CALIFORNIA COMMERCIAL END-USE SURVEY

Chapters 12-13

CONSULTANT REPORT

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This report is dedicated to the memory of Alan Fields, who served as the project manager until his death on February 3, 2004. Alan was a valued colleague and dear friend. He will be missed by his associates at Itron, the California Energy Commission, and the energy industry.

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Publication CEC-400-2006-005APA contains the following 10 appendices that accompany this report:

Appendix A: Basic Survey Instrument
Appendix B: Annotated Survey Instrument
Appendix C: End-Use Mappings
Appendix D: Recruitment Letter
Appendix E: Recruitment Script
Appendix F: Short-Term Metering Protocols
Appendix G: Survey Database Layout
Appendix H: Non-HVAC End-Use Algorithms
Appendix I: Description of Forecasting Climate Zone Results Database
Appendix J: SIC Code to CEUS Building Type Mapping Table

CHAPTER 12: SMUD RESULTS BY SEGMENT

12.1 Introduction

This chapter summarizes the results of the CEUS analysis for the SMUD service area. As noted in Chapter 7, *gas estimates relate to gas provided to SMUD customers by other gas utilities*. Section 12.2 provides an overview of the statewide composition of energy usage by building type. Section 12.3 presents electric and gas fuel shares, energy-use indices (EUIs), and energy intensities at the end-use level by building type. Section 12.4 provides 16-day hourly end-use electric shapes by building type. For all results presented in this chapter, the end uses and building types are as described in Chapter 7 of this report.

Additional results for the California Energy Commission Forecasting Climate Zones within the SMUD service area (6) were also generated. The database containing these results is described in Appendix I.

12.2 Overview of Energy Usage in the SMUD Electric Service Area

Table 12-1, Figure 12-1, and Figure 12-2 depict the estimates of floor stock, whole-building energy intensities, and energy usage by building type for the SMUD service area. Energy intensities and annual usage were generated using normalized weather data and 2002 as the base year. As noted in Chapter 7, these estimates represent total customer consumption rather than just purchases from utilities or other vendors.

Total commercial floor stock in the SMUD electric service area is estimated to be 227 million square feet. The building types with the largest percentage of total commercial floor stock are Retail (with approximately 20% of the total), Large Offices (19%), and Miscellaneous (17%).

Total commercial electric consumption is 3,759 GWh annually. The building types with the largest percentage of total electricity consumption are Large Offices (23%), Miscellaneous (19%), and Retail (17%). Natural gas usage is roughly 61 million therms (Mtherms) per year. Three building types account for over 57% of natural gas usage: Miscellaneous (25%), Restaurants (18%), and Large Offices (14%).

Figure 12-3 and Figure 12-4 depict estimates of SMUD service area electric and gas usage percentages by end use. The primary electric end uses are interior lighting (26%), cooling (15%), ventilation (14.1), and refrigeration (11%). The primary natural gas end uses are space heating (44%) and water heating (31%).

Electric and gas usage and energy intensities by end use and building type are presented in Table 12-2 through Table 12-5. As indicated, the highest overall electric end-use energy intensity is interior lighting (4.32 kWh per square foot), followed by cooling (2.40), ventilation (2.33), and refrigeration (1.74). According to Table 12-4 and Table 12-5, the highest natural gas end-use energy intensities are space heating (11.9 kBtu per square foot), water heating (8.3) and cooking (4.8).

EUIs by building type and end use are presented in Section 12-3.

Table 12-1: Overview of Energy Usage in the SMUD Service Area

		Annual Energy Intensities			Total Annual Usage	
Building Type	Floor Stock (kft^2)	Electricity (kWh/ft^2)	Natural Gas ($therms/ft^2$)	Natural Gas ($kBtu/ft^2$)	Electricity (GWh)	Natural Gas (Mtherms)
All Commercial	227,831	16.50	0.27	26.87	3759	61.20
Small Office (<30k ft2)	18,469	12.41	0.08	8.10	229	1.50
Large Office (>=30k ft2)	42,848	19.95	0.20	19.77	855	8.50
Restaurant	6,132	46.81	1.83	183.45	287	11.20
Retail	44,597	14.28	0.07	6.62	637	3.00
Food Store	5,582	44.79	0.29	28.99	250	1.60
Refrigerated Warehouse	2,722	16.85	0.02	1.58	46	0.00
Unrefrigerated Warehouse	15,307	3.76	0.01	0.64	58	0.10
School	20,005	9.16	0.18	18.45	183	3.70
College	11,968	10.84	0.32	32.48	130	3.90
Health	11,169	23.06	0.75	74.83	258	8.40
Lodging	9,691	12.26	0.42	41.54	119	4.00
Miscellaneous	39,342	18.00	0.39	38.95	708	15.30
All Offices	61,316	17.68	0.16	16.25	1084	10.00
All Warehouses	18,028	5.74	0.01	0.78	103	0.10

