Arlington County Building Energy Study:

Energy End Use Analysis of Key Building Segments in the Commercial and Residential Building Sectors

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1 EXECUTIVE SUMMARY

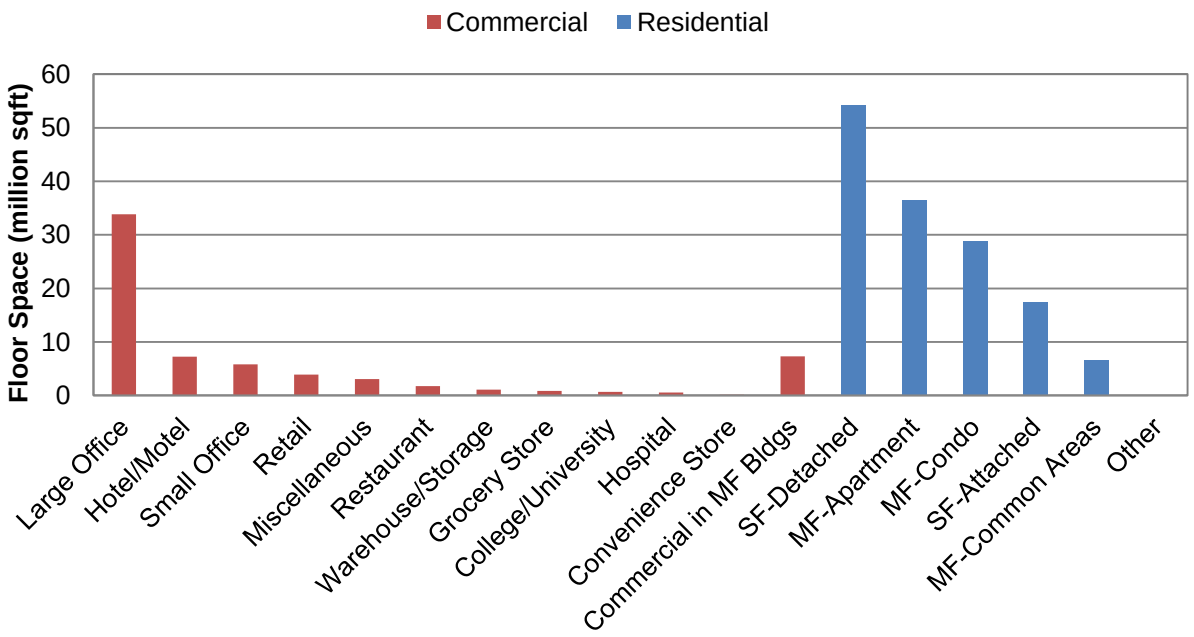
To maximize the impact and benefits of community programs focused on reducing energy consumption and greenhouse gas (GHG) emissions, Arlington County requires a deeper understanding of energy consumption in commercial and residential buildings. This analysis apportions utility-provided, sector-level electricity and natural gas bill data by building segment and end use. This additional granularity provides insights that the County will use to identify potential energy efficiency opportunities and steer future community energy programs.

Leidos utilized available County datasets, supplemented by external and industry-accepted datasets as necessary, to profile Arlington's commercial and residential building sectors from floor space, energy consumption, and energy intensity perspectives. This was accomplished by first breaking down floor space data by building segment using real estate and tax assessment databases maintained by the County. Annual electricity and natural gas intensities for each building segment were then estimated and trued-up to sector-level utility bill data. Next, annual electricity and natural gas intensities for major end uses were estimated and trued-up for each building segment. Lastly, annual electricity and natural gas consumption data was calculated by segment and end use using the trued-up energy intensity and floor space estimates.

Highlighted findings include:

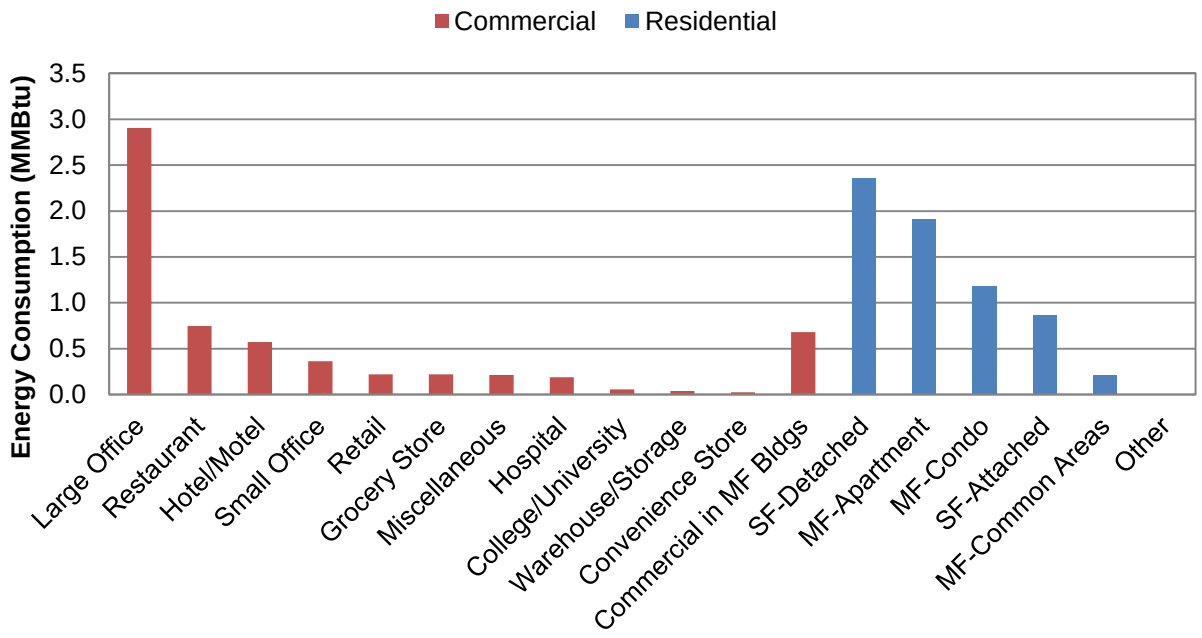
- Commercial sector floor space was estimated to be just over 66 million square feet and dominated by the large office segment.
- Residential sector floor space was estimated to be nearly 144 million square feet and split approximately 50/50 between single family and multifamily housing types.

Figure 1. Floor Space by Building Segment



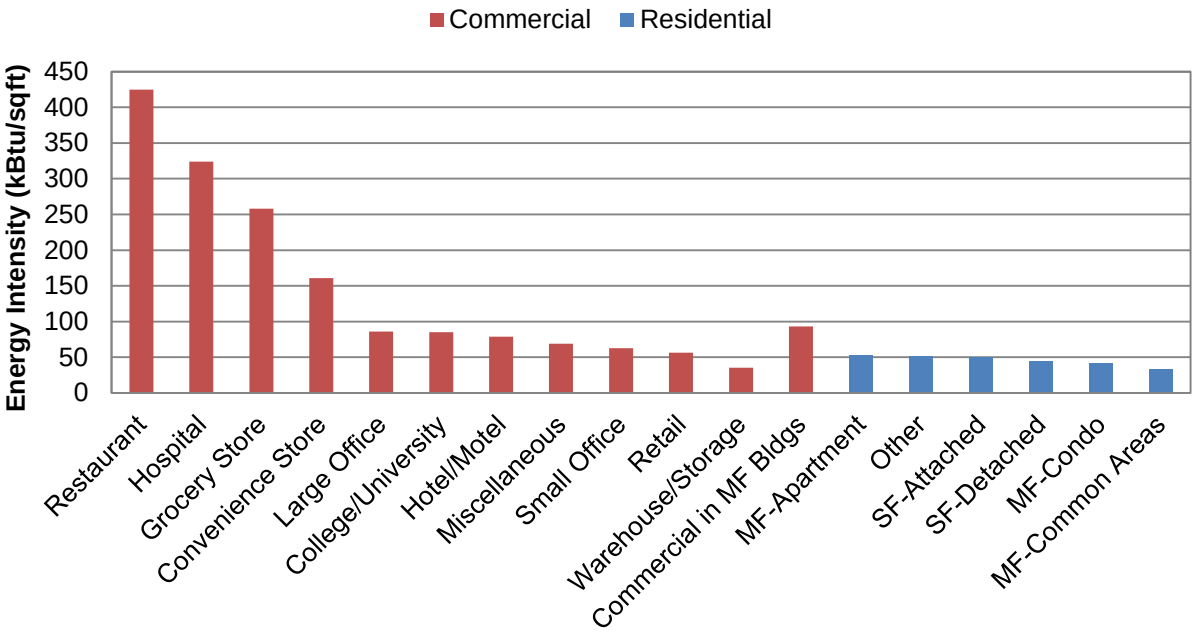
- Commercial sector energy consumption was just over 6.2 million MMBtu in calendar year (CY) 2012 with approximately 2.9 million MMBtu attributable to the large office segment alone.
- Residential sector energy consumption was just over 6.5 million MMBtu in CY 2012. Apartments and detached single family homes accounted for over 65 percent of residential sector energy consumption at 2.4 million MMBtu and 1.9 million MMBtu, respectively.

Figure 2. CY 2012 Energy Consumption by Building Segment



- Average commercial sector energy intensity was about 93 kBtu per square foot in CY 2012. Four commercial segments were considerably more energy intensive than the others; restaurants (425 kBtu/sqft), hospitals (324 kBtu/sqft), grocery stores (258 kBtu/sqft), and convenience stores (161 kBtu/sqft).
- Average residential sector energy intensity was about 46 kBtu per square foot in CY 2012. Apartment units were the most energy intensity residential segment at about 53 kBtu per square foot while common areas in multifamily buildings were the least energy intensive at about 33 kBtu per square foot.

