

Discussion on Passive Energy Efficiency in Buildings

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17 Sept 2009

Introduction to Reading

The following excerpts come directly from the DOE's *Buildings Energy Data Book* and are selected by Steve Ray for the purposes of a roundtable discussion with the MIT Energy Club. More information on the *Buildings Energy Data Book* follows. Some terms you may find useful:

Adjust to SEDS - Energy adjustment EIA uses to relieve discrepancies between data sources. Energy attributable to the residential and commercial buildings sector, but not directly to specific end-uses.

EIA - Department Of Energy's Energy Information Administration

Primary Energy- Refers to energy used at the source (including fuel input to electric power plants)

SEDS - State Energy Data System

Site Energy - Refers to energy used on site (i.e., delivered)

Foreword from the *Buildings Energy Data Book*

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy has developed this *Buildings Energy Data Book* to provide a current and accurate set of comprehensive buildings-related data, and to promote the use of such data for consistency throughout DOE programs. Data has been re-organized up front and there are several new data chapters in the back. The first six chapters are re-organized; Chapter 1 – Buildings Sector, Chapter 2 – Residential Sector, Chapter 3 – Commercial Sector, Chapter 4 – Federal Sector, Chapter 5 – Envelope and Equipment, Chapter 6– Energy Supply. The last three chapters are new and we hope to improve upon them, Chapter 7 – Energy Codes, Standards, and Laws, Chapter 8 – Water Data, and Chapter 9 – Market Transformation. Besides these new chapters, you will also find new data sections on embodied energy, multi-family buildings, office buildings, retail buildings, hospital & medical facilities, hotel/motels, water heaters, on-site power, on-site wind power, natural gas production and distribution, and public benefit funds.

We hope you find the *2008 Buildings Energy Data Book* useful. You are encouraged to comment on errors, omissions, emphases, and organization of this report to the person

listed below. Requests for additional copies of this report, additional data, or information on an existing table should be referred to D&R International.

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The *2008 Buildings Energy Data Book* can be found on the web at:

<http://buildingsdatabook.eere.energy.gov/>

Introduction

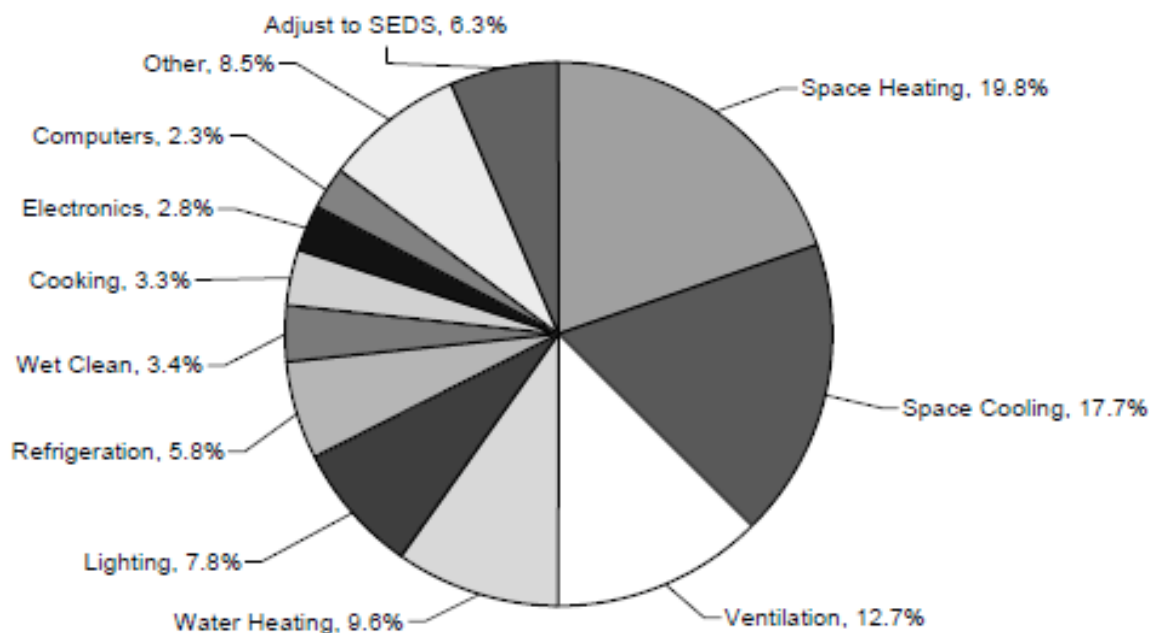
The *2008 Buildings Energy Data Book* is a statistical compendium prepared and published under contract with the National Energy Technology Laboratory (NETL) within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). Pacific Northwest National Laboratory (PNNL) first published the predecessor to the annual *Buildings Energy Data Book* in 1986. PNNL published these through 2004; Oak Ridge National Laboratory 2005-2006, and NETL began publishing the *Buildings Energy Data Book* in 2007. The Department of Energy's Office of Energy Efficiency and Renewable Energy has developed this *2008 Buildings Energy Data Book* to provide a current and accurate set of comprehensive buildings-related data and to promote the use of such data for consistency throughout DOE programs. Additional data (e.g., more current, widely accepted, and/or better documented data) and suggested changes should be submitted to D&R International. Please provide full source references along with all data. The *Buildings Energy Data Book* is a compendium of data and does not provide original data. Much of the data gathered is from government documents, models, and analysis. All data sources are included with each data table.