Figure 12-1: Electricity Use by Building Type

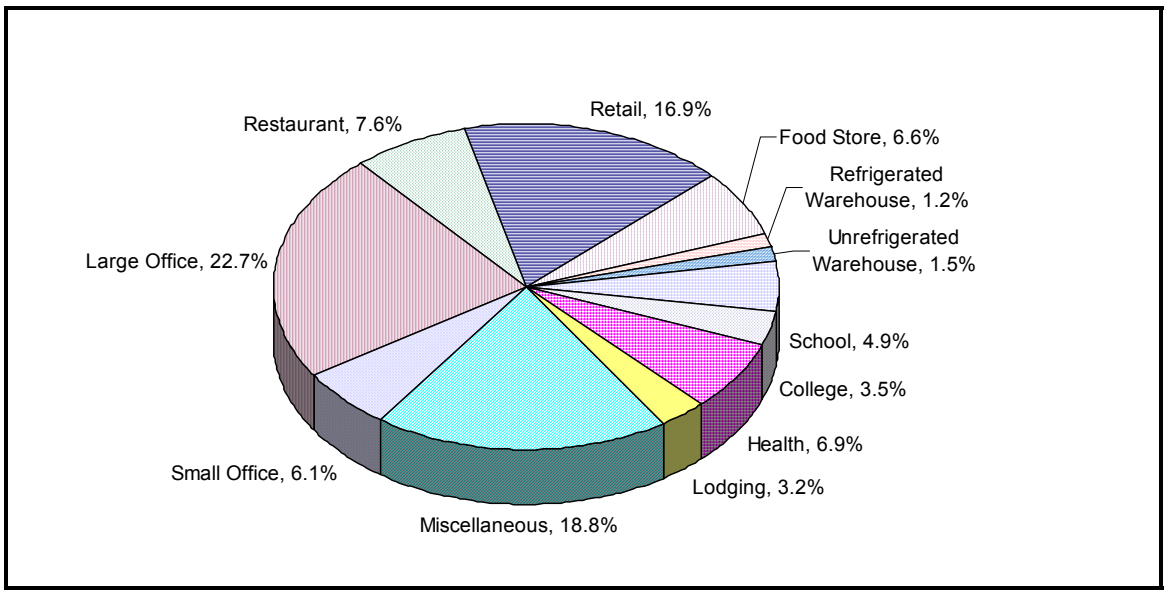


Figure 12-2: Gas Usage by Building Type

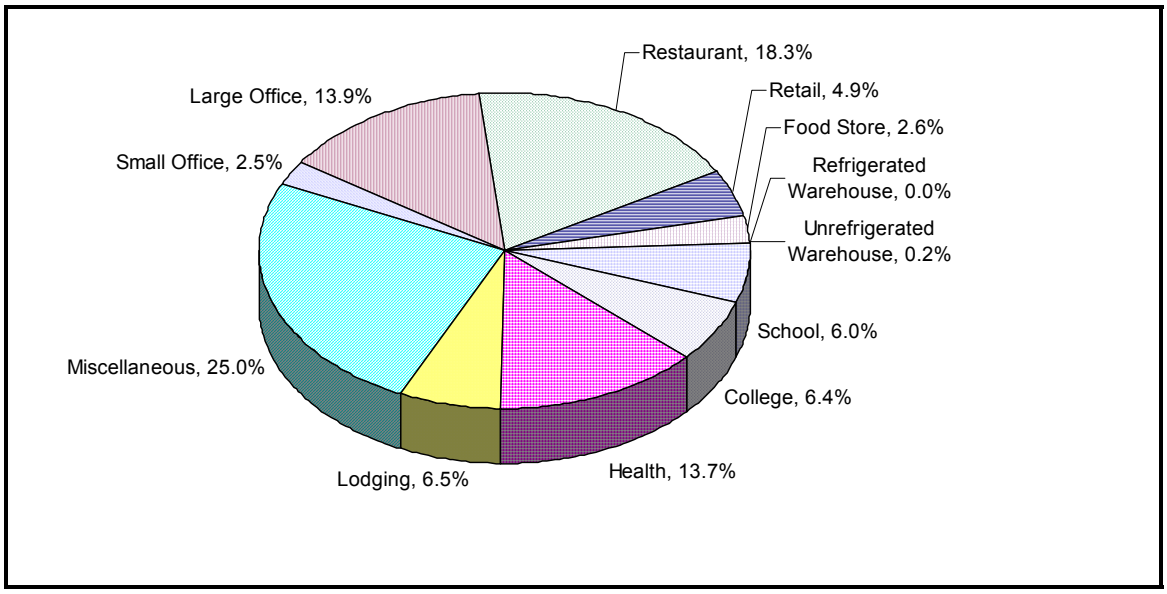


Figure 12-3: Electric Usage by End Use

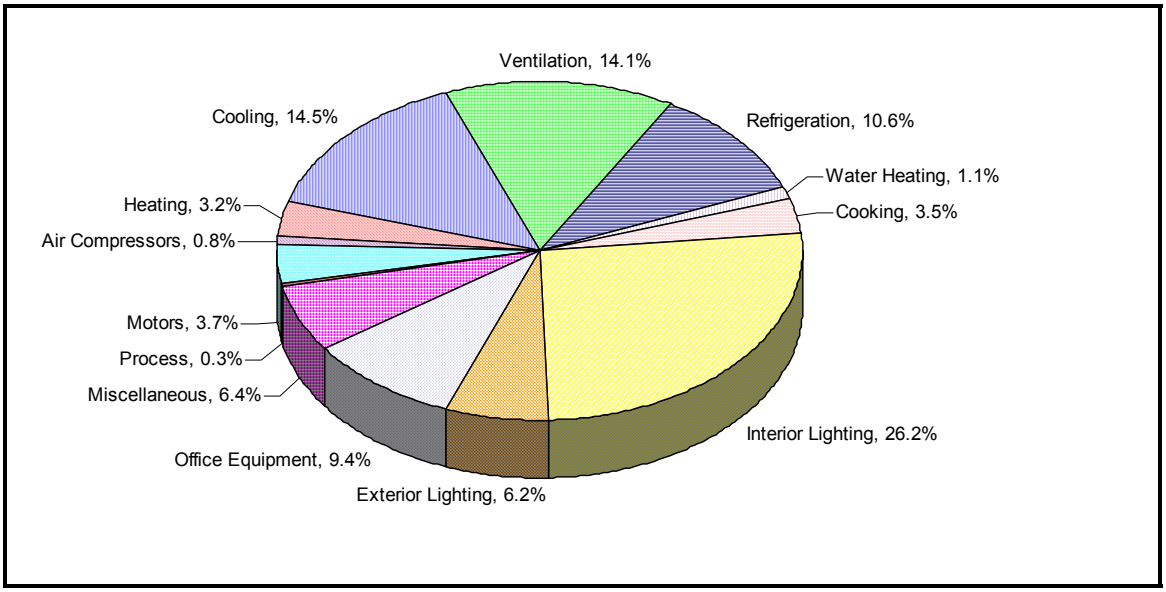


Figure 12-4: Natural Gas Usage by End Use

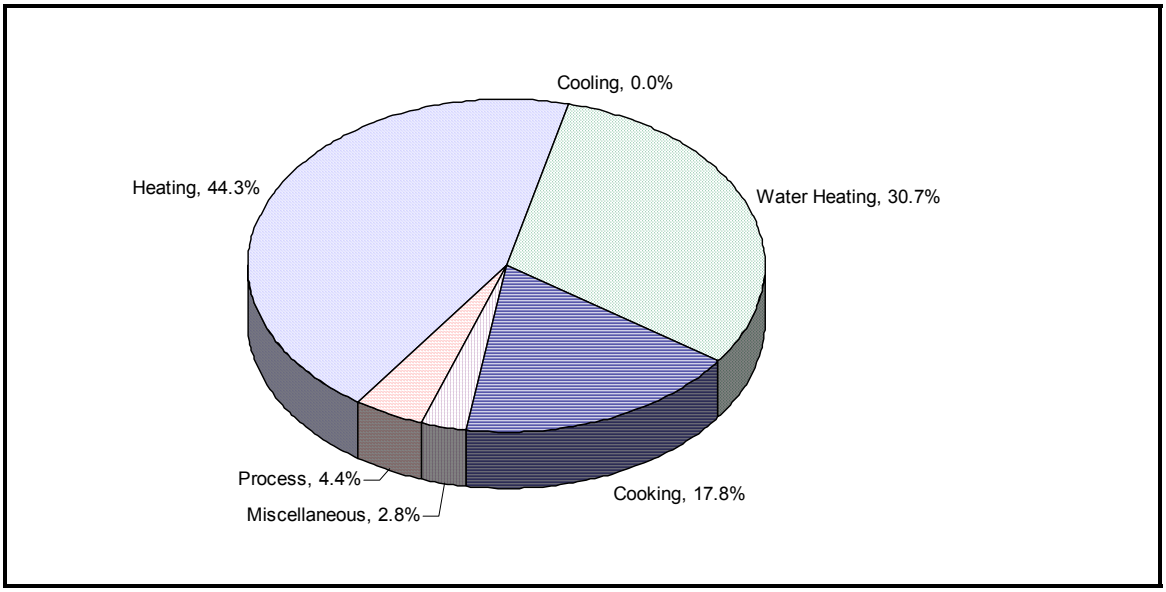


Table 12-2: Electric Usage (GWh) by Building Type and End Use

Building Type	Heat	Cool	Vent.	Refrig.	WH	Cook	Int. Ltg.	Ext. Ltg.	Office Equip.	Misc.	Air Comp.	Motors	Proc.	Total
All Commercial	121.20	546.50	531.00	397.50	39.50	132.10	983.30	231.60	354.50	240.90	11.90	139.90	29.10	3,759.00
Small Office	7.10	38.20	30.00	10.00	5.90	1.60	62.30	10.20	42.80	13.30	0.40	5.00	2.60	229.20
Large Office	63.80	144.10	144.70	12.00	5.70	4.40	202.90	16.40	215.90	20.60	1.60	20.60	2.20	854.80
Restaurant	2.00	43.30	28.50	69.40	1.00	77.90	42.20	6.10	4.10	10.60	0.00	1.90	0.00	287.00
Retail	6.20	81.20	104.10	46.20	7.00	12.90	251.70	53.60	16.30	31.30	4.60	17.30	4.60	637.10
Food Store	0.10	23.80	18.90	128.40	0.80	7.90	58.40	3.60	2.60	4.20	0.00	1.20	0.00	250.00
Refrigerated Warehouse	0.40	0.80	0.30	27.90	0.40	0.10	5.50	1.30	1.20	2.60	0.00	5.40	0.10	45.80
Unrefrigerated Warehouse	1.90	2.90	1.00	7.30	0.40	0.00	28.70	1.70	4.70	6.80	0.00	0.70	1.40	57.60
School	6.30	26.20	23.50	14.30	2.30	2.50	61.90	19.50	20.40	4.50	0.00	1.50	0.30	183.20
College	5.10	25.80	23.50	5.70	2.20	0.80	33.70	14.20	9.40	5.10	0.00	3.20	1.00	129.70
Health	10.10	48.30	64.00	10.40	0.20	7.00	60.90	5.10	13.60	27.10	0.30	8.70	1.90	257.60
Lodging	8.30	23.70	14.60	12.10	3.70	4.90	32.50	3.60	1.40	10.70	0.00	3.20	0.10	118.80
Miscellaneous	10.10	88.20	77.90	53.70	10.00	12.10	142.60	96.10	22.20	104.10	4.90	71.20	15.00	708.20
All Offices	70.80	182.30	174.60	22.00	11.60	6.00	265.20	26.50	258.70	33.90	2.00	25.60	4.70	1,084.00
All Warehouses	2.30	3.70	1.30	35.30	0.80	0.10	34.20	3.00	5.90	9.40	0.00	6.10	1.50	103.40

Table 12-3: Electric Energy Intensities (kWh/ft^2-yr) by Building Type and End Use

Building Type	Total	Heat	Cool	Vent.	Refrig.	WH	Cook	Int. Ltg.	Ext. Ltg.	Office Equip.	Misc.	Air Comp.	Motors	Proc.
All Commercial	16.50	0.53	2.40	2.33	1.74	0.17	0.58	4.32	1.02	1.56	1.06	0.05	0.61	0.13
Small Office	12.41	0.38	2.07	1.62	0.54	0.32	0.09	3.38	0.55	2.32	0.72	0.02	0.27	0.14
Large Office	19.95	1.49	3.36	3.38	0.28	0.13	0.10	4.73	0.38	5.04	0.48	0.04	0.48	0.05
Restaurant	46.81	0.32	7.07	4.65	11.32	0.16	12.70	6.88	1.00	0.66	1.73	0.00	0.31	0.00
Retail	14.28	0.14	1.82	2.33	1.04	0.16	0.29	5.64	1.20	0.37	0.70	0.10	0.39	0.10
Food Store	44.79	0.02	4.26	3.39	23.01	0.15	1.42	10.47	0.65	0.46	0.75	0.00	0.21	0.00
Refrigerated Warehouse	16.85	0.13	0.30	0.10	10.26	0.13	0.02	2.01	0.47	0.43	0.97	0.00	1.99	0.03
Unrefrigerated Warehouse	3.76	0.13	0.19	0.07	0.48	0.03	0.00	1.87	0.11	0.31	0.44	0.00	0.05	0.09
School	9.16	0.31	1.31	1.17	0.71	0.11	0.13	3.10	0.98	1.02	0.23	0.00	0.08	0.01
College	10.84	0.43	2.16	1.97	0.48	0.19	0.07	2.82	1.19	0.78	0.42	0.00	0.27	0.08
Health	23.06	0.90	4.33	5.73	0.93	0.02	0.62	5.45	0.46	1.21	2.42	0.03	0.78	0.17
Lodging	12.26	0.86	2.45	1.51	1.24	0.38	0.50	3.36	0.37	0.14	1.10	0.00	0.33	0.01
Miscellaneous	18.00	0.26	2.24	1.98	1.37	0.25	0.31	3.62	2.44	0.57	2.65	0.12	1.81	0.38
All Offices	17.68	1.16	2.97	2.85	0.36	0.19	0.10	4.33	0.43	4.22	0.55	0.03	0.42	0.08
All Warehouses	5.74	0.13	0.21	0.07	1.96	0.04	0.01	1.89	0.17	0.33	0.52	0.00	0.34	0.08

Table 12-4: Natural Gas Usage (Mtherms) by Building Type and End Use

Building Type	Heat	Cool	WH	Cook	Misc.	Proc.	Total
All Commercial	27.10	0.00	18.80	10.90	1.70	2.70	61.20
Small Office	1.30	0.00	0.20	0.00	0.00	0.00	1.50
Large Office	7.00	0.00	1.10	0.10	0.20	0.10	8.50
Restaurant	0.90	0.00	3.10	7.20	0.00	0.00	11.20
Retail	2.30	0.00	0.20	0.40	0.00	0.10	3.00
Food Store	0.80	0.00	0.30	0.50	0.00	0.00	1.60
Refrigerated Warehouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unrefrigerated Warehouse	0.10	0.00	0.00	0.00	0.00	0.00	0.10
School	2.60	0.00	0.90	0.10	0.00	0.00	3.70
College	3.10	0.00	0.70	0.00	0.00	0.00	3.90
Health	4.20	0.00	3.10	0.40	0.20	0.50	8.40
Lodging	0.60	0.00	2.80	0.50	0.10	0.00	4.00
Miscellaneous	4.10	0.00	6.40	1.70	1.20	2.10	15.30
All Offices	8.30	0.00	1.30	0.10	0.20	0.10	10.00
All Warehouses	0.10	0.00	0.00	0.00	0.00	0.00	0.10

Table 12-5: Natural Gas Usage Intensities (kBtu/ft^2-yr) by Building Type and End Use

Building Type	Total	Heat	Cool	WH	Cook	Misc.	Proc.
All Commercial	26.90	11.90	0.00	8.30	4.80	0.70	1.20
Small Office	8.10	7.00	0.00	1.10	0.00	0.00	0.00
Large Office	19.80	16.30	0.00	2.50	0.20	0.40	0.30
Restaurant	183.40	14.10	0.00	51.30	118.00	0.00	0.00
Retail	6.60	5.20	0.00	0.50	0.80	0.00	0.10
Food Store	29.00	14.80	0.00	4.80	9.40	0.00	0.00
Refrigerated Warehouse	1.60	0.40	0.00	0.60	0.00	0.00	0.60
Unrefrigerated Warehouse	0.60	0.60	0.00	0.00	0.00	0.00	0.00
School	18.40	13.00	0.00	4.70	0.70	0.00	0.00
College	32.50	26.30	0.00	6.00	0.10	0.10	0.00
Health	74.80	37.90	0.00	27.30	3.40	1.90	4.20
Lodging	41.50	6.70	0.00	29.30	4.80	0.70	0.00
Miscellaneous	39.00	10.40	0.00	16.20	4.20	3.00	5.20
All Offices	16.30	13.50	0.00	2.10	0.20	0.30	0.20
All Warehouses	0.80	0.60	0.00	0.10	0.00	0.00	0.10

12.3 Segment-Level Fuel Shares, EUIs, and Energy Intensities

This chapter provides EUIs, fuel shares, and energy intensities for the building types and end uses defined in Chapter 7. Results are not presented in this section for the "All Offices" and "All Warehouses" building types.

All Commercial

Estimated total floor stock for all commercial buildings in the SMUD service area is 227 million square feet. Electric and natural gas EUIs, fuel shares and energy intensities for the overall SMUD commercial sector are presented in Table 12-6 and Table 12-7.

Table 12-6: All Commercial Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.04	51.20	0.53
Cooling	2.97	80.80	2.40
Ventilation	2.81	82.90	2.33
Water Heating	0.34	51.50	0.17
Cooking	0.67	87.00	0.58
Refrigeration	1.86	93.80	1.74
Interior Lighting	4.32	100.00	4.32
Office Equipment	1.58	98.80	1.56
Exterior Lighting	1.14	89.40	1.02
Miscellaneous	1.12	94.00	1.06
Process	1.63	3.20	0.05
Motors	1.11	55.20	0.61
Air Compressors	0.41	30.80	0.13
All End Uses			16.50

Table 12-7: All Commercial Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	20.06	59.30	11.89
Cooling	0.00	0.00	0.00
Water Heating	17.80	46.50	8.27
Cooking	16.19	29.50	4.77
Miscellaneous	10.35	7.00	0.72
Process	34.57	3.50	1.21
All End Uses			26.86

Small Offices

Estimated total floor stock in small office buildings (defined as premises with total floor area less than 30,000 square feet) is just over 18 million square feet. Based on the electric intensities shown in the last column of Table 12-8, the largest electric end uses in this building type are interior lighting, office equipment and cooling. As shown in Table 12-9, the predominant gas end use is space heating.

Table 12-8: Small Office Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.10	34.70	0.38
Cooling	2.53	81.80	2.07
Ventilation	1.98	81.80	1.62
Water Heating	0.44	72.10	0.32
Cooking	0.10	84.50	0.09
Refrigeration	0.55	98.40	0.54
Interior Lighting	3.38	100.00	3.38
Office Equipment	2.32	99.90	2.32
Exterior Lighting	0.64	85.60	0.55
Miscellaneous	0.79	91.50	0.72
Process	0.81	2.80	0.02
Motors	1.01	26.80	0.27
Air Compressors	0.99	14.00	0.14
All End Uses			12.42

Table 12-9: Small Office Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	14.80	47.20	6.98
Cooling	0.00	0.00	0.00
Water Heating	5.42	20.60	1.12
Cooking	0.00	0.00	0.00
Miscellaneous	0.00	0.00	0.00
Process	0.00	0.00	0.00
All End Uses			8.10

Large Offices

Estimated total floor stock in large office buildings (defined as premises with total floor area of 30,000 square feet or more) is over 42 million square feet. Table 12-10 shows that the largest electric end uses in this building type are office equipment, interior lighting, cooling, and ventilation. As shown in Table 12-11, the major gas end use is space heating.