Figure 3. CY 2012 Energy Intensity by Building Segment



- In the commercial sector, energy shares amongst end uses varied considerably between building segments due to diverse building activities and associated energy requirements. Sector-wide, lighting was estimated to consume nearly 1.4 million MMBtu in CY 2012, the largest share of any commercial end use. Combined, lighting (22%), heating (15%), and cooling (14%) accounted for just over half of total commercial energy consumption.
- In the residential sector, end use energy profiles for the different housing segments were very similar. Residential heating was estimated to consume nearly 2.8 million MMBtu in CY 2012, the largest share of any residential end use. The "other" end use, which includes things like lighting, cooking, and electronics such as televisions and computers, accounted for about 1.8 million MMBtu, or 27 percent of the sector total.

Figure 4. Commercial Sector Energy Shares by End Use

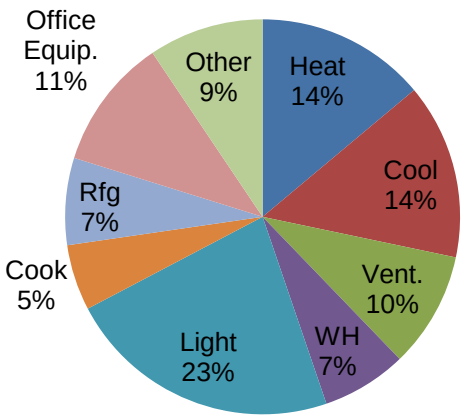
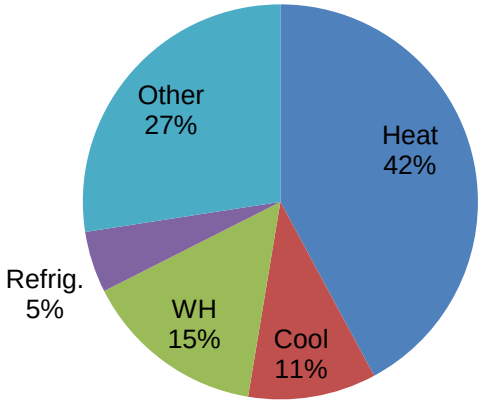


Figure 5. Residential Sector Energy Shares by End Use



- Energy use and intensity results for the commercial sector indicate potential energy reduction opportunities in the following areas:
  - Large office, small office, hotel, and retail lighting
  - Large office HVAC and office equipment
  - Restaurant cooking
  - Restaurant, grocery store, and convenience store refrigeration
  - Hotel, restaurant, and hospital water heating

- Energy use and intensity results for the residential sector indicate potential energy reduction opportunities in the following areas:
  - Heating for all housing types but especially apartments and detached single family homes
  - "Other" for all housing types but especially apartments and detached single family homes
  - Water heating for detached single family homes

2 BACKGROUND

Arlington County requires a deeper understanding of energy consumption in commercial and residential buildings to maximize the impact and benefits of community programs focused on reducing energy consumption and greenhouse gas (GHG) emissions. This insight is needed to develop targeted programs that can help the County reach the energy and GHG goals laid out in the Community Energy Plan (CEP) including a goal to reduce 3.0 metric tons carbon dioxide equivalent (CO_2e) per capita per year by 2050 relative to a 2007 baseline of 13.4 metric ton CO_2e per capita per year.

The purpose of this project is to analyze available County datasets, supplemented by external and industry-accepted datasets as necessary, to profile Arlington's building sector from floor space, energy consumption, and energy intensity perspectives. These profiles will breakdown the commercial and residential building sectors by building segment and energy end use to highlight potential energy efficiency opportunities. The results of this analysis will be used to shape future community energy programs targeting residential and commercial sector buildings.

Project Objectives:

1. Determine floor space for each building segment
2. Estimate annual electricity and natural gas use and intensity per square foot for each building segment
3. Estimate annual electricity and natural gas use and intensity per square foot by building end use for each building segment

3 GENERAL METHODOLOGY

The methodology developed for this analysis was designed to provide granular insights into utility-provided electricity and natural gas bill data aggregated for the commercial and residential sectors in Arlington County. Leidos developed the methodology described below primarily based on data availability and made a concerted effort to utilize local datasets wherever possible. Where local datasets were not available, alternative datasets were collected and tailored, as appropriate, to best represent the conditions and characteristics of Arlington County. The sections below describe the methodology used by Leidos and County staff to estimate electricity and natural gas intensities by building segment and end use.

3.1 DATA COLLECTION

Leidos began this project by gathering and reviewing a number of County-provided datasets related to floor space by building segment, as well as sector and segment-level electricity and natural gas consumption. Based on the data review, Leidos identified data gaps, developed a preliminary plan for completing the project including an assessment of how each dataset would be used in the analysis. To ensure project results specific to Arlington's culture, climate, and building stock, Leidos used local datasets wherever possible. The table below lists the datasets provided by County staff and summarizes how each dataset was ultimately used in the analysis.

Table 1. Summary of Arlington County Datasets

Dataset	Vintage(s)	Source	Use Summary
Sector-level Electricity Bill Data	1999, 2007-2013	Dominion Virginia Power	Used CY 2012 data to true-up segment-level electricity intensity estimates.
Sector-level Natural Gas Bill Data	1995-2002, 2007, 2009-2012	Washington Gas	Used CY 2012 data to true-up segment-level natural gas intensity estimates.
Large Office Energy Consumption and Floor Space Data	2010-2011	Arlington Green Games	Used CY 2010 data to estimate electricity and natural gas intensity values for large office segment.
Commercial Sector Floor Space by Segment	2014	CoStar Database	Used to determine total floor space by commercial segment (including multifamily apartment buildings).
Residential Sector Floor Space by Segment	2014	Residential Tax Assessment Database	Used to determine average floor space per housing unit for each residential segment.
Housing Unit Counts by Segment	2012	2013 Arlington County Profile	Used to calculate total floor space for each residential segment by multiplying unit counts by segment average floor space values from Residential Tax Assessment Database.
Virginia Hospital Center Utility Bill Data	2013-2014	Virginia Hospital Center	UseD to estimate electricity and natural gas intensities for hospital segment.
Energy Consumption Estimates for Single Family Detached Homes from Audit and Retrofit Work	2012-2013	LEAP Monthly Reports	Not used in analysis due to a lack of confidence in dataset.
Total Energy Cost Savings Potential for	2012-2013	LEAP Online Survey	Not used in analysis since data includes cost savings only and electricity and natural gas savings are rolled together.
Segment-level Energy Consumption, Floor Space and Energy Modeling Results	2010	Community Energy Plan	Not used in analysis due to a lack of confidence in the dataset by County staff.

Where data gaps existed, supplemental external data sources were collected and tailored to Arlington as much as possible to fulfill the data requirements for completing the analysis. The table below lists the external datasets collected through research and briefly describes how each dataset was used in the analysis.

Table 2. Summary of Supplemental Industry Datasets

Dataset	Vintage(s)	Source	Use Summary
Commercial Floor Space, End Use and Total Energy Consumption by Segment	2003	CBECS Microdata (filtered to include only survey records in climate zones 3 or 4 within the South Atlantic division)	Used as reference points for estimating electricity and natural gas intensity values for commercial building segments. Also used as basis for estimating electricity and natural gas end use intensity values for commercial building segments.
Commercial Energy Intensities by Fuel, Segment, and End Use	2006	CEUS Final Report (SMUD service territory results only)	Used as reference points for estimating electricity and natural gas segment and end use intensity values for commercial building segments.
Residential Floor Space, End Use and Total Energy Consumption by Segment	2009	RECS Microdata (filtered to include only survey records in VA, DC, MD, WV, and DE)	Used as basis for estimating electricity and natural gas segment and end use intensity values for residential building segments.
Floor Space Share and Energy Intensity of Common Areas in Multifamily Buildings	2014	Fannie Mae. 2014. Transforming Multifamily Housing: Fannie Mae's Green Initiative and Energy Star for Multifamily	Used to estimate total floor space and energy consumption in common areas of multifamily buildings.
Street View Images	n/a	Google Maps	Used to confirm segment classifications for specific addresses in CoStar database.
Household Heating Fuel for Owned and Rented Homes in Arlington County	2012	American Fact Finder/U.S. Census	Used to estimate the share of household using natural gas. Owned households used as a proxy for single family households. Rented used as a proxy for households in multifamily buildings.
Commercial Energy Intensities by Fuel and Segment	2011-2012	DC Building Energy Benchmarking Program	Used as reference points for estimating electricity and natural gas intensity values for large office, hotel, retail, and warehouse building segments.
Commercial Energy Intensities by Fuel and Segment	2012-2013	Philadelphia Building Energy Benchmarking Program	Not used in analysis since dataset includes only source energy intensities rather the site energy intensities.

Ultimately, Leidos used the datasets summarized in the tables above to estimate floor space by segment, as well as segment and end use-level electricity and natural gas intensity values appropriate for Arlington County. The methods used to make these estimates are described in the sections below.

3.2 Floor Area Analysis

Segment-level floor space in Arlington County was estimated primarily using Arlington's CoStar and Residential Tax Assessment databases as described in the sections below.

3.2.1 Commercial Buildings

Data extracted from the CoStar database included floor space for commercial buildings and multifamily apartments by address. The dataset also included property type classifications which were mapped to the building segment definitions used in the CBECS and CEUS datasets. Ultimately, building-level floor space values were aggregated by building segment.

