately one-quarter of these bridges are still deficient"* (see Table 8-5 for details).

Table 8-5. Bridge Conditions by Functional System: 1990 and 1994

Functional System	**1990**	**1994**
Interstate Bridges	**53,183**	**54,726**
Number Deficient	15,208	13,262
Other Arterial Bridges	**124,615**	**129,465**
Number Deficient	39,492	36,199
Collector Bridges	**164,300**	**162,314**
Number Deficient	56,662	45,330

Note: Deficient Bridges include structurally deficient bridges, and functionally deficient bridges

Figure 8-17 and Figure 8-18 show pavement condition in 1994 by functional system for rural and urban roads respectively.

Figure 8-17. Rural Pavement Condition by Functional System: 1994

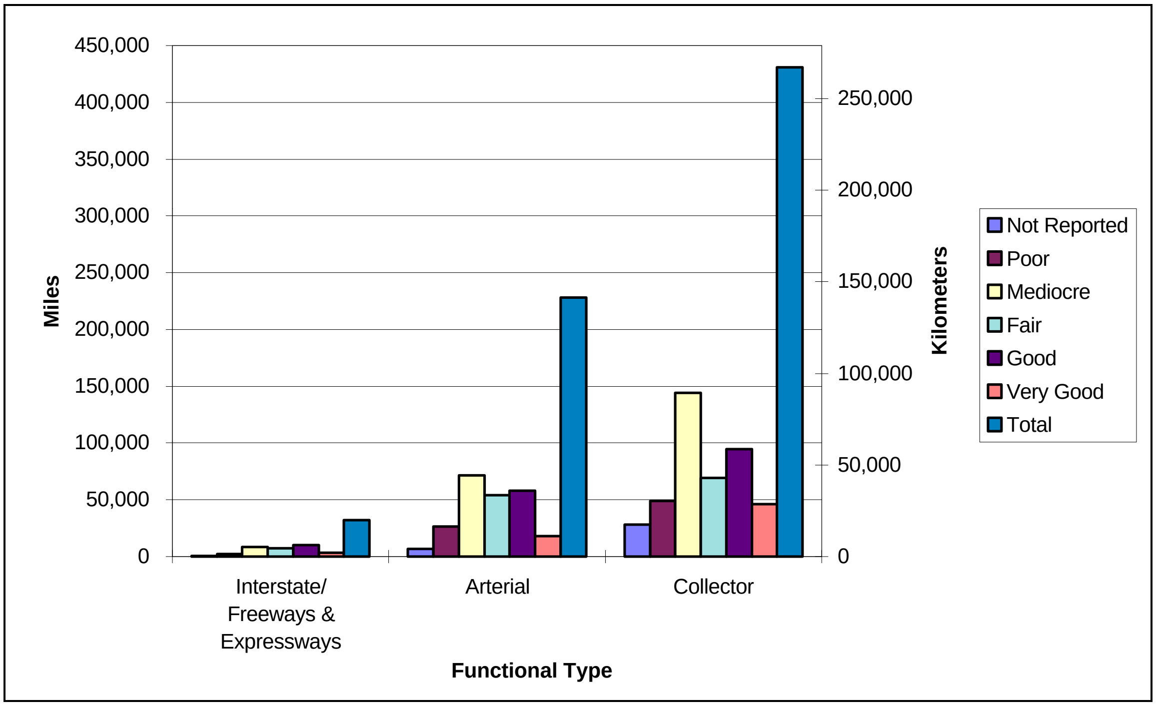
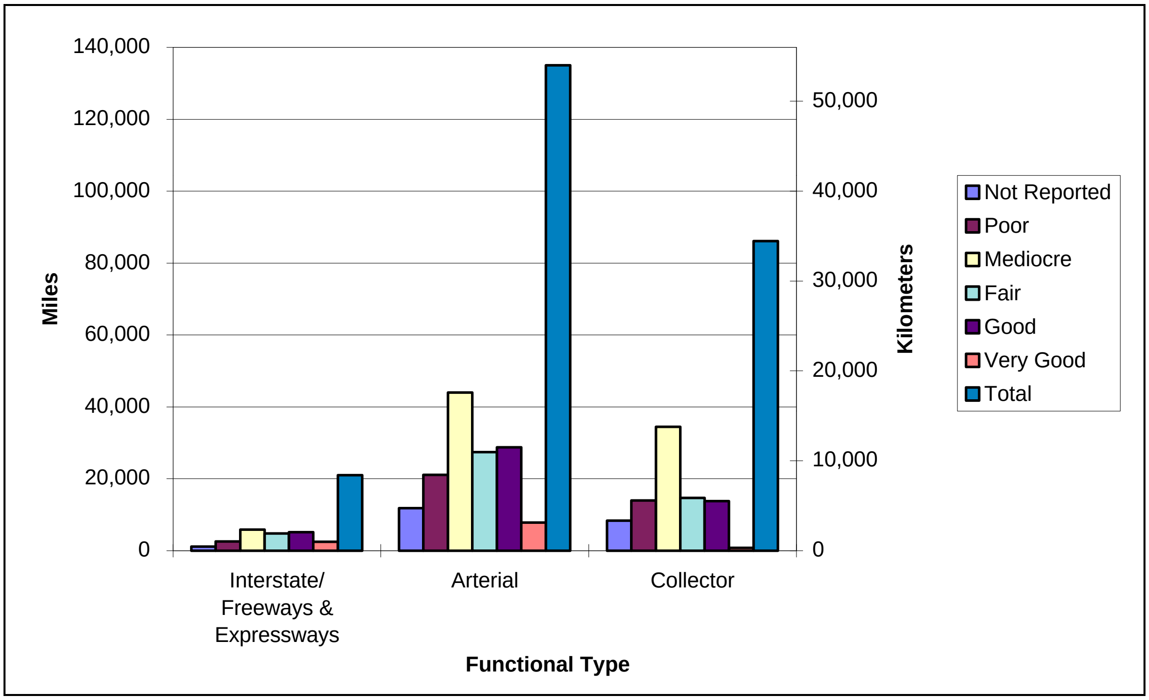


Figure 8-18. Urban Pavement Condition by Functional System: 1994



Finally, Figure 8-19 shows how prices for selected highway construction activities have varied between 1980 and 1994. Reference to the figure indicates that most highway construction costs are rising. Further details are available in the FHWA publication *Price Trends for Federal-aid Highway Construction*, prepared by the Federal-aid and Design Division, Office of Engineering.

Table 8-6, which is reproduced from the publication *Characteristics of Urban Transportation Systems* shows selected highway improvement costs in urban areas in thousands of 1989 dollars per lane mile.

Figure 8-19. Prices for Selected Federal Highway Construction Activities: 1980 to 1994

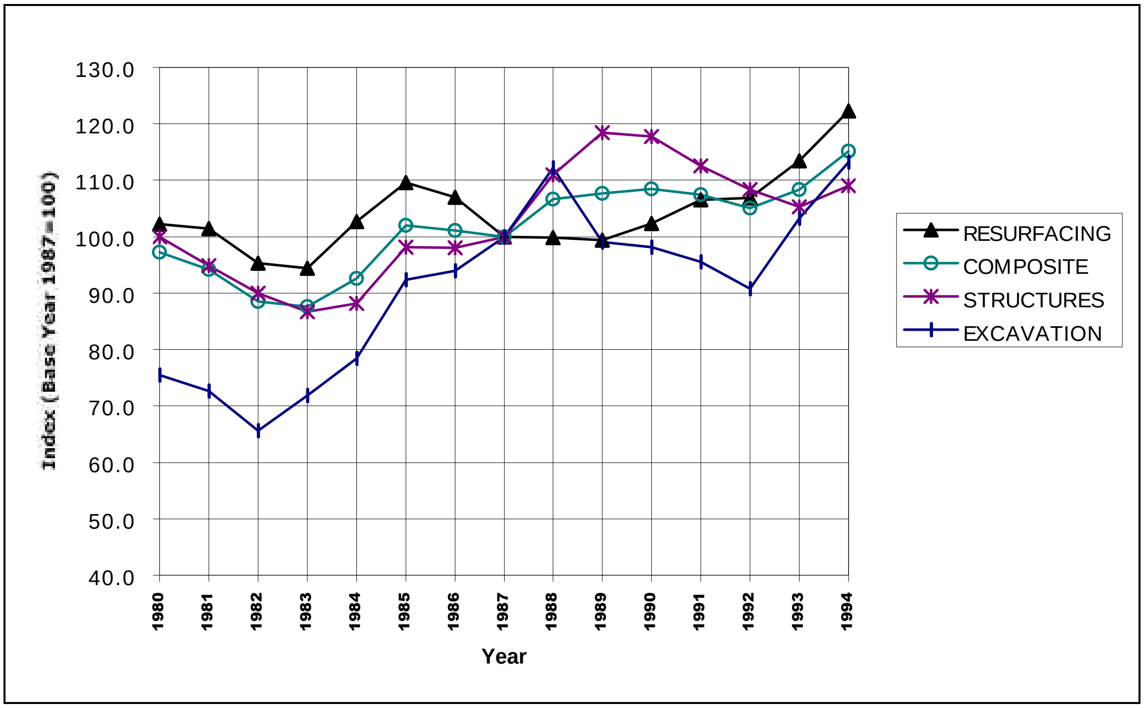


Table 8-6. Highway Improvement Costs in Urban Areas: 1989

Highway Improvement Costs in Thousands of 1989 Dollars per Lane Mile		
FACILITY/IMPROVEMENT TYPE	**BUILT-UP AREAS**	**OUTLYING AREAS**
Freeways and Expressways		
Reconstruction with More Lanes	2,283	1,720
Reconstruction with Wider Lanes	1,676	1,210
Pavement Reconstruction	1,171	1,055
Major Widening	935	750
Minor Widening	676	519
Resurfacing with Shoulder Improvement	319	279
Resurfacing	139	128
Other Divided Highways		
Reconstruction with More Lanes	2,056	1,548
Reconstruction with Wider Lanes	1,510	1,089
Pavement Reconstruction	1,058	950
Major Widening	842	676
Minor Widening	608	466
Resurfacing with Shoulder Improvement	288	252
Resurfacing	126	114
Undivided Highways		
Reconstruction with More Lanes	1,850	1,393
Reconstruction with Wider Lanes	1,359	980
Pavement Reconstruction	954	856
Major Widening	757	608
Minor Widening	547	420
Resurfacing with Shoulder Improvement	260	226
Resurfacing	113	104
Note: Improvement Costs include Right-of-Way		

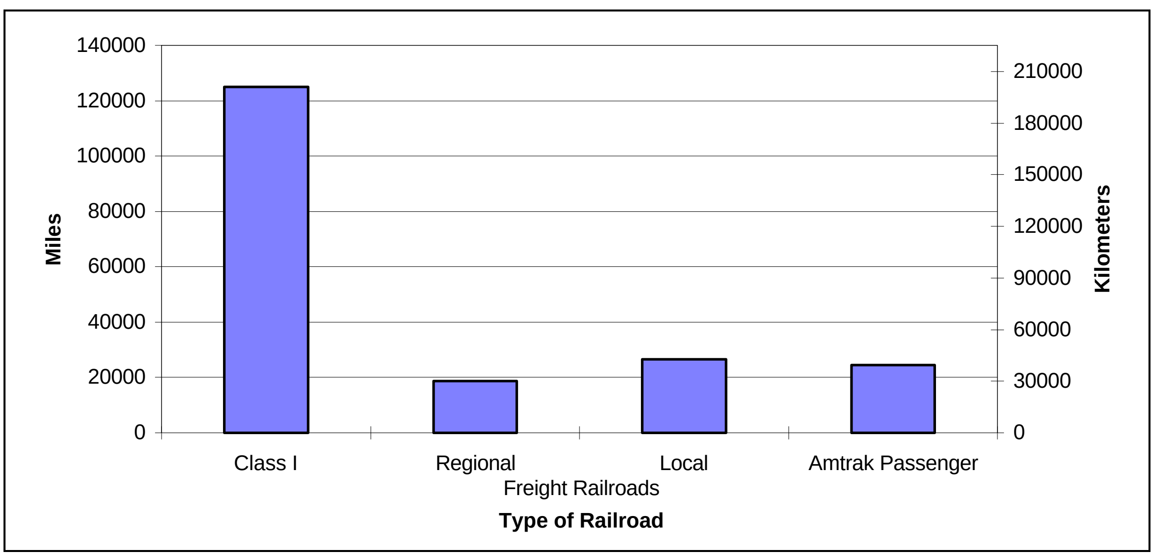
8.1.2.3 General Overview of Railroad Transportation

The elements of the US rail system comprise rail tracks, operating equipment, and the additional capital and human resources necessary to produce freight and passenger services. This document focuses only upon rail track and associated infrastructure. For-hire rail freight is provided by a number of freight rail lines, and passenger service is the responsibility primarily of Amtrak. Other rail-related railroads services are classified under "transit" in this document. Railroads are not classified functionally, as are highways, but an approximate equivalent is found in terms of the main-line, secondary-main, and branch line classifications. However, these rail terms are not precise, and no time-series figures report changes in the extent of facilities for each category. The Association of American Railroads (AAR) uses the following definitions for freight railroads:

- Class I Railroads (as of January 1997, there were 9 Class I railroads in the US, which are defined as any railroad having an annual operating revenue of at least $255.9 million)
- Regional Railroads
- Local Railroads

Class I railroads account for 73 percent of the nations rail mileage, and 91 percent of freight railroad revenue. In 1995, there were 201,241 kilometers (125,072 miles) of Class I railroads operated (this excludes multiple main tracks, yard tracks, and sidings), 30,273 kilometers (18,815 miles) of regional railroad, 42,713 kilometers (26,546 miles) of local railroad, and 39,421 kilometers (24,500 miles) of Amtrak railroad. There were 530 local and regional railroad carriers. This information is presented graphically in Figure 8-20.

Figure 8-20. Railroads Operated in 1995 by Type



Information about Class I railroads is quite extensive, and is used to develop the baseline measures for the rail sub sector. Information for smaller railroads is much more limited.

8.1.2.4 General Overview of Transit Transportation

In this document, transit is defined as encompassing commuter trains, heavy-rail (rapid rail) and light-rail (streetcar) transit systems, local transit buses, vans and other vehicles, and ferry boats. Most transit agencies that provide commuter rail service contract with private railroads or Amtrak to operate the service. Passenger use is split about equally between rail and non-rail systems. The operation of transit systems is overseen by public transit authorities. About 2,250 public agencies provided transit services in US cities of which approximately 6 percent operate one or more forms of rail mass transit. Many of the largest cities received service from several transit operators.

Capital expenses are moneys paid for transit infrastructure and its planning, design, land acquisition, and related costs. Data from the American Public Transit Association show that in 1995, 25 percent of the $7.0 billion total was allotted for vehicles, 53 percent for facilities, and 22 percent for equipment and services. 36 percent was spent on heavy rail, 26 percent on bus, 24 percent on commuter rail, 10 percent on light rail, and the remainder on other modes.

Operating expenses in 1995 were $18.1 billion. Bus accounted for 58 percent, heavy rail for 19.5 percent, commuter rail for 12 percent, demand response[30] for 6 percent, light rail for 2 percent, and other modes for 2.5 percent. About ten percent of operating expenses were devoted to primary facilities maintenance. This figure has varied between about eight and ten percent of total operating expenses between 1985 and 1995. This document focuses only upon infrastructure related operations, maintenance, and energy costs, and excludes vehicles/fleet operations costs.

8.1.2.5 General Overview of Air Transportation

The elements of the air transportation system are airports, air traffic control and navigation aids, aircraft, pilots and other personnel, and suppliers of air passenger and freight services. This document focuses only upon airports and the air traffic control system for the development of baseline measures.

Data from the publication *Transportation Statistics Annual Report 1997* indicate that in 1995 there were a total of 18,224 airports in the US (a decline from 18,343 in 1994, but a substantial increase from the 15,161 operated in 1980). Private-use airports constitute 70 percent of these airports, and 96 percent of all airports are used by general aviation aircraft. There were 5415 public-use airports in 1995.

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[30] Demand responsive transportation usually includes community transport and dial-a-ride services provided by voluntary or statutory organizations for the elderly or other mobility handicapped persons. The term demand responsive system means any system of providing designated public transportation which is not a fixed route system.

General aviation airports are usually rudimentary facilities; only about half have paved runways, and about one quarter have lighted runways. The number of civil certificated airports (serving air carrier operations with aircraft seating more than 30 passengers) is relatively stable at about 570. The majority of US airports are owned and operated by state and local public bodies. Several publicly owned US airports are operated by private bodies under a management contract. Table 8-7 shows the leading US airports in 1995 by passenger emplanements and cargo volume respectively.

Table 8-7. Leading US Airports: 1995

PASSENGERS (arriving and departing)			
Chicago O'Hare	67,254,586	Phoenix	27,820,144
Atlanta	57,734,755	Minneapolis/St Paul	26,782,915
Dallas Ft. Worth	54,298,930	Newark	26,566,948
Los Angeles	53,909,223	St. Louis	25,719,351
San Francisco	36,260,064	Boston	24,743,656
Miami	33,235,658	Houston	24,724,865
Denver	31,028,191	Honolulu	23,580,230
New York Kennedy	30,327,723	Seattle	22,790,920
Detroit	29,013,260	Orlando	22,365,503
Las Vegas	28,001,258	Charlotte	20,937,233
CARGO TONS (enplaned and deplaned)			
Memphis	1,712,066	San Francisco	697,802
Los Angeles	1,597,219	Dayton	632,658
Miami	1,584,680	Philadelphia	564,880
New York Kennedy	1,572,840	Oakland	541,776
Louisville	1,351,147	Indianapolis	520,965
Chicago O'Hare	1,235,806	Honolulu	412,866
Anchorage	987,484	Seattle	407,473
Newark	905,966	Boston	395,589
Atlanta	771,389	Denver	376,074
Dallas Ft. Worth	765,630	Minneapolis/St. Paul	365,194

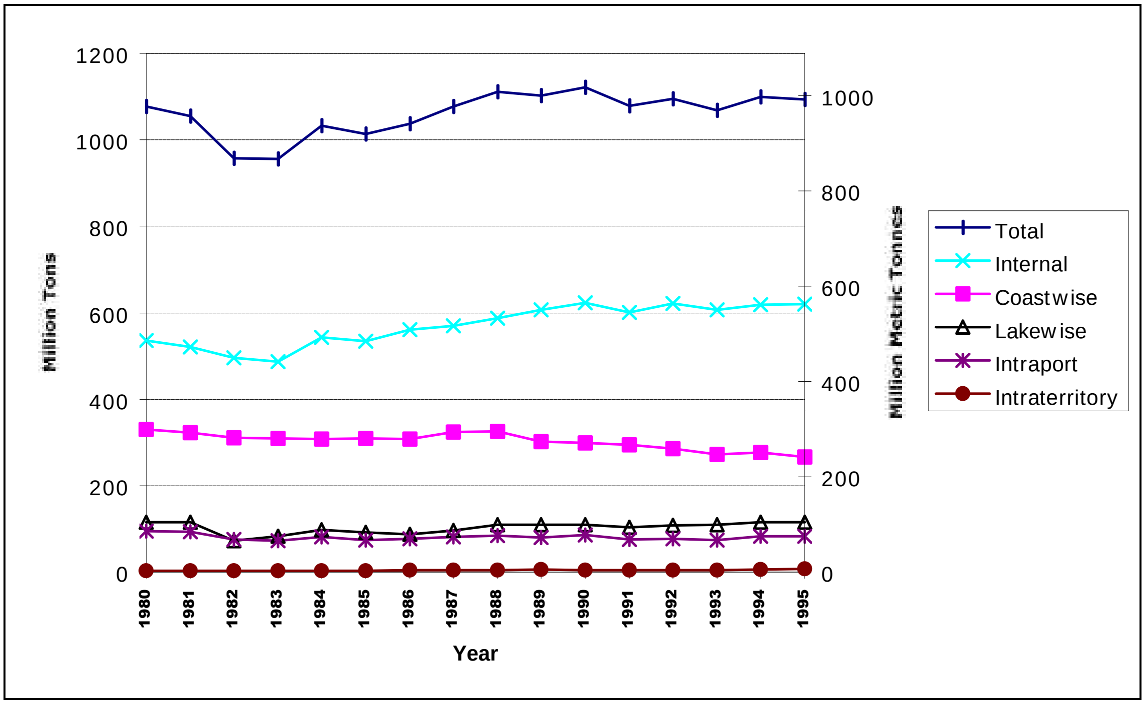
The National Airspace System (NAS), which is operated by the Federal Aviation Administration, comprises over 32,000 facilities and pieces of equipment, including air traffic control equipment, navigation and landing aids, automation systems, communications equipment, and FAA plant facilities. Operations funding for the NAS for FY1996 was $862,595,000, an increase of 2.7 percent from FY1995.[31]

[31] Source: Management Advisory Memorandum on Resource Requirement Planning for Operating and Maintaining the NAS, FAA Report Number AS-FA-7-004 Jan 1997.

8.1.2.6 General Overview of Water Transportation

Water transportation includes domestic movements on the inland waterways, the Great Lakes, and along the coast, as well as between the contiguous 48 states and Alaska, Hawaii, Guam, Puerto Rico, and the Virgin Islands. Water transport also encompasses international ocean shipments. Facilities include harbors and ports, channels, navigation aids, piers, wharves, cargo handling equipment, locks and dams, and storage facilities, as well as vessels of various types. This document focuses upon ports, waterways, and associated infrastructure for the development of baseline measures. Figure 8-21, which is based upon data from the US Army Corps of Engineers, shows the relative proportion of domestic waterborne commerce by type of traffic between 1980 and 1995. Reference to the figure indicates that internal commerce[32] represented about 56 percent of all freight movements in 1995, and that total freight moved by water increased by 12 percent in this time.

Figure 8-21. Domestic Waterborne Traffic by Type of Traffic: 1980 to 1995



Data from the *Transportation Statistics Annual Report 1997* indicate that in 1995 there were 362 terminals on the Great Lakes with 507 berths, 1,811 inland terminals, and 1,578 ocean terminals with 2,672 berths. Of the 19,540 public and private deep-draft terminals at ocean and Great Lakes ports, approximately 75 percent were privately owned. General

[32] Internal commerce comprises all freight which is moved within the continental US via waterways excluding coastal movements, Great Lake movements, and intraport/territory movements.

cargo berths made up 38 percent of all berths (e.g. for coal, grain, and ore) liquid berths made up 20 percent (e.g. for crude and refined petroleum) and passenger berths accounted for 3 percent. The remaining 18 percent were classified as other (e.g. berths for barges, mooring, or inactive). Table 8-8, which is based upon data from the US Maritime Administration, summarizes US seaport terminals and berths by coastal region. Inland waterway ports and terminals generally have shallower water depths (4.3 meters/14 feet or less) and can be located on the 25,000 miles of navigable inland waterways and intracoastal waterways, providing more flexibility than coastal ports. In 1995, there were about 1,800 river terminals in 21 states, of which about 89 percent were privately owned. Of these terminals, approximately 4 percent were for general cargo, 58 percent were for dry bulk cargo, 27 percent were for liquid bulk cargo, and 11 percent were multipurpose. Data for US inland/riverport terminals are shown in Table 8-9, which is based upon data from the US Maritime Administration.

Table 8-8. Summary of U.S. Seaport Terminals and Berths by Coastal Region

Coastal Region	Number of Terminals	Percent of Total	Number of Berths	Percent of Total
North Atlantic	417	21.5%	756	23.8%
South Atlantic	187	9.6%	343	10.8%
Gulf	493	25.4%	790	24.9%
South Pacific	221	11.4%	405	12.7%
North Pacific	260	13.4%	378	11.9%
Great Lakes	362	18.7%	507	15.9%
Total	1,940	100.0%	3,179	100.0%

The US Army Corps of Engineers operates/maintains approximately 19,312 kilometers (12,000 miles) of commercial shallow draft navigation channels. In 1996 the number of locks owned and operated by USACE was 275. Of these, 61 percent were opened before 1960, and 9 percent were over 100 years old. The primary element of navigation channel maintenance is associated with dredging.

Table 8-9. US Inland/Riverport Terminal Facilities by State

State	Number of Terminals	Number and Type of Facilities								
		General	Dry Bulk Cargo				Liquid Bulk Cargo			Multi-
		Cargo	Grain	Coal	Ore	Other	Petrol	LPG	Other	Purpose
Alabama	137	8	16	21	-	41	21	-	15	15
Arkansas	84	2	26	-	-	24	7	-	6	19
Illinois	262	9	62	19	1	59	43	-	35	34
Indiana	60	2	8	14	1	16	9	-	2	8
Iowa	81	1	18	6	-	20	11	-	9	16
Kansas	8	-	4	-	-	1	-	-	2	1
Kentucky	175	3	13	48	-	49	32	1	15	14
Louisiana	66	1	8	2	-	12	19	1	14	9
Minnesota	62	2	13	4	-	16	12	-	7	8
Mississippi	69	1	16	-	-	13	16	1	6	16
Missouri	135	2	23	6	-	59	17	-	16	12
Nebraska	17	1	7	-	-	4	-	-	4	1
Ohio	132	6	7	21	2	43	23	-	19	11
Oklahoma	27	3	5	-	-	9	4	-	2	4
Pennsylvania	145	9	-	41	2	49	18	-	18	8
Tennessee	129	6	21	7	1	47	23	-	12	12
West Virginia	149	9	-	47	1	52	21	1	15	3
Wisconsin	18	-	1	4	-	6	2	-	4	1
Mississippi System Sub-total	1756	65	248	240	8	520	278	4	201	192
Idaho	4	1	2	-	-	1	-	-	-	-
Oregon	17	1	7	-	-	4	-	-	2	3
Washington	34	7	16	-	-	2	2	-	3	4
Columbia/Snake Sub-total	55	9	25	0	0	7	2	0	5	7
Total	1811	74	273	240	8	527	280	4	206	199

Source: Maritime Administration

8.1.3 Overview of the Power Utilities Sub-Sector

This sub-sector is primarily concerned with the production of electricity, gas, or steam from the primary fuel sources. The **1992 Census of Transportation, Communications, and Utilities** provides limited information about the amount of construction activity carried out by establishments in SIC Code 49 (electric, gas, and sanitary services), as well as more detailed information about the size of establishments, revenues, and payroll costs.

Electric services (SIC 491) includes all establishments engaged in the generation, transmission, and/or distribution of electric energy for sale. Gas production and distribution (SIC 492) includes all establishments involved in the transmission and/or storage of natural gas for sale. Combination utility services (SIC 493) includes all establishments engaged in providing electric or gas services in combination with other services. The number of establishments in the sub-sector in 1992 is shown in Table 8-10 (note that component figures may not add up to totals due to some establishments not being operated in 1992).

Table 8-10. Number of Establishments in the Power Utilities Sub-Sector: 1992

NUMBER OF ESTABLISHMENTS BY EMPLOYMENT SIZE: 1992					
		Employment Size			
SIC Code	Total Establishments	*9 or Fewer Employees*	*10-49 Employees*	*50-99 Employees*	*100 or More Employees*
491 - Electric Services	5,374	1,687	2,139	669	793
492 - Gas Production and Distribution	3,968	1,689	1,535	282	317
493 - Combination Utility Services	1,814	502	568	267	429

Information from the EIA report *Natural Gas Monthly, April 1997*, provides a regional summary of natural gas interstate pipeline capacity and planned additions between 1995 and 2000. In 1995, the total pipeline capacity entering the US was 2,371 million cubic meters per day/83,746 million cubic feet per day, while the total pipeline capacity within the US was 8,153 million cubic meters per day (287,918 million cubic feet/day). Natural gas throughput in 1994 was about 1529 million cubic meters per day/54,000 million cubic feet per day (refer to the EIA source document for further details). Natural gas pipelines totaled 1,923,166 kilometers (1,195,000 miles) in 1994 (a slight decrease from 2,018,117 kilometers/1,254,000 miles in 1992). Distribution lines accounted for three-quarters of this total mileage; transmission, field, and gathering lines made up the remaining quarter. Since 1980, the total length of gas pipeline has increased by 24 percent, but transmission pipeline length has only increased three percent over this period. In 1994, there were 150 interstate natural gas pipeline companies employing about 187,000 people. Approximately 19 percent of natural gas pipelines were built before 1950. The effects of corrosion and erosion of pipes over time reduces their ability to support stress and higher pressures[33]. The number of gas pipeline failures was 216 in 1993, compared with a previous 4-year average of 210 cases per year.

All other pipelines are considered in the pipelines sub-sector.

8.1.4 Overview of the Water Sub-Sector

The extent of the water sub-sector comprises water storage, supply, treatment, and flood control. Water transportation and related activities, such as dredging, are considered in the transportation sub-sector.

Data presented in Chapters 3, 5, 6, and 7 provide information regarding the consumption of water in the residential, commercial, and industrial sectors. Data presented in this Chapter for the power utilities sub-sector provide information about water consumption for thermo-electric and hydo-electric power generation.

The **1992 Census of Transportation Communications and Utilities** provides limited information on the amount of construction activity carried out by establishments in SIC Code 4941 (water supply), and SIC Code 4952 (sewerage systems). SIC Code 4941 includes all establishments engaged in distributing water for sale for domestic, commercial, and industrial use. SIC Code 4952 includes all establishments engaged in the collection and disposal of wastes conducted through a sewer system, including such treatment processes as may be provided. The number of establishments in the sub-sector in 1992 is shown in Table 8-11 (note that component figures made not add up to totals due to some establishments not being operated in 1992).