Chapter 1 – Buildings Sector

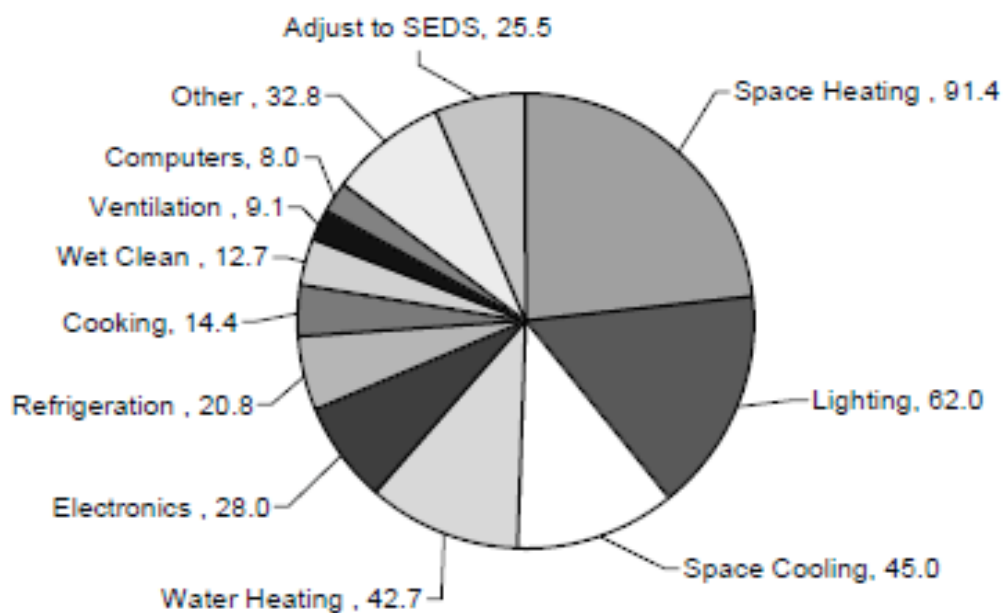
Chapter 1 contains energy consumption, expenditures, environmental impacts, and economic data related to the Buildings Sector. There is also some data from the former Quad Equivalents chapter. A new data section, Embodied Energy of Building Assemblies, contains data on energy used during the life-cycle of building materials. The following pieces of information give some insight into general trends in the Buildings Sector:

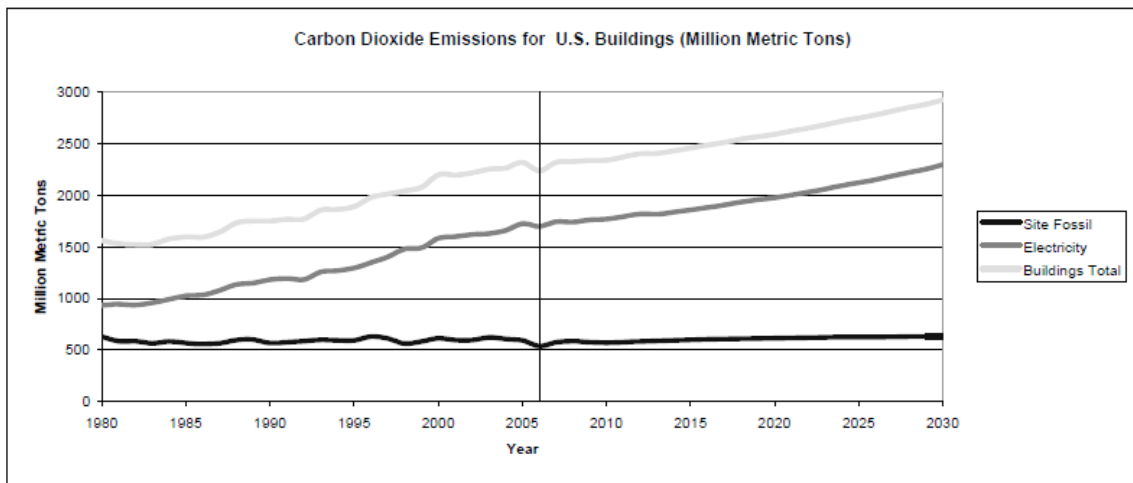
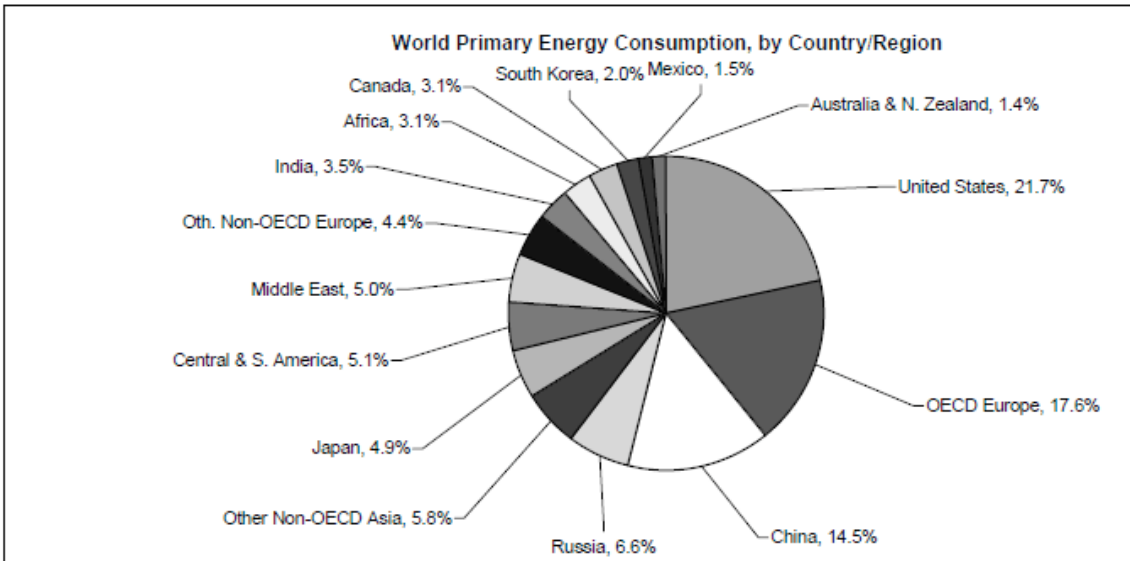
- Electricity energy consumption in the sector is increasing. Natural gas and petroleum energy consumption are declining.
- Less than 2 percent of annual Buildings Sector energy consumption is from renewable energy, each year from 1997 through 2030.
- In 2006, the Residential Sector consumed 37 percent of all electricity produced in the United States. The Commercial Sector consumed 36 percent.
- Space heating is the largest energy end-use in the Buildings Sector. In 2006, it was 34 percent of *site* energy and 20 percent of primary energy.
- From 2006 through 2030, space heating, lighting, and space cooling are the top three energy end-uses (as a percentage of primary energy). Water heating and electronics are the next top two end-uses.
- Aggregate energy expenditures will have doubled from 1980 to 2030; the increase is 28 percent from 2006 to 2030.
- Electricity expenditures make up 67 percent of total Buildings Sector energy expenditures in 2006; in 2030, electricity expenditures are up to 70 percent.
- From 2006 to 2030, Buildings Sector electricity expenditures increase 34 percent to a total of \$353 billion. Natural gas increases 19 percent to a total of \$112 billion. Petroleum increases 5.5 percent to a total of \$36 billion.
- The average price of electricity in the Residential Sector in 2006 was 10.4 cents per kWh; 9.5 cents per kWh for the Commercial Sector.
- Space heating, lighting, and space cooling are the top three energy end-use expenditures.
- New buildings construction is \$785 billion in 2006. Building improvements and repairs is \$438 billion.
- Carbon dioxide emissions by utilities generating, transmitting, and distributing electricity drives the Buildings Sector carbon dioxide emissions.
- The Buildings Sector percentage of carbon dioxide emissions increases from 38 percent in 2006 to 43 percent in 2030. Emissions in 1980 were 33 percent.
- World carbon dioxide emissions increased 1.9 percent per year from 1990 through 2005. Emissions are projected to increase 2.1 percent per year from 2005 to 2010.