The mixed-use nature of many commercial buildings in the County led to concerns regarding the property type assignments in the CoStar database. Essentially, all non-primary building functions are hidden under the umbrella of the primary function assignment in the CoStar data. For example, several large scale grocery stores occupying the ground floor of commercial office or multifamily buildings were identified in the County. Since grocery is not the primary function of these buildings, CoStar assigned "commercial office" or "multifamily" property types for these spaces as appropriate. For these cases, adjustments were made to the CoStar data to apportion the total property square footage between grocery store and the primary building function. The grocery store square footage was estimated as the average of all buildings specifically identified as grocery stores by CoStar.

Similarly, plazas and strip malls are typically classified as "retail" in the CoStar data despite a significant presence of restaurants, convenience stores, and specialty markets in these spaces. As a result, square footages for all buildings classified by CoStar as retail, restaurant, convenience store, and grocery store were initially summed, and then apportioned using business establishment counts from North American Industry Classification System (NAICS) data accessed via American Fact Finder and average floor space values for each property type from the CoStar data.

For multifamily buildings, it was determined that there was overlap between the CoStar database and the County's Residential Tax Assessment Database. For addresses found in both datasets, the floor space from CoStar was used. Total multifamily square footage was initially estimated as the multifamily total from the CoStar data plus the non-overlapping condo square footage from the tax assessment data. An adjustment was then made to account for commercial space housed within multifamily buildings such as banks, laundromats, local markets, and small restaurants. To estimate this commercial space, total multifamily square footage was re-estimated from the bottom up using average dwelling unit sizes from tax assessment data, dwelling unit counts from the 2013 Arlington County Profile, and an estimate of common area floor space as described in section 3.2.3. Commercial space classified as multifamily in the CoStar database was then estimated as the difference between the bottom up multifamily square footage estimate and the initial estimate based on CoStar and tax assessment data. This difference of about 7.3 million square feet was ultimately captured as commercial floor space rather than residential.

Commercial segment floor space data were also aggregated by zip code and used in concert with natural gas intensity assumptions to estimate natural gas consumption by zip code for comparison with the Washington Gas data at the zip code level. This analysis found natural gas consumption, per Washington

Gas bill data, to be much higher than could be explained by natural gas consumption estimates based on floor space. This led to realization that the Virginia Hospital Center (VHC) was not included in the CoStar floor space data and that the Arlington County and WMATA CNG filling stations were unintentionally included as commercial consumption. As a result, VHC floor space data provided by County staff totaling 443,844 square feet was manually added into the commercial floor space data and estimated NG consumption at County and WMATA CNG fueling stations was manually deducted from commercial natural gas bill data as described in section 3.3.2.

Table 3. Commercial Floor Space Breakdown

Building Segment	Total Floor Space (sqft)
Large Office	33,849,886
Small Office	5,796,304
Hotel/Motel	7,248,412
Retail	3,924,820
Restaurant	1,759,881
Grocery Store	855,291
Convenience Store	161,640
Warehouse/Storage	1,096,752
Hospital	582,249
College/University	661,301
Miscellaneous	3,100,162
Commercial Space in MF Buildings	*7,311,727*
Total Commercial Sector	**66,348,424**

3.2.2 Residential Buildings

Floor space data for single family homes and condo units were collected from the County's Residential Tax Assessment Database. Due to concerns regarding the accuracy of the total square footage provided in this dataset, floor space totals by unit type were not used directly. Instead, the data was used to determine an average floor space per housing unit for single family detached, single family attached, and condo unit types. These averages were multiplied by the corresponding unit counts from the 2013 Arlington County Profile to estimate total floor space by unit type. These estimates are summarized in the table below.

Table 4. Residential Floor Space Breakdown

Housing Type	Housing Units (count)	Average Floor Space (sqft/unit)	Total Floor Space (sqft)
Single Family - Detached	28,400	1,909	54,215,240
Single Family - Attached	11,000	1,592	17,509,831
Multifamily - Condos	26,855	1,076	28,884,461
Multifamily - Apartments	41,745	872	36,419,506
Multifamily - Common areas	n/a	n/a	6,530,397
Other	100	1,087	108,696
Total Residential Sector	**108,100**	**1,269**	**143,668,131**

3.2.3 Multifamily Common Areas

To determine common area floor space in the County, total multifamily floor space was first estimated using average condo unit floor space from tax assessment data, national average apartment unit floor space from 2009 RECS, and dwelling unit counts from the 2013 Arlington County Profile. The number of condo units in Arlington was estimated to be 26,855 units by counting the number of units listed in the Residential Tax Assessment Database. The number of apartment units was then estimated by subtracting the number of condo units from the total number of multifamily units (68,600 units) according to the 2013 Arlington County Profile. These counts were multiplied by the corresponding average unit sizes for condos (1,076 sqft) and apartments (872 sqft) and summed to determine the total floor space of multifamily housing units of about 65.3 million square feet. Common areas were assumed to add ten percent to that value based on a study by Fannie Mae resulting in an estimated floor space of about 6.5 million square feet.

3.3 Utility Bill Data Adjustment

Sector-level utility bill data was provided by Dominion Virginia Power ("Dominion") and Washington Gas for CY 2012.

3.3.1 Electricity Data Adjustments

Dominion provided electricity bill data aggregated into residential, commercial, industrial, and government sectors. For the purposes of this study, the limited electricity consumption classified by Dominion as industrial was rolled into the commercial sector. Government sector electricity consumption was ignored since government buildings are outside the scope of this project.

Minor adjustments were required to shift electricity consumption in master metered apartments and common areas in multifamily buildings from the commercial sector to the residential sector. Energy consumption in master metered apartments was estimated by first comparing County household counts by type from the 2013 Arlington County Profile and the count of individual Dominion accounts to determine that there are approximately 28,600 housing units in master metered buildings. Those units were assumed to consume about 7,330 kilowatt hours per unit per year on average based on 2009 RECS data for Virginia, the District of Columbia, Maryland, West Virginia, and Delaware. Total energy

consumption was then estimated by multiplying the number of housing units in master metered buildings by the average annual electricity consumption per unit. As a result, approximately 209,200 megawatt hours of electricity consumption were transferred from the commercial sector to the residential sector.

Annual energy consumption of common areas in multifamily buildings was estimated based on a Fannie Mae study which determined that approximately 11.6 percent of energy consumed and multifamily buildings occurs in common areas and a Leidos assumption that electricity accounts for approximately 60 percent of the energy consumed in common areas. Using these assumptions in concert with multifamily housing unit counts and the RECS-based average annual electricity consumption per unit referenced above, Leidos estimated annual electricity consumption in common areas to be approximately 37,600 megawatt hour per year. The resulting total electricity transferred from the commercial sector to the residential sector was about 246,800 megawatt hours.

3.3.2 Natural Gas Data Adjustments

Washington Gas provided natural gas bill data by zip code for residential, group metered apartments, and commercial and industrial classifications. For the purposes of this study, natural gas consumption at group metered apartments was rolled into the residential sector classification.

A minor adjustment was required to extract federal and County government natural gas consumption from the commercial sector consumption total. Natural gas data collected during the development of Arlington's 2012 Greenhouse Gas Inventory Update for federal and County government buildings totaling about 1.2 million MMBtu was subtracted from the commercial sector consumption total in the Washington Gas data.

A second adjustment to the natural gas data was made to account for Arlington County and WMATA CNG bus fueling stations that are believed to be included as commercial consumption. County staff estimated that these fueling stations consume approximately 400,000 MMBtu of natural gas per year and that amount was subtracted from the commercial sector consumption total. The resulting natural gas subtracted from the commercial sector total provided by Washington Gas was about 1.6 million MMBtu.

3.4 Preliminary Segment Intensity Development

Leidos developed preliminary electricity and natural gas intensity estimates on a square footage basis for all building segments in the commercial and residential sectors using a number of data sources. Each data source provided energy intensity reference points for one or more building segments that Leidos used to hone in on appropriate intensity estimates for each building segment in Arlington. This was accomplished by evaluating and scoring each dataset in consideration of perceived data quality and applicability to Arlington County. These considerations primarily included factors such as climate, building codes, and sample size of the underlying surveyed building sample, as well as data year and industry acceptance. Recent, high quality, local datasets such as from the 2010 and 2011 Arlington Green Games Program were scored the highest, whereas datasets such as California's 2006 Commercial End Use Survey were scored lower due to climatic and building construction differences between California and Arlington, as well as the more dated data vintage. Ultimately, Leidos used the dataset scores as weighting factors and determined preliminary segment intensity estimates as the weighted average of all datasets. For

example, the preliminary intensity estimate for the hotel building segment was determined using three data sources according to the table below.

Table 5. Example Weighted Average Intensity Calculation for Hotel Segment

Data Source	Relative Score/Weight (unitless)	Electricity Intensity (kBtu/sqft)	Natural Gas Intensity (kBtu/sqft)
DC Building Energy Benchmarking Program	1	54.7	38.2
2003 CBECS (Filters Applied: South Atlantic Division Only, Climate Zones 3 & 4 Only)	3	54.6	21.4
DOE Buildings Performance Database (Filter Applied: DC, MD, and VA Only)	1	55.0	35.0
Weighted Average Hotel Segment Intensity	**n/a**	**54.7**	**27.5**

Note: Data sources that were reviewed but given a score of zero are not shown in the table.

In a concerted effort to use local Arlington data as much as possible, Leidos incorporated 2013 utility bill data collected from Virginia Hospital Center (VHC) into the hospital segment intensity estimates. VHC accounts for 76 percent of hospital segment floor space in the County and the bill data was applied only to VHC floor space. The CBECS-based segment intensities were maintained for the remaining 24 percent of hospital segment floor space since VHC is a full service hospital for which the associated high energy intensity is not appropriate for the National Rehabilitation Center which makes up the majority of the non-VHC hospital segment floor space.