Table 8-11. Number of Establishments in the Water Sub-Sector: 1992

NUMBER OF ESTABLISHMENTS BY EMPLOYMENT SIZE: 1992					
		Employment Size			
SIC Code	**Total Establishments**	*9 or Fewer Employees*	*10-49 Employees*	*50-99 Employees*	*100 or More Employees*
4952 - Sewerage Systems	470	331	75	7	
4941 - Water Supply	3,453	2,934	285	75	

The USACE provides historical information on expenditures for flood control and power projects in the US. This information is be used to develop baseline measures for operations and maintenance costs.

[33] US Department of Commerce. 1978. "*Effects of Metallic Corrosion in the United States.*" NBS Special Publication 511. Washington, DC: National Bureau of Standards. Further information about the economic effects of corrosion in the US is available at the National Association of Corrosion Engineers Internet site (URL:http://www.nace.org) .

The USACE manages 383 major lakes and reservoirs, with a total capacity of 483,778 million cubic meters (392.2 million acre-feet). These include 68 projects with authorized irrigation storage, and 118 projects with authorized municipal and industrial water supply storage. USACE is also responsible for 75 hydro-power projects with an installed generating capacity of 20,720 megawatts. In 1994, these generated 68.2 billion kWh, which represented about one-quarter of total US hydropower capacity, or 3 percent of total US electric capacity. In addition, 67 non-federal power plants are operated at Corps facilities, with a capacity of 1,957 megawatts. The Corps also manages 13,679 kilometers (8,500 miles) of levees in the US. Total flood control expenditures between 1928-1993 in current dollars were $34.7 billion.

8.1.5 Overview of the Pipelines Sub-Sector

The extent of this sub-sector comprises all pipelines for the transportation of petroleum and other commodities except natural gas (included in the power utilities sub-sector).

The **1992 Census of Transportation Communications and Utilities** provides limited information on the amount of construction activity carried out by establishments in SIC Code 46 (pipelines except natural gas), as well as more detailed information about the size of establishments, revenues, payroll costs, and so forth.

Pipelines includes SIC 4612 (crude petroleum pipelines), SIC 4613 (refined petroleum pipelines), and SIC 4619 (pipelines not elsewhere classified).

The number of establishments in the sub-sector in 1992 is shown in Table 8-12 (note that component figures made not add up to totals due to some establishments not being operated in 1992).

Table 8-12. Number of Establishments in the Pipelines Sub-Sector: 1992

NUMBER OF ESTABLISHMENTS BY EMPLOYMENT SIZE: 1992					
		Employment Size			
SIC Code	Total Establishments	*9 or Fewer Employees*	*10-49 Employees*	*50-99 Employees*	*100 or More Employees*
4612 - Crude Petroleum Pipelines	405	219	146	15	18
4613 - Refined Petroleum Pipelines	358	220	113	12	5
4619 - Pipelines not elsewhere classified	81	65	9	5	1

Oil pipeline mileage in the US in 1994 was 323,478 kilometers/201,000 miles (a slight increase from 320,259 kilometers/199,000 miles in 1992), which is below that which existed in 1980 (350,836 kilometers/218,000 miles). Crude oil pipeline mileage decreased from 209,214 kilometers (130,000 miles) in 1980 to 183,465 kilometers

(114,000 miles) in 1994 (while oil product line mileage fell slightly from 143,231 kilometers/89,000 miles to 140,012 kilometers/87,000 miles over the same period).

In 1993, there were 228 liquid pipeline failures. For further information about the effects of corrosion on pipeline performance refer to Section 8.1.3 of this document.

8.2 Baseline Measures for the Public Works Sector

This section of the document describes in detail the baseline measures for operations, maintenance, and energy costs in the public works sector for each of the sub-sectors previously identified in this document. For general definitions of "operations", "maintenance", and "energy", refer to Section 3.4 of this document. For detailed information regarding the components within each of these general definitions, refer to Sections 4.1.1 and 4.1.2.

8.2.1 Baseline Measures for the Transportation Sub-Sector

The baseline measures are presented as follows:

- Baselines for highways
- Baselines for railroads
- Baselines for transit
- Baselines for air
- Baselines for water

8.2.1.1 Baseline Measures for Highways Transportation

Data presented in Section 8.1.2.2 of this document examined the size of the highways network, jurisdiction, and key characteristics, such as pavement condition. This section begins by presenting general baseline data about government disbursements for highways in 1994 for all government agencies, before moving on to provide more detailed information about state and local government disbursements in 1994 and 1993 respectively. The FHWA publication *Highway Statistics 1994* provides the source data throughout this section.

Figure 8-22 shows selected government highway disbursements by type in 1994. The source data, which show all categories of disbursement, are presented in Table 8-13. Reference to the table shows that total disbursements, including such items as interest on debt and bond retirements, totaled approximately $90 billion, of which nearly one half was for capital outlays (i.e. costs associated with highway improvements), and one-quarter was for maintenance and traffic services. Administration and research accounted for about 9 percent of the total, and law enforcement and safety accounted for a further 8 percent. Whilst capital outlays on state-administered highways were over twice those for locally-administered highways, the latter required higher maintenance and traffic services funding compared with state highways.

Figure 8-23 shows the proportion of disbursements by type of government. Total federal government disbursements accounted for only two percent of total government disbursements in 1994.

Figures 8-24 through 8-35 show state-administered highway disbursements in increasing level of detail for 1994. Figure 8-24 shows highway disbursements by major cost category. Total disbursements were $54,752,569,000, of which $30,151,637,000 (55 percent) was for capital outlays for roads and bridges, and $10,073,131,000 (18 percent) was for maintenance and highway services.

Figure 8-22. Highway Disbursements, All Government: 1994

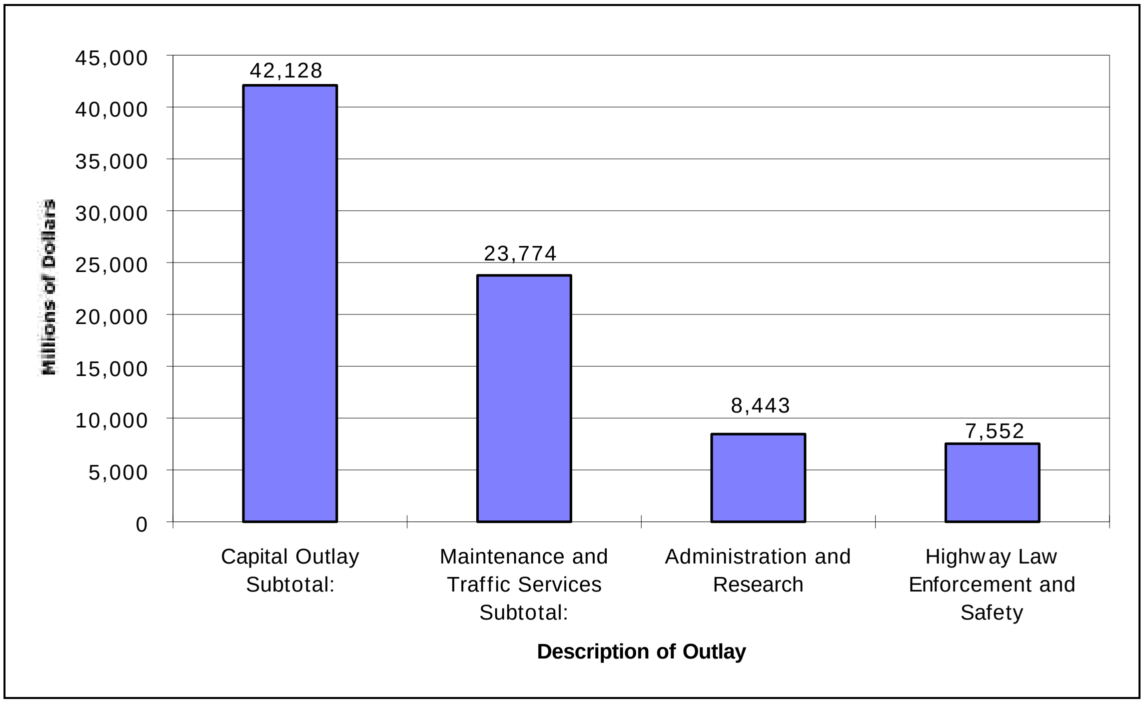


Table 8-13. Highway Disbursements for All Government by Expending Agency: 1994

DISBURSEMENTS FOR HIGHWAYS - BY EXPENDING AGENCIES: 1994		
	TOTAL (millions of Dollars)	% OF TOTAL
Capital Outlay Subtotal:	**42,128**	**46.77%**
On State-Administered Highways	30,152	33.47%
On Locally Administered Roads	11,138	12.37%
Not Classified by System	838	0.93%
Maintenance and Traffic Services Subtotal:	**23,774**	**26.39%**
On State-Administered Highways	10,073	11.18%
On Locally Administered Roads	13,630	15.13%
Not Classified by System	71	0.08%
Administration and Research	**8,443**	**9.37%**
Highway Law Enforcement and Safety	**7,552**	**8.38%**
Interest on Debt	3,801	4.22%
Total Current Disbursements	85,698	95.14%
Bond Retirements	4,376	4.86%
Grand Total Disbursements	**90,074**	**100.00%**

Figure 8-23. Total Highway Disbursements by Type of Government: 1994

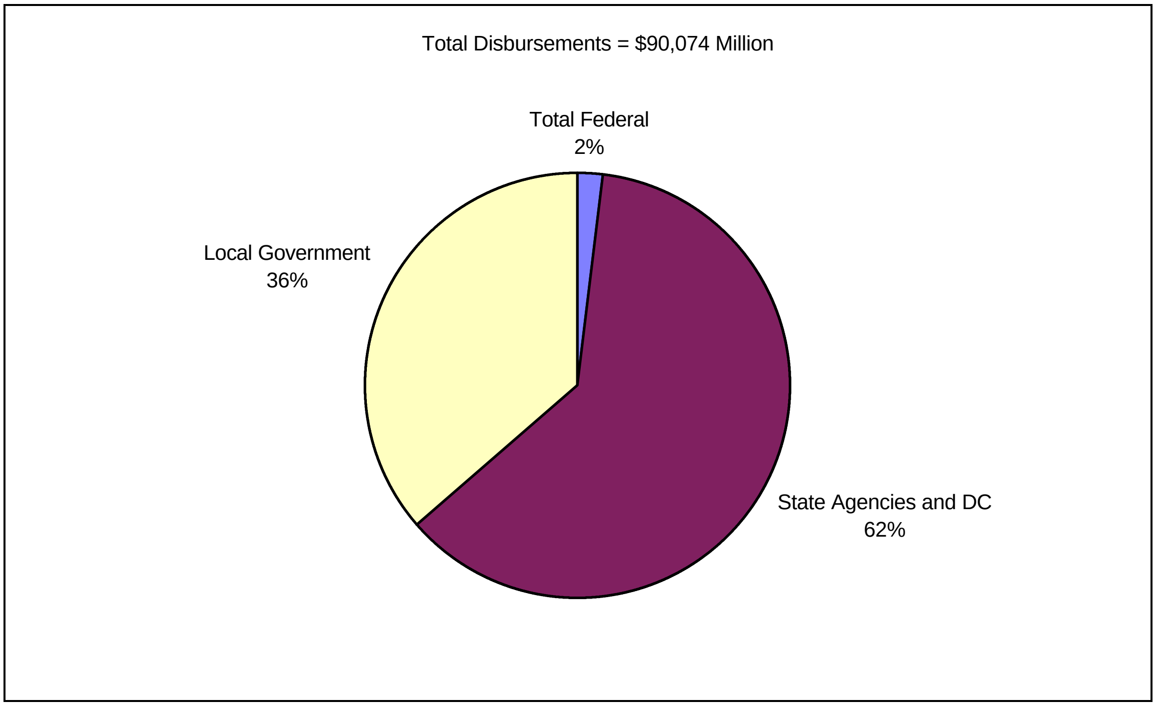


Figure 8-24. State-Administered Highway Disbursements by Type: 1994

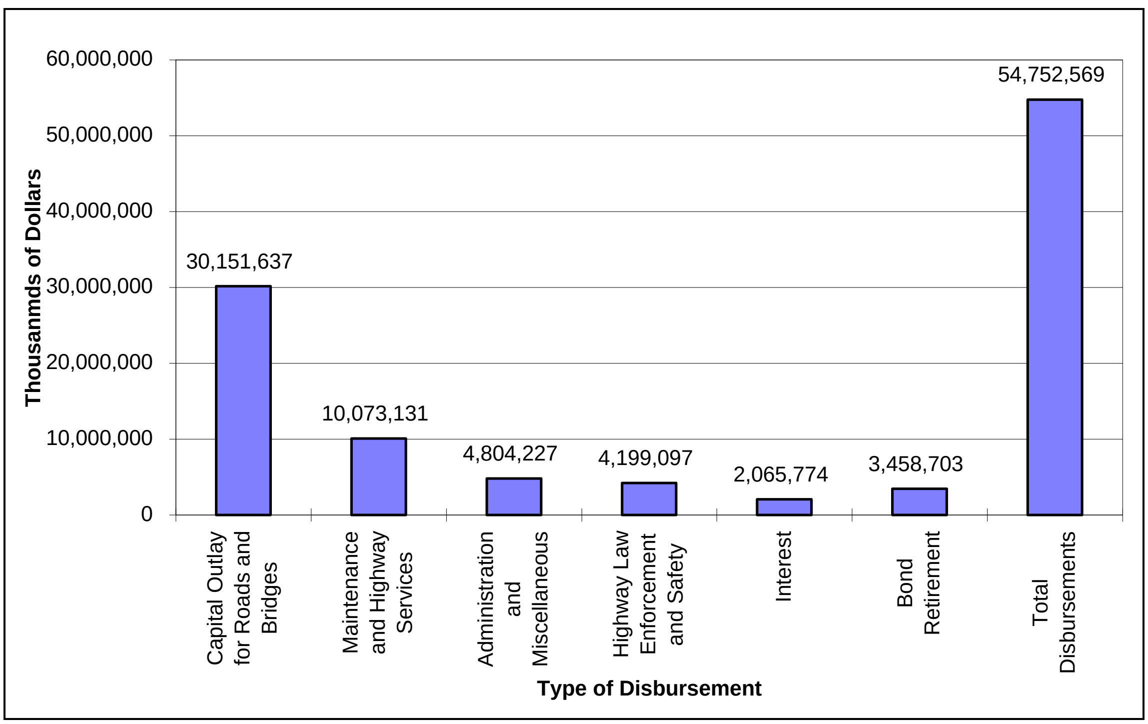


Figure 8-25 indicates that construction costs are the largest component of capital outlays for roads and bridges (about 76 percent), with design costs accounting for about 16 percent, and the remainder required for acquisition of rights of way (ROW). The maintenance and highway services major category can be split into **physical maintenance** ($7,089,411,000) and **highways and traffic services** ($2,983,720,000) which includes *traffic control operations* ($682,023,000) *snow/ice removal* ($1,082,327,000), *other services* such as highway beautification, litter control, vegetation and erosion control, and air quality programs ($226,093,000), and *toll facility collection expenses* ($993,237,000). **General administration** accounted for $4,171,251,000 **research and planning** for $632,976,000, and **highway law enforcement and safety** for $4,199,097,000.

Figure 8-26 and Figure 8-27 examine state highway capital outlays by functional system in urban and rural areas respectively. The source data are presented in Table 8-14, and are shown in a more aggregated form in the two figures (e.g. small urban and urbanized areas are combined, as are some functional system classifications) . Reference to Figure 8-26 shows that state highway capital outlays in urban areas in 1994 were predominantly for Interstates/freeways and expressways and arterial routes, as opposed to collectors. Total capital outlays were $15,770,199,000. This was slightly higher than total capital outlays in rural areas ($12,450,712,000), as shown in Figure 8-27. As one would expect, capital outlays in rural areas were less heavily biased toward Interstates/freeways and expressways compared with urban areas.

In Figures 8-28 through 8-33, state highway capital outlays are shown in greater detail by functional system, for Interstates, arterials, and collectors in rural and urban areas. The expenditure categories which are shown are as follows:

- land acquisition, right of way and engineering
- new highway construction
- highway reconstruction
- major highway widening
- 3R (resurfacing, restoration, and rehabilitation of roadways and structures)
- bridge works
- safety and other (guard rails, fencing, signs, signals, etc.)

Figure 8-28 shows capital outlays for Interstates in urban areas, Figure 8-29 shows capital outlays for arterials in urban areas, and Figure 8-30 shows capital outlays for collectors in urban areas. Comparison of the three figures indicates that ROW/engineering costs are one of the largest cost components irrespective of functional system. Total expenditures for collectors are relatively small. 3R represents about 13 percent of total capital outlays by state authorities for Interstates and arterials, and about 20 percent of total capital outlays for urban collectors.

Figure 8-25. State Highway Disbursements by Type of Disbursement: 1994

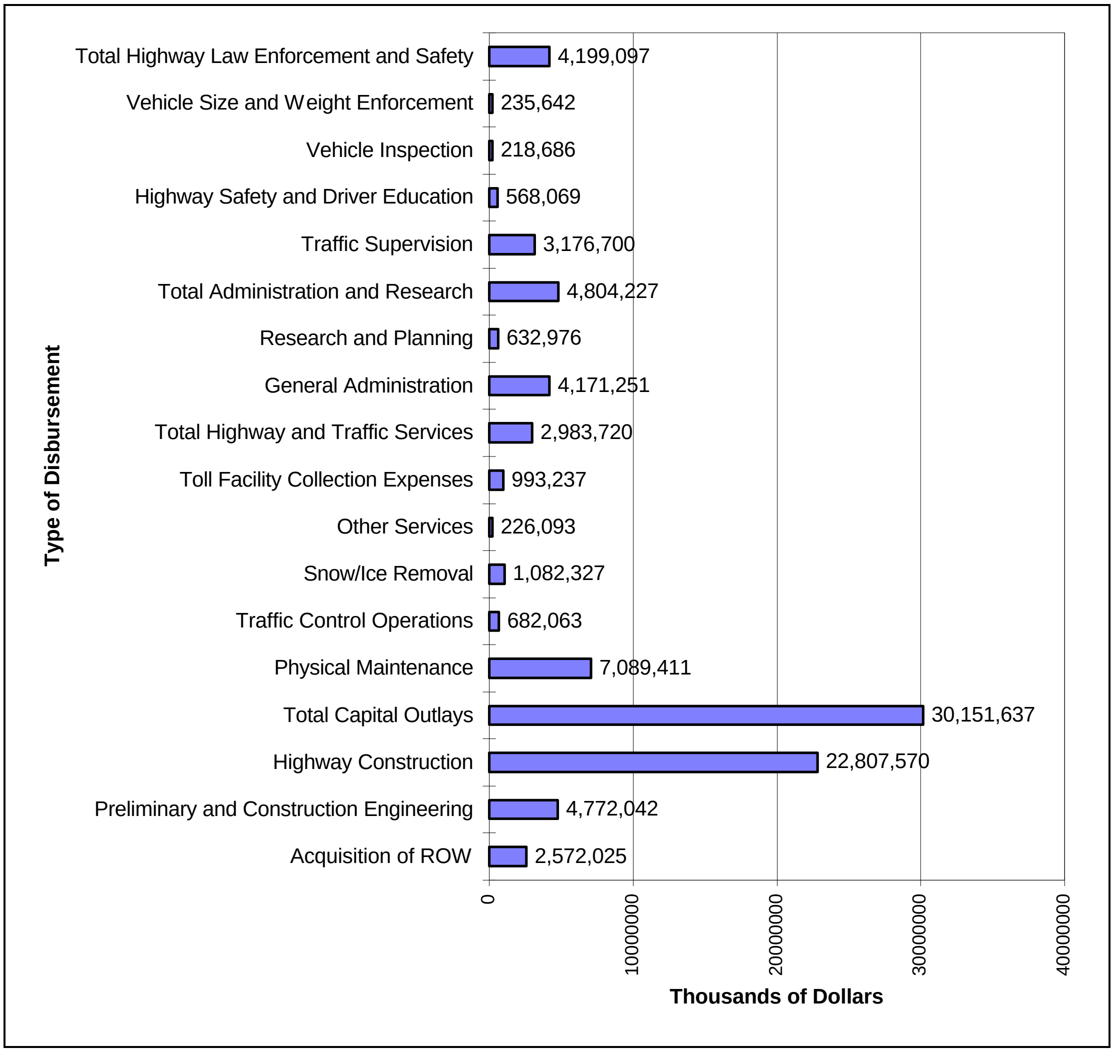


Figure 8-26. State Highway Capital Outlays in Urban Areas by Functional System: 1994

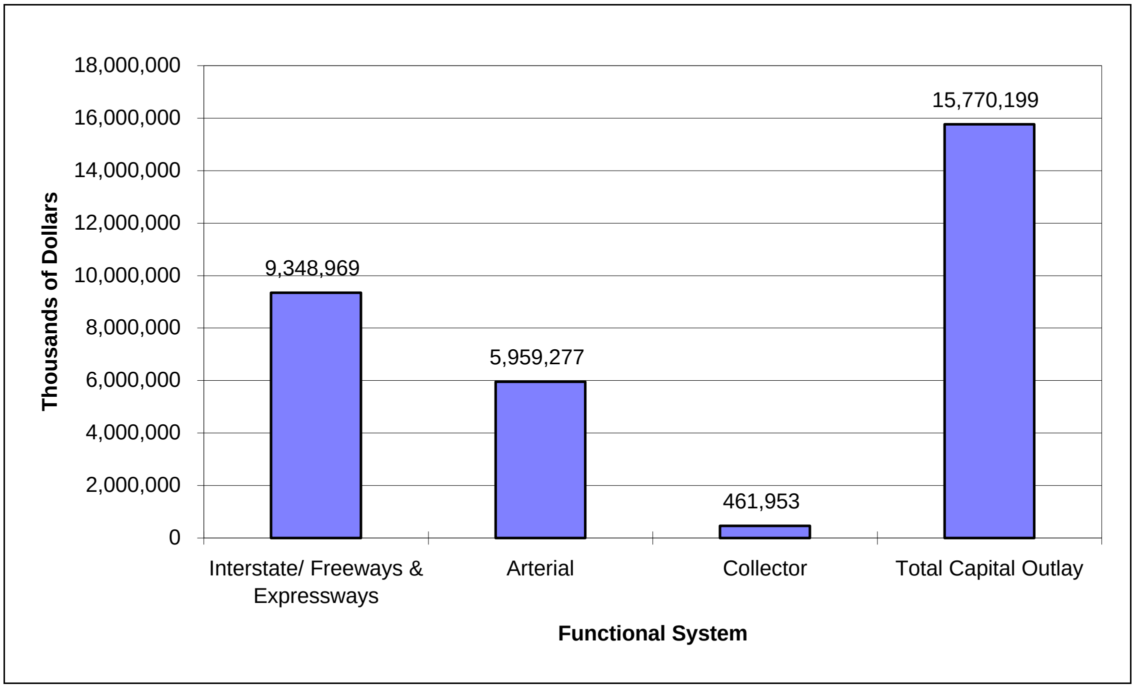


Figure 8-27. State Highway Capital Outlays in Rural Areas by Functional System: 1994

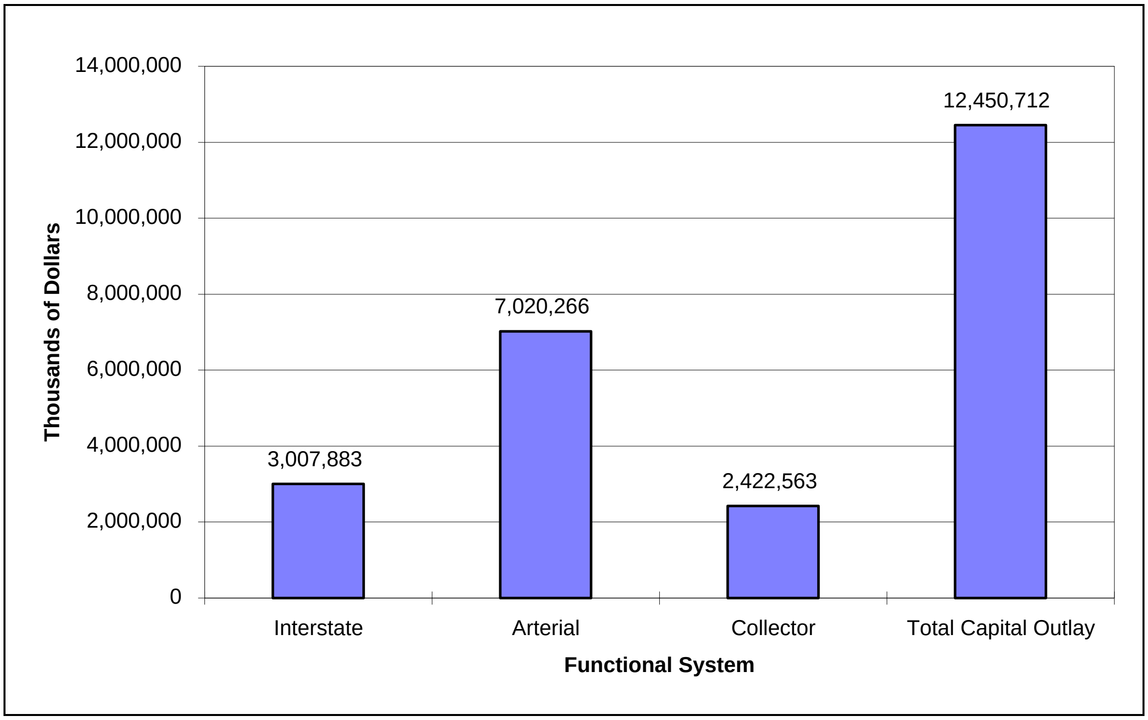


Table 8-14. State Highway Capital and Maintenance Outlays in Rural, Small Urban, and Urbanized Areas by Functional System: 1994

STATE HIGHWAY AGENCY CAPITAL OUTLAY AND MAINTENANCE - 1994 (THOUSANDS OF DOLLARS)							
CAPITAL OUTLAY							
In Rural Areas							
Interstate	Other Principal Arterial	Minor Arterial	Total Arterial	Major Collector	Minor Collector	Total Collector	*Total Capital Outlay*
3,007,883	4,625,364	2,394,902	7,020,266	2,013,412	409,151	2,422,563	*12,450,712*
In Small Urban Areas (5,000 - 49,999 Population)							
Interstate	Other Freeways and Expressways	Other Principal Arterial	Minor Arterial	Total Arterial	Total Collector	*Total Capital Outlay*	
283,368	134,050	776,339	356,918	1,133,257	94,803	*1,645,478*	
In Urbanized Areas (50,000 or more Population)							
Interstate	Other Freeways and Expressways	Other Principal Arterial	Minor Arterial	Total Arterial	Total Collector	*Total Capital Outlay*	
6,359,923	2,571,628	3,485,276	1,340,744	4,826,020	367,150	*14,124,721*	
MAINTENANCE OUTLAY							
In Rural Areas							
Interstate	Other Principal Arterial	Minor Arterial	Total Arterial	Major Collector	Minor Collector	Total Collector	*Total Maintenance Outlay*
816,351	796,542	797,252	1,593,794	886,760	235,554	1,122,314	*3,532,459*
In Small Urban Areas (5,000 - 49,999 Population)							
Interstate	Other Freeways and Expressways	Other Principal Arterial	Minor Arterial	Total Arterial	Total Collector	*Total Maintenance Outlay*	
68,513	45,617	141,582	99,965	241,547	20,715	*376,392*	
In Urbanized Areas (50,000 or more Population)							
Interstate	Other Freeways and Expressways	Other Principal Arterial	Minor Arterial	Total Collector	*Total Maintenance Outlay*		
488,093	324,070	453,696	236,046	60,028	*1,561,933*		

Figure 8-28. State Highway Capital Expenditures for Interstates in Urban Areas: 1994