2006 U.S. Buildings Energy End-Use Splits



2006 Buildings Primary Energy End-Use Expenditures Splits (\$2006 Billion)





Chapter 2 – Residential Sector

Chapter 2 contains data related to the Residential Sector. Energy consumption, expenditure data, and environmental impacts related to residential activity can also be found in this chapter. Additionally, several sections contain details about specific markets and housing types, such as multi-family and low-income housing. The following pieces of information give some insight into general trends in the Residential Sector:

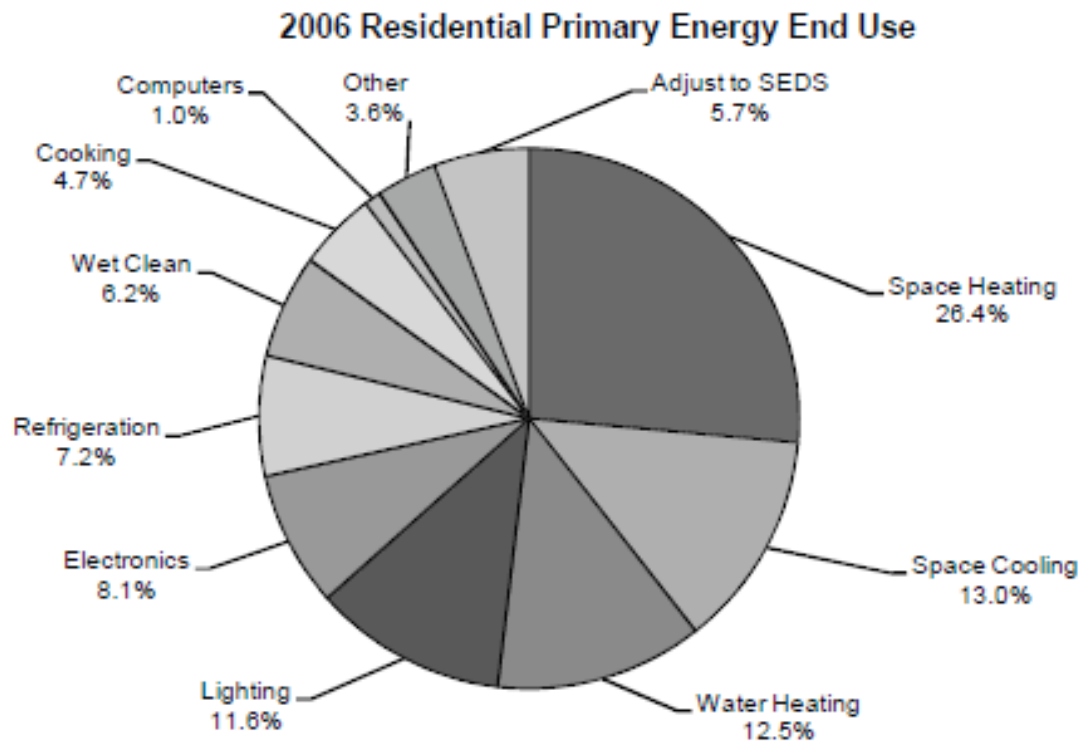
- The average size of a new, single-family home has risen by 756 square feet since 1980 while the average household size has remained relatively constant.