3.5 Key Building Segment Identification

Preliminary intensity estimates were developed for a total of 29 commercial segments and six residential segments. All six residential segments were deemed key segments. Leidos analyzed the preliminary segment energy intensity estimates in concert with segment floor space data to identify the key commercial building segments in the County. The purpose of this effort was to focus efforts on the most critical segments from an energy consumption perspective. Building segments with high relative energy intensities and/or segments representing a significant share of floor space in the County were identified as key segments. Non-key segments were aggregated into the building segment labeled “miscellaneous.”

Table 6. Key and Non-key Building Segments

Key Residential Segments	Key Commercial Segments	Non-key Commercial Segments (Aggregated as Miscellaneous)	
SF – Detached	Large Office	Other	Vehicle Service
SF – Attached	Small Office	Medical Office	Library
MF – Apartments	Hotel/Motel	Mixed-use	Recreational
MF – Condos	Retail	Clinic	Social
MF – Common Areas	Restaurant/Fast Food	Nursing Home	Post Office
Other	Grocery Store	Entertainment	Preschool
	Convenience Store	Vehicle Dealership	Service
	Warehouse/Storage	Repair Shop	
	Hospital	Religious Worship	
	College	Public Assembly	
	Miscellaneous	Bank	

3.6 Segment Intensity True-up

For each key building segment, Leidos multiplied the preliminary electricity and natural gas intensity values by the associated segment floor space to estimate total electricity and natural gas consumption. These totals were summed by sector and compared to the commercial and residential sector consumption totals from utility billing data. The estimated electricity and natural gas consumption values were then "trued-up," or scaled to match the utility billing data using adjustment factors. In total, four segment-level true-up adjustment factors were required, one for each sector and fuel combination (e.g. commercial electricity, commercial natural gas, residential electricity, and residential natural gas). True-up adjustment factors were then multiplied against the applicable preliminary electricity and natural gas intensity values to determine the trued-up segment-level intensity values. The four segment-level true-up adjustment factors are summarized and rounded in the table below.

Table 7. Segment-level True-up Adjustment Factors

Sector	Electricity	Natural Gas
Commercial	0.97	0.95
Residential	0.89	1.29

3.7 Preliminary End Use Intensity Development

For each key building segment, Leidos estimated the portion of energy consumed by major end use and fuel primarily using filtered 2003 CBECS and 2009 RECS datasets. For both datasets, end use electricity and natural gas intensities were calculated for three aggregation levels or filter sets as defined in the table below.

Table 8. Microdata Filter Sets

2003 CBECS	2009 RECS
National	National
Climate Zones 3 & 4	Climate Zones 3 & 4
South Atlantic Division, Climate Zones 3 & 4*	VA, DC, MD, WV, DE*

** Used as the basis for preliminary energy intensity estimates*

The resulting electricity and natural gas end use intensities were analyzed to evaluate the implications of using a more targeted geographic scope on sample size and end use intensity estimates. In other words, there is a tradeoff between geographic scope and sample size; as the geographic scope shrinks so too does the underlying sample size of surveyed buildings. Having too small of a sample size can lead to skewed data since outliers have a greater effect on the average. Analysis of the end use intensity values for each geographic scope found no adverse effects of using the most targeted geographic scope for both the 2003 CBECS and 2009 RECS datasets. As a result, Leidos elected to use the most targeted and geographically relevant CBECS and RECS data as the basis for preliminary electricity and natural gas end use intensity estimates. For each segment and fuel combination, Leidos calculated the average energy intensity for each of the end uses listed below.

Table 9. Major End Uses by Sector and Fuel

Commercial Segments		Residential Segments	
Electricity	Natural Gas	Electricity	Natural Gas
Heating	Heating	Heating	Heating
Cooling	Water Heating	Cooling	Water Heating
Ventilation	Cooking	Water Heating	Other
Water Heating	Other	Refrigeration	
Lighting		Other	
Cooking			
Refrigeration			
Office Equipment			
Other			

3.8 End Use Intensity True-up

The method used to true-up end use intensity estimates is similar to the method used to true-up segment intensity estimates with one difference; end use true-up adjustment factors for a give segment and fuel vary from one end use to another depending on the standard deviation observed for energy consumption intensities in the CBECS and RECS data. Since a higher standard deviation indicates greater variability in the dataset, end use true-up factors were scaled proportionally to the ratio of standard deviation to energy use intensity (EUI). In this way, end uses with higher ratios of standard deviation to EUI are adjusted by a greater percentage than end uses with lower standard deviation to EUI ratios. As an example, consider a heating end use with an EUI of 10 kBtu/sqft and a standard deviation of one compared to a cooling end use with an EUI of 5 kBtu/sqft and a standard deviation of one. The ratio of

standard deviation to EUI is 0.1 for heating and 0.2 for cooling. As a result, the difference between the cooling end use adjustment factor and one (i.e. no adjustment) will be twice difference between the heating end use adjustment factor and one. In other words, the end use adjustment for cooling will be twice that of heating on a percentage basis.

Ultimately, the end use intensity true-up accomplishes the same thing as the segment intensity true-up which is to adjust the individual end use intensity estimates so that when all end uses are multiplied by the applicable segment floor space and summed, the result aligns with utility bill data.

3.9 Critical Review and Adjustment

Once electricity and natural gas end use intensities were estimated and trued-up algorithmically, Leidos and County staff conducted a critical review of the results to identify any anomalies and make manual adjustments based on local knowledge, local data fragments, and professional judgment. This was an iterative process whereby calculated end use intensity values were manually tweaked until Leidos and the County were confident the results fairly represented Arlington's building stock.

Two basic types of manual adjustment were made to commercial segment end uses; (1) lighting end use intensities calculated based on 2003 CBECS data were universally replaced with intensities based on 2006 CEUS data, and (2) a selection of end use intensities calculated based on 2003 CBECS data were adjusted closer to the end use intensity values from 2006 CEUS data.

Lighting end use intensities calculated based on 2003 CBECS data are exceptionally and universally high. The cause of this anomaly is unknown but suspected to be an artifact of the underlying statistical and engineering models used to estimate lighting end use consumption in the 2003 CBECS. Leidos resolved this issue by universally replacing the CBECS intensities with intensities based on the 2006 CEUS dataset. Leidos assumed that climate differences between California and Arlington have no impact on lighting energy intensity and more stringent building codes in California result in an average lighting intensity that is 20 percent better than the average lighting energy intensity of Arlington County.

Where notable differences existed between CBECS-based end use intensities and the CEUS-based intensities that could not be explained by climatic or building construction differences, Leidos generally split the different between the two sources. It should be noted that this is a generalization of the approach and there were exceptions based on experience and professional judgment. In the process of making these adjustments, Leidos avoided making changes to CBECS-based heating and cooling end use intensity estimates due to climatic differences between the CEUS and CBECS datasets. All manual adjustments are listed in the table below.

Table 10. Manual Commercial End Use Adjustments

Segment	Fuel	End-use	Original EI (kBtu/sf)	Revised EI (kBtu/sf)	Rationale
All	EL	Lighting	Multiple	Multiple	CBECS lighting EI's are exceptionally high. CBECS lighting EI's replaced with CEUS EI's plus 20% to account for building code differences.
Large Office	EL	Refrig.	6.6	2	CEUS 2006 EI for CA is 1.4. CEUS 2006 EI for SMUD is 1.0. CBECS 2003 EI is 1.7 after an outlier of 30 was removed.
Large Office	EL	Office Equip.	10.8	14	CEUS 2006 EI for CA is 12.2. CEUS 2006 EI for SMUD is 17.6.
Large Office	EL	Other	11.1	7	CEUS 2006 EI for CA is 4.8. CEUS 2006 EI for SMUD is 3.6.
Hotel	EL	Vent.	1.6	5	CEUS 2006 EI for CA is 6.1. CEUS 2006 EI for SMUD is 5.2.
Hotel	EL	Cooking	0.2	2	CEUS 2006 EI for CA is 2.3. CEUS 2006 EI for SMUD is 1.7.
Hotel	EL	Office Equip.	7.4	3	CEUS 2006 EI for CA is 0.6. CEUS 2006 EI for SMUD is 0.5.
Hotel	NG	WH	13.1	20	CEUS 2006 NG for CA is 29.0. CEUS 2006 NG for SMUD is 29.3.
Restaurant	EL	WH	41.0	20	CEUS 2006 EI for CA is 1.3. CEUS 2006 EI for SMUD is 0.5.
Restaurant	EL	Cooking	18.8	30	CEUS 2006 EI for CA is 35.4. CEUS 2006 EI for SMUD is 43.3.
Restaurant	EL	Refrig.	100.0	70	CEUS 2006 EI for CA is 0.6. CEUS 2006 EI for SMUD is 0.5.
Restaurant	NG	Cooking	77.7	110	CEUS 2006 NG for CA is 153.3. CEUS 2006 NG for SMUD is 118.0.
Restaurant	NG	Water Heating	23.5	35	CEUS 2006 NG for CA is 48.6. CEUS 2006 NG for SMUD is 51.3.
Retail	EL	Vent.	2.4	5	CEUS 2006 NG for CA is 6.2. CEUS 2006 NG for SMUD is 7.9.
Grocery	EL	Refrig.	158.4	120	CEUS 2006 EI for CA is 76.5. CEUS 2006 EI for SMUD is 78.5.
College/ University	EL	Vent.	18.7	13	CEUS 2006 EI for CA is 7.0. CEUS 2006 EI for SMUD is 6.7.

Two basic types of manual adjustment were also made to residential segment end uses; (1) cooling end use intensities were increased by a factor of two for each segment and water heating end use intensities were decreased by an equivalent amount, and (2) the “other” end use intensity estimate for the “other” residential segment was replaced with the average end use intensity of the other four housing types. The rationale behind these changes is described in the table below.