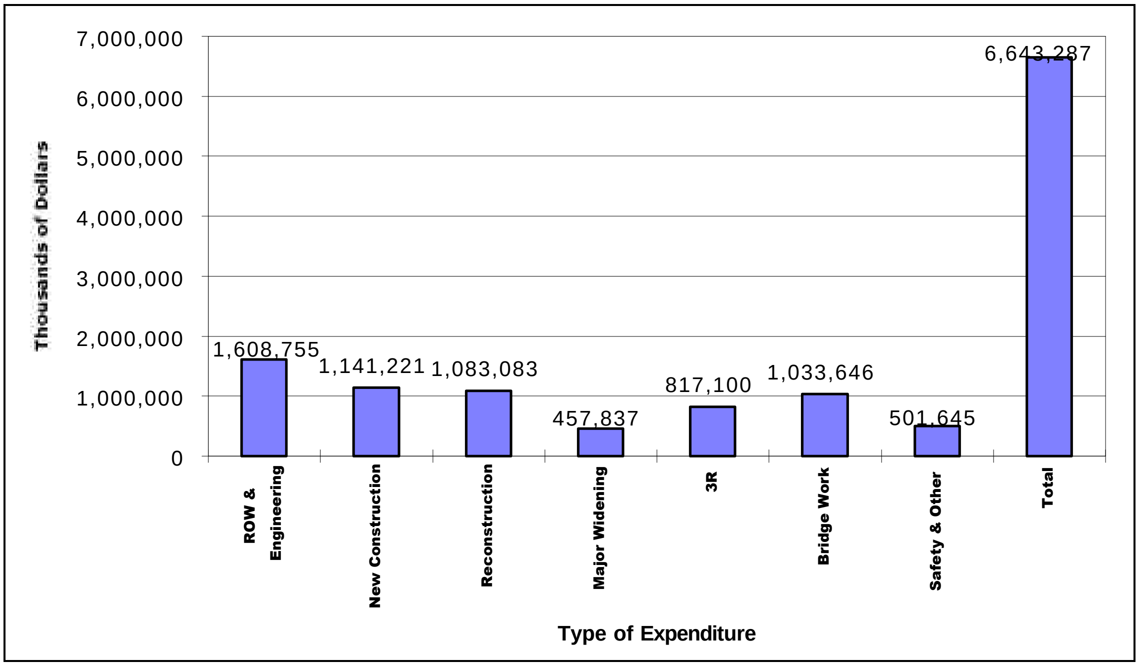


Figure 8-29. State Highway Capital Expenditures for Arterial in Urban Areas: 1994

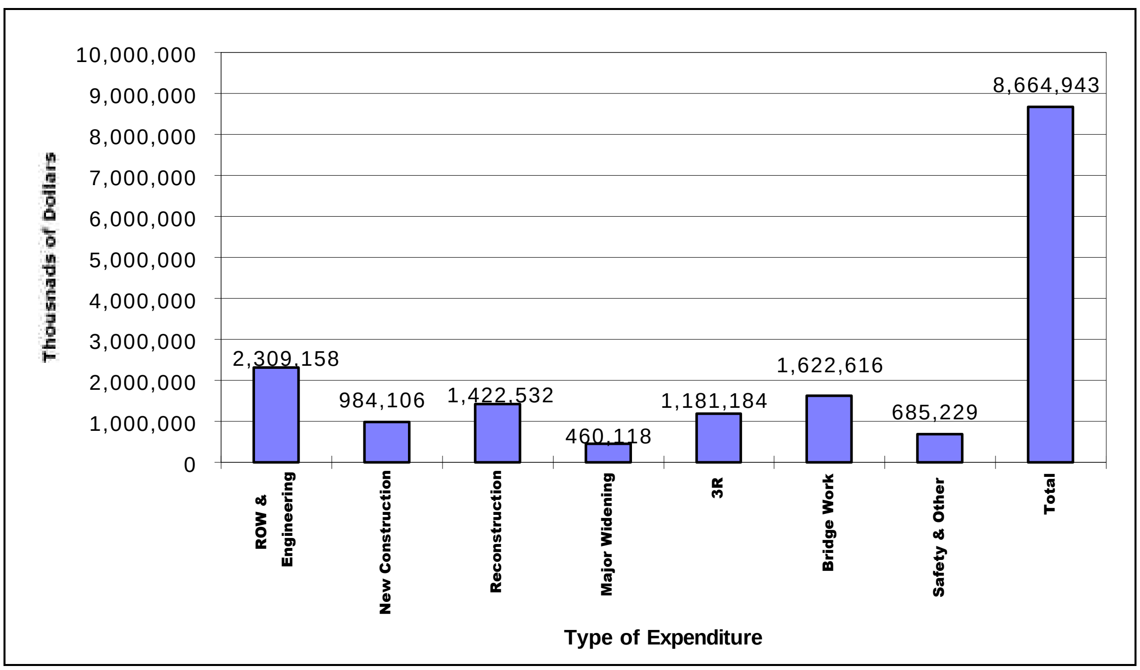
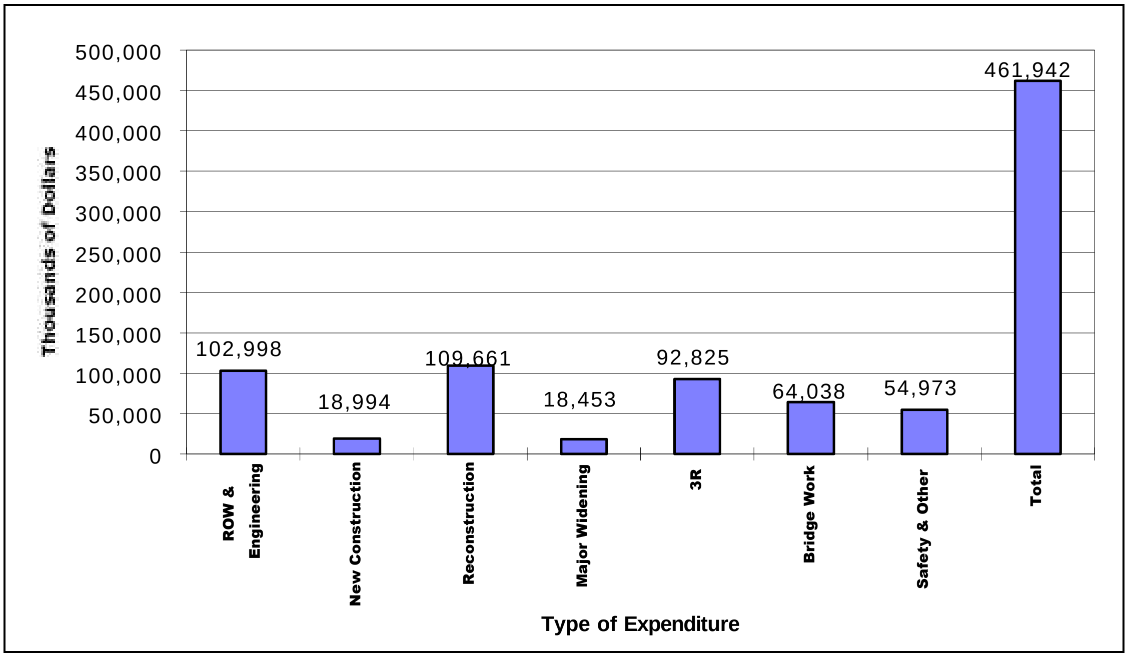


Figure 8-30. State Highway Capital Expenditures for Urban Collectors: 1994



Figures 8-31 through 8-33 show similar information for highways in rural areas. These three figures indicate that the highest state capital outlays are for arterials in rural areas. In comparison with urban highways, 3R is a larger component of total costs. This is particularly true for rural Interstates. ROW and engineering costs also represent a smaller proportion of total costs for rural Interstates, as might be expected. There is a very similar distribution of expenditures by category between urban and rural collectors, with a greater expenditure upon reconstruction rather than new construction compared with Interstates and arterial roads.

Figures 8-34 and 8-35 show how state maintenance outlays vary by functional system in urban and rural areas. Figure 8-34 shows that total expenditures for urban Interstates/freeways and expressways and arterials are of similar magnitude, and are about 11 times greater than those for collectors. Figure 8-35 shows that collector expenditures are much more significant in rural areas.

Figure 8-31. State Highway Capital Expenditures for Rural Interstates: 1994

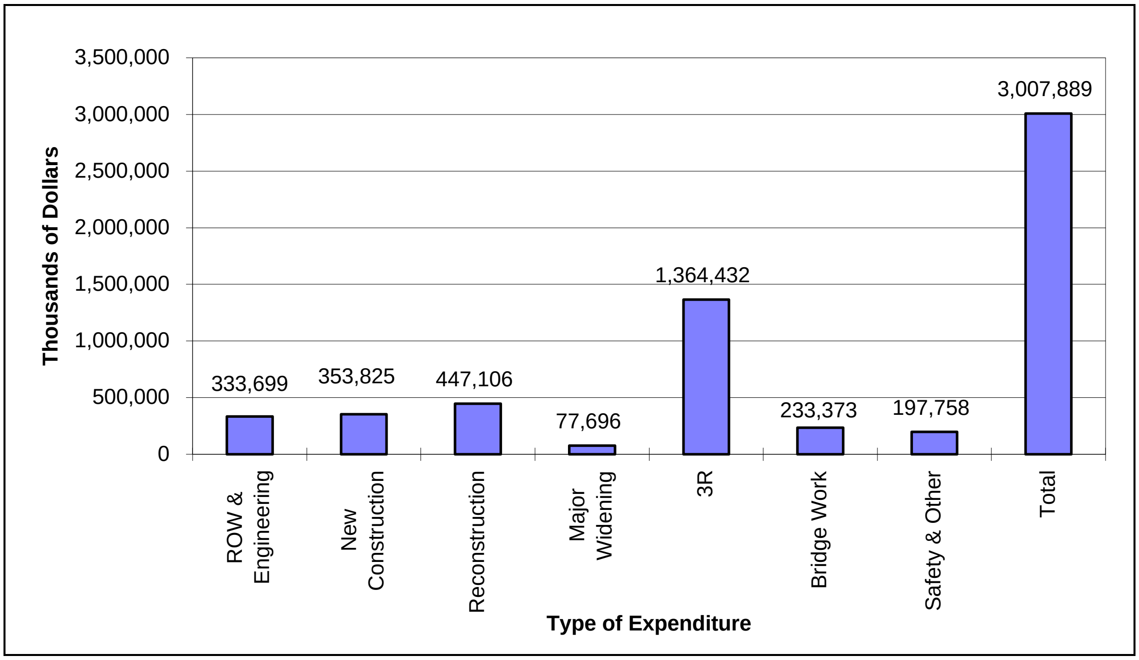


Figure 8-32. State Highway Capital Expenditures for Arterial in Rural Areas: 1994

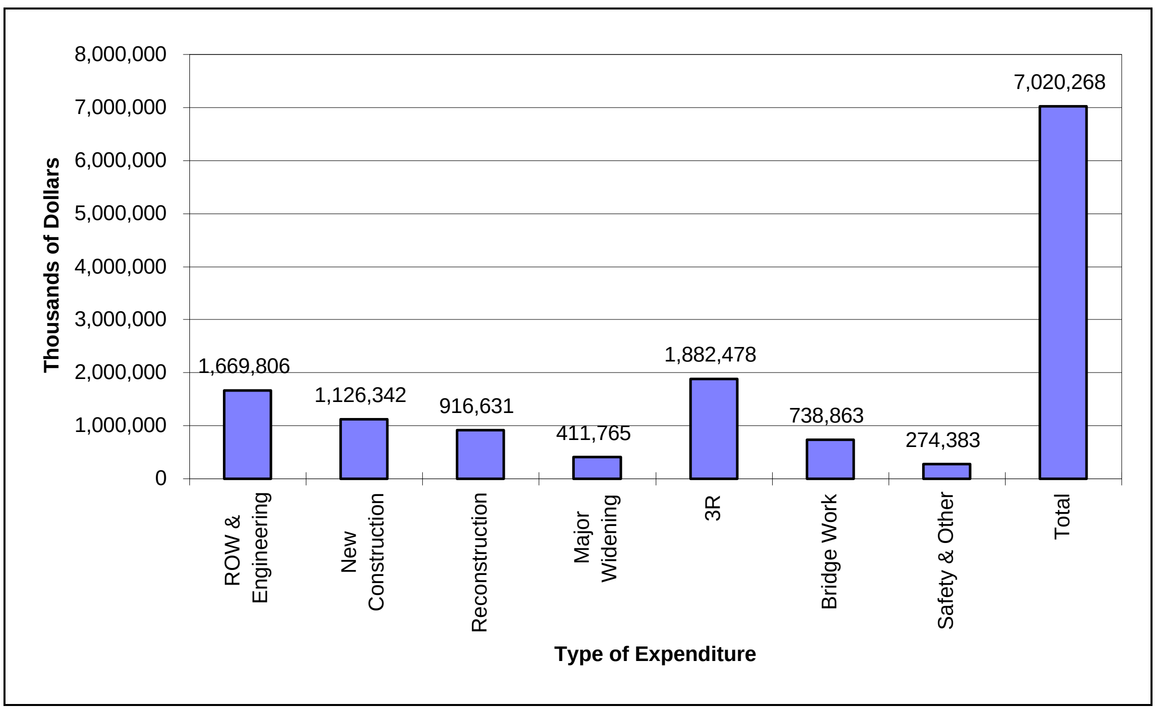


Figure 8-33. State Highway Capital Expenditures for Rural Collectors: 1994

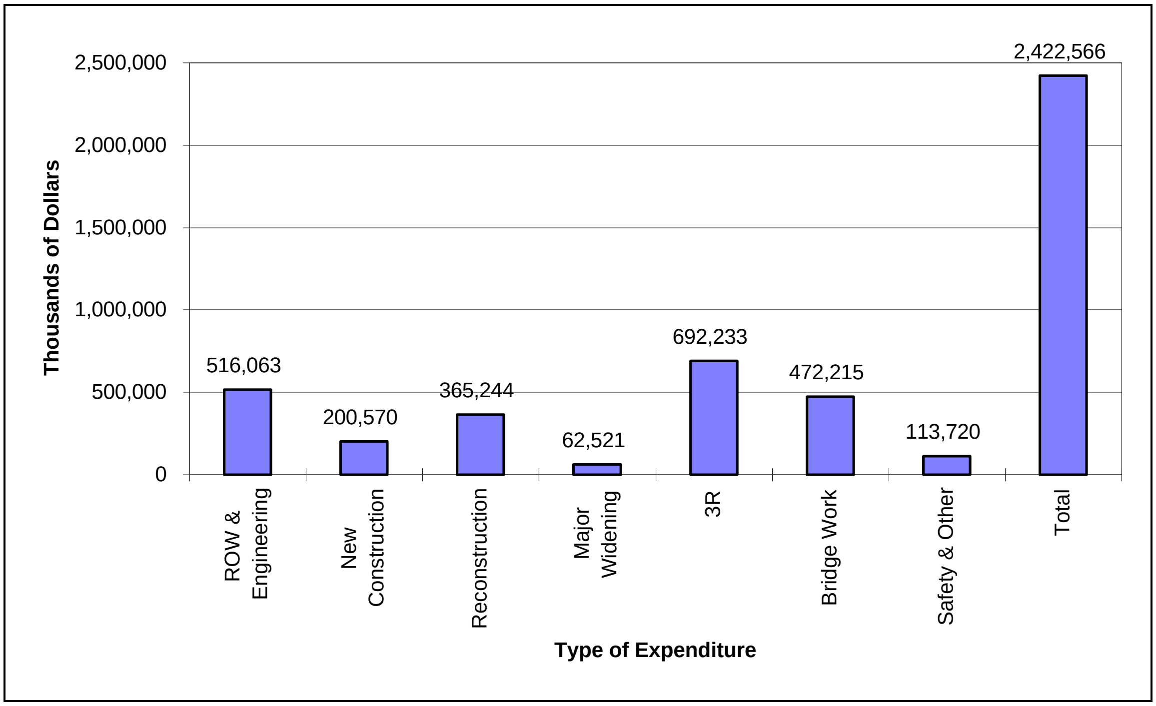


Figure 8-34. State Highway Maintenance Outlays in Urban Areas by Functional System: 1994

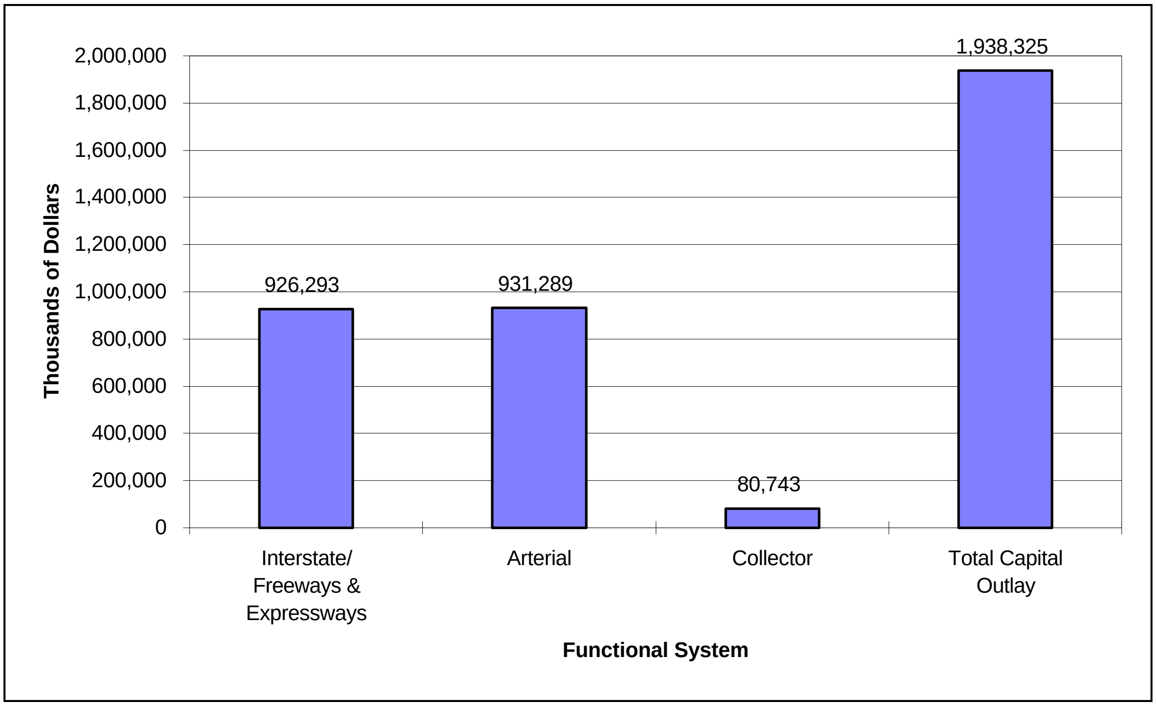
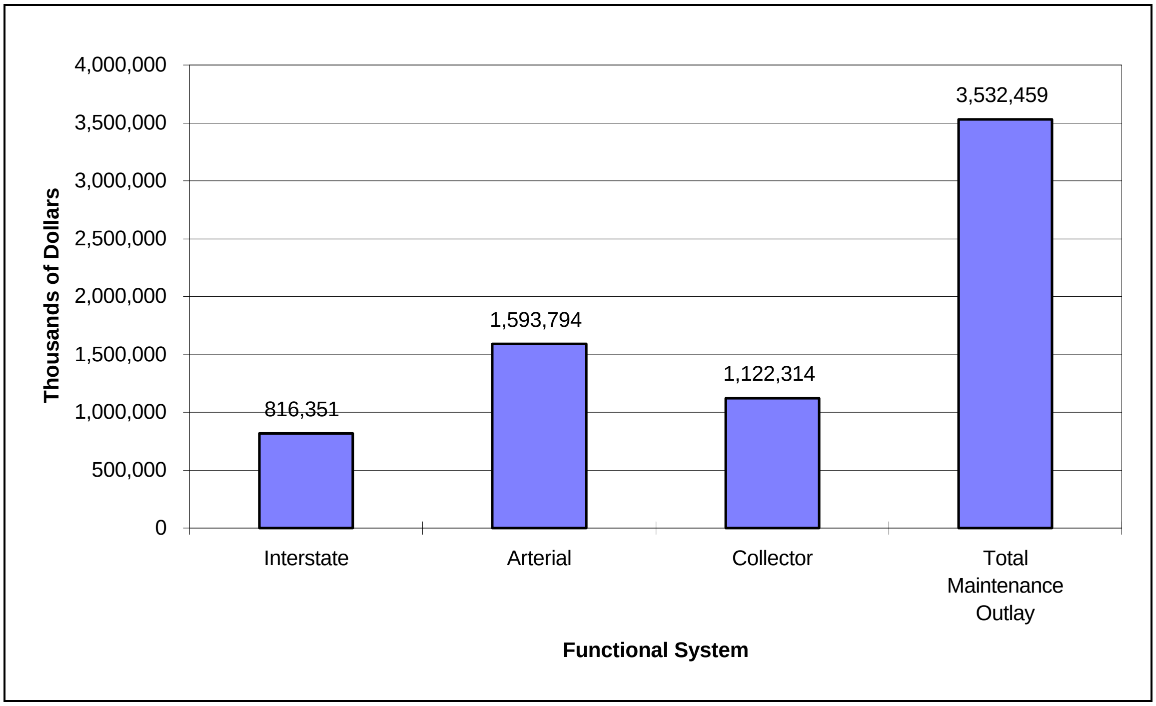


Figure 8-35. State Highway Maintenance Outlays in Rural Areas by Functional System: 1994



The data plotted in Figures 8-34 and 8-35 can be normalized on a "per-kilometer" basis or on a "per-lane kilometer" basis, to allow comparison of maintenance costs by type of road and geographic location. Data are available from FHWA which estimate lane kilometers by functional system for all highways in the US, for urban and rural locations. In addition, data are available for state administered highways, which estimate rural and urban lane kilometers, but do not classify this by functional type. Thus, given that nearly all Interstates/freeways and expressways are controlled by state authorities, we can derive values for maintenance costs per-lane kilometer for Interstates, and for all roads combined, but not for arterials or collectors. These data are summarized in Table 8-15. Reference to the table indicates that maintenance costs per lane kilometer for all state-administered highways are about $1,865 ($3,000/ per lane mile). Rural highway maintenance costs are under half those of urban maintenance costs. However, urban and rural Interstate costs are significantly higher than the average for all highways, with urban costs of about $5,190 per lane kilometer ($8,350 per lane mile) and rural Interstate costs of about $3,853 per lane kilometer ($6,200 per lane mile).

Table 8-15. State Highway Maintenance Outlays: 1994

Functional System	Total Maintenance Cost (Dollars)	Total Miles (including local highways)	Total Lane Miles (estimated)	Estimated Maintenance Cost per Mile (Dollars)	Estimated Maintenance Cost per Lane Mile (Dollars)	Estimated Maintenance Cost per Kilometer (Dollars)	Estimated Maintenance Cost per Lane Kilometer (Dollars)
Urban Interstates/Freeways and Expressways	926,293,000	21,658	111,014	42,769	8,344	26,581	5,186
Urban Arterial	931,289,000	60,920	-	15,287	-	9,501	-
Urban Collector	80,743,000	10,394	-	7,768	-	4,828	-
All Urban Highways	***1,938,325,000***	***110,014***	***346,460***	***17,619***	***5,595***	***10,950***	***3,477***
Rural Interstate	816,351,000	32,457	131,288	25,152	6,218	15,632	3,865
Rural Arterial	1,593,794,000	227,833	-	6,995	-	4,347	-
Rural Collector	1,122,314,000	267,182	-	4,200	-	2,610	-
All Rural Highways	***3,532,459,000***	***690,371***	***1,448,313***	***5,116***	***2,439***	***3,180***	***1,516***
All Highways	**5,470,784,000**	**800,385**	**1,794,773**	**6,835**	**3,048**	**4,248**	**1,894**

Figure 8-36 through 8-38 show local government capital outlays for highways by type of disbursement and functional type in 1993 (not 1994). No data have been located on maintenance outlays by functional type which would be similar to that already presented for state highways. However, data are available for selected local toll facilities in various states, which include toll bridge and tunnel facilities, road facilities, and ferry facilities. For brevity, these data are not included in this document. In general, data for locally-administered highways are much less comprehensive than for state-administered highways.

Figure 8-36 shows local government disbursements for all highways by type of disbursements. Comparison of Figure 8-36 and Figure 8-24 shows that local government allocates a much larger proportion of its budget to highway maintenance than to new road and street construction, compared with state government, which has a much higher proportional expenditure on new construction. For locally-administered highways, maintenance costs in 1993 were $11,529,616,000 or 34 percent of total local government highway expenditures (compared with about 18 percent for state government). Snow removal costs were $1,011,638,000, and other costs, such as highway litter removal, vegetation control, and erosion control, amounted to $759,059,000.

Figure 8-37 and Figure 8-38 show local government highway capital outlays in urban and rural areas respectively. In urban areas, outlays for arterial roads accounted for about 70 percent of total expenditures. In comparison, in rural areas, the major proportion of expenditures was for collectors.

Figure 8-36. Local Government Highway Capital Expenditures by Type: 1993

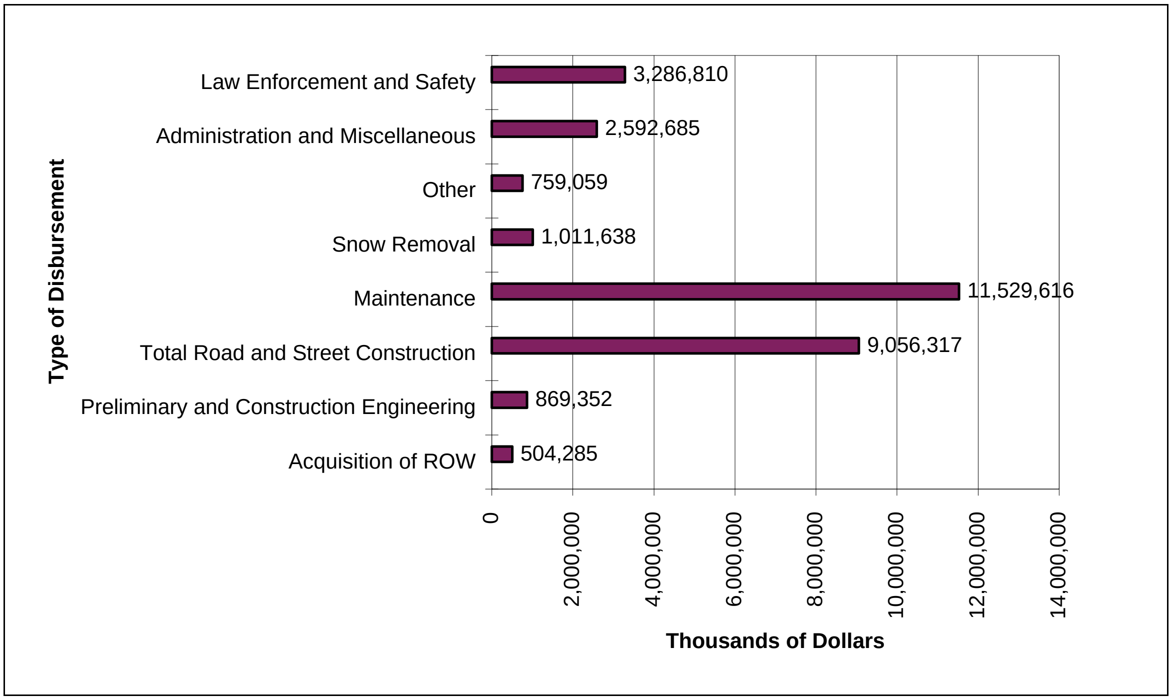


Figure 8-37. Local Government Capital Expenditures in Urban Areas by Type: 1993

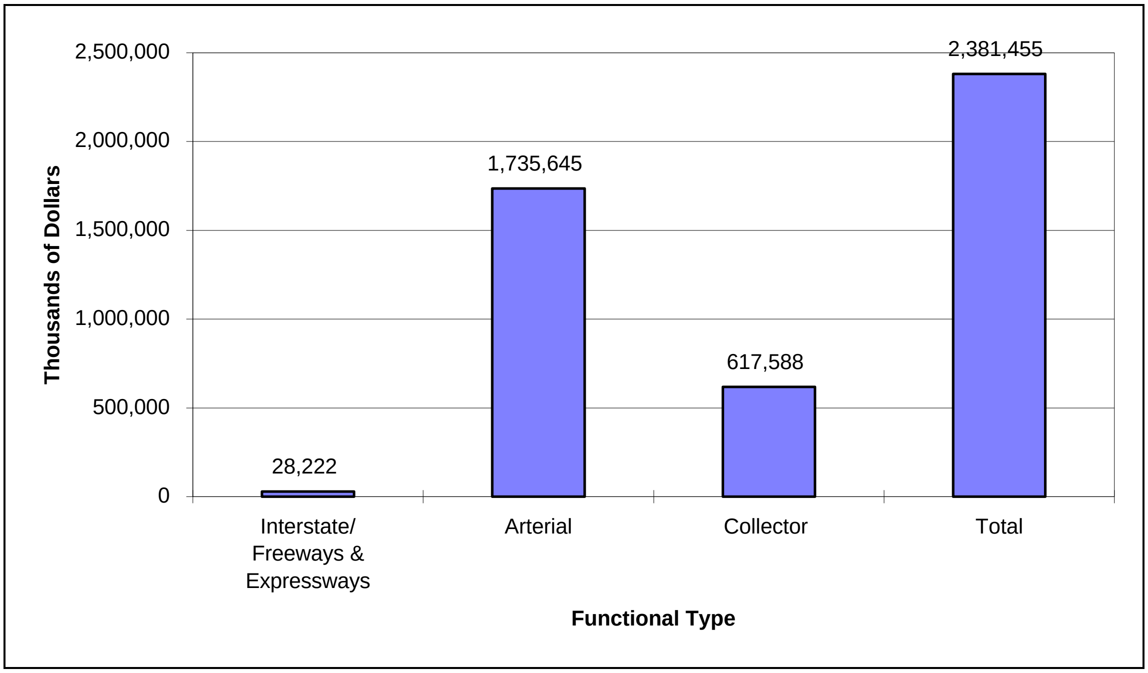
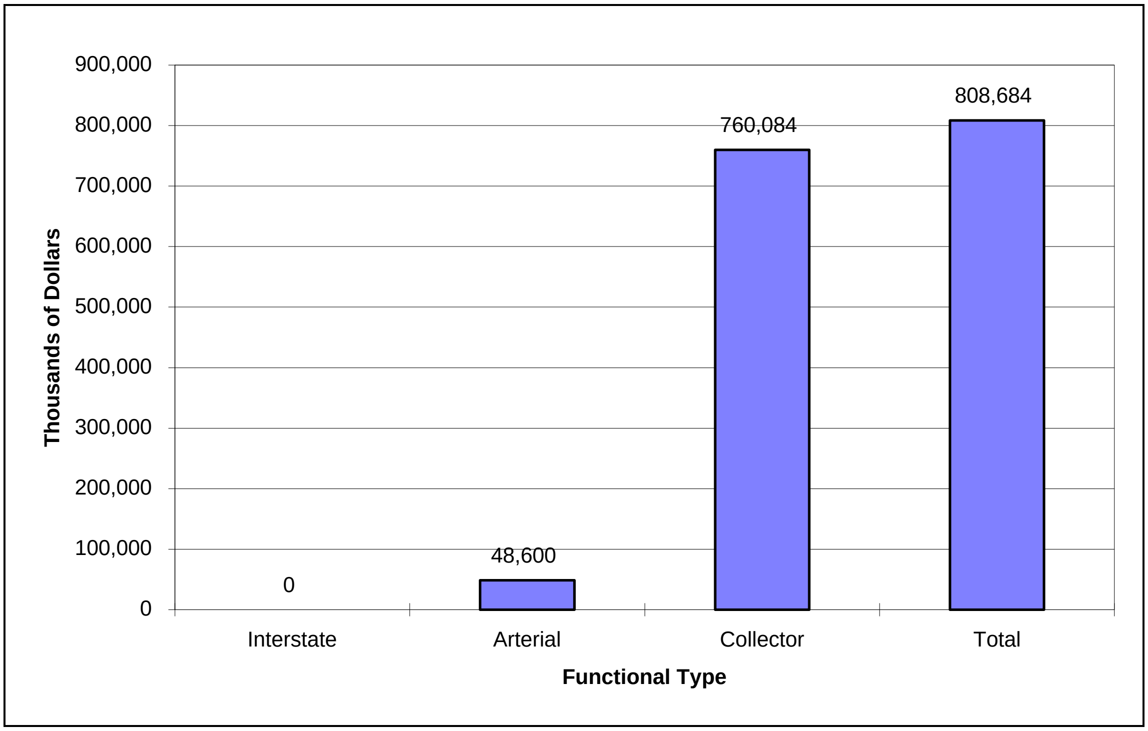