- In 2006, there were approximately 113 million households in the United States. By 2030, there is expected to be 141 million households.
- Internal gains account for 27 percent of a home's cooling load.
- Average annual energy expenditures per household have increased by 20 percent from 1990.
- For every 1 kWh used in the residential sector, another 2.18 kWh is needed to produce and deliver the electricity.
- In 2006, the residential sector consumed 37 percent of all electricity produced in the United States, making it the largest consuming sector of electricity.
- Space heating continues to dominate residential energy expenditures, accounting for 31.5 percent of total energy expenditures; more than double any other single end-use.
- The amount of carbon dioxide attributed to the residential sector is roughly equivalent to the carbon dioxide emitted by all of Central and South America combined.
- The average price of electricity for residential consumers in 2006 was 10.4 cents per kWh.
- On-site renewable energy accounted for approximately 3 percent of all energy consumed in the residential sector. The majority of this energy was derived from wood combustion and was used for space heating.
- Electricity is expected to be the fast growing site energy source for residential consumers averaging a 1 percent growth rate from 2006 to 2030.
- Approximately 63 percent of residential energy expenditures were spent on electricity.
- In 2006, residential consumers spent approximately 225 billion dollars on energy.
- The average family living in public multi-family housing used 32.2 million Btus of natural gas energy, or approximately 322 therms.

2.1.3 Residential Site Renewable Energy Consumption (Quadrillion Btu) (1)						
	Wood	Solar Thermal	Solar PV	GSHP	Total	Growth Rate 2006-Year
1980	0.846	0.000	N.A.	0.000	0.846	-
1990	0.582	0.056	N.A.	0.006	0.644	-
2000	0.430	0.061	N.A.	0.009	0.500	-
2006	0.409	0.013	0.000	0.003	0.426	-
2010	0.440	0.018	0.001	0.004	0.463	2.1%
2015	0.418	0.025	0.001	0.006	0.450	0.6%
2020	0.404	0.032	0.002	0.008	0.446	0.3%
2025	0.390	0.039	0.003	0.011	0.443	0.2%
2030	0.378	0.045	0.007	0.014	0.444	0.2%

Note(s): 1) Does not include renewable energy consumed by electric utilities (including hydroelectric).

Source(s): EIA, State Energy Data 2005: Consumption, Feb. 2008, Tables 8-12, p. 18-22 for 1980-2005; and EIA, Annual Energy Outlook 2008, Mar. 2008, Table A17, p. 143-144 for 2006-2030.



