Energy Efficiency Analysis for a School Building Project

LG Multi F Multi-Zone Duct-Free Split System

White Paper

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All material provided herein is for informational or educational purposes only. It is not intended to be a substitute for professional advice. Please consult with your engineer or design professionals for application to your system.

Contents

Executive Summary

LG Electronics U.S.A. Commercial Air Conditioning (LG CAC) conducted an energy efficiency option analysis for a proposed middle school building design. This analysis assumes the building is located in Department of Energy (DOE) climate zones, 1A, 2A, 3A, 4A, and 5A. This study explores the energy and cost savings of operating LG Multi F heat pump systems (multi-zone, duct-free split systems) compared with typical heating, ventilation, and air conditioning (HVAC) systems described in the Leadership in Energy and Environmental Design (LEED®) for New Construction & Major Renovations™ baseline building. LG CAC created several computer simulations of the proposed and baseline designs, all using the same floor plans, occupancy schedules, lighting power density, ventilation, and envelope types. Only the mechanical system types and associated efficiencies differ for each simulation.

These simulations demonstrate that using LG Multi F systems provide estimated annual utility bill savings compared to all LEED® baseline building systems and American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) minimum efficiency building systems.

Table 1 Summary of Estimated Annual Energy Cost Savings and Percentage Savings with LG Multi F Systems

Location (Climate Zone)	LG Multi F		
	Annual Cost Savings ($) *	Annual Cost Savings (%) *	Annual CO_2 reduction (metric tons) *
Miami, FL (1A)	5,263	17%	33,304
Austin, TX (2A)	5,133	23%	35,042
Atlanta, GA (3A)	5,250	28%	40,681
New York, NY (4A)	5,271	19%	23,463
Chicago, IL (5A)	4,123	22%	33,082

[*Compared to the LEED® baseline ASHRAE Standard 90.1-2007 System 4, packaged rooftop heat pump (PSZ-HP)]

Note: **Legal Disclaimer**: The models described in this report are intended to demonstrate the potential cost-effectiveness of possible energy improvements for new facilities. The choice of models was subject to LG Electronics CAC's professional judgment in accordance with industry standards. The conclusions of this report do not guarantee actual energy costs or savings.

Introduction

Overview

This engineering case study explores the benefits of using LG Multi F heat pump systems in a typical new construction middle school building. The baseline building conditions are defined by the United States Green Building Council's (USGBC®) LEED®[1]. This study calculates the energy saved by the LG Multi F system compared to a typical HVAC system meeting baseline requirements of Leadership in Energy and Environmental Design (LEED®). The baseline building with identical physical properties and architectural plans is studied in five cities, each in a different climate—Miami, FL (1A), Austin, TX (2A), Atlanta, GA (3A), New York, NY (4A), and Chicago, IL (5A).

Table 2 Climate Conditions

Climate	Hot	Mild	Cold
Moist	Miami-1A Austin-2A Atlanta-3A	New York-4A	Chicago-5A

The proposed building consists of a single story with 24,747 ft^2 of conditioned space. The building is of concrete masonry block construction and has a variety of space types including classrooms, lobby, corridors, offices, rest rooms, and storage. (See Table 3).

Table 3 Space Types and Sizes

Space Types	Size (ft^2)
Classroom Area	15,157
Corridor	4,900
Computer Lab	2,175
Office	1,077
Rest Room	1,438
Total	24,747

[1] US Green Building Council (USGBC®) LEED® Green Building Design and Construction 2009 Edition Design Manual.