Figure 8-38. Local Government Capital Expenditures in Rural Areas by Type: 1993

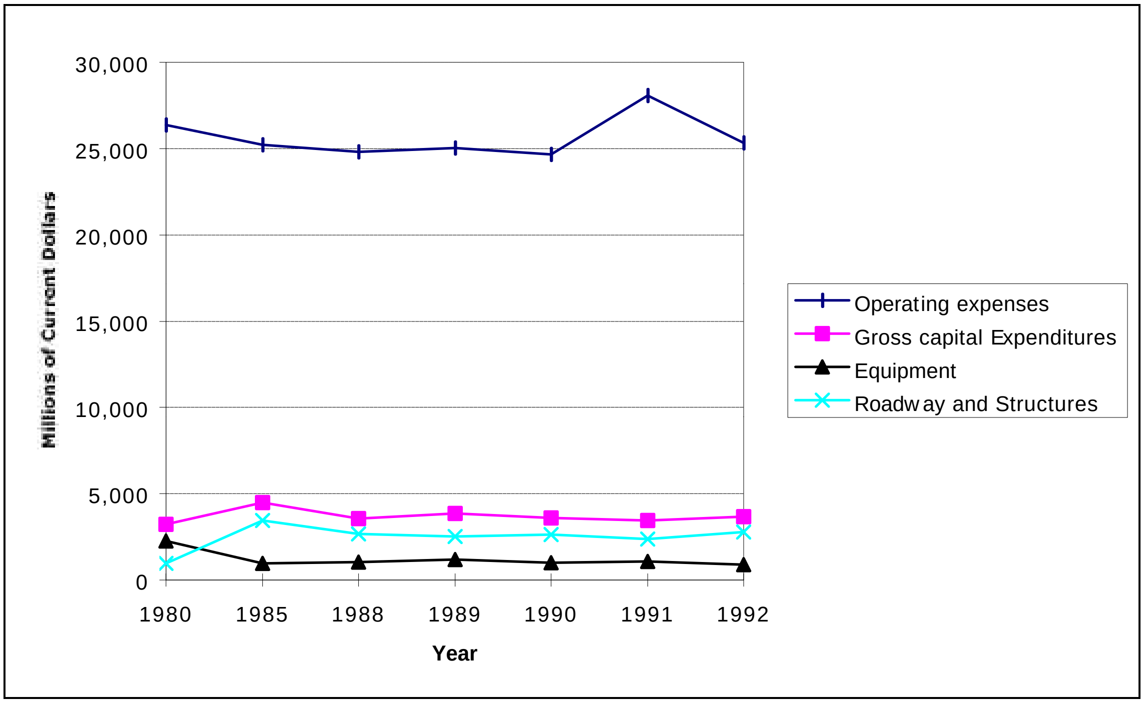


8.2.1.2 Baseline Measures for Railroads

As described in the general overview section, data for railroads other than Class I railroads are very limited. However, some data exist for Class I railroads, which form a large part of total track-miles in the US. These data describe operations and maintenance costs. Energy costs will not be considered in this section, as these are primarily attributable to rolling stock end-use, which is beyond the scope of this document.

Figure 8-39, which is based upon data from the *Statistical Abstract 1996*, shows how total operating expenses, and total gross capital expenditures have varied for Class I railroads between 1980 and 1992. The source data are shown in Table 8-16. Operating expenses include annual payroll (about 40 percent of total expenses in 1992) purchased fuels (7 percent), lease of equipment and rental (10 percent), insurance (5 percent), depreciation (9 percent), taxes and licenses (4 percent), and other expenses (24 percent). Total gross capital expenditures (i.e., new investment in track, facilities and equipment) were $5,035 million in 1994. In 1992, about three-quarters of new investment was in roadways and structures, and most of the remainder was for new equipment.

Figure 8-39. Selected Class I Railroad Expenses by Type: 1980 to 1992



The Surface Transportation Board - a part of the Department of Transportation - provides detailed Class I railroad financial data. The *1996 Annual Report* gives highly detailed information about railway operating expenses for all Class I roadways, tunnels, bridges, other facilities, and rolling stock.

Table 8-16. Detailed Description of Operating Expenses for All Class I Railroads

Unit	Item	1980	1985	1988	1989	1990	1991	1992	1993	1994
Number	Class I line-hauling companies	40	23	17	15	14	14	13	13	13
1,000	Employees	458	302	236	228	216	206	197	193	190
Million Dollars	Compensation	11,318	10,563	9,301	9,043	8,654	8,695	8,753	8,732	8,874
1,000 miles	Railroad line owned	178	162	150	149	146	143	139	137	132
1,000 miles	Railroad track owned	292	269	251	250	244	241	234	231	222
Million Dollars	Operating expenses	26,355	25,225	24,811	25,038	24,652	28,061	25,325	24,517	25,511
Million Dollars	Gross Capital Expenditures (Total)	3,238	4,485	3,546	3,865	3,591	3,439	3,680	4,504	5,035
Million Dollars	Equipment	2280	965	1027	1171	996	1068	874	-	-
Million Dollars	Roadway and Structures	953	3458	2654	2538	2644	2369	2763	-	-
Million Dollars	Other	5	62	-135	156	-49	2	69	-	-

In 1996, total Class I operating expenses were $26,331,375,000. Repairs and maintenance of roadways and structures accounted for $4,455,598,000, or about 17 percent of total operating expenses, with the remainder comprising administrative expenses for roadways and structures ($334,180,000), maintenance and repairs of equipment ($6,960,447,000), train operations ($7,809,600,000), yard operations (2,150,265,000), train and yard common operations (182,964,000), specialized service operations ($761,598,000), and administrative support ($4,010,903,000). These data are shown graphically in Figure 8-40. Selected maintenance and repair costs for Class I roadways and structures are shown in Table 8-17 and Figure 8-41.

Figure 8-40. Comparison of Total Class I Operating Expenses by Type: 1996

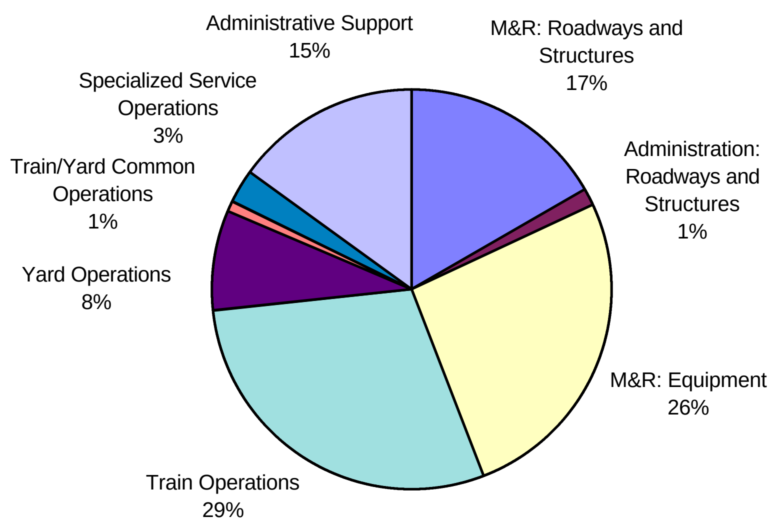
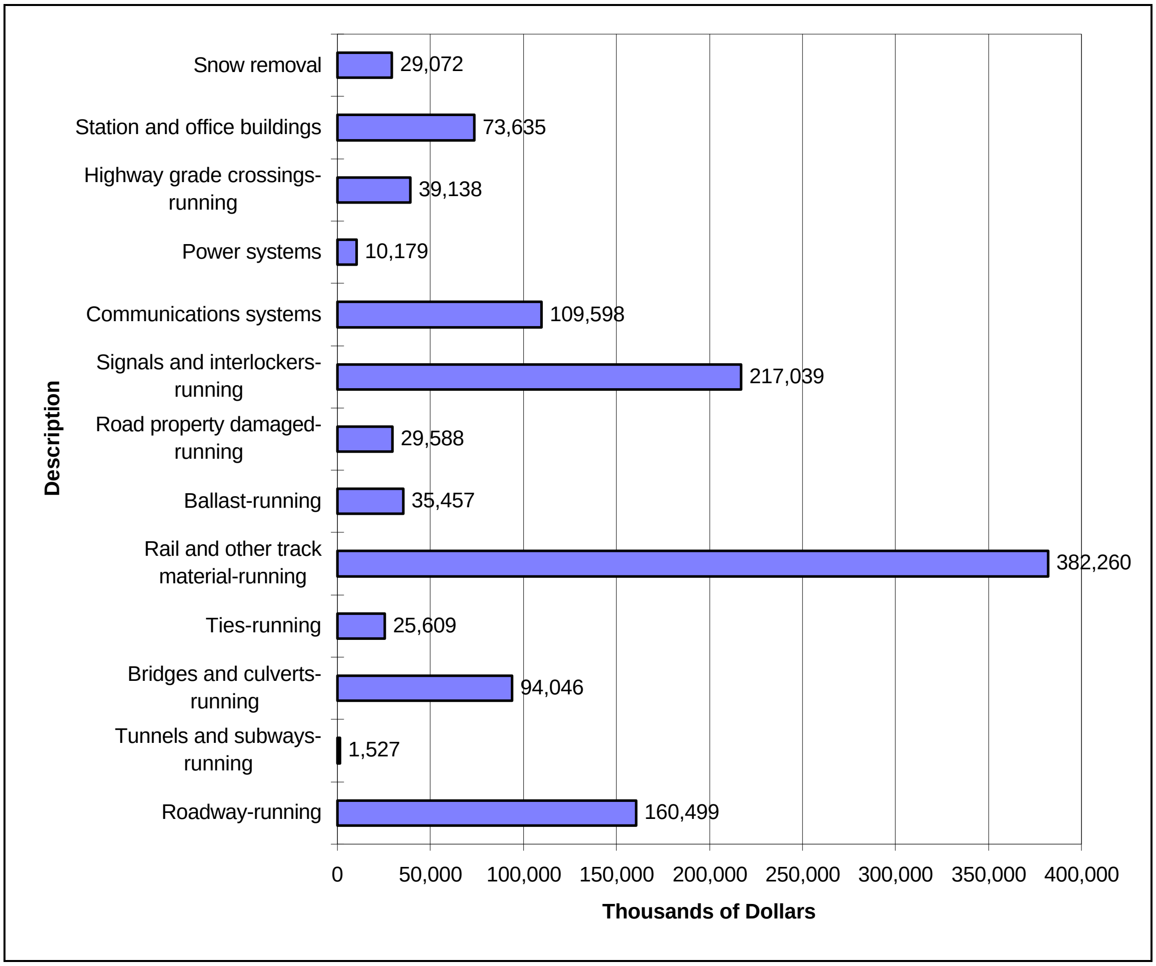


Figure 8-41. Selected Class I Railroad Maintenance and Repair Expenses: 1996



8.2.1.3 Baseline Measures for Transit Systems

As has already been mentioned in Section 8.1, transit systems in the US are controlled by many different public agencies. Data for each of these Transit Agencies are provided in the **National Transit Database**. This database provides information on transit operating expenses by mode. However, it does not appear to be possible to differentiate between vehicle operations and maintenance, and infrastructure operations and maintenance from these data, which combine these cost elements. Thus, this information is of limited usefulness for establishing baselines. Furthermore, it is not considered desirable to examine individual agencies in detail. This section therefore only considers aggregated data for all Transit Agencies in the US.

Table 8-17. Selected Class I Railroad Operating Expenses: 1996

ALL CLASS I RAILROADS - SELECTED OPERATING EXPENSES		
DESCRIPTION	EXPENSE (THOUSANDS OF 1996 DOLLARS)	PERCENTAGE OF SUB-TOTAL
Ways and Structures Administration Sub-Total	**334,180**	**100.00**
Track	117,471	35.15
Bridge and Building	39,225	11.74
Signal	50,534	15.12
Communication	22,152	6.63
Other	104,798	31.36
Repairs and Maintenance Sub-Total	**4,455,598**	**100.00**
Roadway-running	160,499	3.60
Roadway-switching	25,868	0.58
Tunnels and subways-running	1,527	0.03
Tunnels and subways-switching	974	0.02
Bridges and culverts-running	94,046	2.11
Bridges and culverts-switching	11,413	0.26
Ties-running	25,609	0.57
Ties-switching	5,702	0.13
Rail and other track material-running	382,260	8.58
Rail and other track material-switching	62,356	1.40
Ballast-running	35,457	0.80
Ballast-switching	3,970	0.09
Road property damaged-running	29,588	0.66
Road property damaged-switching	2,174	0.05
Road property damaged-other	1,606	0.04
Signals and interlockers-running	217,039	4.87
Signals and interlockers-switching	28,781	0.65
Communications systems	109,598	2.46
Power systems	10,179	0.23
Highway grade crossings-running	39,138	0.88
Highway grade crossings-switching	543	0.01
Station and office buildings	73,635	1.65
Shop buildings-locomotives	26,926	0.60
Shop buildings-freight cars	10,926	0.25
Shop buildings-other equipment	12,740	0.29
Locomotive servicing facilities	11,546	0.26
Miscellaneous buildings and structures	25,839	0.58
Coal terminals	11,075	0.25
Ore terminals	8,085	0.18
Other marine terminals	1,848	0.04
Snow removal	29,072	0.65

Figure 8-42 shows how operating expenses in the passenger transit industry have varied between 1985 and 1995, by expense category. Reference to the figure indicates that vehicle operations is the largest cost component, followed by total maintenance costs (both vehicles and facilities). In 1995, non-vehicle maintenance was $1,868.5 million, or 10.4 percent of total expenses. Non-vehicle maintenance was approximately 36 percent of total transit maintenance. The source data from the *Statistical Abstract 1997*, and American Public Transit Association (APTA), are shown in Table 8-18.

Figure 8-42. Passenger Transit Industry Operating Expenses by Type: 1985 to 1995

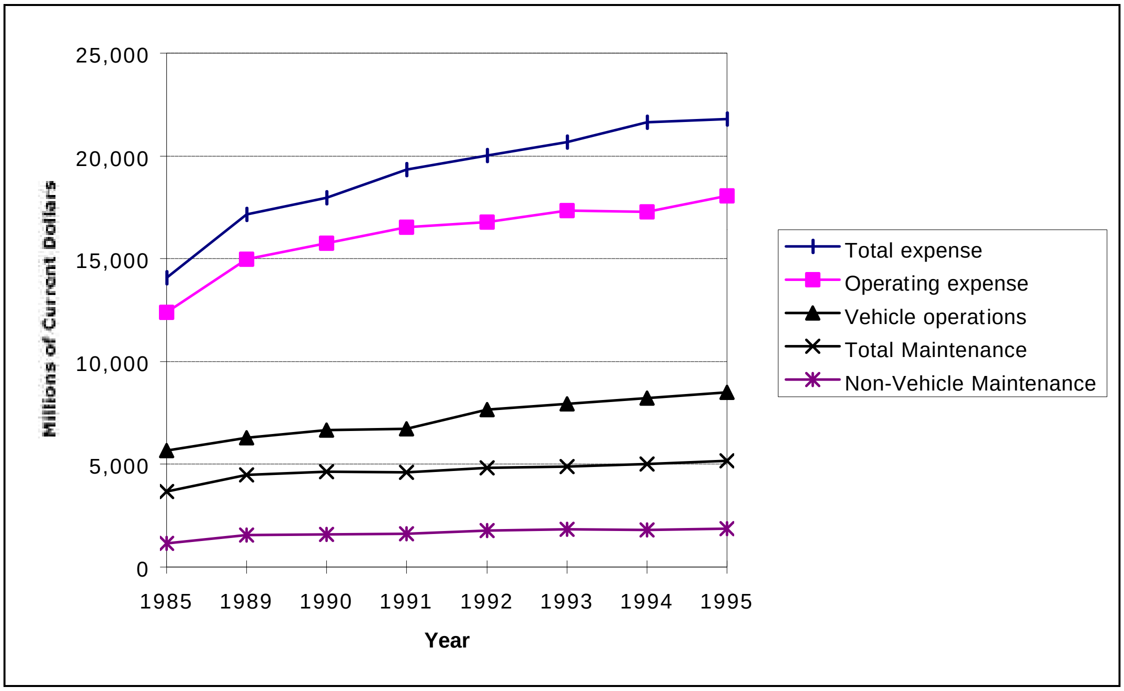


Table 8-18. Passenger Transit Industry Operating Expenses: Source Data

EXPENSE IN MILLIONS OF CURRENT DOLLARS								
Description	**1985**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Total expense	14,077	17,169	17,979	19,332	20,034	20,679	21,653	21,785
Operating expense	12,381	14,972	15,742	16,541	16,781	17,350	17,290	18,052
Vehicle operations	5,655	6,275	6,654	6,727	7,660	7,941	8,212	8,505
Total Maintenance	3,672	4,493	4,631	4,597	4,831	4,894	5,004	5,166
Non-Vehicle Maintenance	1,149	1,551	1,592	1,605	1,784	1,845	1,819	1,869
General Administration	2,505	3,251	3,450	3,585	2,674	2,715	2,725	2,716
Purchased Transportation	549	953	1,008	1,633	1,616	1,800	1,952	1,666
Reconciling Expense	1,696	2,196	2,237	2,791	3,253	3,329	3,733	3,733
Capital Expenditure, Federal	2,510	2,590	2,380	2,396	2,613	3,465	3,577	5,481

Table 8-19, which is extracted from *Characteristics of Urban Transportation Systems 1992*, shows how rail transit operating costs vary by type of transit system for rapid rail, light rail, and commuter rail systems. Reference to the table shows that salaries, wages, fringe benefits, and utilities represent the largest part of operating expenses. In comparison, other expenses, which include maintenance costs, represent between 11.7 and 24.7 percent of total operating expenses.

Table 8-19. Percentage Distribution of Rail Transit Operating Costs by Type of System: 1989

Description	**Percentage of Total Costs**		
	Rapid Rail	**Light Rail**	**Commuter Rail**
Operator Salaries	9.3	18.1	11
Other Salaries and Wages	40.7	34.5	29.6
Fringe Benefits	29.2	26.2	28.6
Utilities	8.7	9.4	6.1
All Other Costs	12.1	11.7	24.7
Total	*100*	*100*	*100*

8.2.1.4 Baseline Measures for Air Transportation

The costs of operating, maintaining, and developing airports are similar to those costs incurred by other transportation facilities. Airport operators seek to recover these costs from airport users and tenants. All airports try to operate as financially self-sufficient enterprises. The problem in establishing baseline measures for airports is that the cost structure of each airport is unique. Operations costs will obviously be highly dependent upon the size of the airport. This can be measured in terms of its "airside capacity", which is calculated by the FAA and expressed in terms of aircraft operations per hour, or its "groundside" capacity, which is the number of passengers per year the airport's roads, parking lots, and terminals can handle. In addition, many of the operational aspects of airport use by airlines are subject to federal regulation, and are linked to the overall functioning of the National Airspace System, which will impact operations costs.

The authors have been unable to locate any data which provide aggregated or normalized operating costs for airports. However, one alternative way of examining airport costs is to look at airport charges to airlines, who pay for their share of the cost of airport facilities and services. The commercial relationship between a public airport operator and an airline company is established through regulations and standards. Federal law requires that the charges to the airlines be reasonably related to the cost of providing the facilities and services.

The relative proportion of the various airline cost elements has fluctuated over the years in response to factors both internal and external to the airlines. However, the proportion of an airlines total costs for its use and lease of airport facilities and services, compared to its total costs, has remained relatively stable. On average, for the US airline industry, approximately 4 percent of total airline costs are required for airport rents, fees, and charges[34]. Increased airline operations resulting from growth in air travel has increased airline costs in absolute terms. Airport facilities have expanded to accommodate this growth. The majority of airport capital development plans are agreed to by tenant airlines in order to meet traffic demand. The Airline Transport Association (ATA) states that airline 'per passenger' costs for airport landing fees and rental rose by 76 percent between 1982-1991. During the same period, inflation increased by 41 percent. Thus, after accounting for traffic growth and inflation, airport costs have been exceptionally stable during this period. The Airports Council International report *Airport Costs and the US Airline Industry* concludes that whilst the US airline industry has lost $8 billion in the last three years, this is not attributable to increased airport costs, which are the most stable of airlines' cost elements.

Information showing Denver International Airport's estimated operations and maintenance costs for FY1996 by cost category has been extracted from the General Accounting Office report *GAO/AIMD-96-27*. This is one of the few information sources located by the authors which shows airport costs in any level of detail. It should be noted that these relative costs may not be representative of other airports in the US. The information is presented in Table 8-20.

8.2.1.5 Baseline Measures for Water Transportation

This section presents baseline measures for ports and waterways. The Maritime Administration provides some data on capital expenditures for US ports, which include expenses relating to port 'modernization and rehabilitation' (also referred to as 'maintenance and repair' by the Maritime Administration).

Capital expenditures for port facilities cover expenditures for the construction of new facilities and the modernization and rehabilitation of existing ones. Table 8-21 shows annual US port expenditures for 1992 through 1994, broken down by coastal region. For 1994, capital expenditures were $929.6 million - a 42 percent increase from 1993. This sharp increase resulted from the purchase of a large tract of land for future port development in the South Pacific region (California) for $243 million.

Table 8-22 shows how 1994 port expenditures were broken down by category. The last row of Table 8-22 records the percentage of total expenditures for each facility type. Port infrastructure improvements represented 21.1 percent (15.1 percent for off terminal expenditures and 6.0 percent for terminal expenditures) of 1994 total expenditures. Off-terminal expenditures were nearly three-quarters of this total. Dredging expenditures

[34] Source: Airports Council International: Airport Costs and the US Airline Industry - A background paper on the relationship between airports, airlines, competition, and economic growth.

amounted to 3.4 percent of total expenditures, with the majority occurring on the east and gulf coasts. Expenditures for new construction represented 75 percent of the 1994 capital expenditures; new construction expenditures totaled approximately $514 million in 1994. Specialized general cargo facilities accounted for 40.3 percent of the new construction, with conventional general cargo accounting for 26.6 percent, and infrastructure accounting for 12.3 percent.

Table 8-20. Estimated Operating Costs for Denver International Airport: 1996

Cost Category	Estimated Cost (Dollars)	Percentage of Total
Personnel	$44,125,000	27.8
Cleaning	20,648,000	13.0
Utilities	19,438,000	12.2
Supplies and materials	9,681,000	6.1
Repairs and maintenance	8,374,000	5.3
Professional services	8,099,000	5.1
Police	7,726,000	4.9
City interfund services	7,014,000	4.4
Stapleton International Airport	5,749,000	3.6
Underground train	5,662,000	3.6
Variable rate bond fees	5,142,000	3.2
Aircraft rescue and firefighting	5,012,000	3.2
Management fees	4,001,000	2.5
Shuttlebus services	3,120,000	2.0
De-icing facility management fee	2,027,000	1.3
Other contractual services	1,431,000	0.9
Fuel line fill-up	985,000	0.6
Miscellaneous	455,000	0.3
Total	**$158,689,000**	**100.0**
Source: GAO Report February 1996 - Denver Airport - Operating Results and Financial Risks		

The remaining 25 percent of capital expenditures were for modernization and rehabilitation (maintenance and repair), and totaled approximately $172 million in 1994. Of this total, 43.6 percent was spent on infrastructure. Other significant categories included specialized general cargo (19.9 percent) and conventional general cargo (21.1 percent). Further information regarding individual port finances is available from the (Internet URL: http://www.aapa-ports.gov).

There are over 400 ports, and 40,233 kilometers (25,000 miles) of navigation channels throughout the US that need to be maintained. The US Army Corps of Engineers (USACE) is responsible for dredging activities in federally maintained channels and harbors, while permit applicants (e.g., port authorities, terminal operators, and other private industry) apply to the Corps for additional dredging of berths, access channels and so forth. Table 8-23, which is based upon data from the USACE, shows how dredging costs and volumes have varied between 1980 and 1995. These data are presented graphically in Figure 8-43 and Figure 8-44. Figure 8-43 shows dredging expenditures for new construction, for maintenance of existing channels/harbors, and combined expenditures, both for work carried out by USACE, and by industry. Figure 8-44 shows total dredging expenditures in dollars per cubic yard/cubic meter.

Table 8-21. US Port Capital Expenditures (Thousands of Dollars): 1992 to 1994

Region	1994		1993		1992	
	Expenditures	Percent	Expenditures	Percent	Expenditures	Percent
North Atlantic	70,299	7.6%	91,198	14.0%	112,190	16.7%
South Atlantic	124,853	13.4%	148,555	22.7%	123,065	18.3%
Gulf	109,297	11.8%	129,805	19.9%	145,358	21.6%
South Pacific	533,992	57.4%	139,275	21.3%	140,296	20.9%
North Pacific	40,628	4.4%	94,331	14.4%	45,632	6.8%
Great Lakes	754	0.1%	22,938	3.5%	3,206	0.5%
AK, HI, PR, & V.I.*	35,420	3.8%	27,561	4.2%	102,021	15.2%
Guam, Saipan	14,377	1.5%	-	-	-	-
Total	$929,620	100.0%	$653,663	100.0%	$671,768	100.0%

Source: Maritime Administration
*** Alaska, Hawaii, Puerto Rico, & Virgin Islands**

The USACE also provides detailed information by state on its civil works expenditures for navigation works between 1936 and 1996. These expenditures are broken down into new construction, and operations and maintenance. Data for 1992 to 1996 are presented graphically in Figure 8-45. Navigation costs comprise harbor and channel maintenance and repair, and lock operations. The USACE provides an inventory of all Corps owned and/or operated locks in its **Navigation Data Center**. However, this information does not include operations costs for locks. Nor does its *Port Series Reports* provide operations cost data for ports.

Table 8-22. US Port Capital Expenditures (Thousands of Dollars) by Type of Facility: 1994

Region	Type of Facility									
	General Cargo	Specialized General Cargo	Dry Bulk	Liquid Bulk	Passenger	Other	Infrastructure		Dredging	Total
							Off-Terminal	On-Terminal		
North Atlantic	6,727	3,696	1,891	-	-	1,946	48,868	1,233	5,938	70,299
South Atlantic	14,566	58,772	60	1,177	19,675	6,957	15,663	314	7,669	124,853
Gulf	53,718	1,450	2,119	904	11,725	25,341	4,080	3,324	6,636	109,297
South Pacific	52,218	152,136	28,982	88	714	1,397	25,856	28,589	1,012	290,992
North Pacific	459	5,659	5,053	-	422	12,830	8,642	7,563	-	40,628
Great Lakes	399	-	135	-	-	-	-	-	220	754
AK,HI,PR, & VI*	28,126	6,132	-	-	-	333	532	-	297	35,420
Guam, Saipan	-	11,391	-	-	-	986	-	-	2,000	14,377
Total	$156,213	$239,236	$38,240	$2,169	$32,536	$49,790	$103,641	$41,023	$23,772	$686,620
Percent by Facility Type	22.8%	34.8%	5.6%	0.3%	4.7%	7.3%	15.1%	6.0%	3.4%	

Source: Maritime Administration

* Alaska, Hawaii, Puerto Rico, & Virgin Islands

Table 8-23. Dredging Costs and Volumes by USACE and Industry: 1980 to 1995.