Table 12-10: Large Office Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.75	84.80	1.49
Cooling	3.57	94.20	3.36
Ventilation	3.57	94.70	3.38
Water Heating	0.34	38.80	0.13
Cooking	0.10	100.00	0.10
Refrigeration	0.28	100.00	0.28
Interior Lighting	4.73	100.00	4.73
Office Equipment	5.04	100.00	5.04
Exterior Lighting	0.39	97.20	0.38
Miscellaneous	0.52	93.40	0.48
Process	4.34	0.90	0.05
Motors	0.55	87.80	0.48
Air Compressors	0.15	34.60	0.04
All End Uses			19.94

Table 12-11: Large Office Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	22.61	72.00	16.29
Cooling	0.00	0.00	0.00
Water Heating	5.04	49.50	2.50
Cooking	0.59	40.10	0.24
Miscellaneous	21.71	2.00	0.43
Process	16.46	1.90	0.32
All End Uses			19.78

Restaurants

Estimated total floor stock for this building type is just over 6 million square feet. As shown in Table 12-12, the largest electric end uses in this building type are cooking, refrigeration, cooling and interior lighting. As shown in Table 12-13, the most important natural gas end uses are cooking and water heating.

Table 12-12: Restaurant Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.70	18.70	0.32
Cooling	8.06	87.70	7.07
Ventilation	5.30	87.70	4.65
Water Heating	2.09	7.90	0.16
Cooking	12.70	100.00	12.70
Refrigeration	11.32	100.00	11.32
Interior Lighting	6.88	100.00	6.88
Office Equipment	0.66	100.00	0.66
Exterior Lighting	2.50	40.00	1.00
Miscellaneous	1.81	95.80	1.73
Process	0.00	0.00	0.00
Motors	0.98	31.80	0.31
Air Compressors	0.00	0.00	0.00
All End Uses			46.80

Table 12-13: Restaurant Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	25.35	55.80	14.14
Cooling	0.00	0.00	0.00
Water Heating	55.66	92.10	51.27
Cooking	165.67	71.20	118.04
Miscellaneous	0.00	0.00	0.00
Process	0.00	0.00	0.00
All End Uses			183.45

Retail

Estimated total floor stock for this building type is just over 44 million square feet. Table 12-14 shows that interior lighting is the predominant electric end use in this building type, although cooling and ventilation account for a substantial portion of usage. As shown in Table 12-15, space heating accounts for most of natural gas consumption in the retail sector.

Table 12-14: Retail Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	0.41	34.00	0.14
Cooling	2.30	79.30	1.82
Ventilation	2.87	81.30	2.33
Water Heating	0.20	76.50	0.16
Cooking	0.39	75.00	0.29
Refrigeration	1.17	88.60	1.04
Interior Lighting	5.64	100.00	5.64
Office Equipment	0.37	98.80	0.37
Exterior Lighting	1.35	89.10	1.20
Miscellaneous	0.80	87.40	0.70
Process	1.36	7.60	0.10
Motors	1.12	34.60	0.39
Air Compressors	0.44	23.80	0.10
All End Uses			14.28

Table 12-15: Retail Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	8.31	62.30	5.18
Cooling	0.00	0.00	0.00
Water Heating	2.55	19.70	0.50
Cooking	14.37	5.50	0.79
Miscellaneous	0.00	0.00	0.00
Process	20.38	0.70	0.14
All End Uses			6.61

Food Stores

Estimated total floor stock for this building type is approximately 5.5 million square feet. Table 12-16 shows that refrigeration is the largest electric end use in this building type, with interior lighting comprising about half of remaining usage. As shown in Table 12-17, space heating, water heating and cooking all account for significant shares of gas consumption.

Table 12-16: Food Store Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	0.07	27.10	0.02
Cooling	5.51	77.20	4.26
Ventilation	4.13	82.10	3.39
Water Heating	0.38	39.50	0.15
Cooking	1.50	95.20	1.42
Refrigeration	23.01	100.00	23.01
Interior Lighting	10.47	100.00	10.47
Office Equipment	0.46	100.00	0.46
Exterior Lighting	0.89	72.20	0.65
Miscellaneous	0.75	100.00	0.75
Process	0.00	0.00	0.00
Motors	0.33	64.60	0.21
Air Compressors	0.00	0.00	0.00
All End Uses			44.79

Table 12-17: Food Store Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	27.30	54.40	14.84
Cooling	0.00	0.00	0.00
Water Heating	7.43	64.20	4.77
Cooking	12.00	78.20	9.38
Miscellaneous	0.00	0.00	0.00
Process	0.00	0.00	0.00
All End Uses			28.99

Refrigerated Warehouses

Estimated total floor stock for this building type is approximately 2.7 million square feet. Table 12-18 shows that refrigeration is the largest electric end use in this building type, accounting for almost two-thirds of total electric usage. As seen in Table 12-19, the largest gas EUI is process, although the process gas energy intensity is low.

Table 12-18: Refrigerated Warehouse Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.09	12.30	0.13
Cooling	2.42	12.40	0.30
Ventilation	0.79	12.50	0.10
Water Heating	0.13	100.00	0.13
Cooking	0.02	100.00	0.02
Refrigeration	10.26	100.00	10.26
Interior Lighting	2.01	100.00	2.01
Office Equipment	0.43	100.00	0.43
Exterior Lighting	0.47	100.00	0.47
Miscellaneous	1.00	96.80	0.97
Process	0.00	0.00	0.00
Motors	1.99	100.00	1.99
Air Compressors	0.22	15.30	0.03
All End Uses			16.84

Table 12-19: Refrigerated Warehouse Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	3.98	9.70	0.39
Cooling	0.00	0.00	0.00
Water Heating	0.86	64.70	0.56
Cooking	0.00	0.00	0.00
Miscellaneous	0.00	0.00	0.00
Process	9.30	6.80	0.63
All End Uses			1.58

Unrefrigerated Warehouses

Estimated total floor stock for this building type is 15.3 million square feet. As shown in Table 12-20, the overall electric energy intensity in this building type is low, with interior lighting accounting for almost half of electric usage. Table 12-21 shows that gas energy intensity is also low, with space heating being the predominant gas end.

Table 12-20: Unrefrigerated Warehouse Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.13	11.10	0.13
Cooling	1.55	12.40	0.19
Ventilation	0.53	12.40	0.07
Water Heating	0.04	62.20	0.03
Cooking	0.01	27.00	0.00
Refrigeration	0.92	51.90	0.48
Interior Lighting	1.87	100.00	1.87
Office Equipment	0.33	94.30	0.31
Exterior Lighting	0.21	51.90	0.11
Miscellaneous	0.45	97.00	0.44
Process	0.00	0.00	0.00
Motors	0.27	16.90	0.05
Air Compressors	0.34	26.50	0.09
All End Uses			3.77

Table 12-21: Unrefrigerated Warehouse Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	11.64	5.50	0.64
Cooling	0.00	0.00	0.00
Water Heating	0.00	0.00	0.00
Cooking	0.00	0.00	0.00
Miscellaneous	0.00	0.00	0.00
Process	0.00	0.00	0.00
All End Uses			0.64

Schools

Estimated total floor stock for this building type is just over 20 million square feet. As shown in Table 12-22, the largest electric end uses in this building type are interior lighting, cooling, and ventilation. Table 12-23 shows that space heating is the major gas end use.

Table 12-22: School Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	0.38	83.20	0.31
Cooling	1.36	95.80	1.31
Ventilation	1.19	98.40	1.17
Water Heating	0.17	66.30	0.11
Cooking	0.13	100.00	0.13
Refrigeration	0.71	100.00	0.71
Interior Lighting	3.10	100.00	3.10
Office Equipment	1.02	100.00	1.02
Exterior Lighting	0.98	100.00	0.98
Miscellaneous	0.23	98.20	0.23
Process	0.00	0.00	0.00
Motors	0.15	51.60	0.08
Air Compressors	0.08	16.40	0.01
All End Uses			9.16

Table 12-23: School Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	14.58	89.50	13.05
Cooling	0.00	0.00	0.00
Water Heating	5.29	89.50	4.74
Cooking	0.84	77.90	0.65
Miscellaneous	0.96	1.20	0.01
Process	0.00	0.00	0.00
All End Uses			18.45

Colleges

Estimated total floor stock for this building type is just under 12 million square feet. As shown in Table 12-24, the largest electric end uses in this building type are interior lighting, cooling and ventilation. Space heating accounts for most of the gas usage in this sector, as shown in Table 12-25.

Table 12-24: College Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.05	40.70	0.43
Cooling	2.31	93.50	2.16
Ventilation	2.01	98.00	1.97
Water Heating	0.69	27.40	0.19
Cooking	0.07	96.10	0.07
Refrigeration	0.48	100.00	0.48
Interior Lighting	2.82	100.00	2.82
Office Equipment	0.78	100.00	0.78
Exterior Lighting	1.19	100.00	1.19
Miscellaneous	0.49	86.90	0.42
Process	0.00	0.00	0.00
Motors	0.33	81.80	0.27
Air Compressors	0.09	91.10	0.08
All End Uses			10.86

Table 12-25: College Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	53.02	49.60	26.28
Cooling	0.00	0.00	0.00
Water Heating	12.71	46.90	5.96
Cooking	0.34	33.60	0.12
Miscellaneous	3.12	3.90	0.12
Process	0.00	0.00	0.00
All End Uses			32.48

Health

Estimated total floor stock for this building type is just over 11 million square feet. Table 12-26 shows that interior lighting, ventilation, and cooling are the largest electric end uses in this building type. As shown in Table 12-27, heating and water heating account for the major shares of gas usage.

Table 12-26: Health Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	1.11	80.90	0.90
Cooling	4.80	90.10	4.33
Ventilation	6.36	90.20	5.73
Water Heating	0.60	3.30	0.02
Cooking	0.62	100.00	0.62
Refrigeration	0.93	100.00	0.93
Interior Lighting	5.45	100.00	5.45
Office Equipment	1.21	100.00	1.21
Exterior Lighting	0.49	93.70	0.46
Miscellaneous	2.58	93.70	2.42
Process	0.40	6.50	0.03
Motors	1.37	56.90	0.78
Air Compressors	0.27	63.40	0.17
All End Uses			23.05

Table 12-27: Health Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	48.10	78.80	37.90
Cooling	0.00	0.00	0.00
Water Heating	30.49	89.60	27.32
Cooking	5.51	62.60	3.45
Miscellaneous	7.88	24.50	1.93
Process	12.70	33.40	4.24
All End Uses			74.84

Lodging

Estimated total floor stock for this building type is approximately 9.7 million square feet. As shown in Table 12-28, the biggest single end use in this sector is interior lighting, followed by cooling and ventilation. Water heating accounts for most of the gas consumption, as shown in Table 12-29.

Table 12-28: Lodging Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	0.89	96.70	0.86
Cooling	2.53	96.90	2.45
Ventilation	1.56	96.90	1.51
Water Heating	1.92	19.70	0.38
Cooking	0.50	100.00	0.50
Refrigeration	1.24	100.00	1.24
Interior Lighting	3.36	100.00	3.36
Office Equipment	0.16	89.20	0.14
Exterior Lighting	0.37	100.00	0.37
Miscellaneous	1.10	100.00	1.10
Process	0.00	0.00	0.00
Motors	0.54	61.80	0.33
Air Compressors	0.02	33.30	0.01
All End Uses			12.25

Table 12-29: Lodging Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	12.02	55.70	6.70
Cooling	0.00	0.00	0.00
Water Heating	36.49	80.30	29.31
Cooking	9.73	49.40	4.81
Miscellaneous	1.26	57.70	0.73
Process	0.00	0.00	0.00
All End Uses			41.55

Miscellaneous

Estimated total floor stock for this building type is approximately 39 million square feet. Table 12-30 shows that interior lighting is the largest electric end use in this building type, with the remaining electric usage spread out over several other end uses. As shown in Table 12-31, space heating and water heating account for most of the gas consumption in this diverse building type, with process and cooking uses accounting for most of the rest of consumption.

Table 12-30: Miscellaneous Electric EUIs, Fuel Shares, and EIs

End Use	Electric EUI (kWh/End-Use ft^2)	Electric Fuel Share	Electric EI (kWh/ft^2)
Heating	0.72	35.80	0.26
Cooling	2.79	80.20	2.24
Ventilation	2.30	86.10	1.98
Water Heating	0.51	49.40	0.25
Cooking	0.34	90.60	0.31
Refrigeration	1.41	96.50	1.37
Interior Lighting	3.62	100.00	3.62
Office Equipment	0.57	99.10	0.57
Exterior Lighting	2.58	94.50	2.44
Miscellaneous	2.66	99.40	2.65
Process	2.15	5.80	0.12
Motors	2.91	62.20	1.81
Air Compressors	1.13	33.80	0.38
All End Uses			18.00

Table 12-31: Miscellaneous Natural Gas EUIs, Fuel Shares, and EIs

End Use	Natural Gas EUI (kBtu/End-Use ft^2)	Natural Gas Fuel Share	Natural Gas EI (kBtu/ft^2)
Heating	18.47	56.20	10.37
Cooling	0.00	0.00	0.00
Water Heating	32.25	50.10	16.16
Cooking	22.41	18.90	4.23
Miscellaneous	19.16	15.50	2.96
Process	70.91	7.40	5.23
All End Uses			38.95

12.4 Segment-Level Hourly End Use Electric Shapes

This section presents 16-day hourly stacked end-use graphs from DrCEUS for the basic set of building types (that is, excluding “All Offices” and “All Warehouses”). The 16-day type basis (4 day types X 4 seasons), as defined in Chapter 7, are as follows:

- **Four Day Types.** Typical Day (weekday), Hot Day (weekday), Cold Day (weekday) and Weekend (Saturday, Sunday, and holidays). Note that the Hot and Cold day types are the hottest\coldest[1] *single* days during a season, whereas the Typical and Weekend day types are an *average* of all days of those respective types during the season.
- ***Four Seasons.*** Winter (December through February), Spring (March through May), Summer (June through September), Fall (October through November).