Table 11. Manual Residential End Use Adjustments

Segment	Fuel	End Use	Original EI (kBtu/sqft)	Revised EI (kBtu/sqft)	Rationale
All	EL	Cooling	2.4*	4.8*	Original trued-up energy intensity estimates for each housing segment were doubled. Original estimates were extremely low compared to national average values from other data sources and in consideration of Arlington's dated housing stock.
All	EL	Water Heating	3.3*	2.4*	Original trued-up energy intensity estimates for each housing segment were decreased by 25% to align with NG adjustment to WH.
All	NG	Water Heating	5.9*	4.4*	Original trued-up energy intensity estimates for each housing segment were decreased by 25%. A small sample of NG bills from County staff indicate a ratio of heating use to WH use of between 3:1 and 5:1. Since we are confident in the heating energy intensities, WH must be lowered to an acceptable ratio (near 3:1)
Other	EL	Other	22.3	9.9	Original trued-up energy intensity estimates for other residential was replaced with the average of the other four housing types. Original estimates were inexplicably high compared to the other housing types. The issue appears to be an artifact of the 2009 RECS dataset.
Other	EL	Heating	10.6	23	Original trued-up energy intensity estimates for other residential was increased by an equivalent amount to the downward adjustment made for the "Other" end-use.

** Original and revised energy intensities displayed in the table are for all housing segments combined, however, manual adjustments were made to each housing segment independently.*

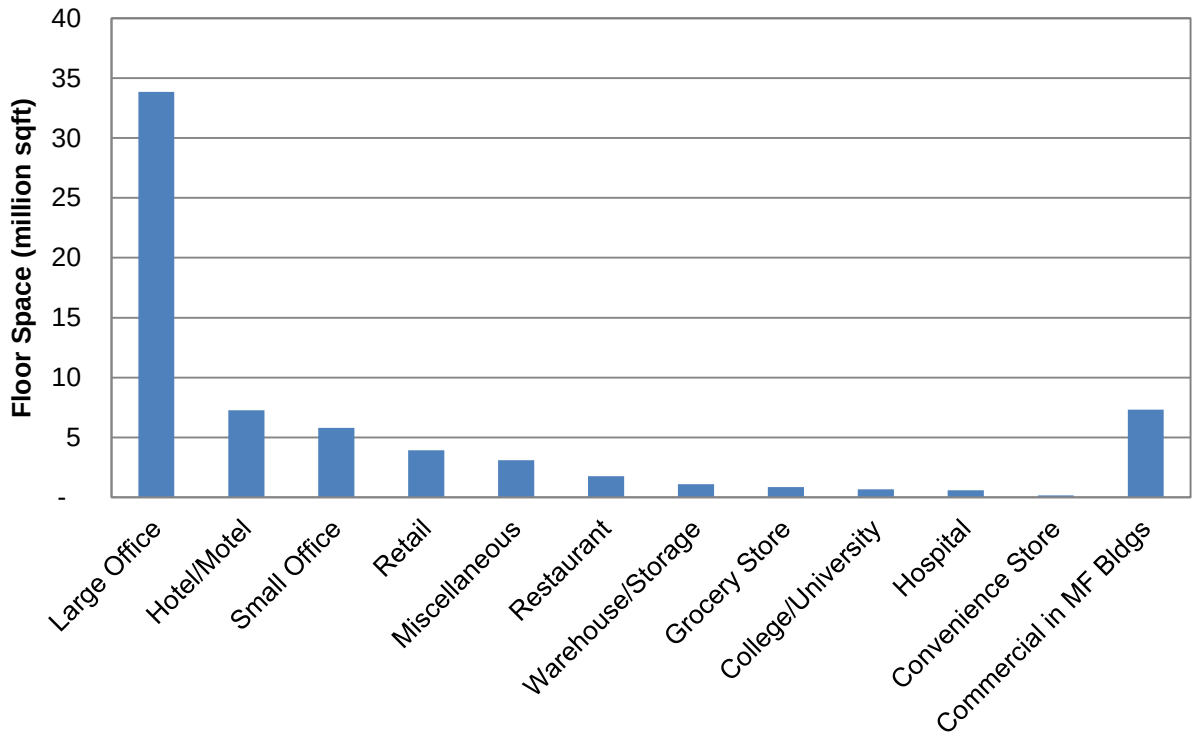
4 RESULTS

The following sections detail the results of this analysis including estimates of floor space, energy intensity, and energy consumption by commercial and residential building segment. For each segment, estimates of energy intensity and consumption by major end use are also provided.

4.1 FLOOR SPACE

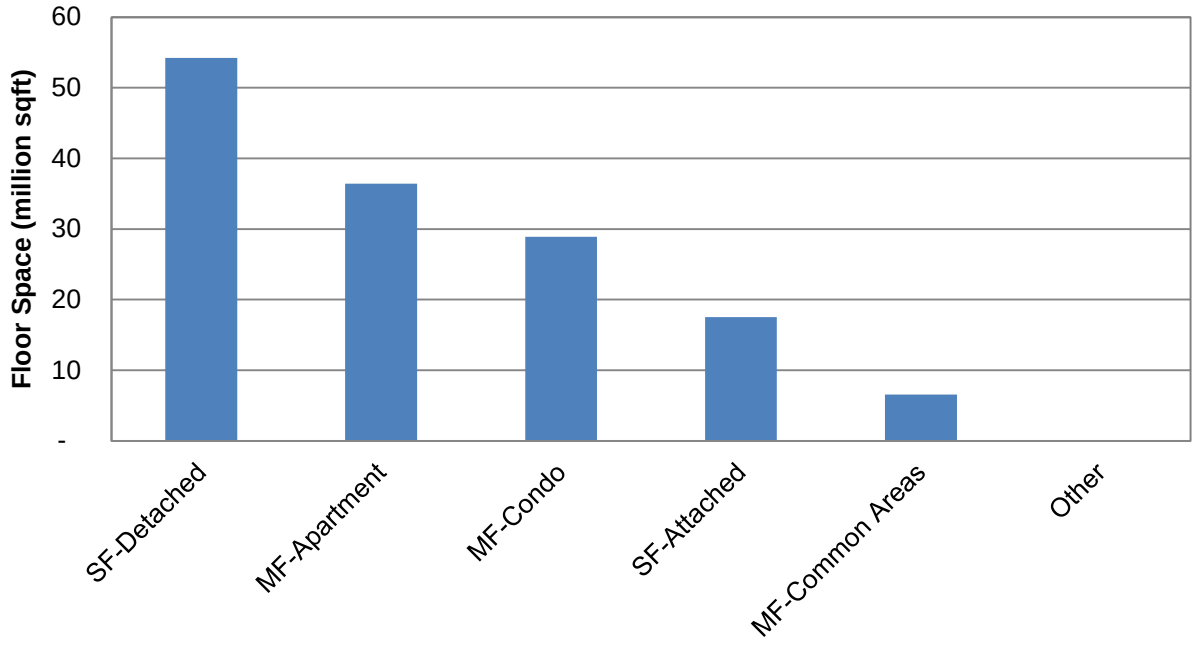
Total commercial floor space in Arlington County was estimated to be just over 66 million square feet. The large office segment dominates the commercial sector, accounting for over half of the total floor space (51%). The building segments with the next highest shares of total commercial floor space are hotels (11%), small office (9%), and retail (6%). As described in section 3.2.1, an adjustment was made in floor space calculations to account for commercial space operating in multifamily buildings (e.g. banks, laundromats, small restaurants, etc.). This adjunct segment is displayed at the right of the figure below.

Figure 6. Floor Space by Commercial Segment



Total residential floor space in Arlington County was estimated to be about 144 million square feet. The split between single family (including "other" housing types) and multifamily (including common areas) floor space is very near 50/50. The housing segments with the highest shares of total residential floor space are single family detached (38%), apartments (25%), condos (20%), and single family attached (12%).

Figure 7. Floor Space by Residential Segment



4.2 Energy Consumption and Intensity

Total commercial and residential energy consumption was nearly 12.8 million MMBtu in CY 2012 according to utility bill data. The energy split between the commercial and residential sectors in that year was nearly 50/50; however, the respective fuel splits within each sector differed considerably. Commercial sector energy consumption was dominated by electricity (81%). By contrast, similar amounts of electricity (52%) and natural gas (48%) were consumed in the residential sector. Overall, the fuel split across these sectors was 66/34 for electricity and natural gas, respectively.

Table 12. CY 2012 Energy Consumption by Sector and Fuel (MMBtu).