	US ARMY CORPS OF ENGINEERS								
YEAR	**Expenditures (millions of Dollars)**			**Volume (Million Cubic Yards)**			**Volume (Million Cubic Meters)**		
	Maintenance	***New Work***	***Total***	***Maintenance***	***New Work***	***Total***	***Maintenance***	***New Work***	***Total***
1980	92.0	3.0	95.0	81.0	1.0	82.0	61.9	0.8	62.7
1981	104.0	0.0	104.0	88.0	0.0	88.0	67.3	0.0	67.3
1982	76.0	0.0	76.0	60.0	0.0	60.0	45.9	0.0	45.9
1983	64.0	1.0	65.0	48.0	1.0	49.0	36.7	0.8	37.5
1984	80.0	1.0	81.0	49.0	0.0	49.0	37.5	0.0	37.5
1985	73.0	0.0	73.0	65.0	0.0	65.0	49.7	0.0	49.7
1986	80.0	0.0	80.0	64.0	0.0	64.0	48.9	0.0	48.9
1987	66.0	0.3	66.3	47.7	0.3	48.0	36.5	0.2	36.7
1988	73.4	0.0	73.4	58.2	0.1	58.3	44.5	0.1	44.6
1989	68.5	0.0	68.5	58.7	0.0	58.7	44.9	0.0	44.9
1990	61.8	0.0	61.8	35.0	0.0	35.0	26.8	0.0	26.8
1991	99.6	0.0	99.6	62.4	0.0	62.4	47.7	0.0	47.7
1992	89.2	0.0	89.2	52.4	0.0	52.4	40.1	0.0	40.1
1993	75.1	0.7	75.8	38.3	0.1	38.4	29.3	0.1	29.4
1994	84.3	0.0	84.3	52.5	0.0	52.5	40.1	0.0	40.1
1995	88.8	6.5	95.3	53.8	7.9	61.7	41.1	6.0	47.2
	INDUSTRY								
YEAR	**Expenditures (millions of Dollars)**			**Volume (Million Cubic Yards)**			**Volume (Million Cubic Meters)**		
	Maintenance	***New Work***	***Total***	***Maintenance***	***New Work***	***Total***	***Maintenance***	***New Work***	***Total***
1980	213.0	95.0	308.0	162.0	53.0	215.0	123.9	40.5	164.4
1981	240.0	115.0	355.0	174.0	97.0	271.0	133.0	74.2	207.2
1982	234.0	135.0	369.0	157.0	55.0	212.0	120.0	42.1	162.1
1983	291.0	88.0	379.0	206.0	32.0	238.0	157.5	24.5	182.0
1984	376.0	93.0	469.0	245.0	52.0	297.0	187.3	39.8	227.1
1985	313.0	63.0	376.0	208.0	30.0	238.0	159.0	22.9	182.0
1986	242.0	64.0	306.0	218.0	33.0	251.0	166.7	25.2	191.9
1987	222.2	98.9	321.2	167.4	42.8	210.2	128.0	32.7	160.7
1988	222.0	177.9	399.9	154.6	73.0	227.6	118.2	55.8	174.0
1989	249.6	164.0	413.6	222.4	52.7	275.1	170.0	40.3	210.3
1990	244.2	187.0	431.2	174.7	63.3	238.0	133.6	48.4	182.0
1991	323.4	89.4	412.9	209.2	28.4	237.6	159.9	21.7	181.7
1992	280.3	116.2	396.5	164.0	27.8	191.8	125.4	21.3	146.6
1993	335.2	103.9	439.1	197.2	33.4	230.6	150.8	25.5	176.3
1994	342.4	100.8	443.2	212.2	37.0	249.2	162.2	28.3	190.5
1995	319.4	116.3	435.7	163.4	26.1	189.5	124.9	20.0	144.9

Figure 8-43. Total Expenditures for Dredging by USACE and Industry, by Type: 1980 to 1995

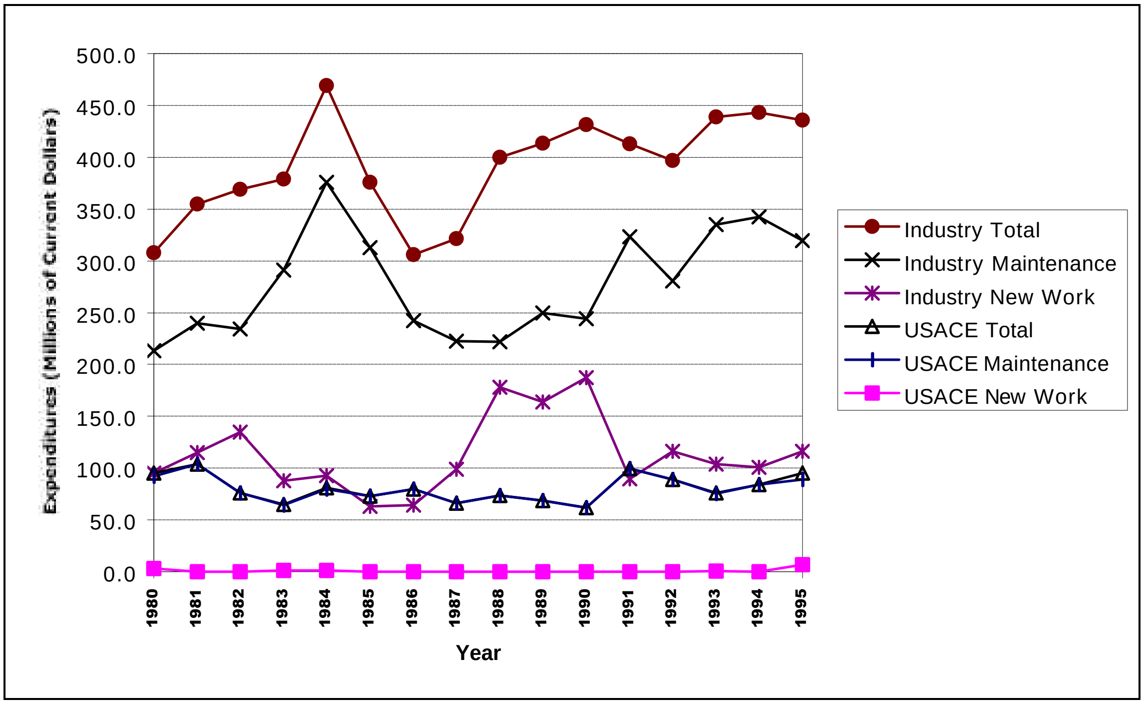


Figure 8-44. Dredging Expenditures Per Cubic Yard/Cubic Meter: 1980 to 1995

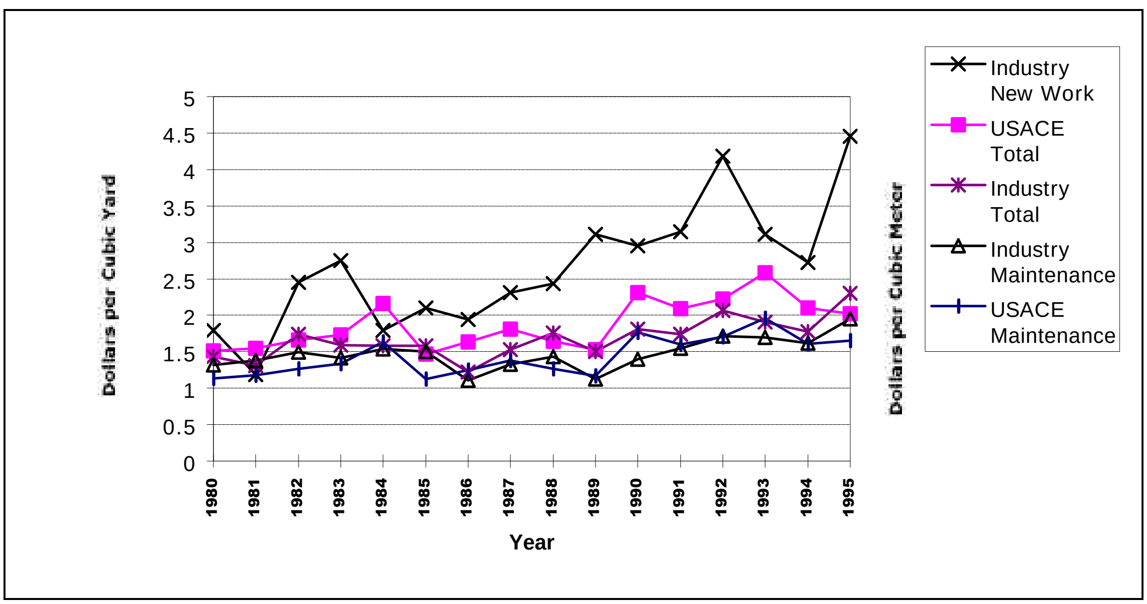
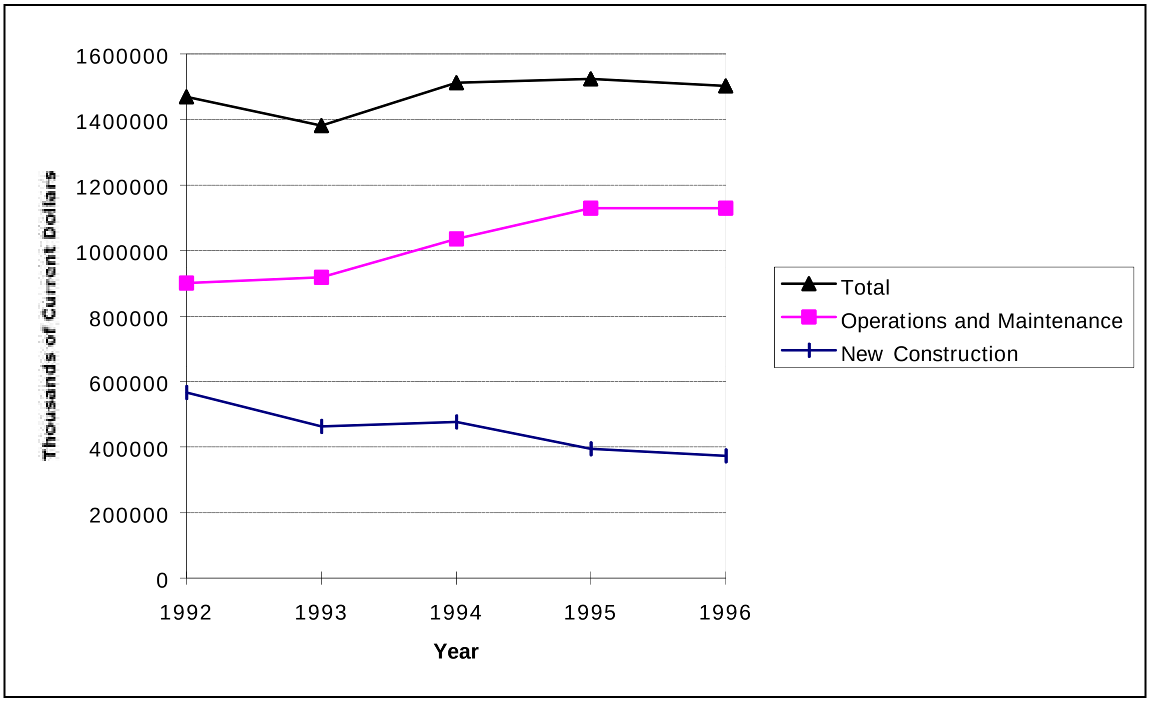


Figure 8-45. USACE Total Expenditures for Navigation: 1992 to 1996



8.2.2 Baseline Measures for the Power Utilities Sub-Sector

The power utilities sub-sector as defined in this document comprises electric utilities, non-utility power producers, and gas production/distribution. The EIA *Annual Energy Review 1996*, provides data on net generation by the different types of power station, and on retail sales of electricity by end-use sector.

Table 8-24 shows electric power industry net generation by energy source, between 1992 and 1996. Total net generation in 1996 was 3.1 trillion kilowatt hours, of which 88 percent was produced by electric utilities. Figure 8-46 shows how electric utility net generation was composed by power source in 1996. Reference to the figure shows that coal-fired power stations comprised 56 percent of total net generation, with nuclear power comprising a further 22 percent. Hydroelectric power (HEP) represented a further 11 percent of the remainder. Figure 8-47 shows similar information for non-utility power producers. In comparison with the utility power sector, natural gas was the largest power source for non-utilities, followed by other energy sources, which include HEP, petroleum, renewable sources, nuclear, propane, butane, and so forth.

Table 8-24. Electric Power Industry Net Generation: 1992 to 1996

NET GENERATION IN BILLION KILOWATTHOURS												
Year	**Coal**	**Natural Gas**	**Petroleum**	**Hydroelectric Power**	**Geothermal Energy**	**Wood**	**Waste**	**Solar**	**Wind**	**Nuclear**	**Other**	**Total**
Electric Utilities												
1992	1575.9	263.9	88.9	239.6	8.1	0.8	1.3	s	s	618.8	0.0	**2797.2**
1993	1639.2	258.9	99.5	265.1	7.6	0.9	1.1	s	s	610.3	0.0	**2882.5**
1994	1635.5	291.1	91.0	243.7	6.9	0.8	1.2	s	s	640.4	0.0	**2910.7**
1995	1652.9	307.3	60.8	293.7	4.7	0.6	1.0	s	s	673.4	0.0	**2994.5**
1996	1735.9	263.3	67.9	328.8	5.2	0.8	1.2	s	s	674.8	0.0	**3077.9**
Nonutility Producers												
1992	45.2	154.4	10.5	9.4	8.3	34.8	16.5	0.7	2.9	0.1	3.4	**286.1**
1993	50.9	169.5	12.8	11.4	9.5	35.9	17.4	0.9	3.0	0.1	3.1	**314.4**
1994	56.2	174.8	14.5	13.1	9.8	37.0	17.9	0.8	3.4	0.1	15.5	**343.1**
1995	54.8	191.1	16.3	14.6	9.6	35.5	19.0	0.8	3.2	0.0	17.1	**361.9**
1996	60.8	214.2	19.6	16.5	10.7	37.2	22.1	0.9	3.5	0.0	17.9	**403.5**
Total												
1992	1621.1	418.3	99.4	124.9	16.4	35.6	17.8	0.7	2.9	618.8	3.4	**3083.4**
1993	1690.0	428.4	112.4	276.5	17.0	36.8	18.5	0.9	3.0	610.4	3.1	**3196.9**
1994	1691.7	465.9	105.5	256.5	16.8	37.8	19.1	0.8	3.4	640.5	15.5	**3253.8**
1995	1707.7	498.4	77.1	308.3	14.4	36.1	20.0	0.8	3.2	673.4	17.1	**3356.4**
1996	1796.7	477.5	87.5	345.4	15.9	38.0	23.3	0.9	3.5	674.8	17.9	**3481.4**
Note: 's' indicates less than 0.01 billion kilowatthours												

Figure 8-46. Net Generation at Electric Utilities by Source of Power: 1996

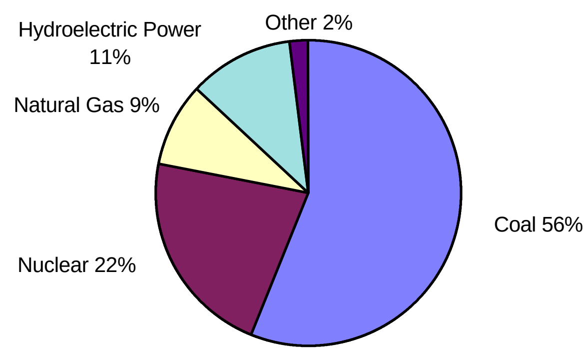
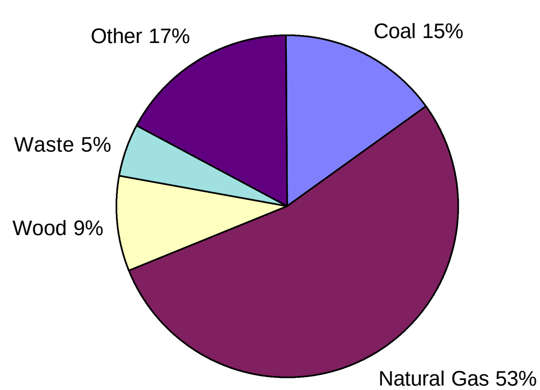


Figure 8-47. Net Generation at Non-Utility Power Producers by Source of Power: 1996



Since 1980, total electric utility net generation has risen from 2,286 billion kWh in 1980 to 3,078 billion kWh in 1996. Electric utility net generation from coal has risen steadily from 1,162 billion kWh in 1980 to 1,736 billion kWh in 1996. In comparison natural gas and petroleum usage have declined. Overall, fossil fuel usage has risen from 1,754 billion kWh in 1980 to 2,067 billion kWh in 1996. Nuclear power net generation has also risen steadily over this period from 251 billion kWh in 1980 to 675 billion kWh in 1996. In contrast, net generation from renewable sources (HEP, geothermal, solar, etc.) increased from 282 billion kWh in 1980 to 339 billion kWh in 1996. In 1990, fossil fuel net generation accounted for 67 percent of total net generation, nuclear electric power accounted for 22 percent, and HEP accounted for 11 percent of the total. The relative distribution of power from fossil fuel, nuclear, and HEP is compared with water consumption data presented later in this section.

Table 8-25 shows electric utility retail sales of electricity by end-use sector between 1980 and 1996. In all sectors, there has been a steady increase in electricity retail sales over this period. Figure 8-48 shows the relative proportions of electricity sales in each sector for 1996. Reference to the figure indicates that the residential sector is the largest consumer of utility electricity, with 35 percent of total sales.

Table 8-26 Part A and Part B shows water use by the thermoelectric power industry in 1990, by water resources region. This includes fossil fuel, nuclear, and geothermal energy. Most of the water withdrawn by thermoelectric plants is used for condenser and reactor cooling. Consumptive use occurs where water is evaporated in cooling towers or ponds. In 1990, 495,889 million liters (131,000 million gallons) per day of freshwater were delivered to power stations, with a further 244,159 million liters (64,500 million gallons) per day of saline water delivered. Thermoelectric power represented 39 percent of total US freshwater withdrawals, and 48 percent of combined fresh and saline water withdrawals. Less the 0.1 percent of water for thermoelectric plants was delivered from the public water supply, and only about 2 percent of total water withdrawals were consumed.

Fossil fuel power plants, which accounted for 67 percent of net generation in 1990, accounted for about 73 percent of total water withdrawals, nuclear plants for 27 percent, and geothermal plants for less than 1 percent.

Table 8-27 shows HEP water use in the US in 1990, by water resources region. Water use is classified as the water used at plants where the turbine generators are driven by falling water. Where water is used only once, accurate measurements of flow rates can be made, and water use figures are accurate. However, when water is recycled (i.e., there is pumped storage of water in elevated reservoirs using excess generating capacity in off-peak times to supplement peak-load capacity) calculating net water use is more difficult. No calculation of consumptive use is made, even though evaporation from reservoirs may be substantial.

Table 8-25. Electric Utility Retail Sales of Electricity by End-Use Sector: 1980 to 1996

Retail Sales in Billion Kilowatthours					
Year	**Residential**	**Commercial**	**Industrial**	**Other**	**Total**
1980	717	488	815	74	*2,094*
1981	722	514	826	85	*2,147*
1982	730	526	745	86	*2,086*
1983	751	544	776	80	*2,151*
1984	780	583	838	85	*2,286*
1985	794	606	837	87	*2,324*
1986	819	631	831	89	*2,369*
1987	850	660	858	88	*2,457*
1988	893	699	896	90	*2,578*
1989	906	726	926	90	*2,647*
1990	924	751	946	92	*2,713*
1991	955	766	947	94	*2,762*
1992	936	761	973	93	*2,763*
1993	995	795	977	95	*2,861*
1994	1,008	820	1,008	98	*2,935*
1995	1,043	863	1,013	95	*3,013*
1996	1,078	888	1,017	101	*3,084*
"Other" includes public street and highway lighting, other sales to public authorities, sales to railroads and railways, and interdepartmental sales.					

Figure 8-48. Total Electric Utility Retail Sales by Sector: 1996

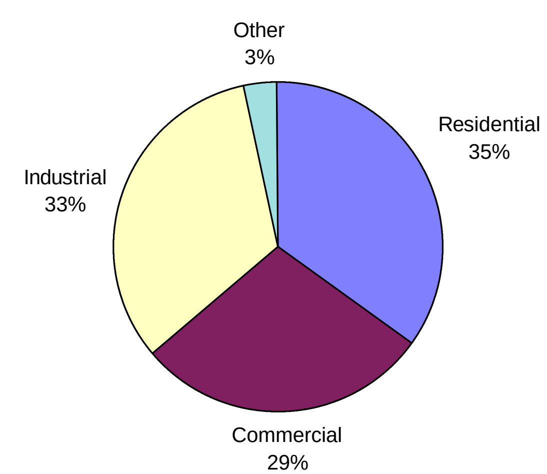


Table 8-26. Water Use By The Thermoelectric Power Industry: 1990

Part A: Million Gallons Per Day

	Self-supplied withdrawals by source and type					Total Use				
Region	Ground Water	Surface Water			Public Supply Deliveries	Withdrawals and Deliveries	Consumptive Use			
	Fresh	*Fresh*	*Saline*	*Total*	*Fresh*	*Fresh*	*Fresh*	*Saline*	*Total*	Power Generated in million KWH
New England	3	2,400	9,090	11,500	7	2,410	48	182	230	93,000
Mid Atlantic	5	12,200	25,000	37,200	1	12,200	187	226	413	279,000
South Atlantic-Gulf	41	19,700	10,700	30,300	6	19,700	272	2	273	404,000
Great Lakes	3	22,800	0	22,800	0	22,800	476	0	476	179,000
Ohio	65	23,800	0	23,800	1	23,900	881	0	881	436,000
Tennessee	0	7,070	0	7,070	0	7,070	15	0	15	60,800
Upper Mississippi	21	16,500	0	16,500	6	16,500	635	0	635	194,000
Lower Mississippi	75	5,570	1,060	6,620	1	5,640	87	42	129	73,500
Souris-Red-Rainy	0	26	0	26	0	26	1	0	1	338
Missouri Basin	50	9,980	0	9,980	7	10,000	195	0	195	159,000
Arkansas-White-Red	31	4,500	0	4,500	26	4,550	144	0	144	132,000
Texas-Gulf	46	4,660	3,150	7,820	7	4,720	207	9	217	192,000
Rio Grande	16	2	0	2	0	18	12	0	12	7,780
Upper Colorado	0	177	0	177	0	177	165	0	165	91,400
Lower Colorado	47	62	0	62	1	110	107	0	107	54,000
Great Basin	7	24	0	24	0	31	31	0	31	17,300
Pacific Northwest	10	345	0	345	0	355	21	0	21	21,600
California	5	241	11,400	11,600	13	258	6	7	13	80,100
Alaska	5	26	0	26	1	32	3	0	3	3,820
Hawaii	95	0	1,550	1,550	0	96	2	15	17	8,320
Caribbean	3	0	2,570	2,570	3	6	1	1	2	15,000
Total	**525**	**130,000**	**64,500**	**194,000**	**80**	**131,000**	**3,500**	**484**	**3,980**	**2,500,000**

Part B: Million Liters per Day

	Self-supplied withdrawals by source and type					Total Use				
Region	Ground Water	Surface Water			Public Supply Deliveries	Withdrawals and Deliveries	Consumptive Use			
	Fresh	*Fresh*	*Saline*	*Total*	*Fresh*	*Fresh*	*Fresh*	*Saline*	*Total*	Power Generated in million KWH
New England	11	9,084	34,406	43,528	25	9,122	182	689	871	93,000
Mid Atlantic	17	46,177	94,625	140,802	4	46,177	708	855	1,563	279,000
South Atlantic-Gulf	155	74,565	40,500	114,686	23	74,565	1,030	6	1,033	404,000
Great Lakes	12	86,298	0	86,298	0	86,298	1,802	0	1,802	179,000
Ohio	246	90,083	0	90,083	3	90,462	3,335	0	3,335	436,000
Tennessee	0	26,760	0	26,760	0	26,760	57	0	57	60,800
Upper Mississippi	79	62,453	0	62,453	22	62,453	2,403	0	2,403	194,000
Lower Mississippi	284	21,082	4,012	25,057	3	21,347	329	159	488	73,500
Souris-Red-Rainy	0	98	0	98	0	98	2	0	2	338
Missouri Basin	189	37,774	0	37,774	26	37,850	738	0	738	159,000
Arkansas-White-Red	117	17,033	0	17,033	98	17,222	545	0	545	132,000
Texas-Gulf	174	17,638	11,923	29,599	27	17,865	783	36	821	192,000
Rio Grande	61	7	0	7	0	68	45	0	45	7,780
Upper Colorado	0	670	0	670	0	670	625	0	625	91,400
Lower Colorado	178	235	2	235	3	416	405	2	405	54,000
Great Basin	27	91	0	91	0	117	117	0	117	17,300
Pacific Northwest	38	1,306	0	1,306	0	1,344	79	0	79	21,600
California	17	912	43,149	43,906	49	977	24	25	49	80,100
Alaska	18	98	0	98	4	121	12	0	12	3,820
Hawaii	360	0	5,867	5,867	2	363	6	57	64	8,320
Caribbean	10	0	9,727	9,727	12	22	4	4	8	15,000
Total	**1,987**	**492,050**	**244,133**	**734,290**	**303**	**495,835**	**13,248**	**1,832**	**15,064**	**2,500,000**

Table 8-27. Hydroelectric Power Water Use: 1990

Region	Million Gallons per Day	Million Liters per Day	Thousand acre-feet per year	Million cubic meters	Power Generated in million kWh
New England	168,000	635,880	188,000	231,896	8,080
Mid Atlantic	192,000	726,720	215,000	265,200	11,700
South Atlantic-Gulf	275,000	1,040,875	308,000	379,915	18,500
Great Lakes	506,000	1,915,210	567,000	699,388	30,100
Ohio	147,000	556,395	165,000	203,526	5,860
Tennessee	294,000	1,112,790	330,000	407,051	19,700
Upper Mississippi	73,200	277,062	82,100	101,269	2,200
Lower Mississippi	26,600	100,681	29,800	36,758	1,250
Souris-Red-Rainy	1,280	4,845	1,430	1,764	45
Missouri Basin	109,000	412,565	122,000	150,486	12,600
Arkansas-White-Red	109,000	412,565	122,000	150,486	8,370
Texas-Gulf	12,100	45,799	13,600	16,775	953
Rio Grande	3,520	13,323	3,950	4,872	569
Upper Colorado	11,900	45,042	13,300	16,405	4,760
Lower Colorado	34,700	131,340	38,900	47,983	6,640
Great Basin	2,360	8,933	2,650	3,269	284
Pacific Northwest	1,250,000	4,731,250	1,400,000	1,726,885	142,000
California	69,000	261,165	77,300	95,349	23,700
Alaska	1,790	6,775	2,010	2,479	980
Hawaii	264	999	296	365	89
Caribbean	362	1,370	406	501	108
Total	**3,290,000**	**12,452,650**	**3,690,000**	**4,551,574**	**299,000**

Fresh surface water provides virtually all water for HEP generation. The Pacific Northwest region had the largest use of water, and accounted for about 38 percent of total usage in the US. Almost half of the water used for HEP generation in the US was in Washington, Oregon (primarily on the Columbia River) and New York (on the Niagara and St. Lawrence River systems).

The **Census of Transportation Communications and Utilities**, provide limited information on construction capital expenditures, and maintenance and repair expenditures for SIC 491 (electric services), SIC 492 (gas production and distribution), and SIC 493 (combination utility services). The data are shown in Table 8-28.

The figures for construction capital expenditures shown in Table 8-28 are similar to those from the *Value of New Construction Put in Place* figures for 1992 for electric light and power ($17,136 million) and gas ($6,901 million), thus the figures for maintenance and repair (of both machinery and building) are probably reasonably representative of the whole industry. It should be noted that the figures for gas utility construction expenditures are different to those presented in the *Statistical Abstract 1997* (based upon

American Gas Association Data for the gas utility industry) which show 1992 expenditures as $11,068 million. This suggests that a large proportion of SIC 493 is attributable to the gas industry. The American Gas Association data show that the largest component of capital costs is for transmission (52 percent), followed by distribution (35 percent), and production and storage (3 percent). In 1995, total expenditures were $10,829 million. Other data relating to gas utility performance are available from the American Gas Association (URL: http://www.aga.com), such as its 1995 publication *Performance Benchmarks for Natural Gas Utilities*.

Table 8-28. Construction and Maintenance and Repair Expenditures: 1992

	CONSTRUCTION CAPITAL EXPENDITURES		MAINTENANCE AND REPAIR EXPENSES	
SIC CODE	Total ($1000)	Percentage work carried out by Own Employees	Total ($1000)	Percentage work carried out by Own Employees
491	15,345,135	44	8,449,911	58
492	6,222,152	32	1,969,822	57
493	7,942,133	43	4,463,348	64

Data relating to electric utility operating performance are available from the Electric Power Research Institute (URL: http://www.epri.com). Information is available about the generation and transmission of electricity.