Only electric hourly end-use shapes are presented here, although gas end-use hourly shapes are also available from DrCEUS.

[1] The hottest/coldest days are determined as the first weekday during a season that has the highest or lowest hourly temperature.

Figure 12-5: All Commercial 16-Day Hourly End-Use Shapes

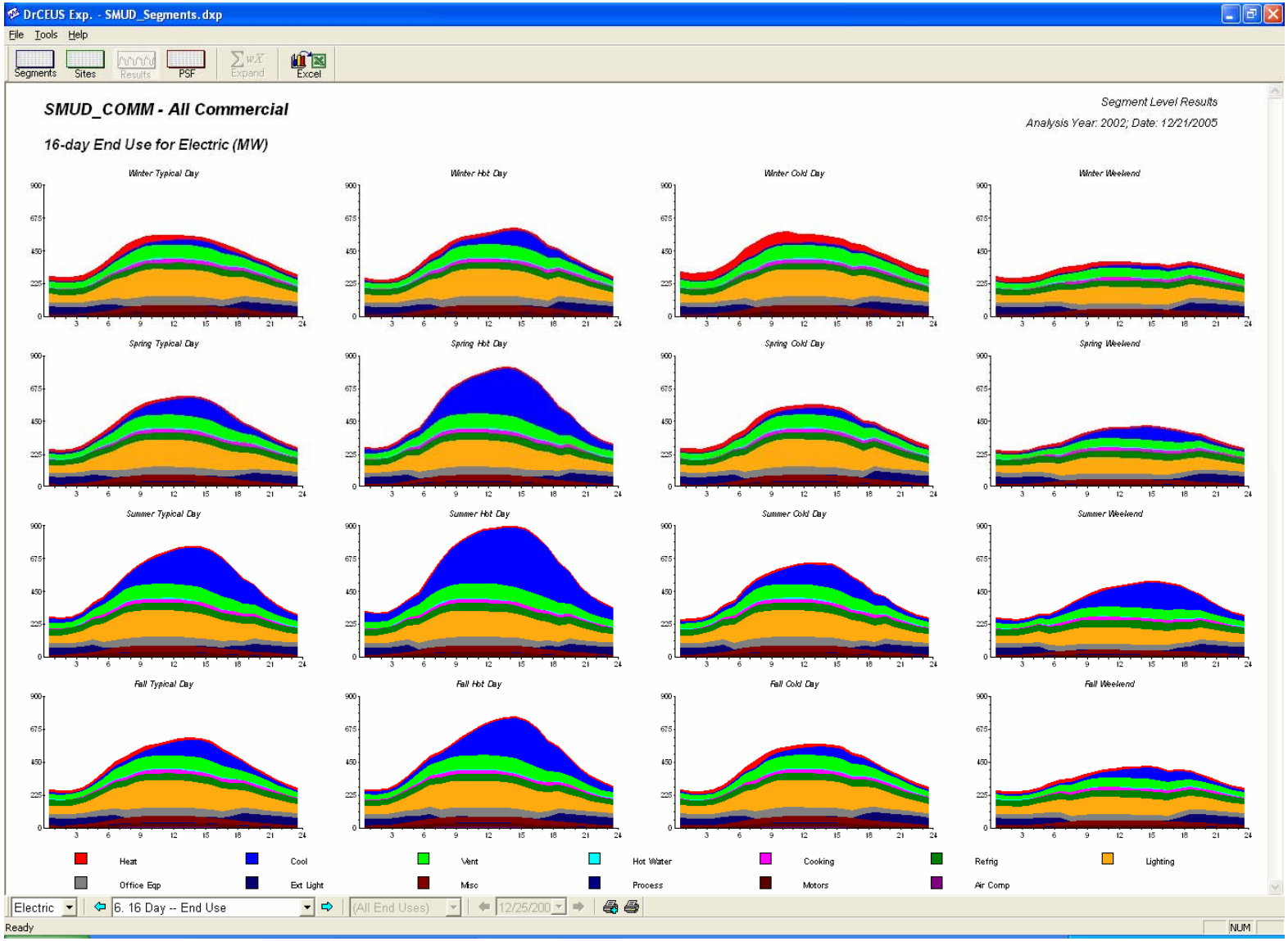


Figure 12-6: Small Office 16-Day Hourly End-Use Shapes

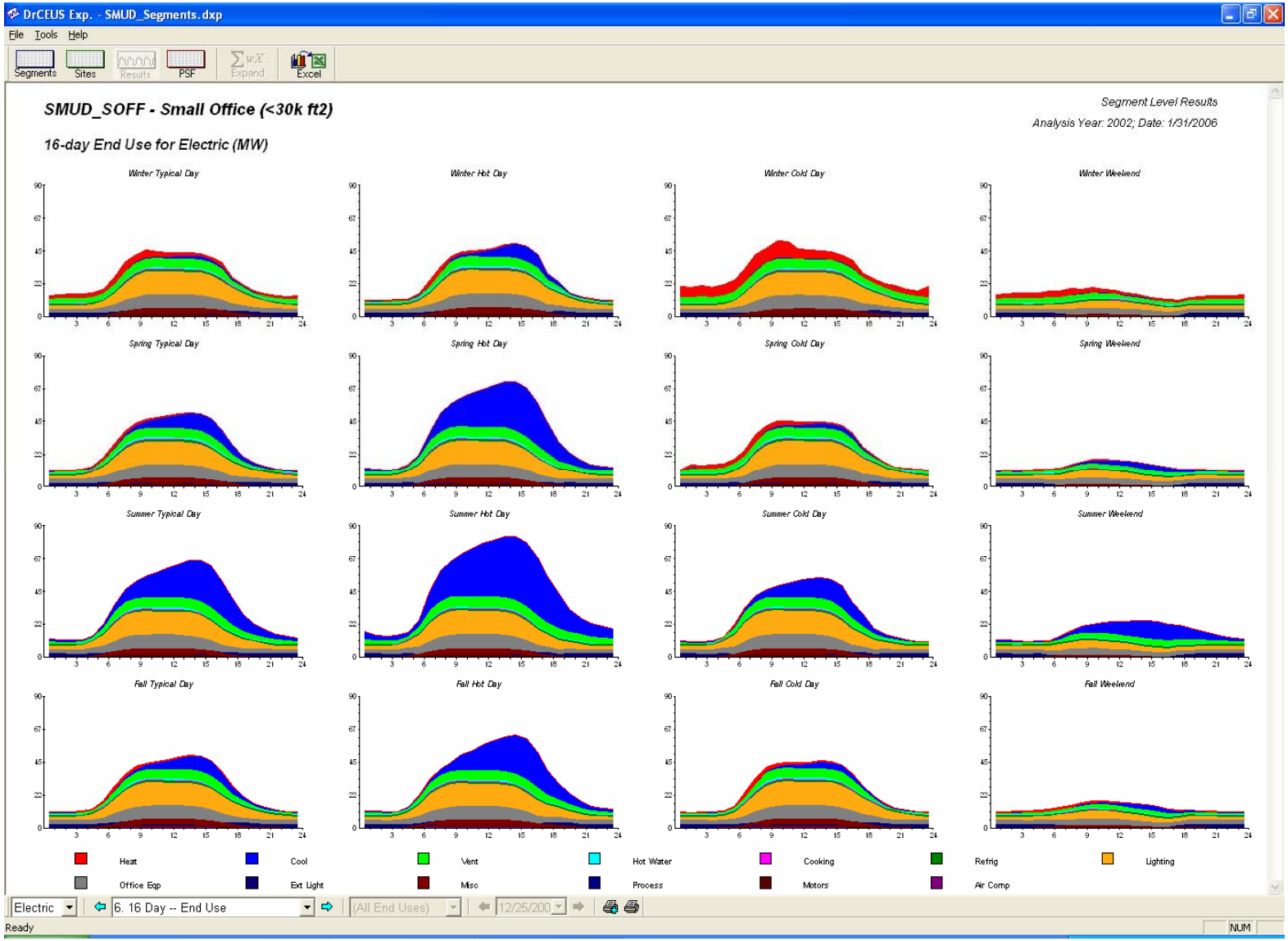


Figure 12-7: Large Office 16-Day Hourly End-Use Shapes