Fuel Type	Residential Sector	Commercial Sector	County Total
Electricity	3,374,185	5,015,630	**8,389,815**
Natural Gas	3,171,707	1,205,759	**4,377,466**
Total Energy	**6,545,892**	**6,221,390**	**12,767,281**

Figure 8. Energy Shares by Sector

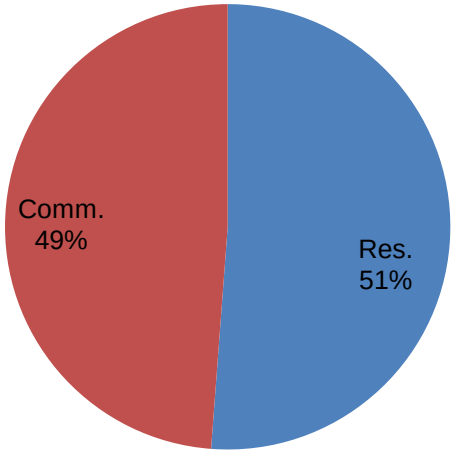
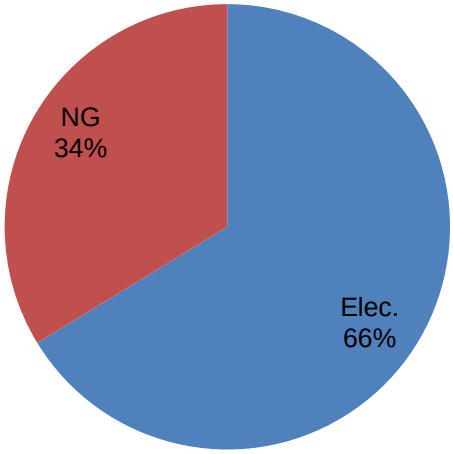


Figure 9. Energy Shares by Fuel



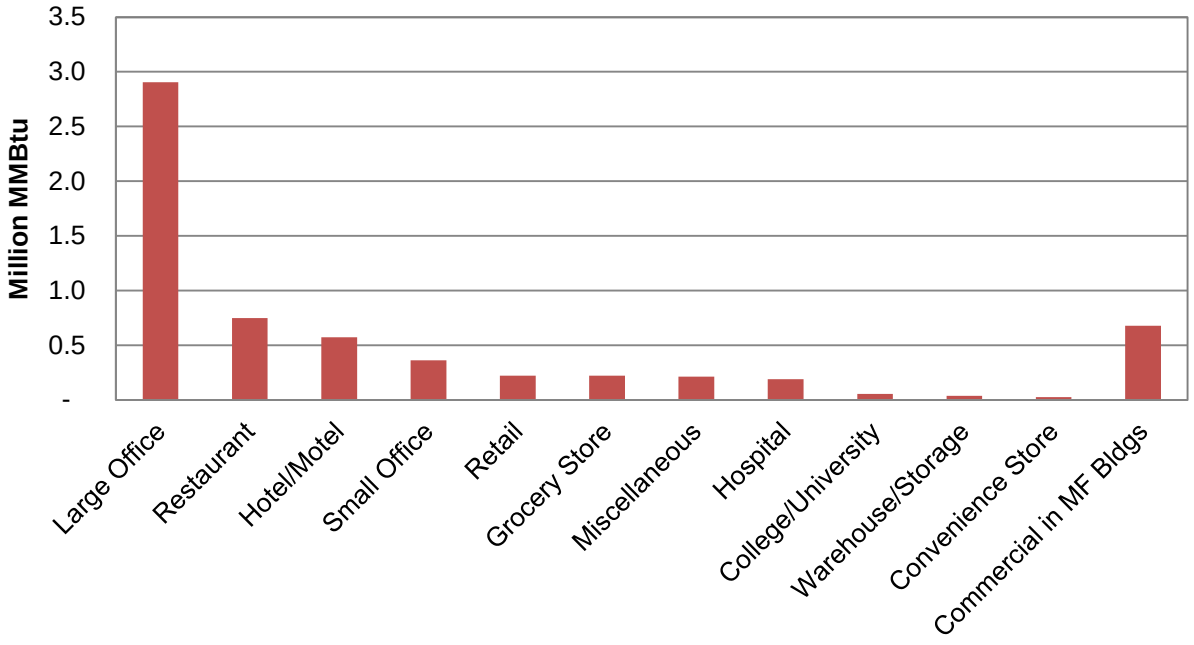
4.2.1 Commercial Sector Energy Consumption and Intensity

Commercial sector energy consumption was just over 6.2 million MMBtu in CY 2012 according to utility bill data. With just over 66 million square feet of commercial floor space, the sector average energy intensity was approximately 93 kBtu per square foot.

4.2.1.1 Commercial Energy Consumption and Intensity by Segment

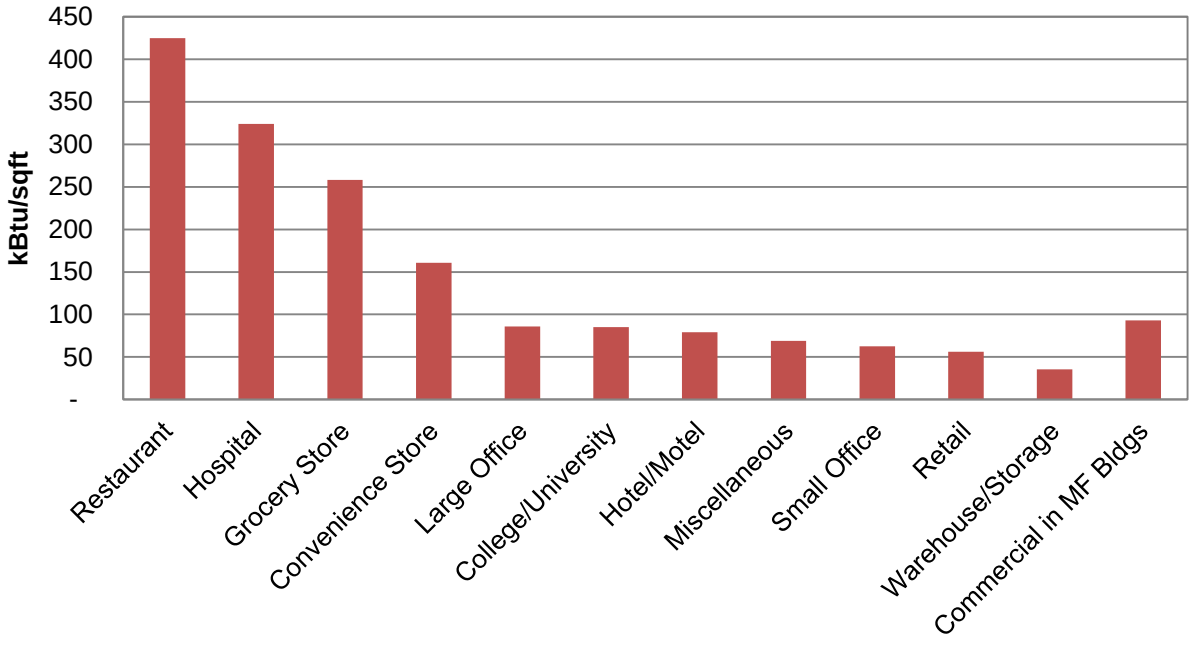
The large office segment was estimated to consume about 2.9 million MMBtu in CY 2012, two and a half times more than the next closest commercial building segment. This is due in large part to the fact that large offices make up about 51 percent of the total commercial floor space in the County. The building segments with the next highest shares of commercial energy consumption are restaurants (19%), hotels (9%), and small offices (6%). Using the sector average energy intensity, commercial space operating in multifamily buildings was estimated to consume about 680,000 MMBtu or 11% of the commercial sector total in CY 2012. This segment is represented at the right of the figure below.

Figure 10. CY 2012 Energy Consumption by Commercial Segment



The most energy intensive commercial segment was determined to be restaurants with an estimated energy intensity of about 425 kBtu per square foot. This high intensity can be attributed primarily to large cooking, refrigeration, and water heating demands. Three other commercial building segments with high relative energy intensities were hospitals (324 kBtu/sqft), grocery stores (258 kBtu/sqft), and convenience stores (161 kBtu/sqft). Most other commercial building segments ranged between about 60 and 90 kBtu per square foot.

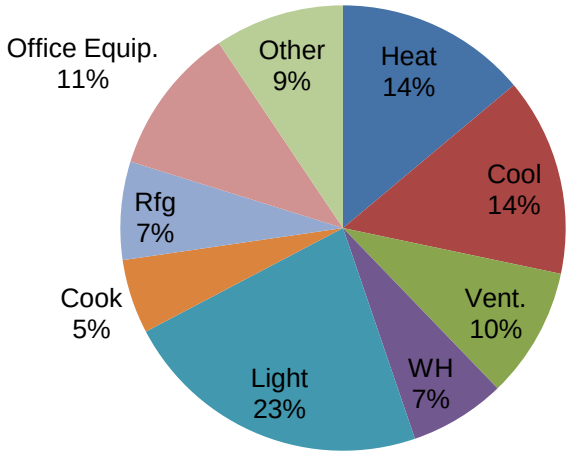
Figure 11. CY 2012 Energy Intensity by Commercial Segment