8.2.3 Baseline Measures for the Water Sub-Sector

This section considers baseline measures for water supply/treatment, for flood control, and for hydroelectric power projects.

Data from the **1992 Census of Transportation Communications and Utilities** provided limited information on expenditures for new construction, and for maintenance and repair for SIC Code 495 (sanitary services). This information is shown in Table 8-29.

Table 8-29. Construction and Maintenance and Repairs Expenditures: 1992

	CONSTRUCTION CAPITAL EXPENDITURES		MAINTENANCE AND REPAIR EXPENSES	
SIC CODE	Total ($1000)	Percentage work carried out by Own Employees	Total ($1000)	Percentage work carried out by Own Employees
495	828,005	12	264,444	46

The figure for total construction capital expenditures shown in Table 8-29 is significantly lower than the *Value of New Construction Put in Place* figure for 1992. The VIP data for water supply facilities in 1992 show new construction amounting to $5,170 million. However, this category is broader than SIC 495, as it includes potable water distribution systems and storage facilities such as water lines, aqueducts, water pumping stations, treatment plants, dams, reservoirs, artificial lakes, brooks, ponds, and water wells.

The US Army Corps of Engineers (USACE) provides data on the total Corps expenditures for new construction, and for maintenance and repair, both for flood control, and for HEP projects.

Table 8-30 shows USACE total expenditures for these categories between 1990 and 1996. Flood control expenditures for the Mississippi River and tributaries are broken out as a separate category by the Corps.

Table 8-30. Total USACE Expenditures for New Construction and Operations and Maintenance for Flood Control and Power Projects: 1990 to 1996

YEAR	TOTAL ANNUAL USACE EXPENDITURES IN MILLIONS OF CURRENT DOLLARS								
	FLOOD CONTROL			FLOOD CONTROL (MISSISSIPPI AND TRIBUTARIES)			HEP PROJECTS		
	New Construction	*Operations and Maintenance*	*Total*	*New Construction*	*Operations and Maintenance*	*Total*	*New Construction*	*Operations and Maintenance*	*Total*
1992	764,090	423,724	1,187,814	240,581	131,656	372,237	84,352	376,986	461,338
1993	615,764	405,459	1,021,223	191,271	119,069	310,340	78,909	376,237	455,146
1994	683,292	471,273	1,154,565	228,155	147,192	375,347	83,783	427,435	511,218
1995	607,741	507,526	1,115,267	111,582	271,990	383,572	124,559	460,662	585,221
1996	587,783	534,025	1,121,808	73,639	228,260	301,899	111,537	432,904	544,441

These data are shown graphically in Figure 8-49 and Figure 8-50. More detailed data on maintenance and repair expenditures in the water sub-sector have not been located by the authors.

8.2.4 Baseline Measures for the Pipelines Sub-Sector

Limited information relating to pipeline operations and maintenance costs has been located by the authors. The **1992 Census of Transportation Communications and Utilities** provides some information regarding expenditures for new construction, and for maintenance and repair for SIC Code 4613 (refined petroleum pipelines), and SIC Code 4612 and 4619 (crude petroleum pipelines, and pipelines not elsewhere classified). These data are presented in Table 8-31.

Figure 8-49. USACE Total Expenditures for Flood Control: 1992 to 1996

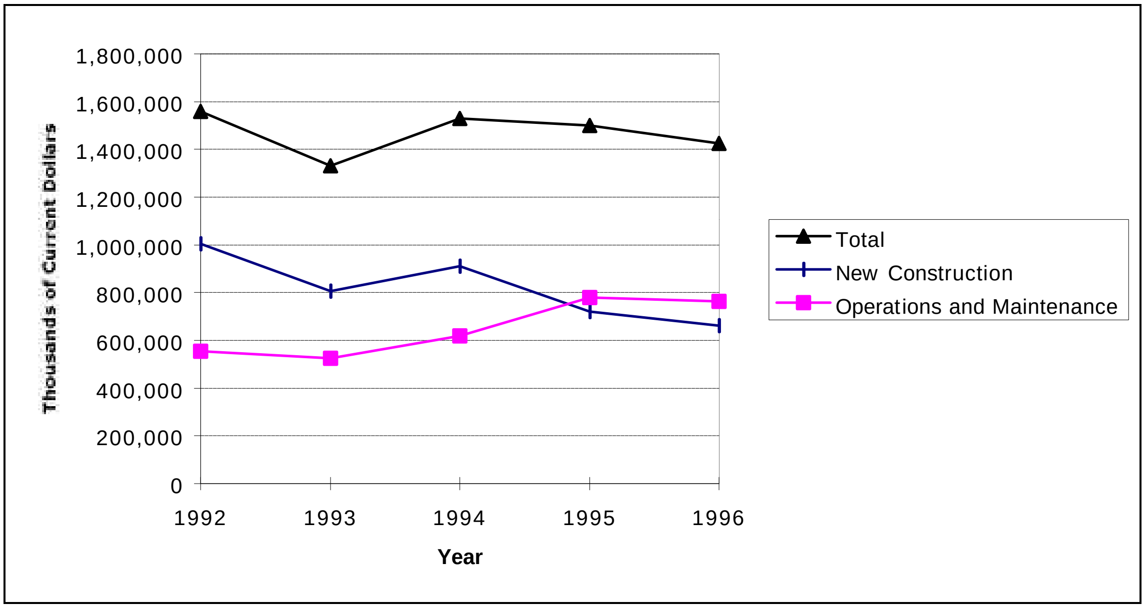


Figure 8-50. USACE Expenditures for Multi-Purpose Power Projects: 1992 to 1996

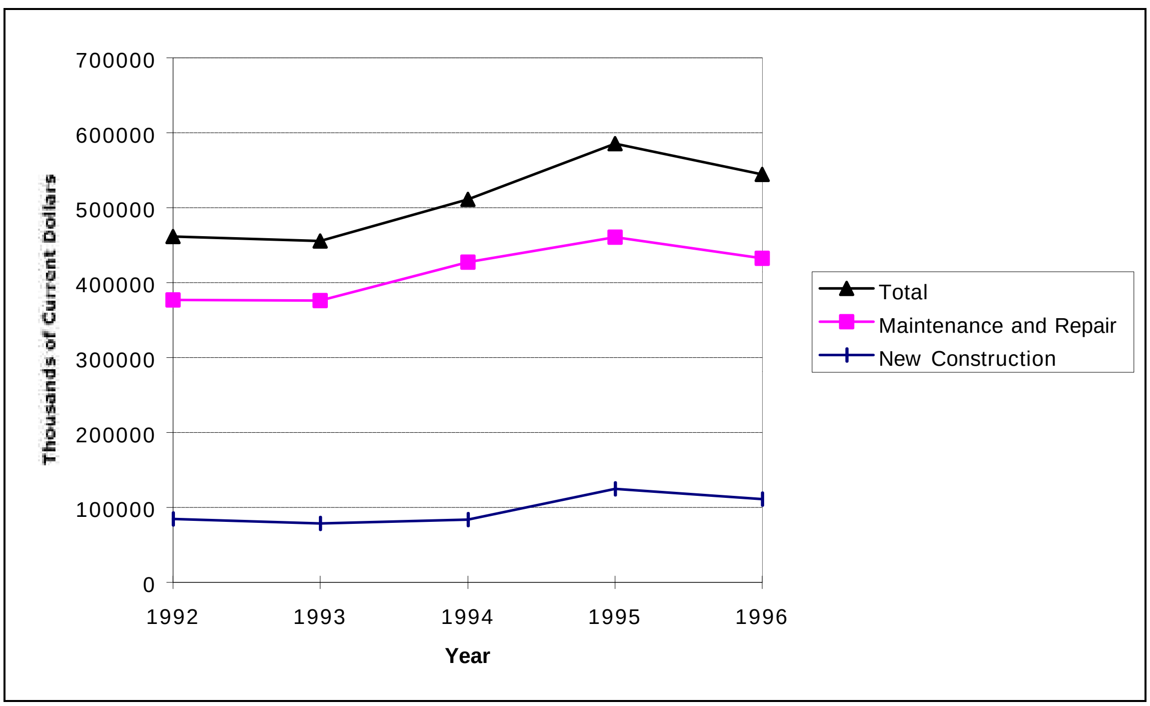


Table 8-31. New Construction and Maintenance and Repair: 1992

	CONSTRUCTION CAPITAL EXPENDITURES		MAINTENANCE AND REPAIR EXPENSES	
SIC CODE	Total ($1000)	Percentage work carried out by Own Employees	Total ($1000)	Percentage work carried out by Own Employees
4613	161,420	14	231,160	31
4612, 4619	465,106	18	537,379	34

The figures for capital expenditures in Table 8-31 are somewhat lower than the comparable figure for *Value of New Construction Put in Place* in 1992 for petroleum pipelines ($849 million). However, the latter figure also includes an element of non-pipeline construction, such as buildings for the pipeline industry.

Other data may be available from organizations such as the Independent Petroleum Association of America (URL: http://www.ipaa.org), but this is likely to be at a company-specific level, which is beyond the scope of this document.

8.3 Summary of Baseline Measures for the Public Works Sector

This section summarizes the baseline measures for the public works sector which are presented in Sections 8.2.1 through 8.2.4. The summary data concentrate upon cost rather than consumption. They are presented in Table 8-32 below.

Table 8-32 shows general information relating to the public works sector, as well as key operations, maintenance, and energy baseline data for each of the sub-sectors identified in Chapters 4 and 8 of this document. The 'General Information' section describes the *total expenditures for new construction, maintenance and repairs, and improvements* in the public works sector in 1994.

The **transportation sub-sector** provides baseline measures for each mode of transportation and provides *selected key characteristics* for each mode. This section of the table also presents general information about *total government construction outlays* for *highways, transit, air,* and *water* transportation modes.

The *highways* section briefly describes the extent of the US highway system, its geographic distribution, and jurisdiction. The baseline measures focus upon capital and maintenance expenditures by State government, grouped by generic type of expenditure, and by highway functional system (i.e., interstate, arterial, or collector road). The baselines present both aggregated costs, and costs normalized per highway mile/kilometer. Note that more detailed baselines in Section 8.2.1.1 also provide some information on a 'cost per lane mile' basis.

The *railroads* section briefly describes the extent of the US railroad system, in terms of miles of track operated (this excludes multiple mainline tracks and sidings). The baseline measures focus upon maintenance and repair expenditures by all Class I railroad operators (for definition of Class I railroads see Section 8.1.2.3), by generic type of expenditure. Selected maintenance and repair cost components for running lines are shown in the table. Detailed statistics are broken down by running and switching lines. Given the high-level focus of this section, only data for running lines are shown. The full list of cost components is very detailed. For this reason, the percentage of total maintenance and repair costs for infrastructure (excluding vehicles and yards - see Section 8.2.1.2) represented by each component is also shown.

The *transit* section provides limited baseline measures for all transit systems combined. The baseline measures focus upon non-vehicle/primary facilities maintenance and repair expenditures. The difficulties in obtaining more detailed baseline data are explained in Section 8.2.1.3.

The *air transportation* section provides limited information about US airports. The difficulties in establishing baseline measures for airports, each of which is likely to have an unique operating cost structure, are explained in Section 8.2.1.4.

The *water transportation* section briefly describes the extent of the US water freight system, in terms of terminals operated. The baseline measures focus upon capital/ maintenance and repair expenditures for all US ports, as well as dredging expenditures for harbors and waterways by the US Army Corps of Engineers (USACE), and by industry. Data are also shown for USACE expenditures for navigation (this would include cost components such as lock operations).

The **power utilities sub-sector** provides baseline measures for power generation, including the distribution of natural gas. This section of the table presents general information about the size of the sub-sector, in terms of number of operating establishments, and miles of pipeline operated. The baselines focus upon water use by the sub-sector, as well as capital expenditures for construction, and for maintenance and repair by SIC Code.

The **water sub-sector** provides baseline measures for water supply, treatment, and flood control, as well as information regarding hydroelectric power related works by USACE. This section presents general information about the size of the sub-sector, in terms of number of operating establishments. The baselines focus upon capital expenditures for new construction, and for maintenance and repair, by SIC Code, and for work carried out by USACE.

The **pipelines sub-sector** provides baseline measures for petroleum and other pipelines in the US, excluding natural gas pipelines. This section presents general information about the size of the sub-sector, in terms of number of operating establishments, and miles of pipeline operated. The baselines focus upon capital expenditures for new construction, and for maintenance and repair, by SIC Code.

Summary of Abbreviations Used in Table 8-32

VIP	Value of New Construction Put in Place
DOT	Department of Transportation
FHWA	Federal Highway Administration
STB	Surface Transportation Board
FAA	Federal Aviation Administration
ATA	Airline Transport Association
MARAD	Maritime Administration
USACE	US Army Corps of Engineers
USGS	US Geological Survey

Table 8-32. Summary of Baseline Measures: Public Works Sector

DESCRIPTION	YEAR	BASELINE	SOURCE[35]
GENERAL INFORMATION			
Value of New Construction Put in Place	1994	$103,360 million (constant 1992 dollars)	Census VIP Data
Total Maintenance and Repair Expenditures	1994	$24,714 million (constant 1992 dollars)	Census Data
Total Expenditures for Improvements	1994	$31,404 million (constant 1992 dollars)	Census Data
TRANSPORTATION SUB-SECTOR			
Total Government Outlays	1993	43.0 billion (constant 1992 dollars)	DOT
Outlays for Highways	1993	33.2 billion (constant 1992 dollars)	DOT
Outlays for Airports	1993	4.6 billion (constant 1992 dollars)	DOT
Outlays for Transit	1993	4.2 billion (constant 1992 dollars)	DOT
Outlays for Water Transportation and Terminals	1993	0.7 billion (constant 1992 dollars)	DOT
Outlays for Parking Facilities	1993	0.3 billion (constant 1992 dollars)	DOT
Highways			
Total Mileage, Location, and Jurisdiction	1994	6,285 million kilometers (3,906 million miles) - 21% urban, 79 % rural. Jurisdiction: 75% Local, 20% State, 5% Federal	FHWA
State Capital Outlays	1994	$30,152 million	FHWA
State Maintenance and Traffic Services Outlays	1994	$10,073 million	FHWA
State Physical Maintenance Outlays	1994	$7,089 million	FHWA
State Snow/Ice Removal	1994	$1,082 million	FHWA
State Traffic Control Operations	1994	$682 million	FHWA
State Other (erosion, vegetation control etc.)	1994	$226 million	FHWA

[35] See accompanying text for description of abbreviations used in this table.

Table 8-32. Summary of Baseline Measures: Public Works Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
State Maintenance Outlays - Urban Interstates	1994	$26,581 per kilometer ($42,769 per mile)	FHWA
State Maintenance Outlays - Urban Arterials	1994	$9,501 per kilometer ($15,287 per mile)	FHWA
State Maintenance Outlays - Urban Collectors	1994	$4,828 per kilometer ($7,768 per mile)	FHWA
State Maintenance Outlays - Rural Interstates	1994	$15,632 per kilometer ($25,152 per mile)	FHWA
State Maintenance Outlays - Rural Arterials	1994	$4,347 per kilometer ($6,995 per mile)	FHWA
State Maintenance Outlays - Rural Collectors	1994	$2,610 per kilometer ($4,200 per mile)	FHWA
State Maintenance Outlays - All Highways	1994	$4,248 per kilometer ($6,835 per mile)	FHWA
Railroads			
Railroad Mileage by Classification	1996	Class I - 201,241 kilometers operated (125,072 miles) Regional - 30,273 kilometers operated (18,815 miles) Local - 42,713 kilometers operated (26,546 miles) Amtrak - 39,421 kilometers operated (24,500 miles)	STB
Class I Railroad M&R Costs for Roadways and Structures	1996	$4,456 million (17% of total operating expenses)	STB
M&R Costs for Roadways - Running	1996	$160,499,000 (3.60% of total M&R-excludes vehicle costs)	STB
M&R Costs for Tunnels and Subways - Running	1996	$1,527,000 (0.03% of total M&R-excludes vehicle costs)	STB
M&R Costs for Bridges and Culverts - Running	1996	$94,046,000 (2.11% of total M&R-excludes vehicle costs)	STB
M&R Costs for Ties - Running	1996	$25,609,000 (0.57% of total M&R-excludes vehicle costs)	STB
M&R Costs for Rail and Track Material - Running	1996	$382,260,000 (8.58% of total M&R-excludes vehicle costs)	STB
M&R Costs for Ballast - Running	1996	$35,457,000 (0.80% of total M&R-excludes vehicle costs)	STB
M&R Costs for Signals - Running	1996	$217,039,000 (4.87% of total M&R-excludes vehicle costs)	STB

Table 8-32. Summary of Baseline Measures: Public Works Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
Transit			
Total Capital Outlays	1995	$7.0 billion	FTA
Total Operating Expenses	1995	$18.1 billion	FTA
Non-Vehicle Maintenance	1995	$1.868.5 million (10.4% of total operating expenses)	FTA
Air Transportation			
Number of Airports in the US	1995	18,224 Airports 5,415 Public Use Airports	FAA
Airline Costs for Use and Lease of Airport Facilities	1995	Stable at approximately 4% of Total Airline Operating Costs	ATA
National Airspace System Operating Budget	1996	$863 million	
Water Transportation			
Number of Terminals	1995	362 Terminals on the Great Lakes with 507 Berths 1811 Inland Terminals 1578 Ocean Terminals	MARAD
Total Port Capital and M&R Expenditures	1994	$687 million (excluding $243 million for land purchase in California). New Construction - 75% M&R - 25% (172 million)	MARAD
Dredging Expenditures	1994	*USACE Expenditures:* New Construction - 0 M&R - $84.3 million *Industry expenditures:* New Construction - $116.3 million M&R - $342.4 million	USACE
Navigation Expenditures	1994	*USACE Expenditures:* New Construction - $477 million M&R - $1,035 million	USACE

Table 8-32. Summary of Baseline Measures: Public Works Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
POWER UTILITIES SUB-SECTOR			
Number of Establishments by SIC Code	1992	SIC 491 (Electric Utilities)- 5374 Establishments SIC 492 (Gas Production and Distribution) - 3968 Establishments SIC 493 (Combination Utilities) - 1814 Establishments	Census Data
Length of Natural Gas Pipelines in US	1994	1,922,755 kilometers (1,195,000 miles)	DOT
Water Consumption by Power Utilities	1990	*Thermoelectric Generation:* 496,000 million liters fresh water per day (131,000 million gallons per day) 244,000 million liters saline water per day (64,500 million gallons per day) *Hydroelectric Generation:* 12,500,000 million liters fresh water per day (3,290,000 million gallons per day)	USGS
Construction Capital Expenditures by SIC Code	1992	SIC 491 - $15,345 million SIC 492 - $6,222 million SIC 493 - $7,492 million	Census Data
Maintenance and Repair Expenditures by SIC Code	1992	SIC 491 - $8,450 million SIC 492 - $1,970 million SIC 493 - $4,463 million	Census Data
WATER SUB-SECTOR			
Number of Establishments by SIC Code	1992	SIC 4952 (Sewerage Systems)- 470 Establishments SIC 4941 (Water Supply) - 3453 Establishments	Census Data
USACE Total Flood Control Expenditures (including Mississippi)	1994	New Construction - $911 million M&R - $619 million	USACE
USACE Hydropower Expenditures	1994	New Construction - $84 million M&R - $427 million	USACE

Table 8-32. Summary of Baseline Measures: Public Works Sector (continued)

DESCRIPTION	YEAR	BASELINE	SOURCE
PIPELINES SUB-SECTOR			
Number of Establishments by SIC Code	1992	SIC 4612 (Crude Petroleum)- 405 Establishments SIC 4613 (Refined Petroleum) - 358 Establishments SIC 4619 (Pipelines n.e.c) - 81 Establishments	Census Data
Length of Selected Pipelines in US	1994	*Oil Pipeline:* 323,000 kilometers total (201,000 miles) 183,000 kilometers crude oil pipeline (114,000 miles)	DOT
Construction Capital Expenditures by SIC Code	1992	SIC 4613 - $161 million SIC 4612 & 4619 - $465 million	Census Data
Maintenance and Repair Expenditures by SIC Code	1992	SIC 4613 - $231 million SIC 4612 & 4619 - $537 million	Census Data

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9. Summary and Suggestions for Further Research

9.1 Summary

The Construction and Building Subcommittee of the National Science and Technology Council is developing baseline measures of current construction industry practices and measures of progress for each of the seven National Construction Goals (NCGs). The seven NCGs are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. Baseline measures are being produced for each of the four key construction industry sectors. The four sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works. This report provides a detailed set of baseline measures for NCG 2 (reductions in operations, maintenance, and energy (OM&E) costs). These baseline measures will assist in determining the success of actions taken to improve the competitiveness of the US construction industry.

Chapter 1 provides background information about the project, its purpose, and scope. Chapter 2 describes the NCGs in more detail, explains BFRL's strategy for collecting information on each NCG, and the limitations of this approach, and reports on progress to date. Chapter 3 provides an overview of the construction industry. This examines the size of the industry, and its importance to the US economy. The chapter also presents general non-sector specific data relevant to the generation of baseline measures. Chapter 4 presents the data classification hierarchies that were used to define each sector, to identify critical factors influencing NCG 2, and to establish data linkages. It also discusses data sources and availability. Chapters 5 through 8 present an overview and detailed baseline measures for each of the four industry sectors, as well as a description of data sources used to develop the baselines. The overview of each sector examines the sector size, changes in the sector, and key sector characteristics. The detailed baseline measures examine operations, maintenance, and energy categories separately. These are summarized in tabular form at the end of each chapter.

Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed. Sufficient data have been collected to establish baselines for OM&E costs across all four sectors. However, the level of detail of the baselines is highly variable, depending upon data availability. In general, energy baselines are more detailed than operations and maintenance baselines, due to the wealth of data available.

9.2 Suggestions for Further Research

The work for this report uncovered areas of research that might be of value to government agencies and private bodies who are responsible for the operations and maintenance of the built environment. These areas of research are concerned with: (1) accounting for the discrepancies between data which quantify annual construction outputs for new construction, additions and alterations, and maintenance and repair; (2) additional data collection; and (3) evaluations of progress toward achievement of NCG 2.

As has been discussed in detail in Chapter 3, there are *significant differences between different data sources* which attempt to quantify the annual output of the construction industry. At the most aggregated level, this makes it difficult to accurately assess how the construction industry is changing over time, and, perhaps more importantly, to attribute these changes to particular causes. Thus, further research to examine the reasons for these discrepancies would be valuable.

In order to be able to generate useful baseline measures, detailed source information is required. As this document has shown, there are a number of areas where data appear to be either absent, or only of a very generalized nature. In particular, *additional data collection* is required in the following areas:

- Water consumption costs in the commercial/institutional, industrial, and public works sectors.
- Operations and maintenance costs in the commercial/institutional sector grouped by principal building activity in a manner comparable with the EIA classifications, for buildings other than commercial office buildings, shopping centers, and education facilities.
- Local Government expenditures for maintenance of highways.
- Railroad operations and maintenance costs for non-freight railroads.
- Airport and runway pavement maintenance and repair costs.
- Water transportation operations costs (locks, navigation channels, ports).
- Pipeline maintenance and repair costs.

Finally, in order to be able to measure progress toward NCG 2, *periodic reports* need to be produced which re-visit the same data sources used to generate the original baselines, and refine or expand the original baselines as necessary to meet the changing needs of the construction industry stakeholders. This subject is discussed briefly in Chapter 2.

Appendix A. Data Classification Hierarchies for the Residential Sector

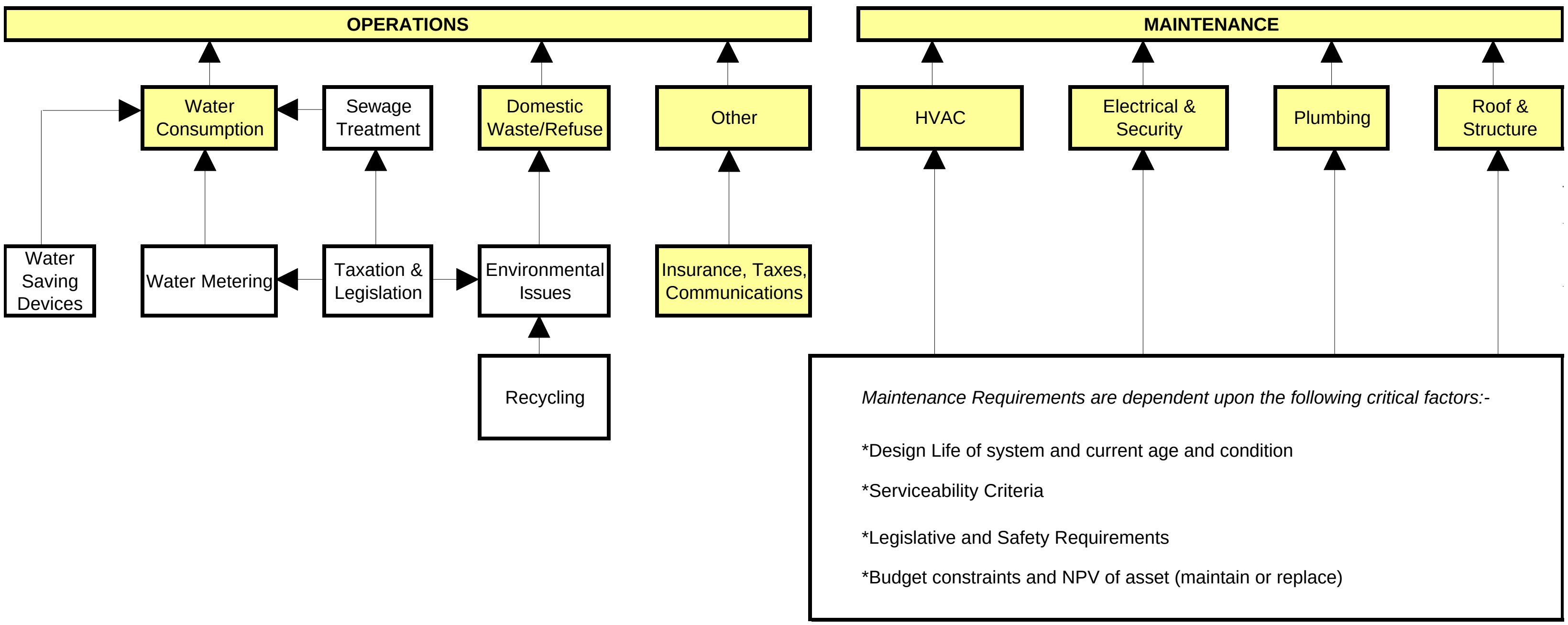
This appendix includes two data classification hierarchies for the residential sector. The first hierarchy covers operations and maintenance costs. The second hierarchy covers energy consumption and energy costs.

The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies was to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints.

Each of the two hierarchies—operations and maintenance costs and energy consumption and energy costs—presents the "idealized" hierarchy overlaid by the data oriented hierarchy. In each case, the data oriented hierarchy is represented with shading. Specifically, those "blocks" in the hierarchy which are shaded correspond to cases for which data were collected ***and*** which are summarized in Chapter 5 of this document.