2.1.11 2005 Delivered Energy End-Uses for an Average Household, by Region (Million Btu per Household)

	<u>Northeast</u>	<u>Midwest</u>	<u>South</u>	<u>West</u>	<u>National</u>
Space Heating	69.8	56.5	20.9	25.2	39.3
Space Cooling	4.6	6.3	14.7	7.7	9.8
Water Heating	21.8	20.2	15.8	20.8	19.0
Refrigerator	4.5	5.1	4.9	4.4	4.8
<u>Other Appliances & Lighting</u>	<u>23.7</u>	<u>28.8</u>	<u>25.8</u>	<u>24.9</u>	<u>25.5</u>
Total (1)	120.5	113.5	80.9	77.6	95.0

Note(s): 1) Due to rounding, sums do not add up to totals.

Source(s): EIA, A Look at Residential Energy Consumption in 2005, October 2008, Table US-14.

2.1.16 Operating Characteristics of Electric Appliances in the Residential Sector

	Power Draw (W) (1)			Annual Usage (hours/year)			Annual Consumption (kWh/year)	Annual Cost (\$) (2)
	Active	Idle	Off	Active	Idle	Off		
Kitchen								
Coffee Maker	1,000	70	0	38	229	8,493	58	5
Dishwasher (3)	0	0	0	(4)	365	0	120	11
Microwave Oven	1,500	0	3	70	0	8,690	131	12
Refrigerator-Freezer							660	62
Freezer							470	44
Lighting								
18-W Compact Fluorescent	18	0	0	1,189	0	0	20	2
60-W Incandescent Lamp	60	0	0	672	0	0	40	4
100-W Incandescent Lamp	100	0	0	672	0	0	70	7
Torchiere Lamp-Halogen	300	0	0	1,460	0	0	440	41
Bedroom and Bathroom								
Hair Dryer	710	0	0	50	0	0	40	4
Waterbed Heater	350	0	0	3,051	0	0	1,070	101
Laundry Room								
Clothes Dryer				(4)	359		1,000	94
Clothes Washer (3)	0	0	0	(4)	392	0	(3) 110	10
Home Electronics								
CPU & Monitor	182/30	0	1,337/632			0	260	24
Stereo Systems	33	30	3	1,510	1,810	5,440	119	11
Television	113		4	1,460		7,300	193	18
Analog, <40"	86			(5) 1,095			184	17
Analog, >40"	156			(5) 1,825			312	29
Digital, ED/HD TV, <40"	150			(5) 1,095			301	28
Digital, ED/HD TV, >40"	234			(5) 1,825			455	43
Set-top box	20	0	20	6,450	0	2,310	178	17
DVD/VCR	17	13	3	170	5,150	3,430	78	7
Heating and Cooling								
Dehumidifier	600	0		1,620	0		970	91
Furnace Fan	295	0		1,350	0		400	38
Ceiling Fan (only fan motor)	35			2,310			81	8
Water Heating								
Water Heater-Family of 4	4,500			(6) 64	N.A.	0	4,770	448
Water Heater-Family of 2	4,500			(6) 32	N.A.	0	2,340	220
Portable Spa	4,350	275	0	25	8,735	0	2,525	237
Miscellaneous								
Pool Pump	1,000	0		792	0		790	74
Well Pump	725	0		115	0		80	8
Total Standby	0	57		0	8,760		500	47

Note(s): 1) Power draw will vary due to appliance components and modes of operation. 2) \$0.096/kWh. 3) Excludes electricity for water heating and drying. 4) Cycles/year. 5) TVs <40" are estimated on 3 hours/day and TVs >40" are estimated on 5 hours/day. 6) Gallons/day.