4.2.1.2 Commercial Energy Consumption by End Use

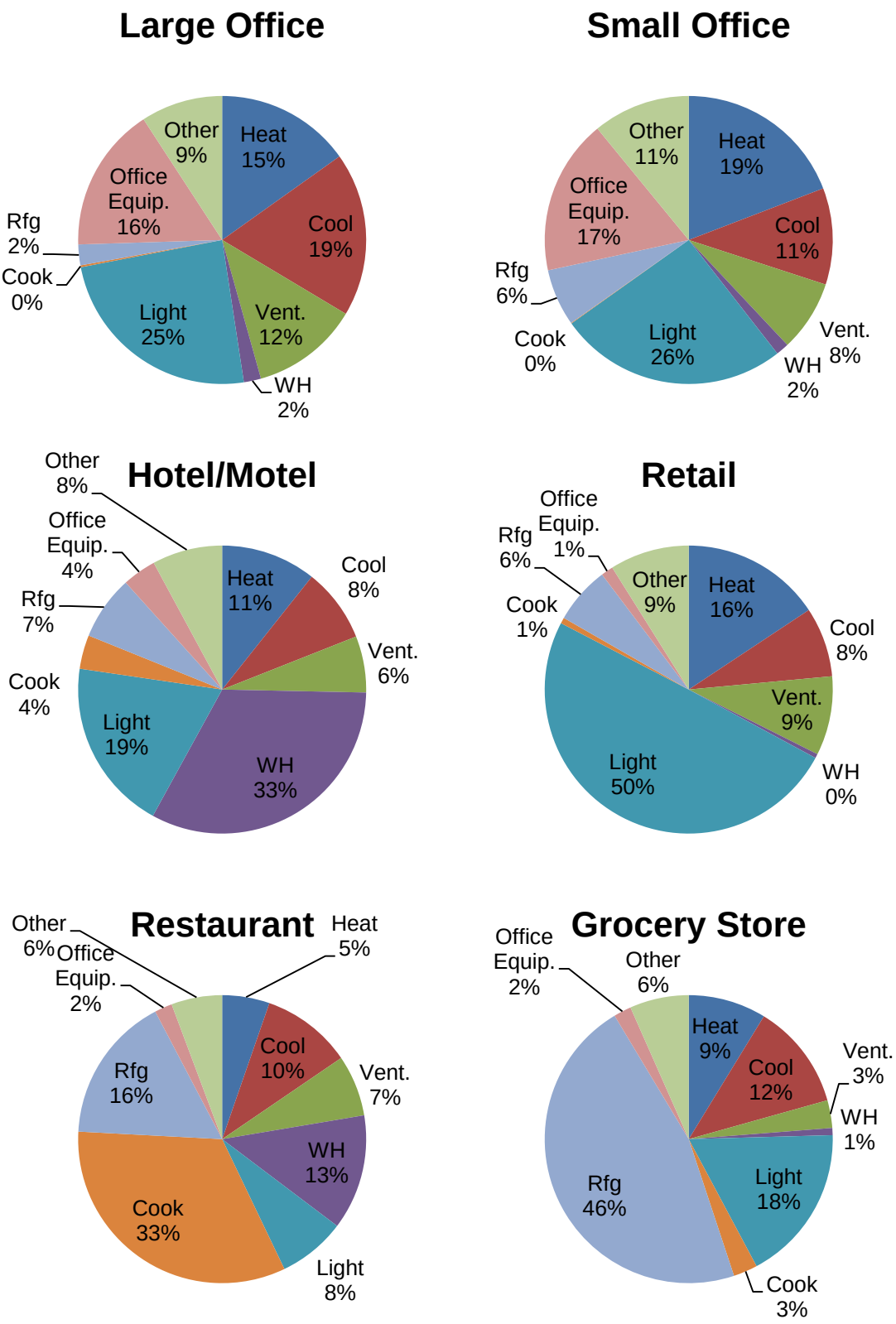
Commercial lighting was estimated to consume nearly 1.4 million MMBtu in CY 2012, the largest share of any commercial end use. Combined, lighting (22%), heating (15%), and cooling (14%) accounted for just over half of total commercial energy consumption. The end uses with the next highest energy shares were office equipment (11%), ventilation (9%), other (9%), and water heating (8%).

Figure 12. Commercial Sector Energy Shares by End Use

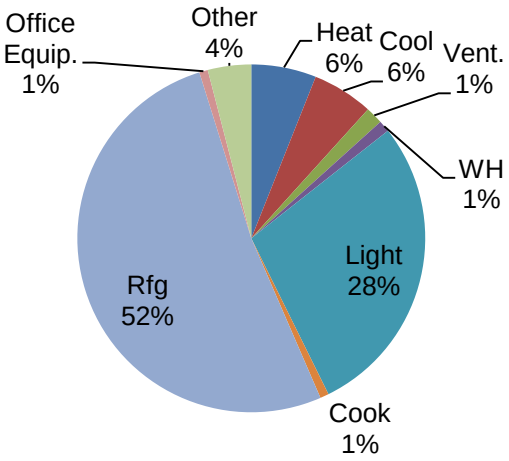


End use energy shares varied considerably between building segments due to the diverse building activities and energy requirements. Office equipment, for example, represents a much larger energy share in large and small offices than in any other building segment. Similarly, grocery and convenience stores require substantial amounts of electricity to power refrigeration equipment. To a lesser degree, restaurants also utilize large refrigeration equipment but total energy consumption is dominated by cooking appliances. Other noteworthy end use observations include lighting used to display merchandise in retail stores and water heating in hospitals where significant amounts of hot water are required for sanitation and sterilization purposes. The pie charts below display the unique end use energy shares for each major commercial building segment.

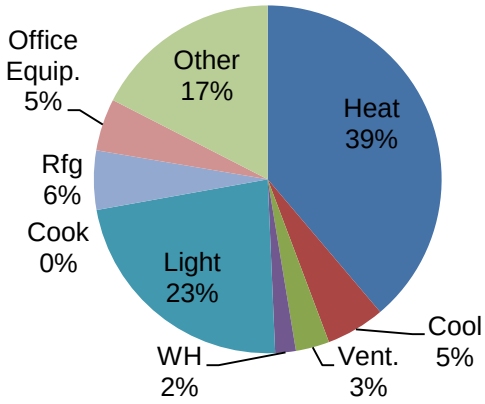
Figure 13. Commercial Segment Energy Shares by End Use



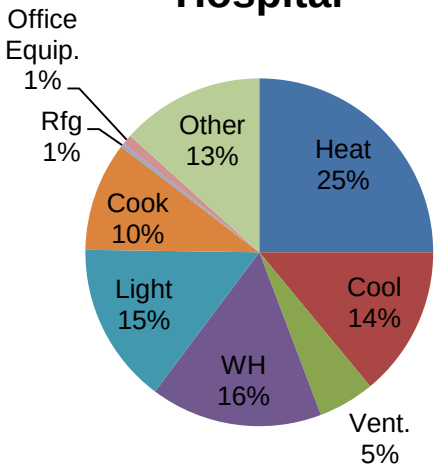
Convenience Store



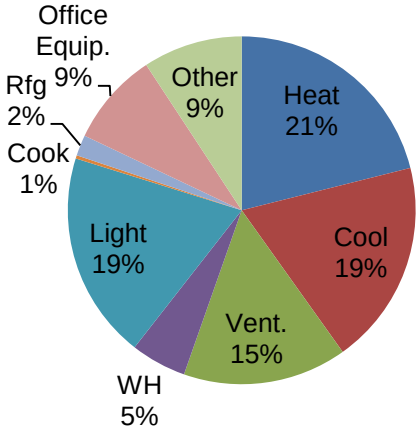
Warehouse/Storage



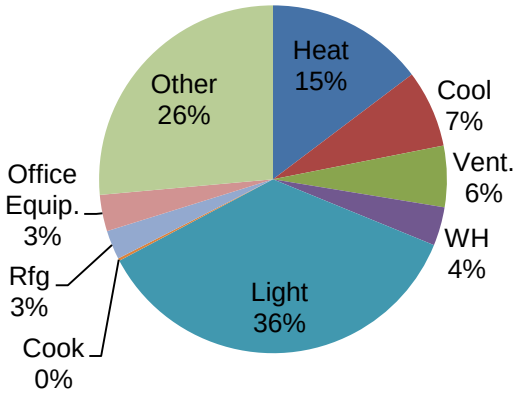
Hospital



College/University



Miscellaneous



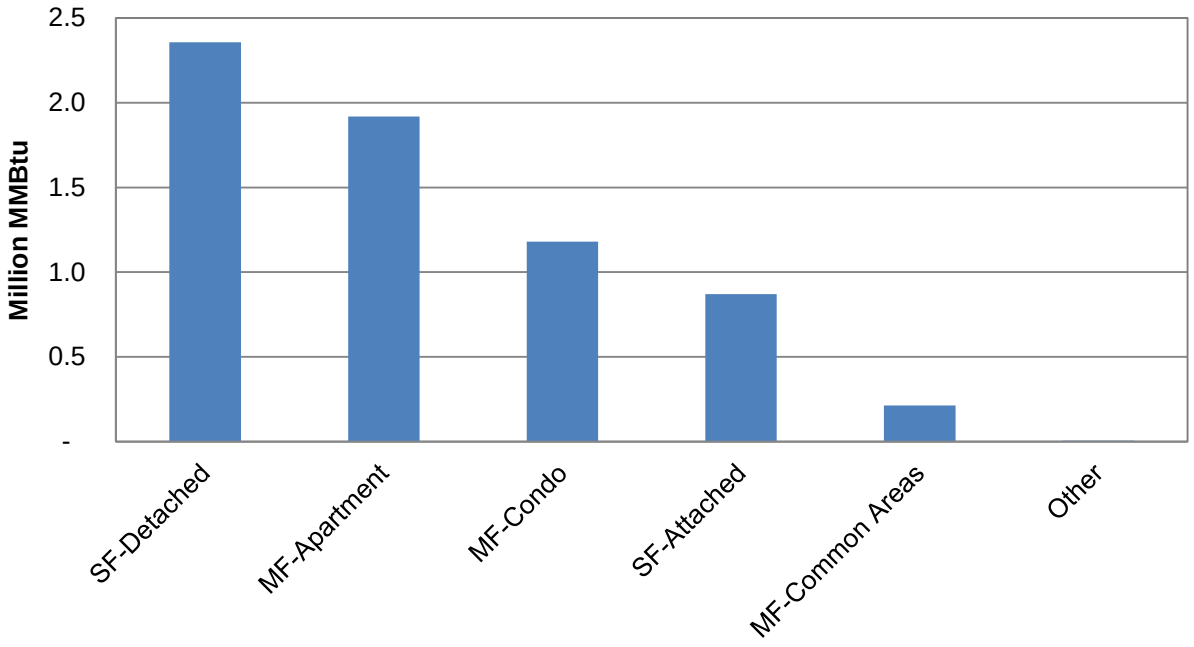
4.2.2 Residential Sector Energy Consumption and Intensity

Residential sector energy consumption was just over 6.5 million MMBtu in CY 2012 according to utility bill data. With nearly 144 million square feet of residential floor space, the sector average energy intensity was about 46 kBtu per square foot.