NATIONAL CONSTRUCTION GOAL 2 - 50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS - FACTORS INFLUENCING GOAL

Residential Sector - Operations and Maintenance

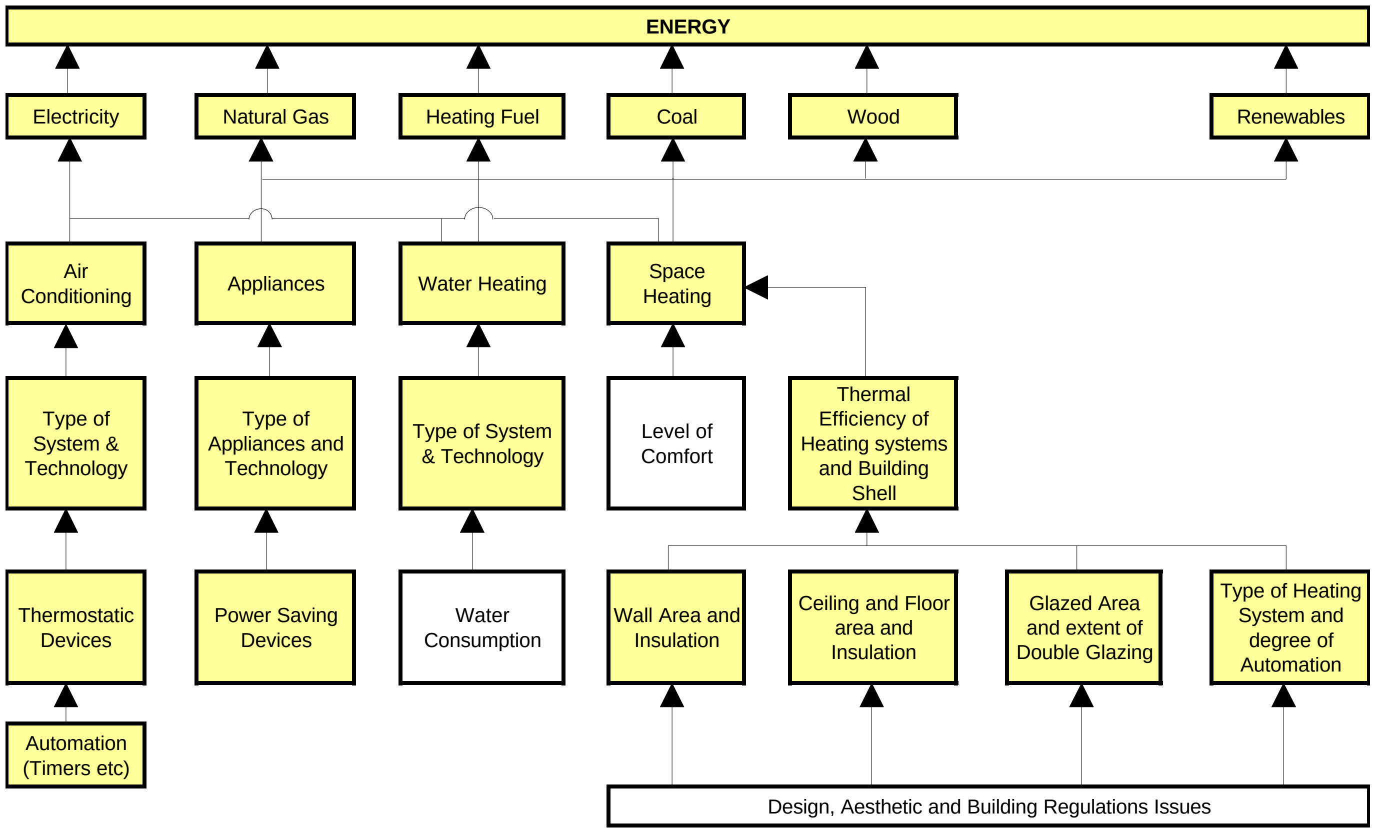


Notes:-

(a) Buildings are Grouped according to geographic location, type, size and age of structure.
(b) Data Availability is indicated where cells in hierarchy are shaded

NATIONAL CONSTRUCTION GOAL 2 - 50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS

Residential Sector - Energy



Notes:-

(a) Energy costs exclude costs associated with constructing building
(b) Energy Figures based on Annual Average Figures, including transmission/distribution losses
(c) Buildings are Grouped according to geographic location, type, size and age of structure.
(d) Data Availability is indicated where cells in hierarchy are shaded

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Appendix B. Data Classification Hierarchies for the Commercial/ Institutional Sector

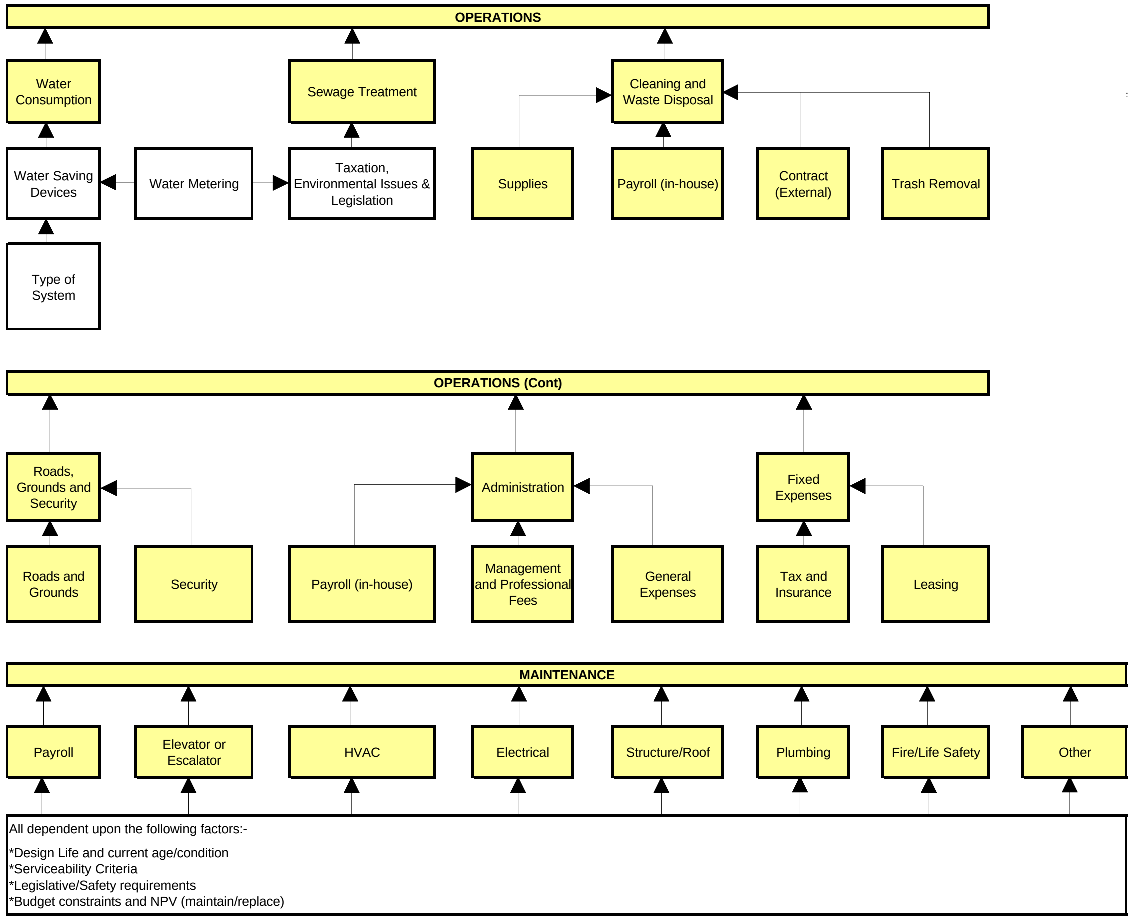
This appendix includes two data classification hierarchies for the commercial/institutional sector. The first hierarchy covers operations and maintenance costs. The second hierarchy covers energy consumption and energy costs.

The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies was to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints.

Each of the two hierarchies—operations and maintenance costs and energy consumption and energy costs—presents the "idealized" hierarchy overlaid by the data oriented hierarchy. In each case, the data oriented hierarchy is represented with shading. Specifically, those "blocks" in the hierarchy which are shaded correspond to cases for which data were collected ***and*** which are summarized in Chapter 6 of this document.

NATIONAL CONSTRUCTION GOAL 2 - 50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS - FACTORS INFLUENCING GOAL

Commercial Sector - Operations and Maintenance

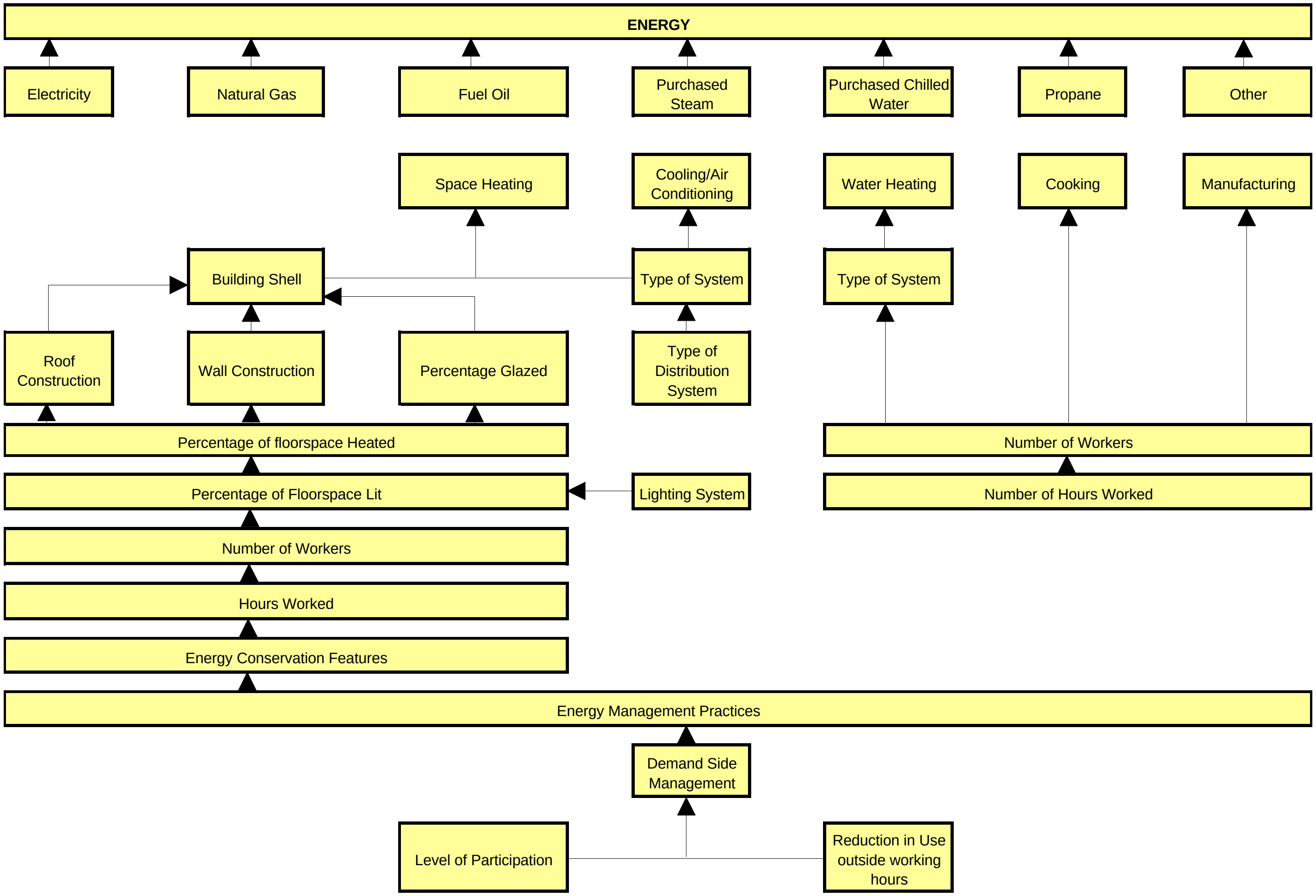


Notes:-

(a) Energy costs exclude costs associated with constructing building
(b) Energy Figures based on Annual Average Figures, including transmission/distribution losses
(c) Buildings are Grouped according to geographic location, type, size and age of structure.
(d) Data Availability is indicated where cells in hierarchy are shaded (selected parts of sector)

NATIONAL CONSTRUCTION GOAL 2 - 50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS - FACTORS INFLUENCING GOAL

Commercial Sector - Energy



Notes:-

(a) Energy costs exclude costs associated with constructing building
(b) Energy Figures based on Annual Average Figures, including transmission/distribution losses
(c) Buildings are Grouped according to geographic location, type, size and age of structure.
(d) Data Availability is indicated where cells in hierarchy are shaded (selected parts of sector)

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Appendix C. Data Classification Hierarchies for the Industrial Sector

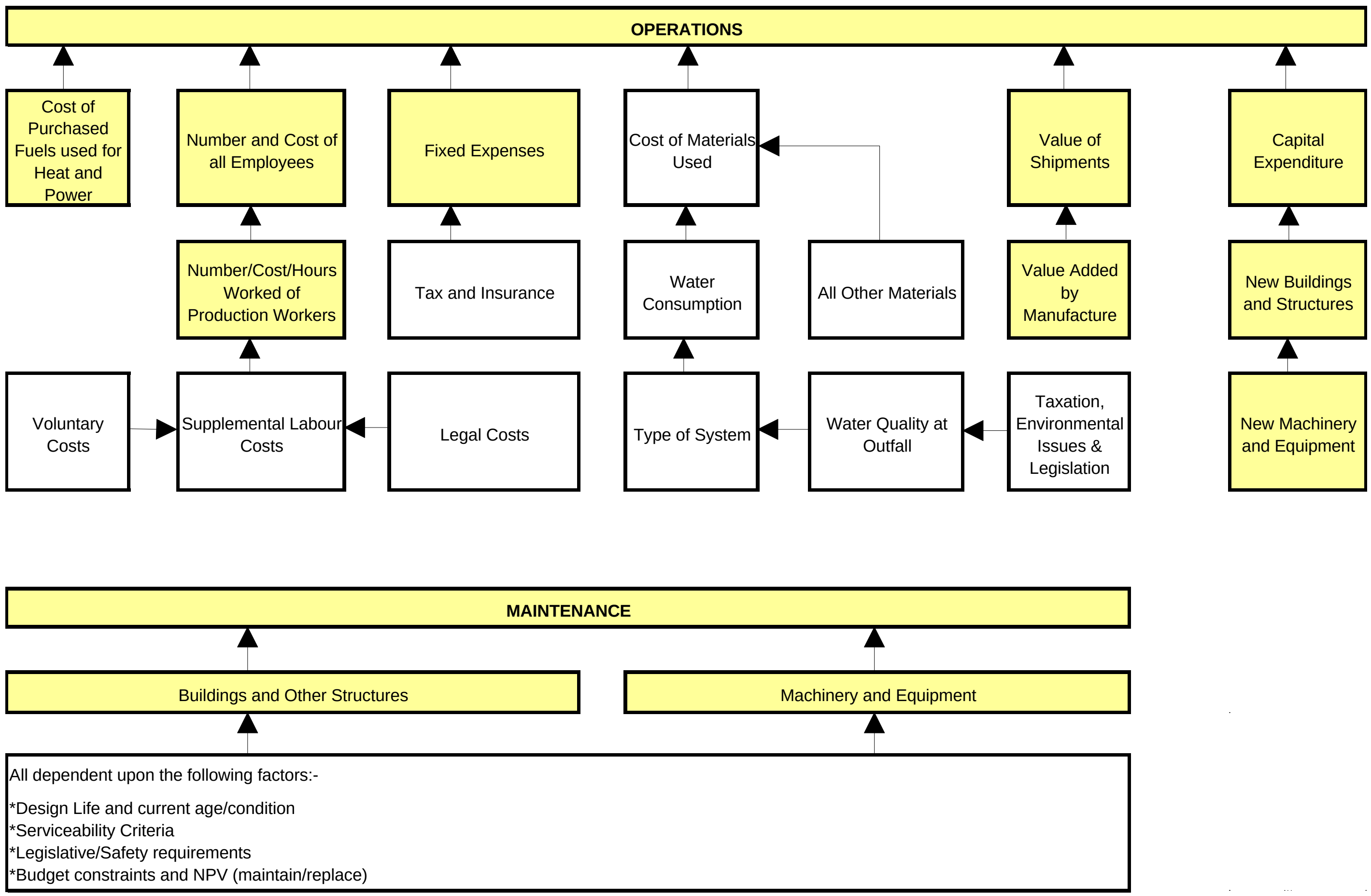
This appendix includes two data classification hierarchies for the industrial sector. The first hierarchy covers operations and maintenance costs. The second hierarchy covers energy consumption and energy costs.

The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies was to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints.

Each of the two hierarchies—operations and maintenance costs and energy consumption and energy costs—presents the "idealized" hierarchy overlaid by the data oriented hierarchy. In each case, the data oriented hierarchy is represented with shading. Specifically, those "blocks" in the hierarchy which are shaded correspond to cases for which data were collected ***and*** which are summarized in Chapter 7 of this document.

NATIONAL CONSTRUCTION GOAL 2 - REDUCTION IN OPERATIONS, MAINTENANCE & ENERGY COSTS - FACTORS INFLUENCING GOAL

Industrial Sector - Operations and Maintenance

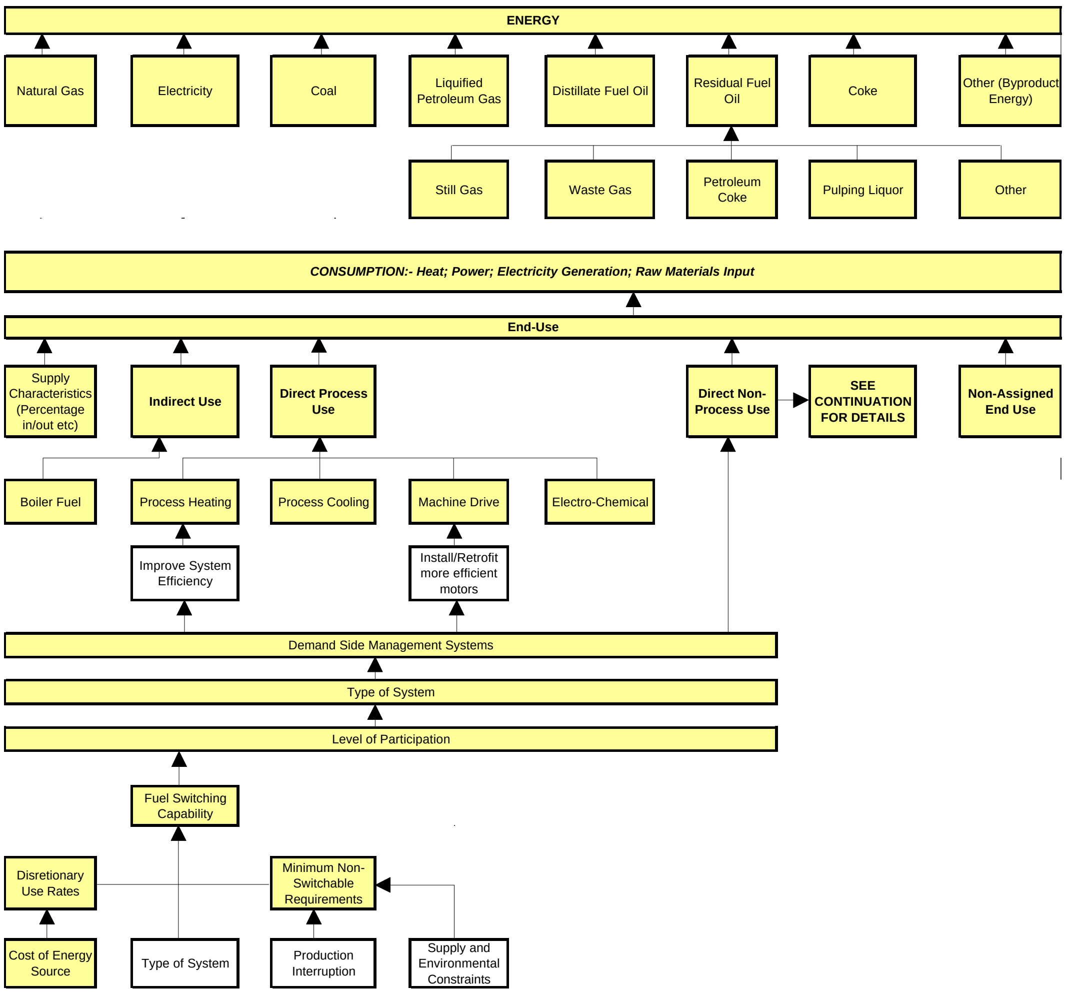


Notes:-

(a) Energy costs exclude costs associated with constructing facility
(b) Energy Figures based on Annual Average Figures, including transmission/distribution losses
(c) Facilities are Grouped according to geographic location and type.
(d) Facilities Classifications are :- Food and Allied Products, Paper and Allied Products, Chemicals and Allied Products, Petroleum and Coal Products, Stone Clay and Glass Products, Primary Metals, Other.
(e) Data Availability is indicated where cells in hierarchy are shaded.

NATIONAL CONSTRUCTION GOAL 2 - 50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS - FACTORS INFLUENCING GOAL

Industrial Sector - Energy



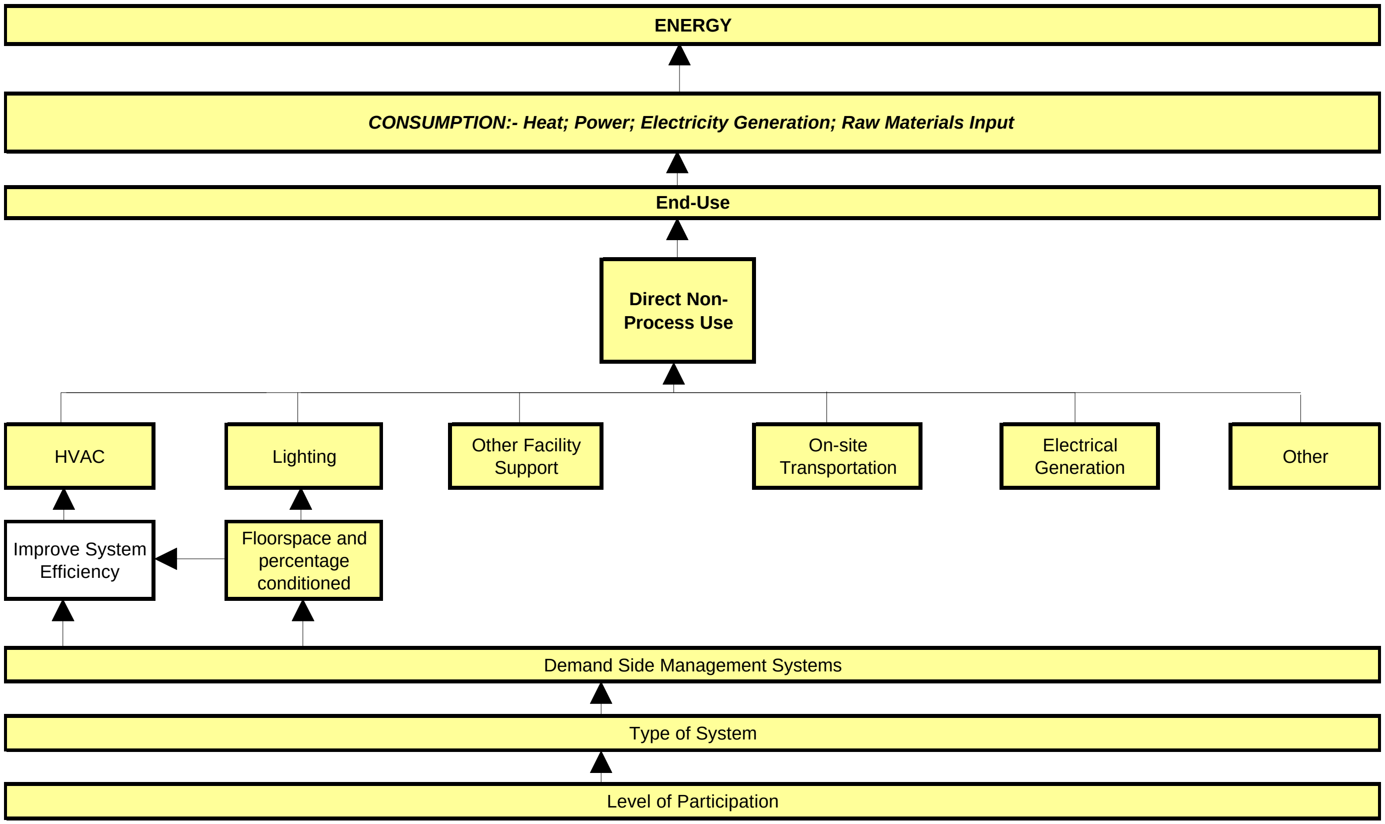
Notes:-

(a) Energy costs exclude costs associated with constructing facility

(b) Energy Figures based on Annual Average Figures, including transmission/distribution losses

NATIONAL CONSTRUCTION GOAL 2 - 50% REDUCTION IN ENERGY COSTS - FACTORS INFLUENCING GOAL

Industrial Sector - Energy (continuation)



Notes:-

(a) Energy costs exclude costs associated with constructing facility
(b) Energy Figures based on Annual Average Figures, including transmission/distribution losses
(c) Facilities are Grouped according to geographic location and type.
(d) Facilities Classifications are :- Food and Allied Products, Paper and Allied Products, Chemicals and Allied Products, Petroleum and Coal Products, Stone Clay and Glass Products, Primary Metals, Other.
(e) Data Availability is indicated where cells in hierarchy are shaded

Appendix D. Data Classification Hierarchies for the Public Works Sector

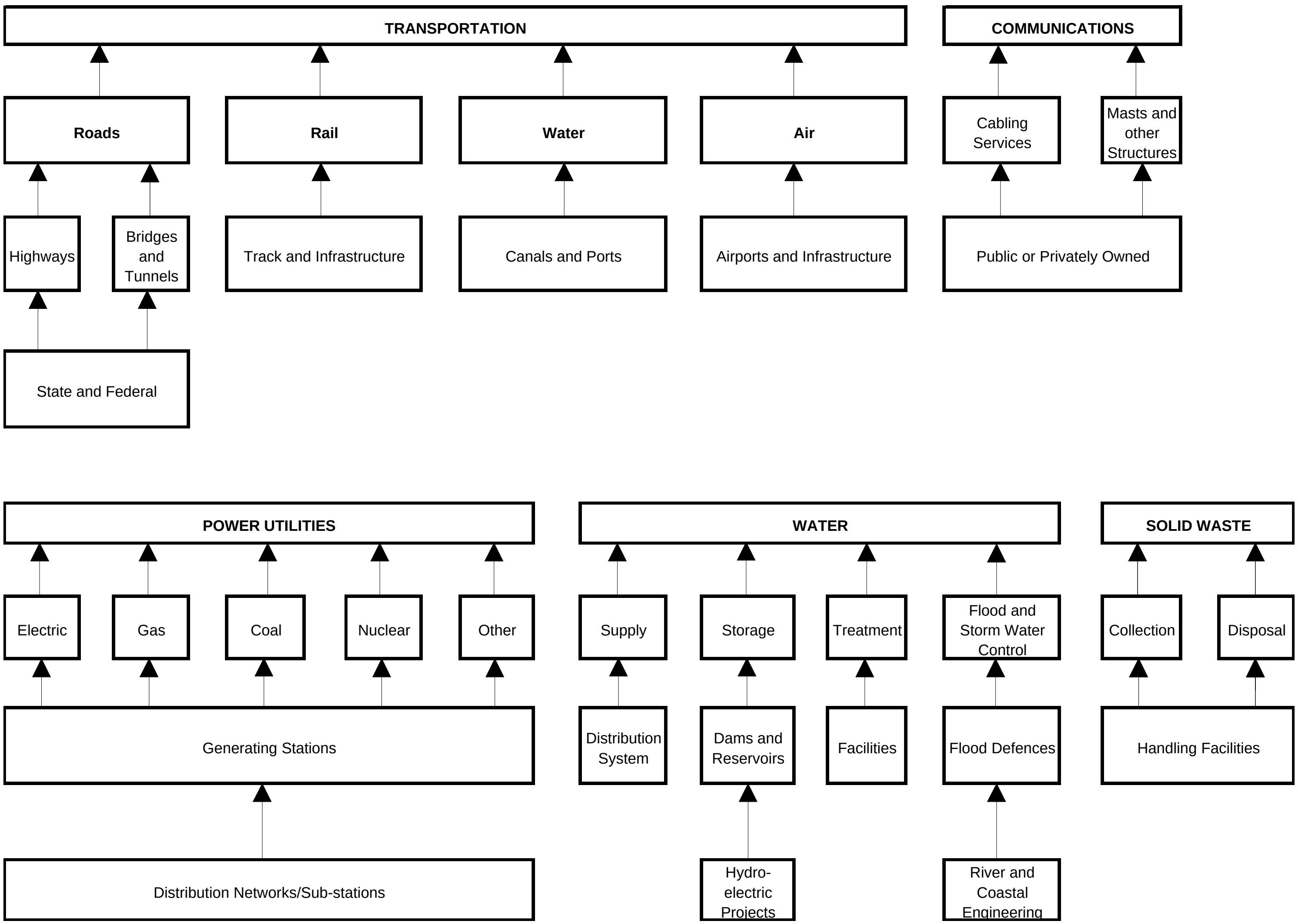
This appendix includes six data classification hierarchies for the public works sector. The first hierarchy covers the entire public works sector; it serves to define each of the five key sub-sectors covered in this document. The five key sub-sectors are: (1) transportation; (2) communications; (3) power utilities; (4) water; and (5) solid waste. The second hierarchy covers the transportation sub-sector. The third hierarchy covers the communications sub-sector. The fourth hierarchy covers the power utilities sub-sector. The fifth hierarchy covers the water sub-sector. The sixth hierarchy covers the solid waste sub-sector.

The two-stage process through which these hierarchies were developed and modified is described in detail in Chapter 4. A brief description of the process is as follows. First, a series of "idealized" industry oriented hierarchies were produced. The purpose of these "idealized" hierarchies was to sort data into relevant categories, to prioritize data, and to establish data linkages. Second, as the data collection effort progressed, these "idealized" hierarchies were modified. The resultant data oriented hierarchies represent the modification of the "idealized" hierarchies to reflect data availability and other constraints.

With the exception of the first hierarchy, each of the five sub-sector hierarchies presents the corresponding "idealized" hierarchy overlaid by the data oriented hierarchy. In each case, the data oriented hierarchy is represented with shading. Specifically, those "blocks" in the hierarchy which are shaded correspond to cases for which data were collected ***and*** which are summarized in Chapter 8 of this document.