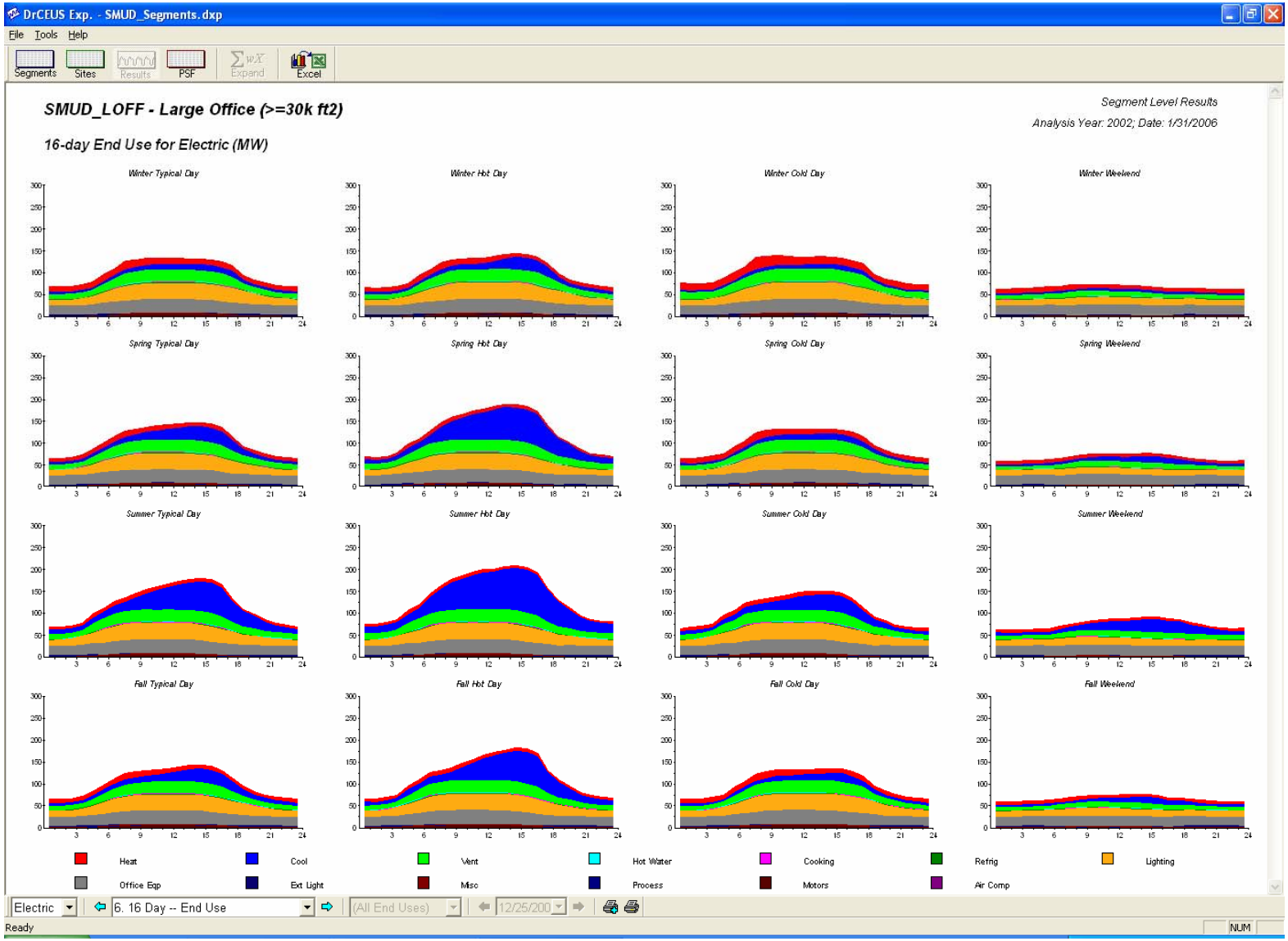


Figure 12-8: Restaurant 16-Day Hourly End-Use Shapes

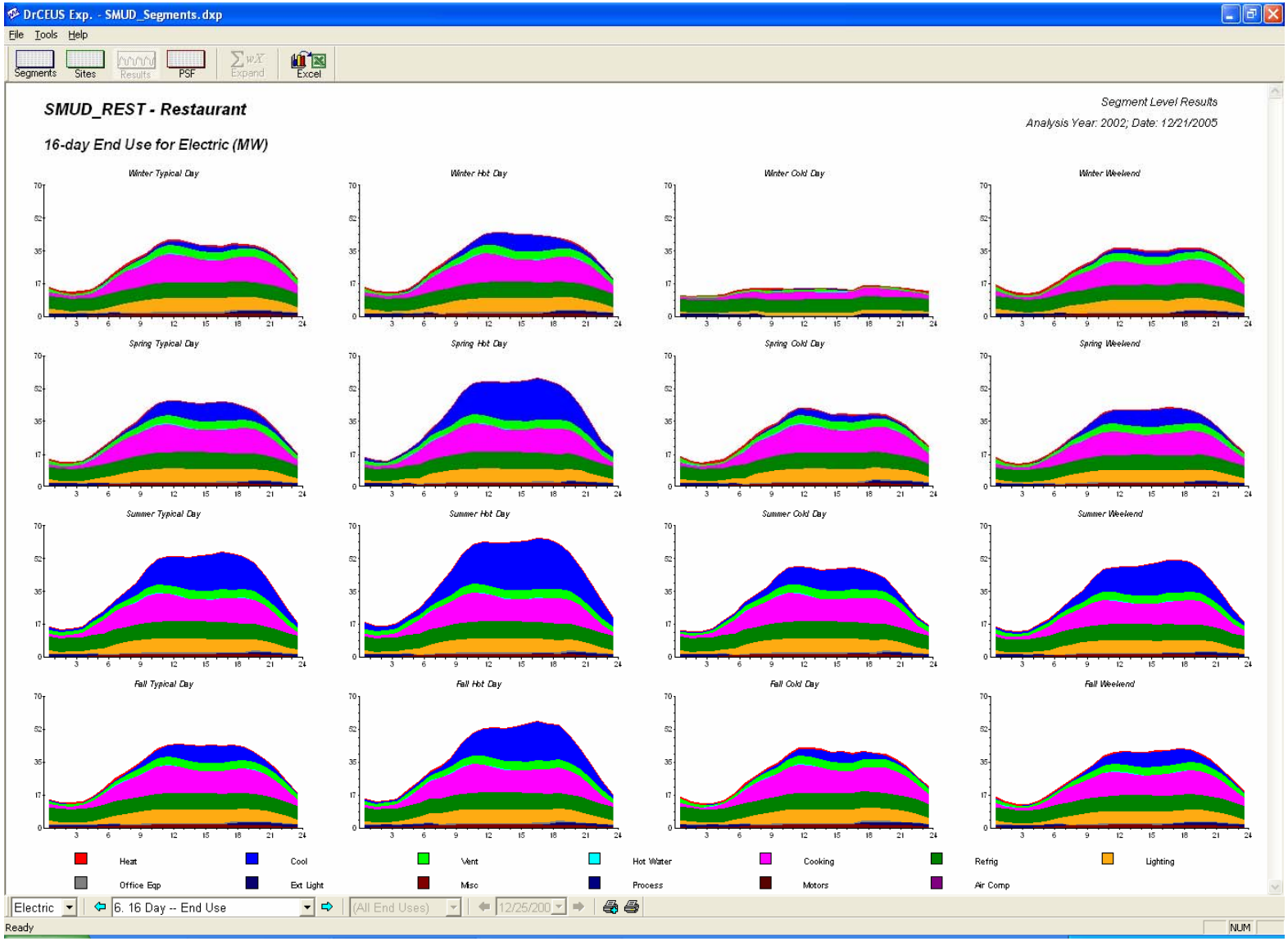


Figure 12-9: Retail 16-Day Hourly End-Use Shapes

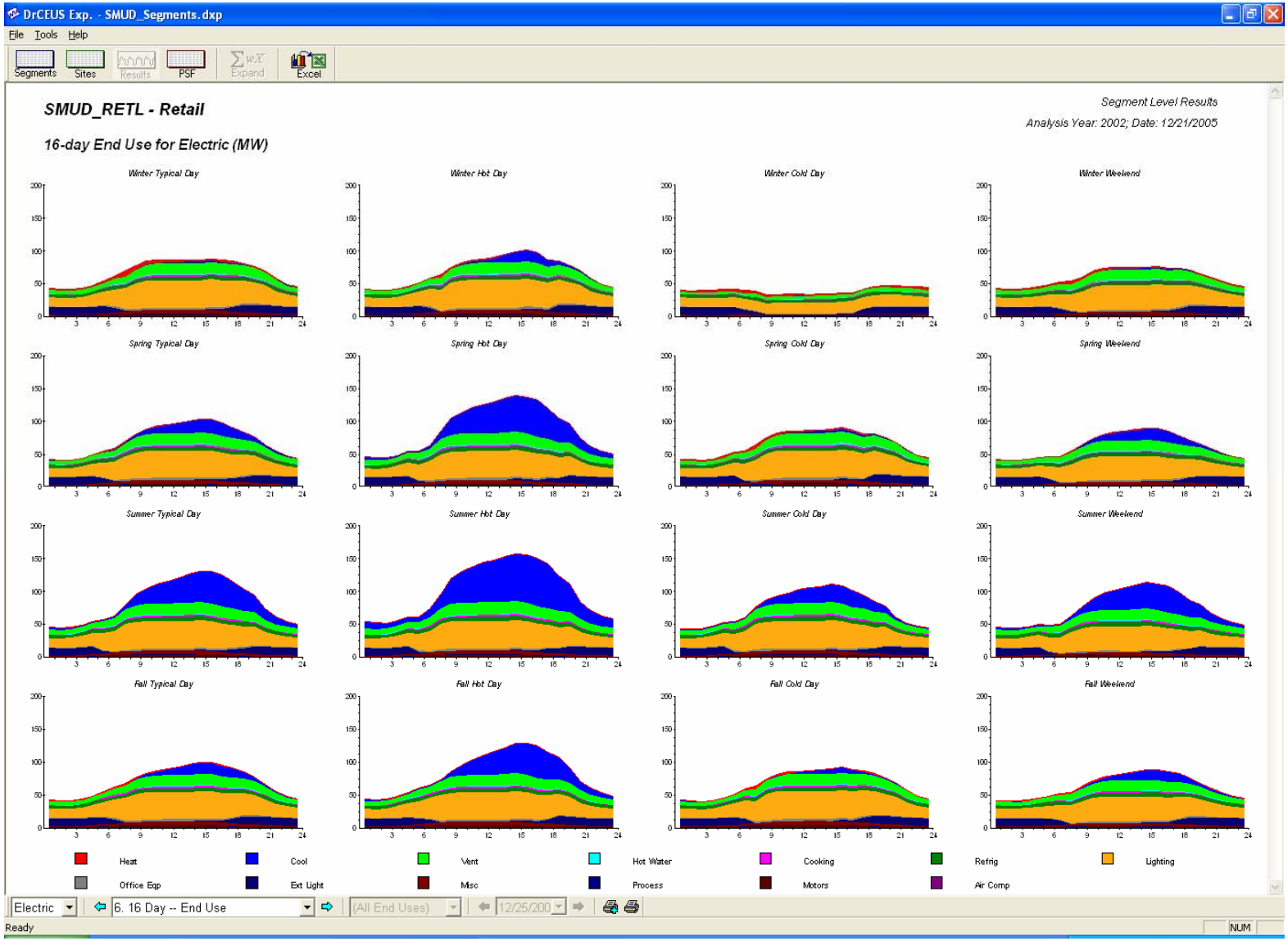


Figure 12-10: Food Store 16-Day Hourly End-Use Shapes

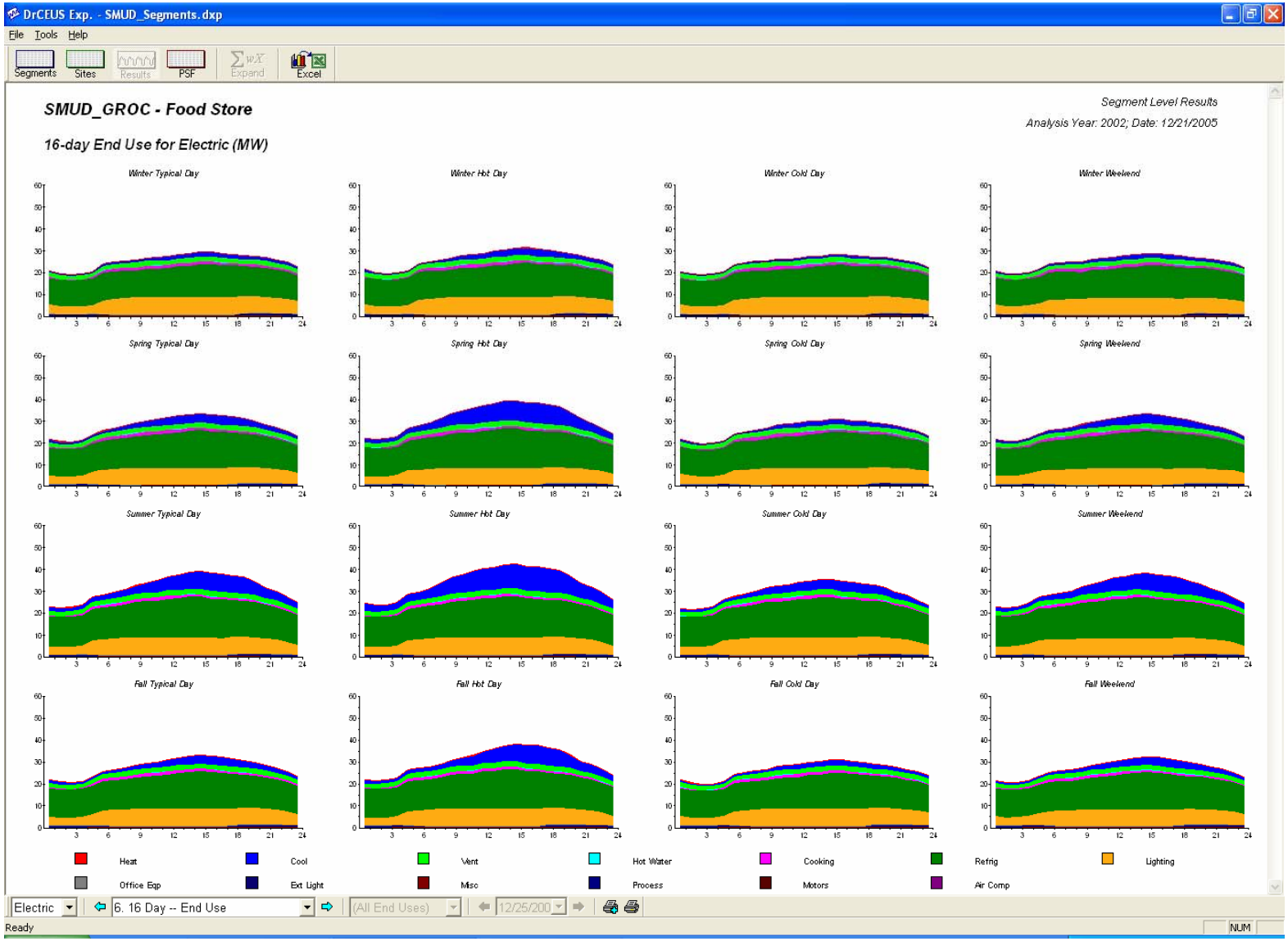


Figure 12-11: Refrigerated Warehouse 16-Day Hourly End-Use Shapes

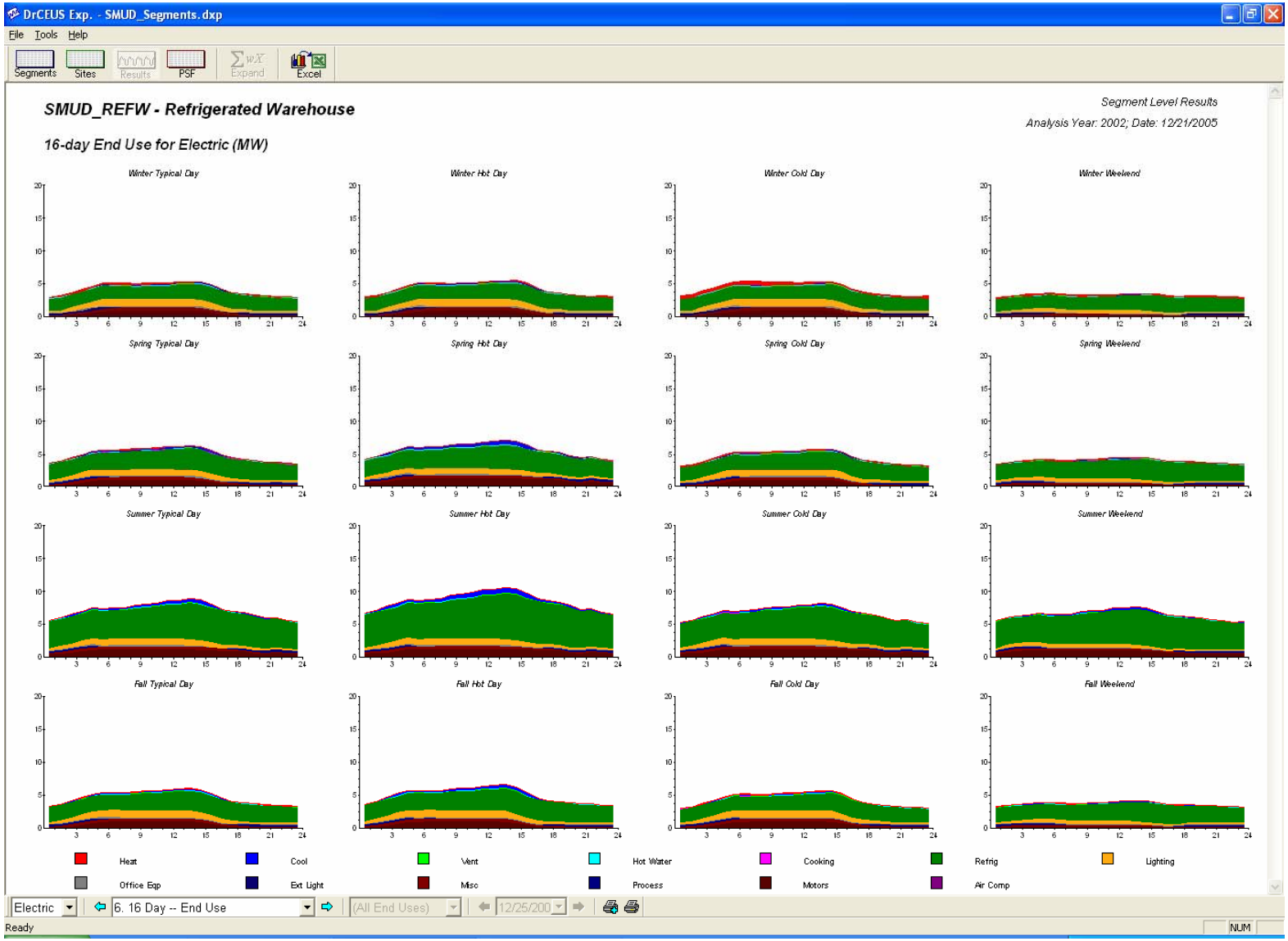


Figure 12-12: Unrefrigerated Warehouse 16-Day Hourly End-Use Shapes

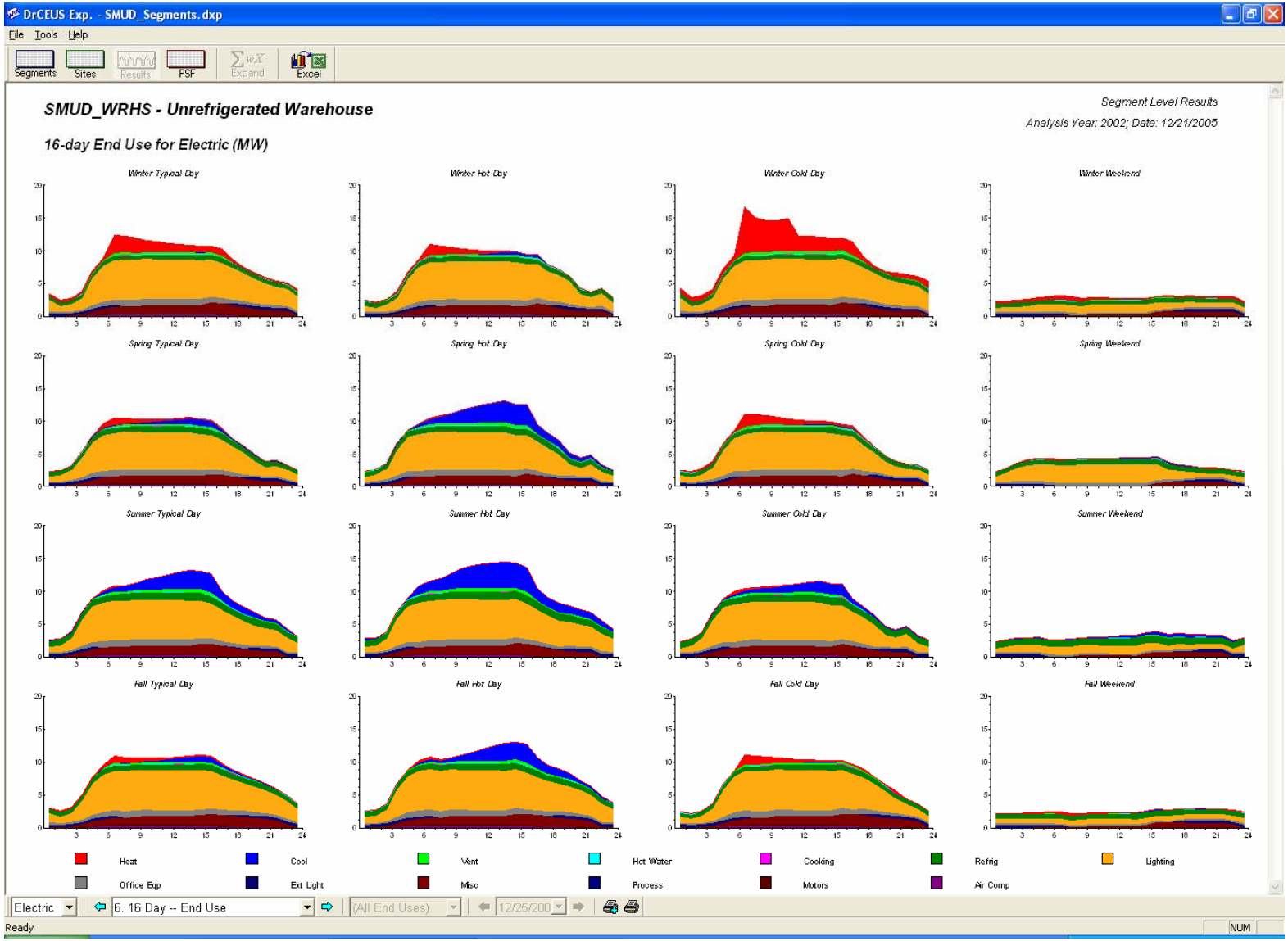