Source(s): BTS/AD, Little, Electricity Consumption by Small End Uses in Residential Buildings, Aug. 1998, Exhibit 6-8, p. 6-10 for clothes washer, computer, dehumidifier, dishwasher, furnace fan, pool pump, torchiere lamp-halogen, waterbed heater, and well pump; LBNL, Energy Data Sourcebook for the U.S. Residential Sector, LBNL-40297, Sept. 1997, p. 100-102 for clothes dryers, Table 10.2, p. 108 for lighting, and p. 62-67 for water heaters; LBNL, Miscellaneous Electricity Use in the U.S. Residential Sector, LBNL-40295, Apr. 1998, Appendix D for hair dryers; EIA, Supplement to AEO 2008, June 2008, Table 21 for refrigerator and freezer; GAMA, Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment, Apr. 2000 for water heater power draw; EIA/TIA, Commercial and Residential Sector Miscellaneous Electricity Consumption: FY2005 and Projections to 2030, Sept. 2006, p. 41-60 for coffee maker, microwave oven, stereo systems, TVs, set-top box, DVD/VCR, ceiling fan, and portable spa; and LBNL for total standby.

2.1.14 Aggregate Residential Building Component Loads as of 1998 (1)

Component	Loads (quads) and Percent of Total Loads			
	Heating		Cooling	
Roof	-0.65	12%	0.18	14%
Walls	-1.00	19%	0.11	10%
Foundation	-0.76	15%	-0.07	-
Infiltration	-1.47	28%	0.19	16%
Windows (conduction)	-1.34	26%	0.01	1%
Windows (solar gain)	0.43	-	0.37	32%
Internal Gains	0.79	-	0.31	27%
Net Load	-3.99	100%	1.08	100%

Note(s): 1) "Loads" represents the thermal energy losses/gains that when combined will be offset by a building's heating/cooling system to maintain a set interior temperature (which then equals site energy).

Source(s): LBNL, Residential Heating and Cooling Loads Component Analysis, Nov. 1998, Figure P-1, P-1 and Appendix C: Component Loads Data Tables.

2.3.16 1998 Cost Breakdown of a 2,150-Square-Foot, New Single-Family Home (\$2006) (1)

	Cost	
Finished Lot	64,626	24%
Construction Cost		
Inspection/Fees	4,223	2%
Shell/Frame		
Framing	30,927	11%
Windows/Doors	10,272	4%
Exterior Finish	11,304	4%
Foundation	16,131	6%
Wall/Finish Trim	28,212	10%
Flooring	7,211	3%
Equipment		
Plumbing	8,837	3%
Electrical Wiring	5,638	2%
Lighting Fixtures	1,560	1%
HVAC	6,171	2%
Appliances	2,165	1%
Property Features	17,567	6%
Financing	5,152	2%
Overhead & General Expenses	15,645	6%
Marketing	3,840	1%
Sales Commission	9,238	3%
Profit	25,163	9%
Total	273,882	100%

Note(s): 1) Based on a NAHB Survey asking builders to provide a detailed breakdown of the cost of constructing a 2,150 SF house with 3 or 4 bedrooms on a 7,500- to 10,000SF lot. Average sales price of a new home in 42 surveyed markets was \$226,660 (in \$1998).

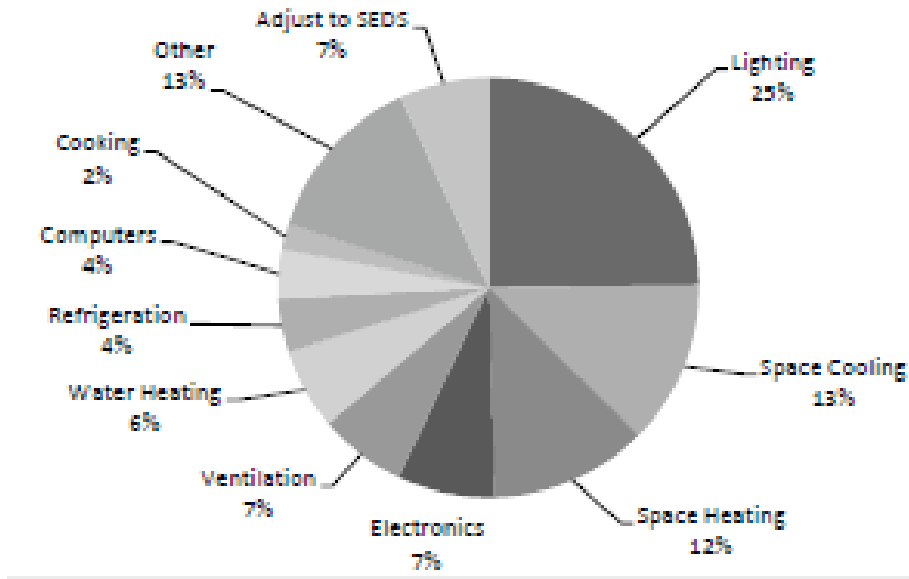
Source(s): NAHB, The Truth About Regulatory Barriers to Housing Affordability, 1999, p. 4; and EIA, Annual Energy Review 2007, June 2008, Appendix D, p. 377 for price infators.