NATIONAL CONSTRUCTION GOAL 2 - 50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS

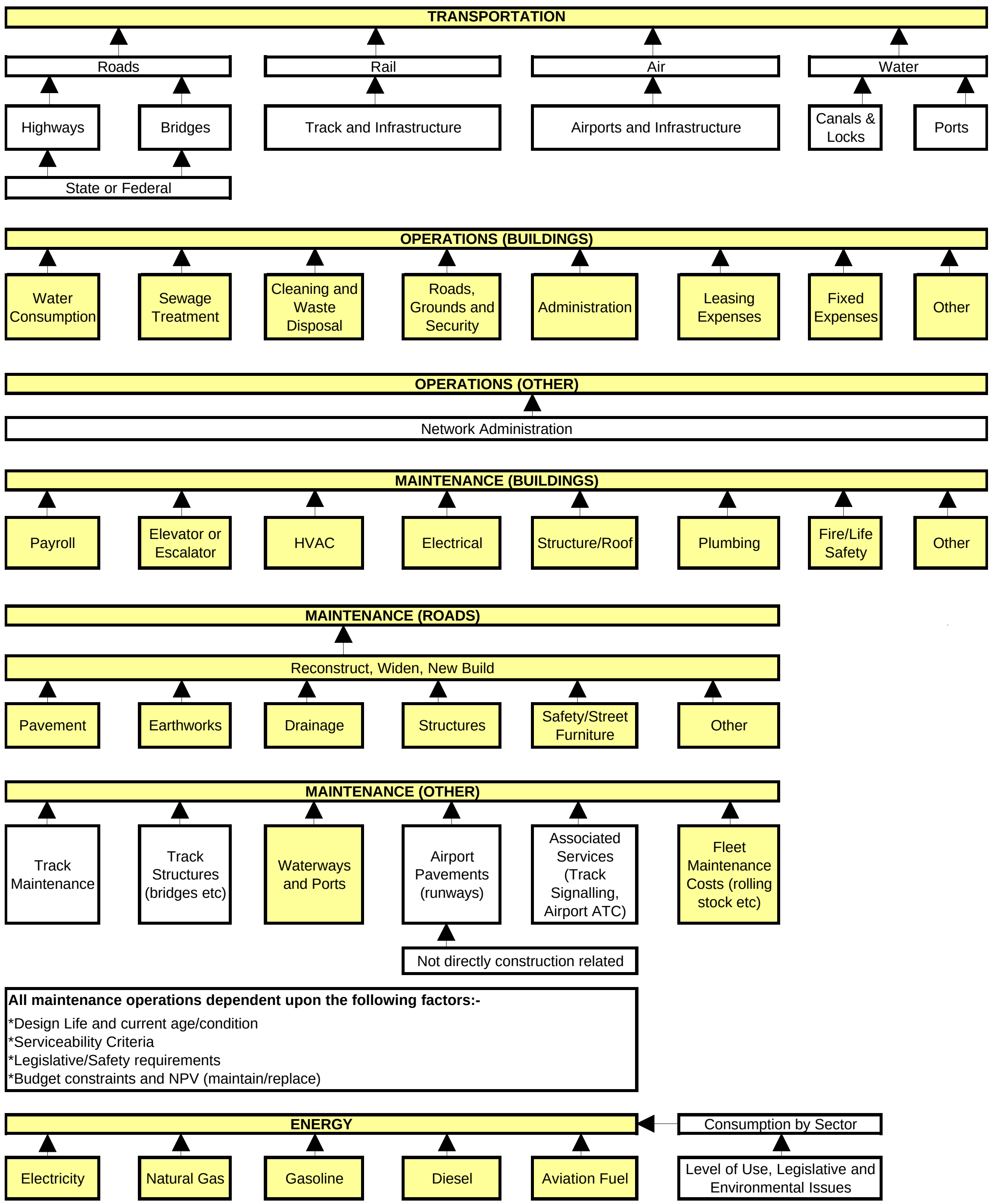
PUBLIC WORKS SECTOR - DEFINITION OF SUB-SECTORS



NATIONAL CONSTRUCTION GOAL 2

50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS

PUBLIC WORKS SECTOR - TRANSPORTATION SUB-SECTOR

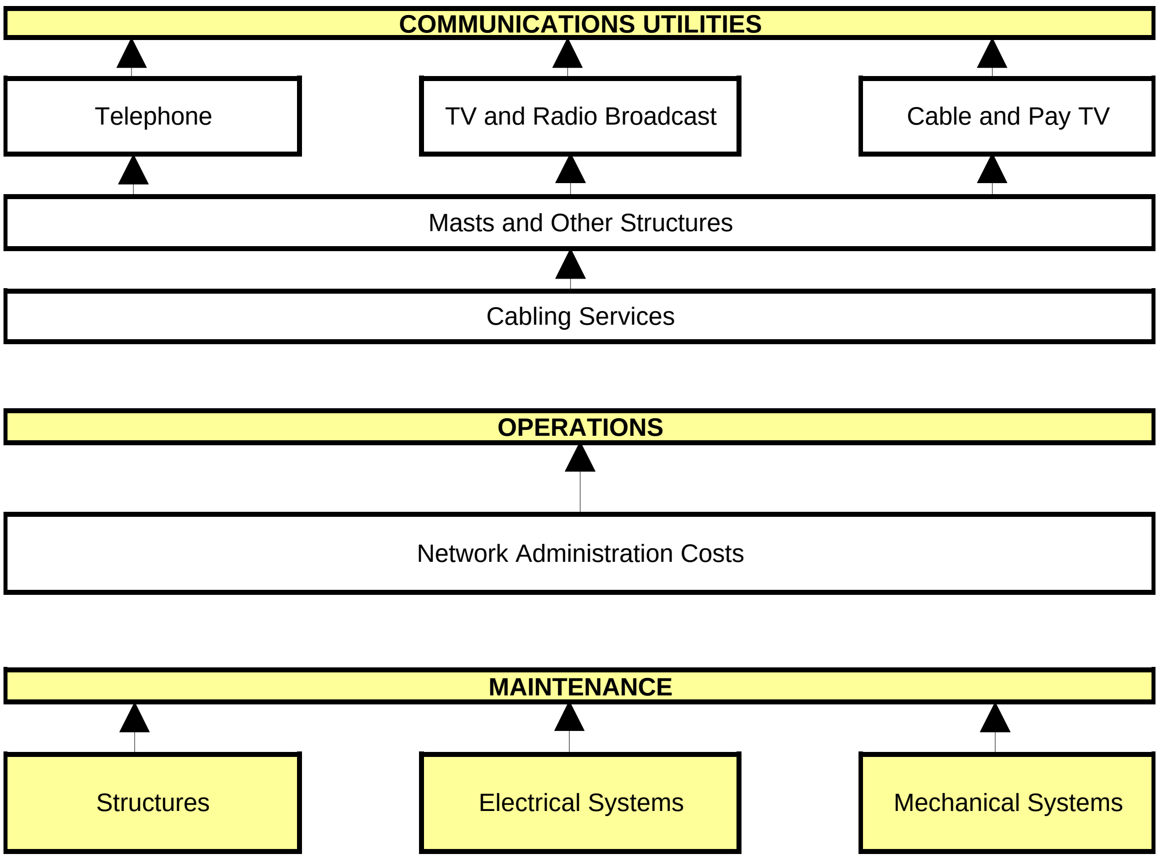


Notes:- (a) Data Availability is indicated where cells in hierarchy are shaded

NATIONAL CONSTRUCTION GOAL 2

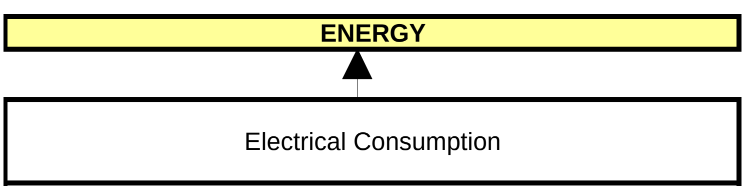
50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS

PUBLIC WORKS SECTOR - COMMUNICATIONS SUB-SECTOR



All maintenance operations dependent upon the following factors:-

*Design Life and current age/condition
*Serviceability Criteria
*Legislative/Safety requirements
*Budget constraints and NPV (maintain/replace)

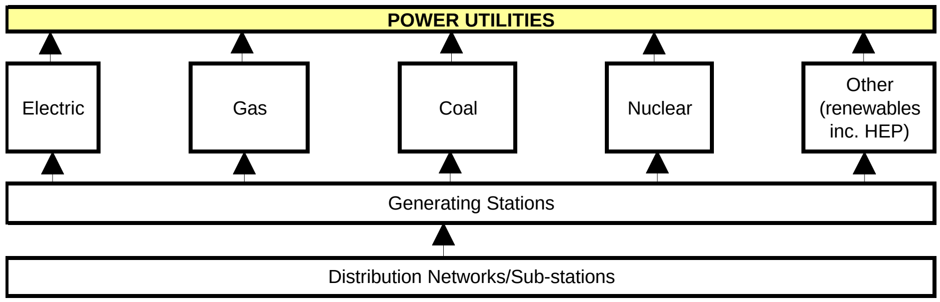


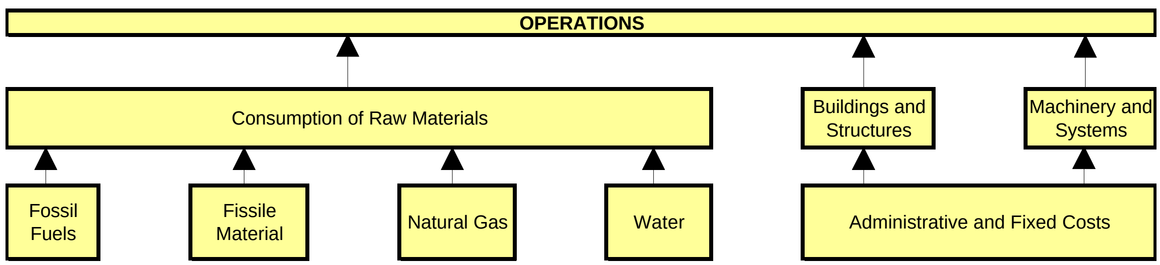
Notes:- (a) Data Availability is indicated where cells in hierarchy are shaded

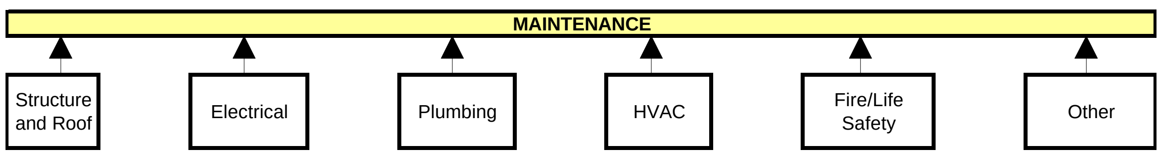
<u>**NATIONAL CONSTRUCTION GOAL 2**</u>

50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS

<u>**PUBLIC WORKS SECTOR - POWER UTILITIES SUB-SECTOR**</u>

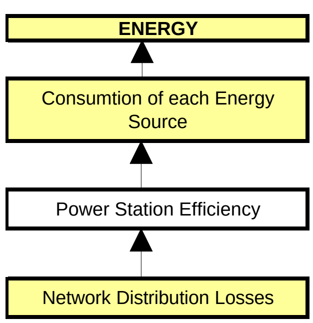






All maintenance operations dependent upon the following factors:-

*Design Life and current age/condition
*Serviceability Criteria
*Legislative/Safety requirements
*Budget constraints and NPV (maintain/replace)

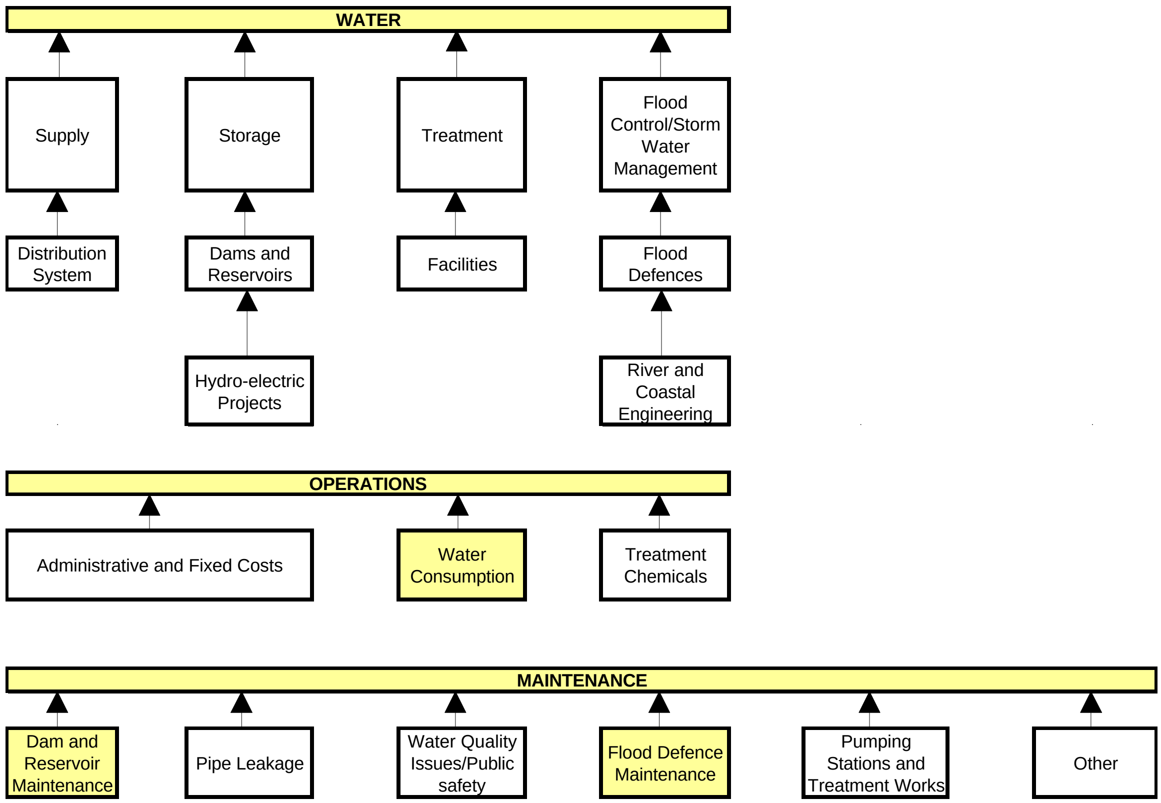


Notes:- (a) Data Availability is indicated where cells in hierarchy are shaded

NATIONAL CONSTRUCTION GOAL 2

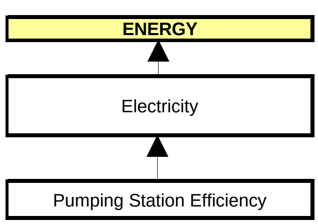
50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS

PUBLIC WORKS SECTOR - WATER SUB-SECTOR



All maintenance operations dependent upon the following factors:-

*Design Life and current age/condition
*Serviceability Criteria
*Legislative/Safety requirements
*Budget constraints and NPV (maintain/replace)

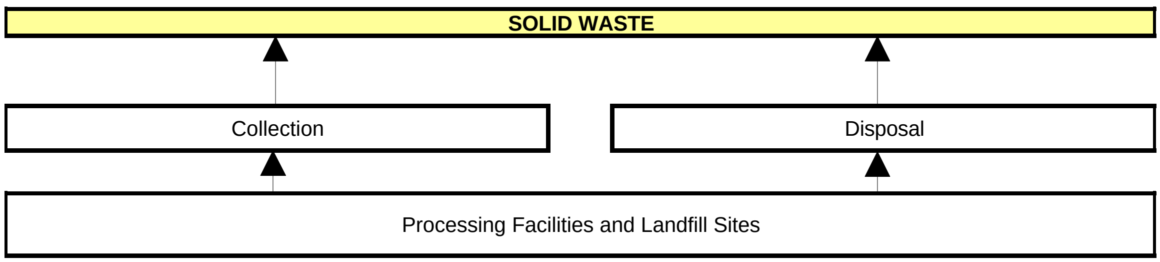


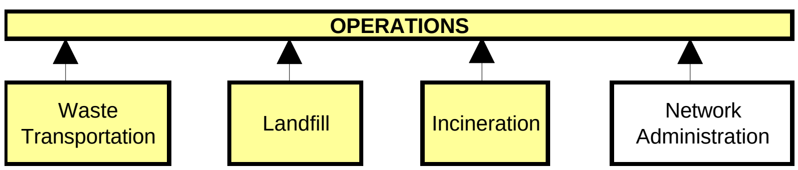
Notes:- (a) Data Availability is indicated where cells in hierarchy are shaded

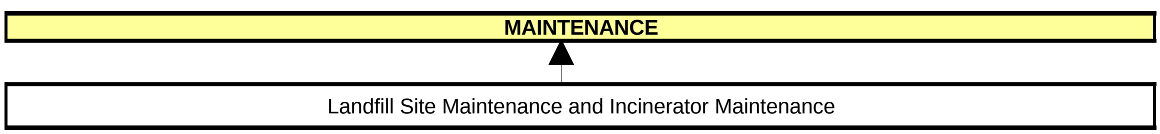
NATIONAL CONSTRUCTION GOAL 2

50% REDUCTION IN OPERATIONS, MAINTENANCE AND ENERGY COSTS

PUBLIC WORKS SECTOR - SOLID WASTE SUB-SECTOR

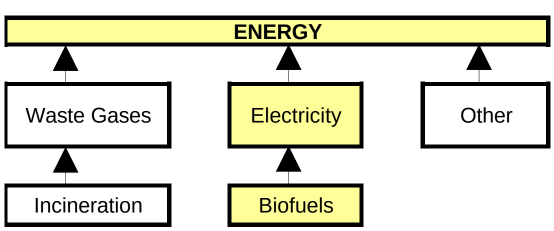






All maintenance operations dependent upon the following factors:-

*Design Life and current age/condition
*Serviceability Criteria
*Legislative/Safety requirements
*Budget constraints and NPV (maintain/replace)



Notes:- (a) Data Availability is indicated where cells in hierarchy are shaded

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Appendix E. Assignment of States to Census Regions

NORTHEAST	SOUTH
New England States	**South Atlantic States**
Connecticut	Delaware
Maine	District of Columbia
Massachusetts	Florida
New Hampshire	Georgia
Rhode Island	Maryland
Vermont	North Carolina
Mid Atlantic States	South Carolina
New Jersey	Virginia
New York	West Virginia
Pennsylvania	**East South Central States**
	Alabama
MIDWEST	Kentucky
East North Central States	Mississippi
Illinois	Tennessee
Indiana	**West South Central States**
Michigan	Arkansas
Ohio	Louisiana
Wisconsin	Oklahoma
West North Central States	Texas
Iowa	
Kansas	**WEST**
Minnesota	**Mountain States**
Missouri	Arizona
Nebraska	Colorado
North Dakota	Idaho
South Dakota	Montana
	Nevada
	New Mexico
	Utah
	Wyoming
	Pacific States
	Alaska
	California
	Hawaii
	Oregon
	Washington
Source: US Bureau of the Census	

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Appendix F. Two-Digit Standard Industrial Classification (SIC) Codes

SIC Code	Label
01	Agricultural production - crops
02	Agricultural production livestock and animal specialties
07	Agricultural services
08	Forestry
09	Fishing, hunting, and trapping
10	Metal mining
12	Coal mining
13	Oil and gas extraction
14	Mining and quarrying of nonmetallic minerals, except fuels
15	Building construction - general contractors and operative builders
16	Heavy construction other than building construction - contractors
17	Construction - special trade contractors
20	Food and kindred products
21	Tobacco products
22	Textile mill products
23	Apparel and other finished products made from fabrics and similar materials
24	Lumber and wood products, except furniture
25	Furniture and fixtures
26	Paper and allied products
27	Printing, publishing, and allied industries
28	Chemicals and allied products
29	Petroleum refining and related industries
30	Rubber and miscellaneous plastic products
31	Leather and leather products
32	Stone, clay, glass, and concrete products
33	Primary metal industries
34	Fabricated metal products, except machinery and transportation equipment
35	Industrial and commercial machinery and computer equipment
36	Electronic and other electrical equipment and components, except computer equipment
37	Transportation equipment
38	Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
39	Miscellaneous manufacturing industries
40	Railroad transportation
41	Local and suburban transit and interurban highway passenger transportation
42	Motor freight transportation and warehousing
43	United States Postal Service

44	Water transportation
45	Transportation by air
46	Pipelines, except natural gas
47	Transportation services
48	Communications
49	Electric, gas, and sanitary services
50	Wholesale trade - durable goods
51	Wholesale trade - nondurable goods
52	Building materials, hardware, garden supply, and mobile home dealers
53	General merchandise stores
54	Food stores
55	Automotive dealers and gasoline service stations
56	Apparel and accessory stores
57	Home furniture, furnishings, and equipment stores
58	Eating and drinking places
59	Miscellaneous retail
60	Depository institutions
61	Nondepository credit institutions
62	Security and commodity brokers, dealers, exchanges, and services
63	Insurance carriers
64	Insurance agents, brokers and service
65	Real estate
67	Holding and other investment offices
70	Hotels, rooming houses, camps, and other lodging places
72	Personal services
73	Business services
75	Automotive repair, services, and parking
76	Miscellaneous repair services
78	Motion pictures
79	Amusement and recreation services
80	Health services
81	Legal services
82	Educational services
83	Social services
84	Museums, art galleries, and botanical and zoological gardens
86	Membership organizations
87	Engineering, accounting, research, management, and related services
88	Private households
89	Miscellaneous services

Appendix G. List of Acronyms

Acronym	Definition
AAO	Average Actual Occupancy
AAR	Association of American Railroads
AER	Annual Energy Review
AFUE	Annual Fuel Utilization Efficiency
AHS	American Housing Survey
APPA	The Association of Higher Education Facilities Officers
APTA	American Public Transit Association
ATA	Airline Transport Association
BFRL	Building and Fire Research Laboratory
BOMA	Buildings Owners and Managers Association
BTS	Bureau of Transportation Statistics
C&B	Construction and Building
CBECS	Commercial Buildings Energy Consumption Survey
CCI	Census of the Construction Industry
CDD	Cooling degree days
CSI	Census of Service Industries
DOE	Department of Energy
DOT	Department of Transportation
DSM	Demand-Side Management
EER	Energy Efficiency Ratio
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EREN	Energy Efficiency and Renewable Energy Network
FAA	Federal Aviation Administration
FEMP	Federal Energy Management Program
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FTE	Full-Time Equivalent
GDP	Gross domestic product
GSF	Gross square foot
GSM	Gross square meter
HDD	Heating degree days
HEP	Hydro-electric power
HID	High intensity discharge
HUD	Department of Housing and Urban Development
HVAC	Heating, ventilation and air conditioning
IFMA	International Facility Management Association
IREM	Institute of Real Estate Management
M&R	Maintenance and Repair

MA	Metropolitan Areas
MADA	Multiattribute Decision Analysis
MARAD	Maritime Administration
MECS	Manufacturing Energy Consumption Survey
MHI	Manufactured Housing Institute
NAHB	National Association of Home Builders
NAS	National Airspace System
NCG	National Construction Goal
NIST	National Institute of Standards and Technology
OIT	Office of Industrial Technologies
OM&E	Operations, Maintenance and Energy
RD&D	Research, development and deployment
RECS	Residential Energy Consumption Survey
ROW	Rights of Way
RSF	Rentable Square Foot
RSM	Rentable Square Meter
SEER	Seasonal Energy Efficiency Rating
SIC	Standard Industrial Classification
STB	Surface Transportation Board
USACE	US Army Corps of Engineers
USBC	US Bureau of the Census
USGS	United States Geological Survey
VIP	Value of Construction Put in Place
3R	Resurfacing, Restoration, and Rehabilitation

References

American Society for Testing and Materials. 1995. *Standard Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems*. E 1765. Philadelphia, PA: American Society for Testing and Materials.

The Association of Higher Education Facilities Officers. 1995. *Comparative Costs and Staffing Report for College and University Facilities: 1993-94*. Alexandria, VA: The Association of Higher Education Facilities Officers.

Building Owners and Managers Association (BOMA). 1994. *1994 BOMA Experience Exchange Report.* Washington, DC: Building Owners and Managers Association.

Building Owners and Managers Association (BOMA) International. 1996. *1996 BOMA Experience Exchange Report*. Washington, DC: Building Owners and Managers Association International.

The Center to Protect Workers' Rights. 1997. *The Construction Chart Book: The US Construction Industry and Its Workers*. Report D1-97. Washington, DC: The Center to Protect Workers' Rights.

Institute of Real Estate Management. 1996. *1996 Income/Expense Analysis: Shopping Centers*. Chicago, IL: Institute of Real Estate Management.

International Facilities Management Association. 1994. *Benchmarks II*. Research Report #13. Houston, TX: International Facilities Management Association.

Lufkin, Peter S. and Anthony J. Pepitone. 1997. *The Whitestone Building Maintenance and Repair Cost Reference 1997*. Seattle, WA: Whitestone Research.

US Department of Commerce. 1997. *Current Construction Reports: Expenditures for Residential Improvements and Repairs.* ***C50***. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1997. *Current Construction Reports: Value of Construction Put in Place.* ***C30***. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1997. *Overview of Construction Statistics Programs*. Draft Mimeo. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1997. *Statistical Abstract of the United States: 1997*. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1992. *Census of the Construction Industry*. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1992. *Census of Manufactures*. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1992. *Census of Services Industries*. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1992. *Census of Transportation Communications and Utilities*. Washington, DC: US Bureau of the Census.

US Department of Commerce. 1990. *Census of Housing.* Washington, DC: American Housing Survey.

US Department of Commerce. 1978. "*Effects of Metallic Corrosion in the United States.*" NBS Special Publication 511. Washington, DC: National Bureau of Standards.

US Department of Energy. 1997. *Annual Energy Review 1996*. DOE/EIA - 0384(96). Washington, DC: Energy Information Administration.

US Department of Energy. 1997. *Natural Gas Monthly, April 1997*. Washington, DC: Energy Information Administration.

US Department of Energy. 1995. *Commercial Buildings Energy Consumption and Expenditures:1992*. DOE/EIA-0318(92). Washington, DC: Energy Information Administration.

US Department of Energy. 1994. *Commercial Buildings Characteristics: 1992*. DOE/EIA-0246(92). Washington, DC: Energy Information Administration.

US Department of Energy. 1994. *Manufacturing Energy Consumption Survey*. Washington, DC: Energy Information Administration.

US Department of Energy. 1993. *Residential Energy Consumption Survey*. Washington, DC: Energy Information Administration.

US Department of Transportation. 1997. *Transportation Statistics Annual Report, 1997*. Washington, DC: US Bureau of Transportation Statistics.

US Department of Transportation. 1996. *Transportation Statistics Annual Report, 1996*. Washington, DC: US Bureau of Transportation Statistics.

US Department of Transportation. 1995. *Characteristics of Urban Transportation System*. Washington, DC: US Bureau of Transportation Statistics.
US Department of Transportation. 1995. *Transportation Statistics Annual Report, 1995*. Washington, DC: US Bureau of Transportation Statistics.

US Department of Transportation. 1994. *Highway Statistics*. Washington, DC: Federal Highway Administration.

Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1995. *Construction and Building: Federal Research and Development in Support of the US Construction Industry*. Washington, DC: National Science and Technology Council.

Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1994. *Rationale and Preliminary Plan for Federal Research for Construction and Building*. NISTIR 5536. Washington, DC: National Science and Technology Council.

Electronic Media

US Government Sources

US Department of Commerce

US Bureau of the Census
http://www.census.gov

US Department of Defense

US Army Corps of Engineers

Annual Summary of Operations
http//www.usacpw.belvoir.army.mil/pubs/RedBook

Civil Works Activities
http://www.usace.army.mil/inet/functions/cw/prog-man/cwmprog.htm

Water Resources Support Center
http://www.wrc-ndc.usace.army.mil

US Department of Energy

Energy Efficiency and Renewable Energy Network Associated Organizations
http://www.eren.doe.gov/buildings/energy_savers/sourcelist.html

Energy Efficiency Rating System - Energy Star
http://www.energystar.gov

Energy Information Administration
http://www.eia.doe.gov

Federal Energy Management Program
http://www.eren.doe.gov/femp/procurement/begin.html

Office of Industrial Technologies
http://www.oit.doe.gov

Transportation Technologies
http://www.ott.doe.gov

US Department of the Interior

US Geological Survey
http://www.usgs.gov

US Department of Transportation

Bureau of Transportation Statistics
http://www.bts.gov

Federal Highway Administration
http://www.fhwa.dot.gov

Federal Transit Administration
http://www.fta.dot.gov

Maritime Administration
http://marad.dot.gov

Surface Transportation Board
http://www.stb.dot.gov

US Environmental Protection Agency
http://www.epa.gov

Other Sources

American Gas Association
http://www.aga.com

American Public Works Association
http://www.pubworks.org

Association of American Port Authorities
http://www.aapa-ports.org

Association of American Railroads
http://www.aar.org

The Association of Higher Education Facilities Officers
http://www.appa.org

Best Manufacturing Practices Center of Excellence
http://www.bmpcoe.org

Building Owners and Managers Association
http://www.boma.org

Electric Power Research Institute
http://www.epri.com

Independent Petroleum Association of America
http://www.ipaa.org

Institute of Real Estate Management
http://www.irem.org

International Facility Management Association
http://www.ifma.org

Manufactured Housing Institute
http://www.mfghome.org

Definitions of types of manufactured housing
http://www/mfghome.org/media/definemh.html

National Association of Manufacturers
http://www.nam.org