Figure 12-13: School 16-Day Hourly End-Use Shapes

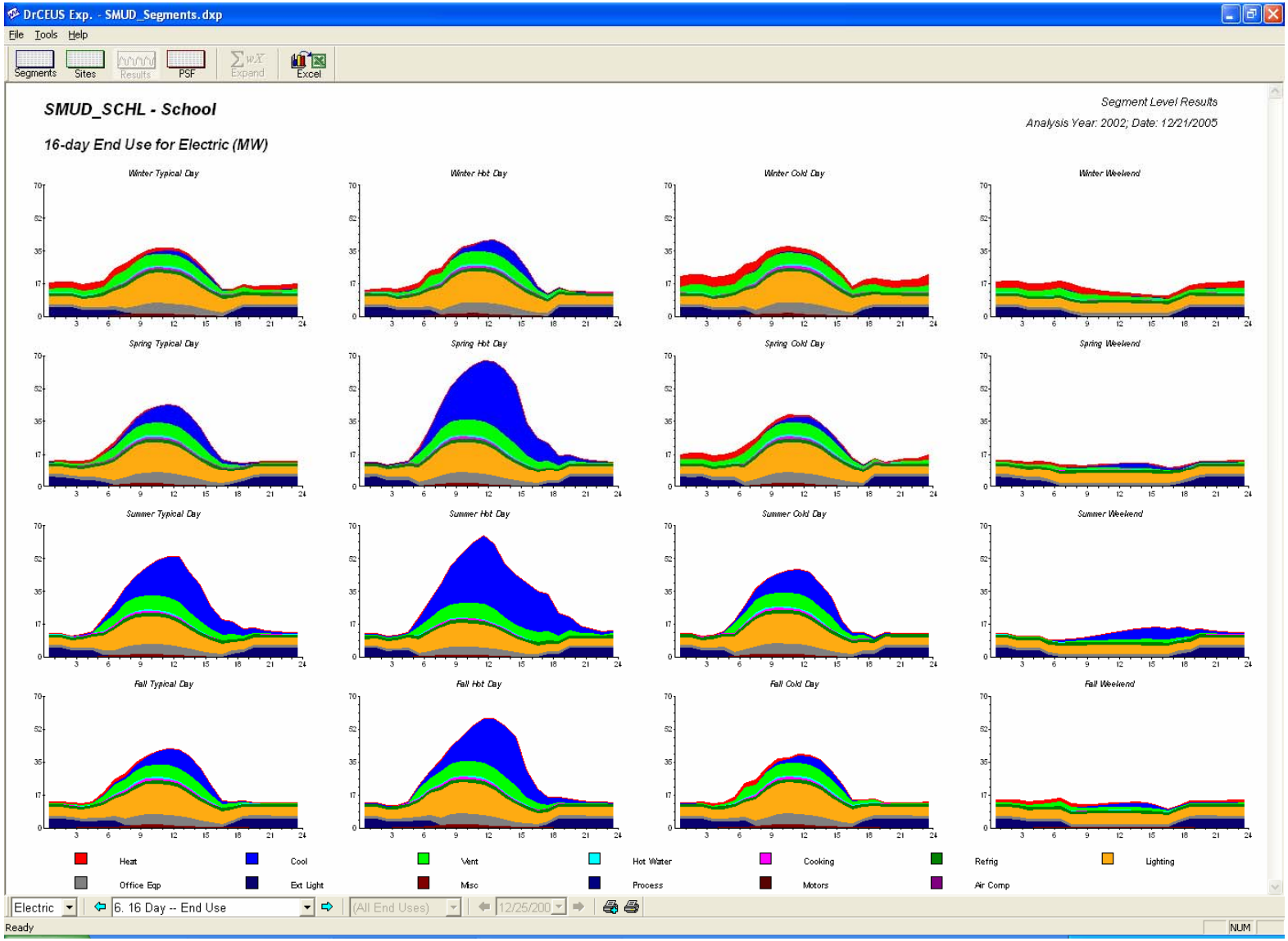


Figure 12-14: College 16-Day Hourly End-Use Shapes

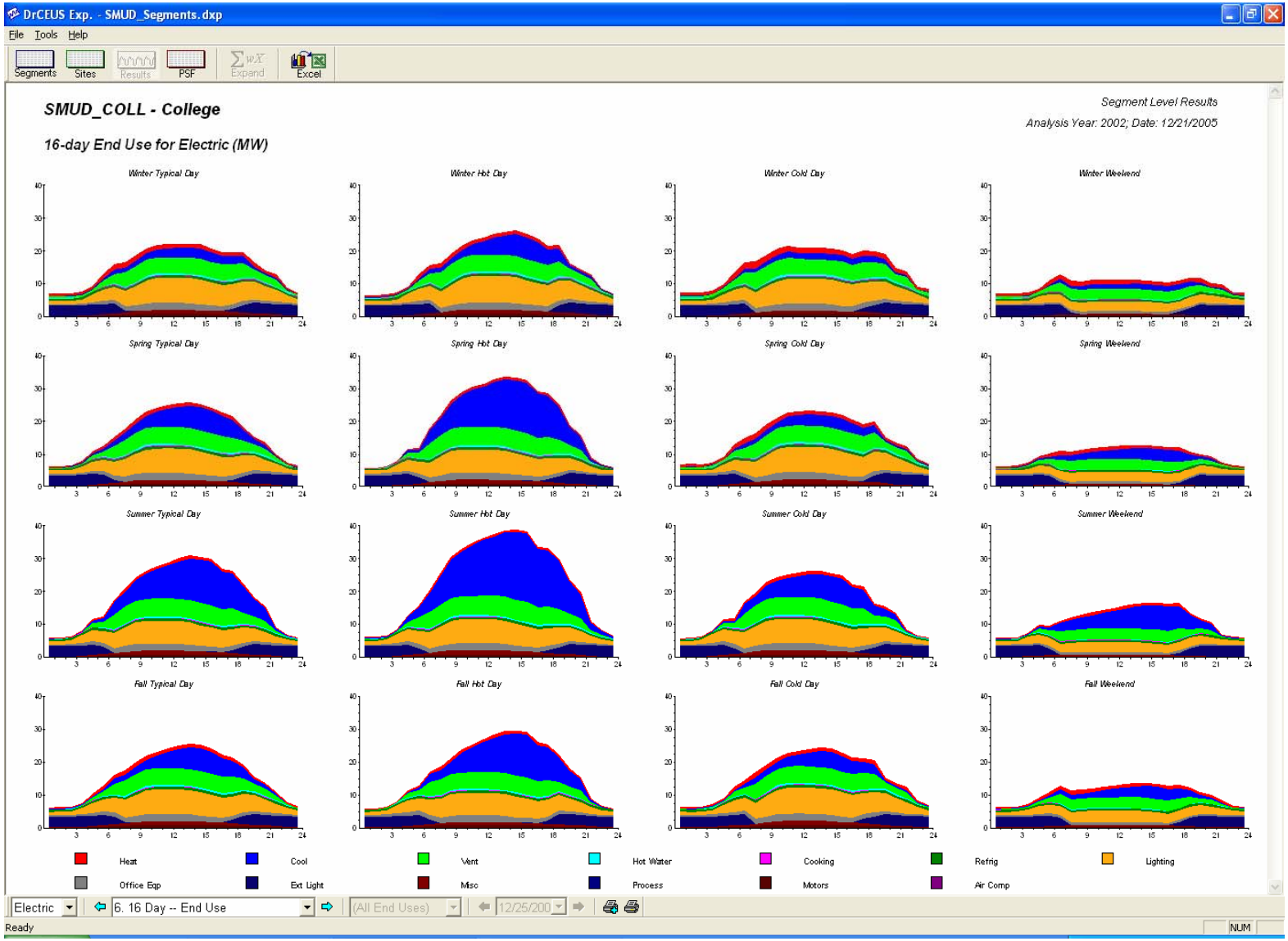


Figure 12-15: Health 16-Day Hourly End-Use Shapes

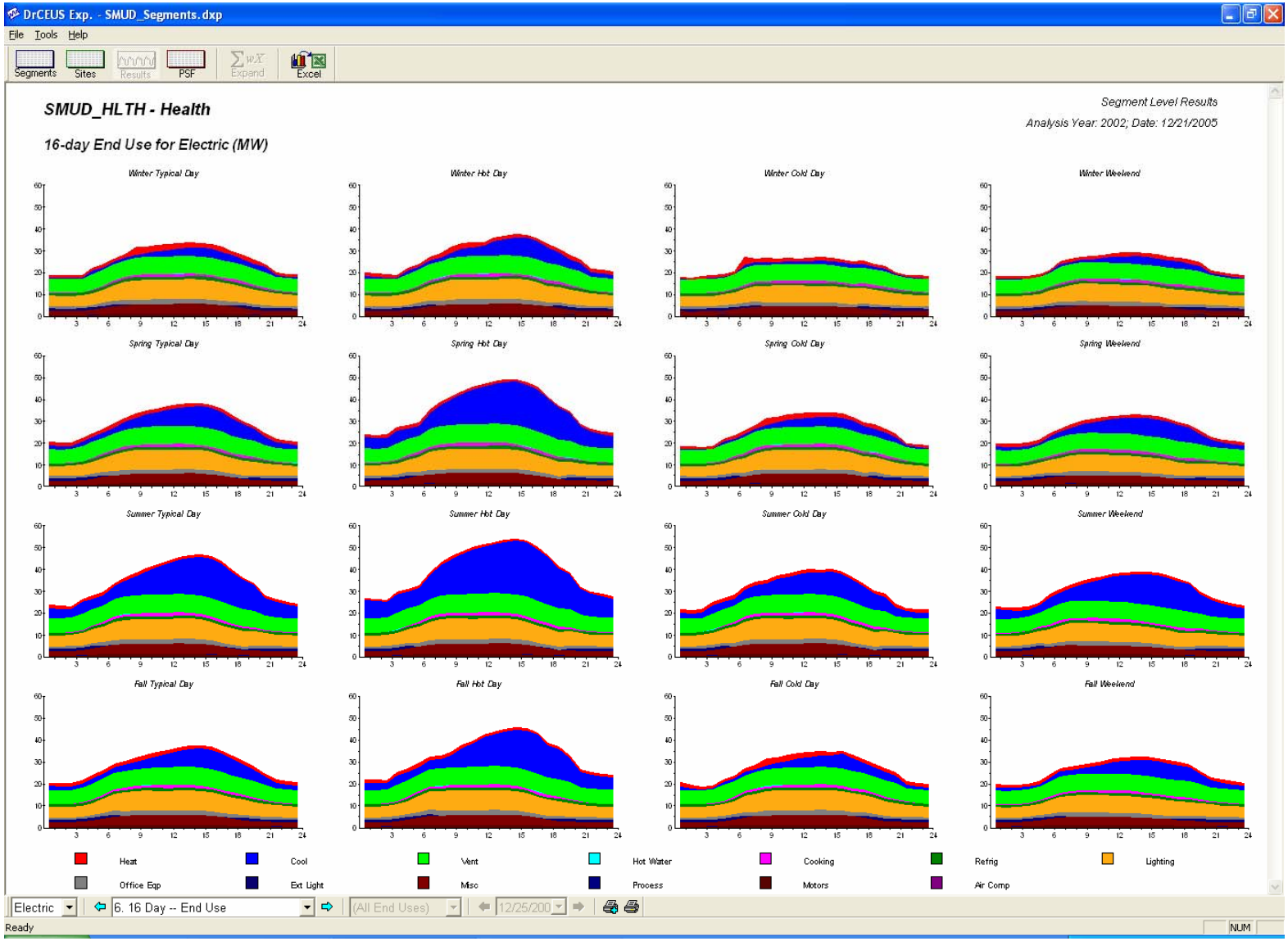


Figure 12-16: Lodging 16-Day Hourly End-Use Shapes

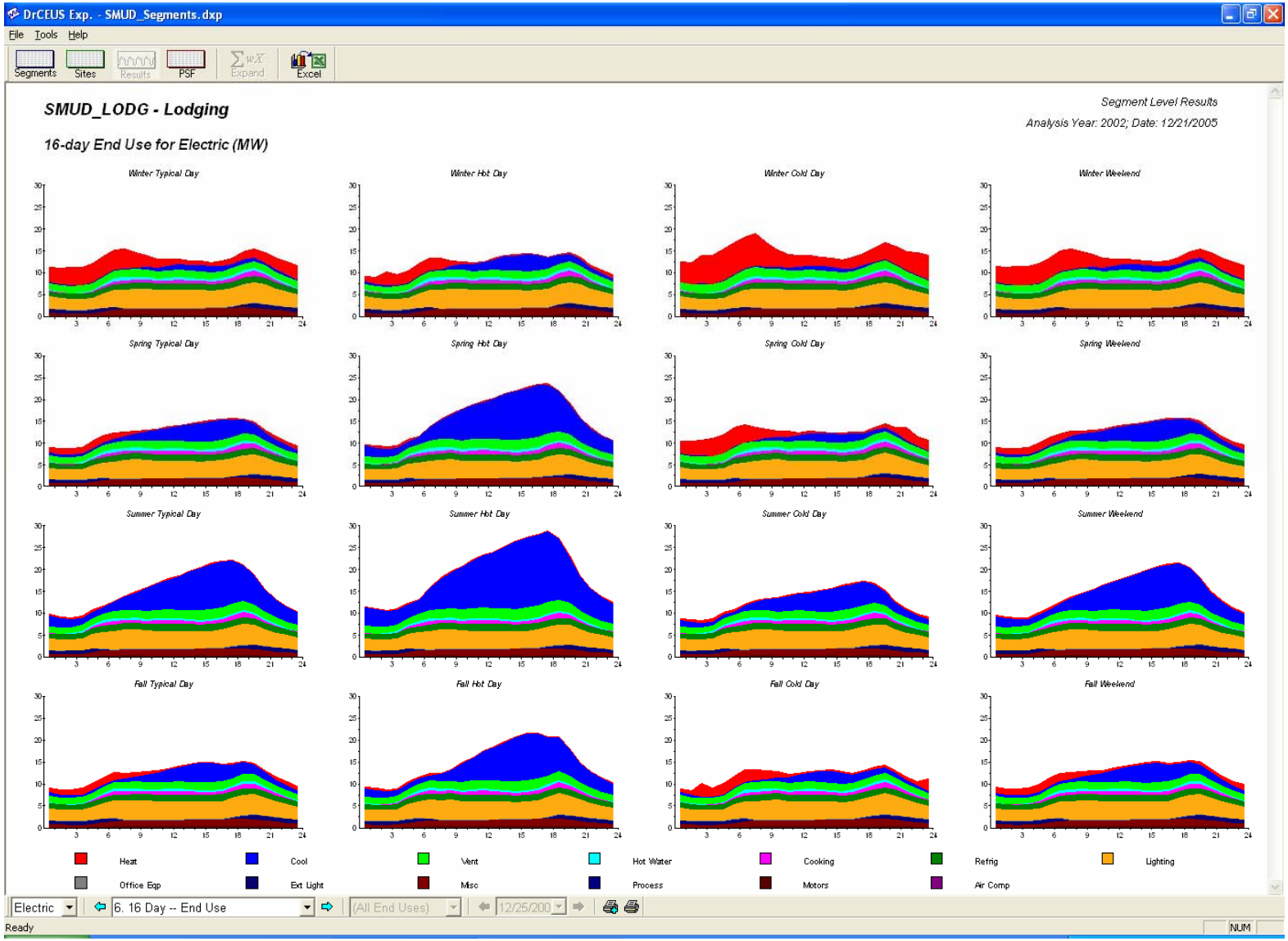
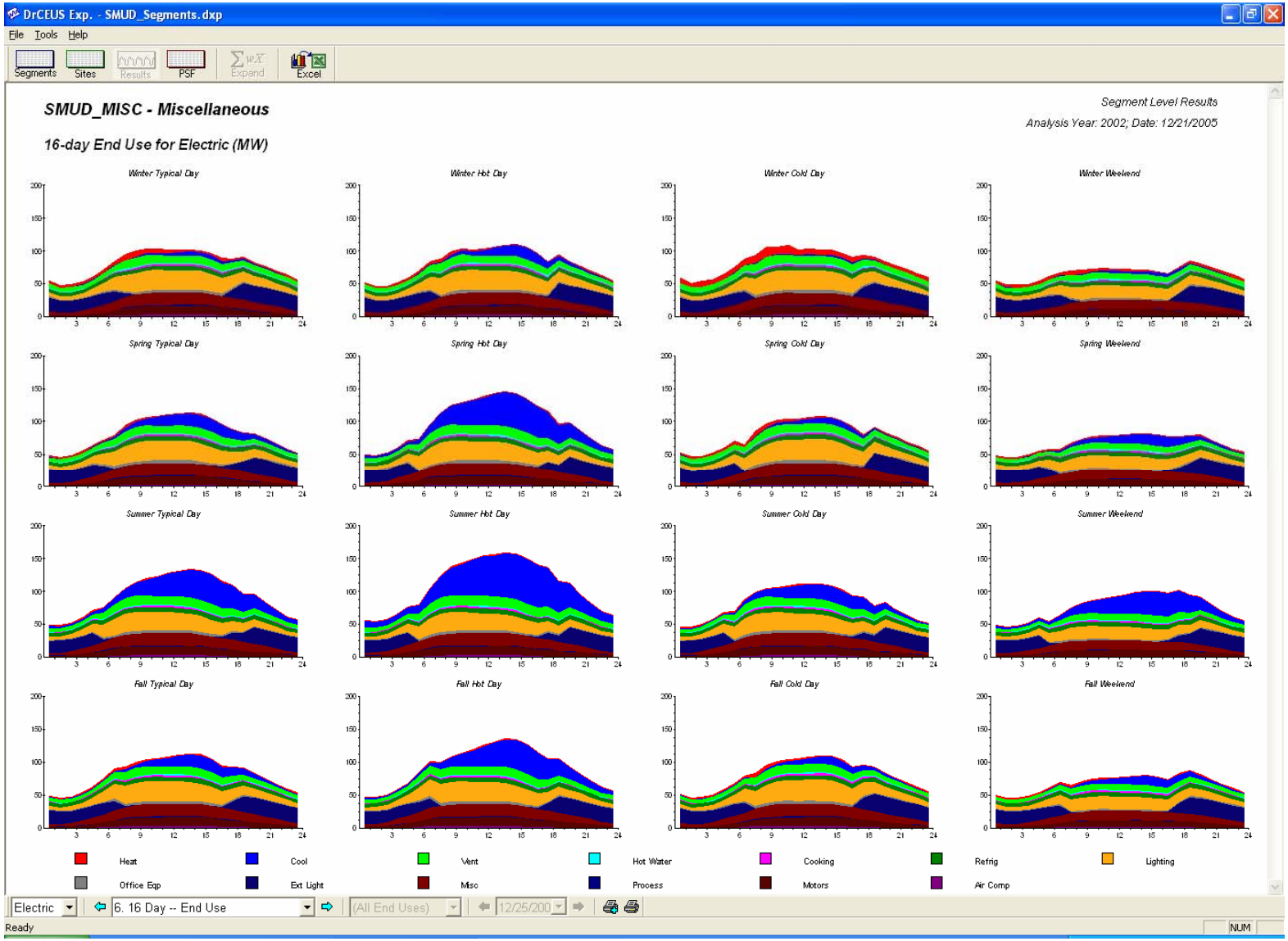


Figure 12-17: Miscellaneous 16-Day Hourly End-Use Shapes



CHAPTER 13: SUMMARY AND RECOMMENDATIONS

13.1 Summary of Project Scope and Methods

The project's general tasks included collecting commercial building characteristics data through on-site surveys, collecting electricity and natural gas use information on commercial facilities, developing a software system designed to facilitate the analysis of energy consumption patterns, using the software system to develop site-specific estimates of end-use load profiles, and developing overall commercial building-type characterizations. Itron's approaches to these tasks are summarized below.