Chapter 3 – Commercial Sector

Chapter 3 contains information related to the Commercial Sector. Energy consumption, expenditure data, and environmental impacts related to energy consumption and construction activity are also examined. The remaining sections provide data on specific building types such as offices, hotels, and education facilities. The following pieces of information give some insight into general trends in the Commercial Sector:

- Floor space devoted to commercial activity totaled 74.8 billion square feet in 2006. Commercial floor space is expected to reach 100.8 billion square feet by 2030.
- Commercial floor space located in the south represents 37 percent of the total floor space, the largest amount of any region.
- In 2006, lighting used 24.8 percent of primary energy attributed to the commercial sector. This is approximately twice the energy used for space cooling, the next closest end-use.
- Lighting accounts for 42 percent of a commercial building's cooling load.
- In 2003, the most energy intensive buildings were those related to food sales using 535.5 thousand Btus per square foot. The building type with the lowest energy intensity (excluding vacant buildings) was religious worship buildings using 77.0 Btu's per square foot.
- Electricity accounted for 74 percent of all energy expenditures in the commercial sector.
- 80 percent of all carbon dioxide attributed to the commercial sector comes from electricity consumption.
- The carbon dioxide attributed to the commercial sector is roughly equivalent to all the carbon dioxide emitted by Australia, New Zealand, and South Korea combined.
- In 2003, buildings devoted to office space consumed 19 percent of primary energy attributable to commercial buildings, the most of any building type.
- In 2003, 35 percent of all commercial floor space was found in only 2.2 percent of the commercial building stock.
- The most expensive city to operate a commercial building in terms of energy costs was New York City, where the average energy cost was \$3.99 per square foot annually.
- Hotels consumed on average 110 thousand Btus per square foot in 2003.
- The average price of electricity for a commercial consumer in 2006 was 9.5 cents per kWh.

2006 Commercial Primary Energy End-Use Splits



3.1.12 Aggregate Commercial Building Component Loads as of 1998 (1)

Component	Loads (quads) and Percent of Total Loads			
	Heating		Cooling	
Roof	-0.103	12%	0.014	1%
Walls (2)	-0.174	21%	-0.008	-
Foundation	-0.093	11%	-0.058	-
Infiltration	-0.152	18%	-0.041	-
Ventilation	-0.129	15%	-0.045	-
Windows (conduction)	-0.188	22%	-0.085	-
Windows (solar gain)	0.114	-	0.386	32%
Internal Gains				
Lights	0.196	-	0.505	42%
Equipment (electrical)	0.048	-	0.207	17%
Equip. (non-electrical)	0.001	-	0.006	1%
People	0.038	-	0.082	7%
NET Load	-0.442	100%	0.963	100%

Note(s): 1) Loads represents the thermal energy losses/gains that, when combined, will be offset by a building's heating/cooling system to maintain a set interior temperature (which then equals site energy). 2) Includes common interior walls between buildings.

Source(s): LBNL, Commercial Heating and Cooling Loads Component Analysis, June 1998, Table 24, p. 45 and Figure 3, p. 61.