4.2.2.1 Residential Energy Consumption and Intensity by Segment

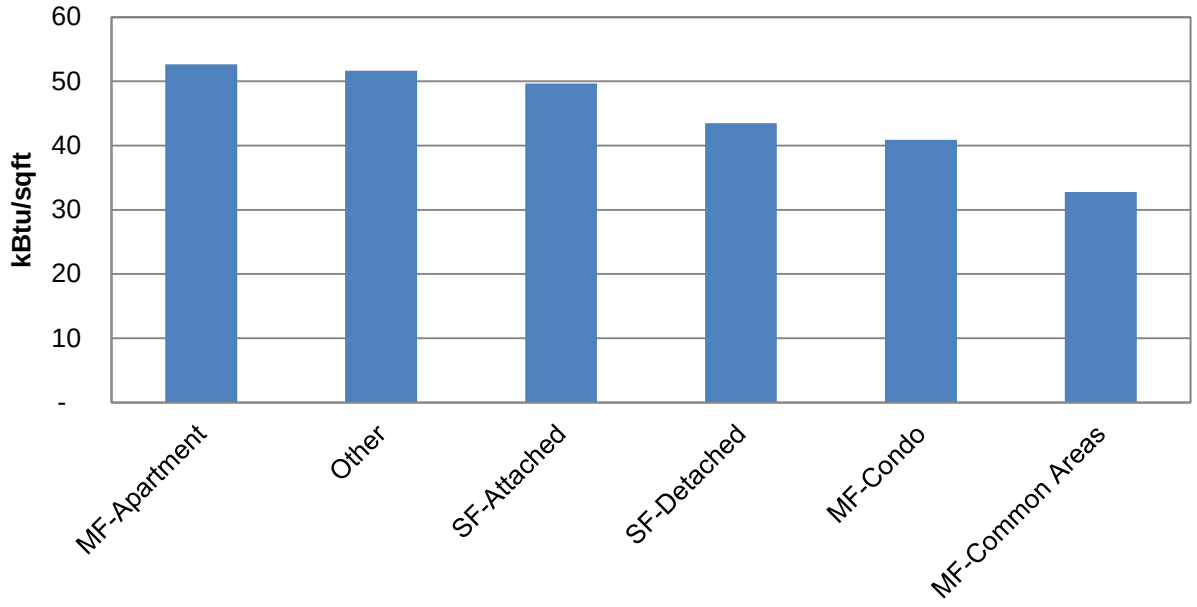
Single family detached homes were estimated to consume nearly 2.4 million MMBtu in CY 2012 or about 36 percent of the sector total. The housing types with the next highest shares of residential energy consumption were apartments (29%) and condos (18%) followed by attached single family homes (13%).

Figure 14. CY 2012 Energy Consumption by Residential Segment



The most energy intensive residential segment was determined to be apartment units with an estimated energy intensity of about 53 kBtu per square foot but all housing types shared similar energy intensities between 41 and 53 kBtu per square foot. Common areas in multifamily buildings were slightly less energy intensity at approximately 33 kBtu per square foot.

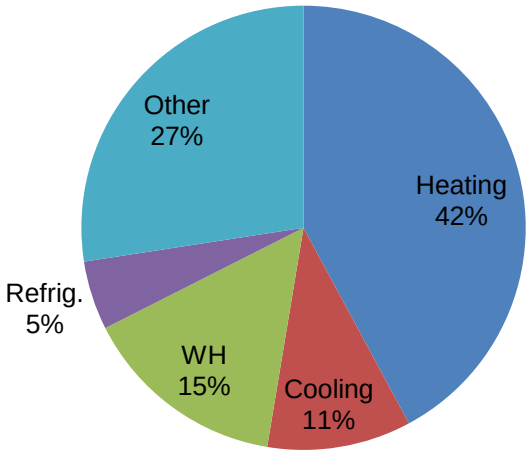
Figure 15. CY 2012 Energy Intensity by Residential Segment



4.2.2.2 Residential Energy Consumption by End Use

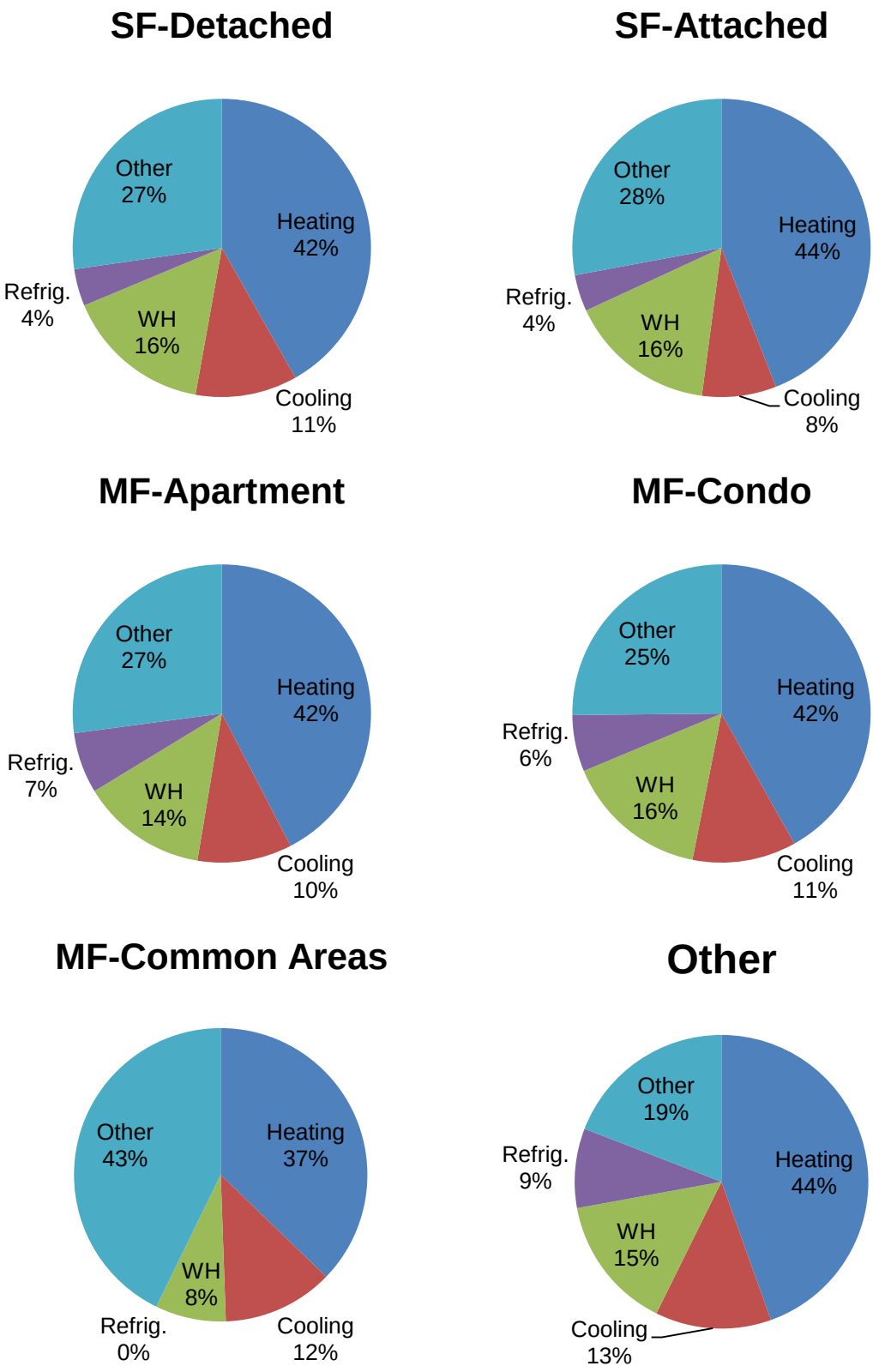
Residential heating was estimated to consume nearly 2.8 million MMBtu in CY 2012, the largest share of any residential end use. The "other" end use, which includes things like lighting, electronics, and cooking appliances, accounted for 27 percent of the sector total. The end uses with the next highest energy shares were water heating (15%), cooling (11%), and refrigeration (5%).

Figure 16. Residential Sector Energy Shares by End Use



The end use energy profiles for the different housing segments were very similar. The energy share of water heating, cooling, and refrigeration ranged less than 4 percent across all the four primary housing segments. The energy share of heating ranged from 36-42 percent in those same housing segments. As might be expected for such a diverse end use, "other" ranged from 25 percent in condos to 36 percent in attached single family homes. The pie charts below display the unique end use energy share for each housing segment.

Figure 17. Residential Segment Energy Shares by End Use



5 POTENTIAL OPPORTUNITY AREAS

Generally, segments and end uses with high relative energy consumption and intensity represent the best opportunities for energy efficiency improvements. From a County energy program perspective, energy intensive segments and end uses often provide opportunities to make a significant energy impact for each program participant, while high total energy consumption often indicates a large pool of potential program participants. Since the goal of energy programs is typically to maximize total energy reductions, segments and end uses with high relative energy consumption and intensity may provide the best opportunities for a large number of participants to individually achieve significant reductions.

Analysis of energy consumption and intensity results for the commercial sector distinguished the following end uses and segments as potential energy reduction opportunities:

- Large office, small office, hotel, and retail lighting
- Large office HVAC and office equipment
- Restaurant cooking
- Restaurant, grocery store, and convenience store refrigeration
- Hotel, restaurant, and hospital water heating

Analysis of energy consumption and intensity results for the residential sector marked the following end uses and segments as potential energy reduction opportunities:

- Heating for all housing segments but especially apartments and detached single family homes
- "Other" for all housing segments but especially apartments and detached single family homes (the other end use category includes things like lighting, cooking, and electronics such as televisions and computers)
- Water heating in detached single family homes