Survey Design

The survey initially covered the service areas of three of California's major investor-owned utilities (IOUs): Pacific Gas & Electric Company (PG&E), Southern California Edison Company (SCE), and San Diego Gas & Electric Company (SDG&E). The service area of the remaining IOU, Southern California Gas Company (SoCalGas), was partially covered by surveys in the SCE area. The survey was eventually expanded to cover the Sacramento Utility District (SMUD) service area. Billing data for the commercial sector were provided by the utilities under agreements with the California Energy Commission (Energy Commission).

As discussed in Chapter 2, the primary sampling unit was the premise, defined as a single commercial enterprise operating at a contiguous location. A total sample size of 2,800 premises was targeted. The sample was stratified by service area, climate zone, building type, and size class. The sample design within service areas was optimized by using the Dalenius-Hodges approach for defining strata and Neyman allocation of the samples across strata.

Collection of On-Site Survey Data

The on-site survey was one of the largest conducted in the United States, and the most comprehensive conducted in California. It was used to collect information on equipment stocks, operating schedules, efficiency levels, and shell characteristics of commercial buildings via facility manager interviews, building inspections, and inspection of site documents and records. For a subset of premises, the survey also included the collection of logger data for interior lighting and/or HVAC fans. The survey instrument that was used for the survey was relatively detailed, especially in the characterization of thermal zones within the premise.

Collection of Information on Energy Usage for Sampled Sites

A primary task required for this study involved assembling energy usage information for the surveyed sites. This information consisted of three basic types of data:

- Utility billing records, consisting of account and meter numbers, rate codes, meter read dates, monthly electric and gas consumption, and when available, time-of-use consumption and maximum demand values,
- Interval-metered electricity data collected by California's utilities as part of load research samples, as well as interval-metered data used for billing of large customers, and
- Short-term metering data, where the operation of a sample of HVAC and lighting systems for a target of 500 premises was monitored with time-of-use data loggers.

Usage data for surveyed sites informed the engineering analysis and ensured the development of accurate estimates of end-use energy consumption and hourly load profiles. The five utilities whose service areas were covered by the survey provided billing records and interval-metered data.[1]

Development of Demand Analysis System

The project entailed the development of a comprehensive demand analysis system designed to facilitate the study team's and the Energy Commission's use of the engineering models to analyze commercial consumption patterns. This demand analysis system, called DrCEUS, is database oriented and was designed to (a) accommodate building simulations for individual sites, (b) facilitate batch simulations for sets of user-selected sites, (c) enable parametric simulations, (d) allow comparison of base case and alternative simulation results, (e) produce population estimates at the segment level using statistical weights, (f) produce population estimates for user-defined segments, (g) perform rate analysis using user-supplied rate schedules, (h) view results graphically, (i) store simulation results in databases, and (j) allow export of results to spreadsheets and other common formats.

Analysis of Premise-Level Hourly End-Use Energy

The next major phase of the study required the development of calibrated energy simulation models for all of the CEUS premises. These models generated energy consumption estimates at the end-use level for all 8,760 hours of the year. The simulation work generally occurred within a reasonable time of completing the on-site survey. This facilitated the mitigation of problems identified in the survey data that were only realized during the modeling process. The analysis consisted of several discrete steps:

[1] These data are confidential under the terms of Title 20 of the California Code of Regulations.

- First, survey data were entered into the DrCEUS system and initial building simulations were performed using actual historical weather corresponding to the billing period. Simulated HVAC loads were developed using the DOE-2.2 engine incorporated into DrCEUS through eQuest. Non-HVAC end uses were calculated using a variety of algorithms that used survey information to estimate occupancy schedules, equipment operating schedules, and connected loads. Simulation model output was summarized in several formats, including tabulation of end-use indices, 16-day[2] hourly end-use load profiles, and 8760 hourly load profiles.
- Second, simulation results were judgmentally calibrated against all available energy consumption information. It was necessary to first validate the list of accounts and meters for the premise so an accurate history of energy use could be established. Billed usage (both energy and demand) was compared against the simulation results so that potential problems in the assumptions underlying the simulations could be identified. Short-term metering data, when available, was also used to validate assumptions concerning lighting hourly use patterns and HVAC system operating schedules. Finally, if a site had interval-metered electricity data, it was used to construct 16-day hourly load profiles, which were then compared to the simulated profiles during the calibration process. The interval-metered data were invaluable for providing information on actual operation of the site.
- Third, simulation results were weather normalized by replacing the historical weather data with normalized weather data and rerunning the simulations. Itron developed normal weather data in DOE-2 compatible format for twenty weather stations specifically chosen for the CEUS project. More information on this process can be found in the *California Energy Commission Commercial End-Use Survey: Weather and Data Normalization* report.

Analysis of Segment-Level End-Use Energy Consumption

In the next step of the analysis, premise-level information (including simulated end-use load profiles) was used to characterize commercial segments. Projecting premise-level results to the population segment level was accomplished using an expansion module in DrCEUS, which applied expansion (case) weights developed from the final sample structure. For each service area and commercial building-type segment, the following characteristics were estimated:

- Floor stocks,
- Fuel shares,

[2] The 16-day hourly shapes approach uses four day types—weekday, weekend, hot day (weekday), cold day (weekday)—for four seasons (winter, spring, summer, fall).

- Electric and gas energy consumption,
- Electric and natural gas energy-use indices, which express the end-use energy consumption per square foot of floor stock with the end uses in question,
- Electric and natural gas energy intensities, which express the end-use consumption per whole-premise square foot, and
- Hourly end-use load profiles.

13.2 Recommendations

Recommendations for future work in this area are categorized as either project-specific "lessons learned" or as general commercial sector research issues. Lessons learned are recommendations that could help ensure an effective follow-on CEUS project. General commercial sector issues are those related to improving the data development.

Lessons Learned

The CEUS study was an extremely large undertaking, involving intensive work over a period of four years. The project team learned a considerable amount in the course of the study. Some of the major lessons are discussed below.

Developing Initial Sampling Frames. The development of sampling frames was a time-consuming and frustrating process. Requests for non-residential billing data were made of the three electric IOUs early in the project, and several months passed before final consistent frame databases could be constructed. To some extent, this was due to substantially different formats of the frames received by Itron. A common format probably should have been requested from all utilities. The need for Itron to put confidentiality agreements in place with the IOUs exacerbated the problem. This process cost several additional months and wasted project resources. The administrative mechanism for exchanging data between the utilities and contractors working for regulatory agencies needs to be further developed.

Updating Frames. The initial sample design was based on 2000 billing data, with the intention that analysis would also be done with 2000 data. Given a variety of delays in getting the survey under way, it eventually became apparent that the analysis should use more recent data, and the year 2002 was chosen as the analysis year. Switching base years required Itron to make additional requests for 2002 consumption data from the utilities, and this process took a substantial amount of additional time. In retrospect, sample design in an extensive project like this one should follow a number of other steps, including the design of the survey instrument and perhaps even the pre-testing of the instrument.

Conducting Survey Fieldwork. Survey fieldwork took far longer than anticipated. To some extent, this was due to early delays in getting utility billing system data and changes made to the survey form after the pre-test survey. Subcontractors understandably reassigned surveyors temporarily to other activities, so in a sense the project had to bear a certain amount of start-up costs for a second time. In addition, the complexity of the unique survey instrument, which incorporates several building simulation concepts, aggravated the problem. This affected the need for more intensive surveyor training than is typical for an on-site survey effort, because the survey was more than just a census of equipment; it involved understanding some of the basic building simulation concepts as well. Moreover, as the needs of the survey became clearer, it became apparent that the fieldwork was under-budgeted. Subcontractors found it difficult to complete the survey in the time they had anticipated, and this in turn made it necessary to re-contact many site managers to clarify and/or confirm information. The interaction between Itron and the fieldwork subcontractors was extensive and time-consuming. In future efforts like this, it will be necessary to simplify some aspects of the survey or to recognize the need for higher survey budgets.

Reconciling Meters. One of the key steps in any on-site survey is the verification of meters present at the site. While premises were initially defined in terms of groups of meters and accounts for the entire frame, the aggregation results are imperfect. Reconciling meters to premises after the site visit was a manual process that precluded automation. This process was far more difficult and time consuming than previous on-site survey efforts for several reasons. First, due to the length of time from the original sample design to the end of the study, a higher than normal turnover of commercial business and changes to existing businesses occurred.

Second, meter reconciliation was further complicated by the massive meter change-outs driven by Assembly Bill 29X. This bill provided state money to utilities for replacing older technology meters with newer time-of-use meters on a very large scale. Unsurprisingly, surveyors discovered that many of the meters expected to be found in the field had been replaced. Closer cooperation with utilities early in the project would help minimize the time to resolve meter assignments.

Interval Data for Calibration of Energy Simulation Models. Equipment operating schedules are usually the most difficult information to obtain from an on-site survey. Building owners and operators frequently cannot characterize equipment operation in the detail necessary for simulation modeling, and information is not always available from building control systems. Assumptions made during the energy simulation process regarding schedules directly affect the shape of load profiles at the whole-building and end-use levels. Therefore, it is essential to maximize the number of premises included in the sample that have interval-metered electricity data so that calibration of the simulation models is

based on known building performance. The number of premises with interval-metered data for this study was significantly limited and future efforts should take full advantage of the wealth of data available.

Recommendations for Additional Commercial Sector Research

Itron offers several recommendations for further commercial sector research to build on the current effort.

Updating the Current Study. While the CEUS project was an extremely ambitious undertaking, it does not exhaust the need for commercial sector information. Some means of refreshing the CEUS database will need to be determined, whether this entails statewide surveys like this one or surveys conducted periodically by individual utilities.

Enhancing New Construction Information. By agreement with the Energy Commission, the CEUS sample design did not entail over-sampling of new construction. Even though the total sample size is large enough to contain a significant number of new sites (depending, of course, on the definition of this vintage), the importance of differences between new and existing construction for forecast and other purposes may warrant collecting additional information on new construction. Ideally, this information would be collected with the same survey instrument (albeit perhaps simplified in some areas) as used in this study, and subjected to the same kind of simulation analysis.

Improving the Simulation of Remote Refrigeration. It was agreed early in the project not to use DOE-2.3 (a detailed remote refrigeration system simulation tool) for the simulations, in that it was still being developed by J.J. Hirsch & Associates and VaCom Technologies. However, DOE-2.3 could yield improved results versus the DrCEUS remote refrigeration algorithm, which was also developed with the assistance of VaCom. As such, it may be useful to modify DrCEUS at some point to use DOE-2.3, at least for supermarkets and refrigerated warehouses.

Refining Commercial Building Types. The summary of CEUS results contained in Chapters 8 through 12 makes use of the traditional commercial building types. However, the CEUS database is large enough that it could easily be used to develop a finer resolution of building types. For instance, the miscellaneous building type (24% of all CEUS premises) could be further disaggregated into churches, gas stations, prisons, movie theaters, and a variety of other significant customer segments. This might have a number of useful applications, including refining end-use forecasts and allowing closer targeting of key sectors by energy efficiency programs.

Refining HVAC End Uses. The analysis conducted under this project makes use of fairly traditional HVAC end-use definitions: space heating, space cooling, and ventilation. The system could be enhanced to use a finer resolution of

HVAC end uses, consistent with the DOE-2 HVAC end use distinctions of heat rejection and pumps/auxiliary energy.