Modeling Approach

Overview

LG CAC used the Trane Air Conditioning Economics (TRACE) 700 software program version 6.2.9[2] to model the baseline building with both typical HVAC systems and the proposed LG Multi F heat pump system. TRACE 700 is US Department of Energy approved and is an industry-standard design and analysis tool. HVAC engineers use TRACE 700 to optimize lighting, heating, ventilating, and air conditioning system design based on energy use and life-cycle cost. The program performs energy and thermal calculations on an hour-by-hour basis for a typical one-year period, resulting in a detailed energy consumption model for both designs.[3]

LG CAC gathered the following building information based on typical examples of:

- Envelope properties
- Floor plan and geometry
- HVAC components
- Lighting design
- Occupancy schedules

To determine savings, the energy consumption of the proposed LG Multi F system design is compared to a building meeting (but not exceeding) the LEED® 2009 building baseline requirements.

Baseline Building

The LEED® design guide uses envelope building material specifications defined by ASHRAE Standard 90.1-2007 such as U-values for walls, roofs, floors, and windows.

This study uses two different baseline systems, each consisting of multiple HVAC systems.

1. Baseline system one consists of packaged rooftop heat pump (PSZ-HP) units composed of a central, constant volume fan supplying conditioned air to each room. This system conforms to ASHRAE Standard 90.1-2007 System 4.
2. Baseline system two consists of packaged rooftop variable air volume (VAV) with reheat units with chilled water cooling and hot-water heating boiler composed of a central, variable-volume fan supplying conditioned air to each room. This system conforms to ASHRAE Standard 90.1-2007 System 7.

The school building is assumed to be fully heated and cooled. Setup and setback schedules are implemented during unoccupied hours (nighttime), when the HVAC system is set to cycle to maintain temperature requirements for setup and setback and maintain humidity requirements. Although humidity may not typically be controlled during unoccupied periods,

[2] http://www.trane.com/Commercial/Dna/View.aspx?i=1136
[3] TRACE 700 Energy Modeling for LG Multi V (http://lg-vrf.com)

avoiding mold and moisture is good practice. See Table 6 for specification details of the baseline systems and the proposed LG Multi F HVAC system.

Proposed Building

The proposed building models use LG Multi F heat pump air conditioning systems (Figure 1), designed for small to medium-scale facilities such as commercial office buildings, hotels, hospitals, schools, and multi-family buildings. This model school building includes classrooms, corridors, a lobby, a gymnasium, and kitchen and food preparation rooms. Through LG Multi F design, the building can achieve an estimated average energy savings of 22% compared to an average baseline Energy Use Intensity (EUI) of 30.4 kBtu /ft^2/year.

LG Multi F heat pump systems provide air conditioning for two, three, or four separate zones. A variety of indoor units are available for any application; systems can be configured with all non-ducted, all ducted, or both, and all LG indoor units are Air Conditioning, Heating, and Refrigeration Institute (ARHI) 1230 certified. The LG Multi F heat pump system provides an advanced increased inverter range for better load matching. It reduces operational costs while providing reliable heat in colder regions, and system's advanced rapid start feature enables the compressors to come on faster to meet startup load. The LG Multi F heat pump system's compact space-saving design and industry-leading piping capabilities provide the ultimate in design flexibility.

Features and benefits of the LG Multi F heat pump system include:[4]

- Inverter variable-speed compressor in the outdoor unit for energy-saving operation
- Defrost / de-icing capabilities
- Restart delay of three minutes
- Self diagnostic capabilities
- Soft start reduces power surges to electrical systems
- Auto operation and auto restart operation
- Operates down to 14 °F in cooling mode
- Gold Fin™ Anti-Corrosion

Figure 1 shows a typical Multi F outdoor unit and typical indoor units. Table 4 lists specifications of the outdoor unit.

[4] www.lg-dfs.com

Figure 1: LG Multi F Outdoor Unit (LMU369HV) and Typical Indoor Units.

Table 4: Product Specifications

Outdoor Unit Model Number		LMU369HV
Capacity (Btu/h)		34,000 Class
Power Input (Min.–Rated–Max.)	**Cooling (kW)**	0.77–2.72–3.92
	Heating (kW)	1.12–3.58–4.10
Running Current (Min.–Rated–Max.)	**Cooling (A)**	3.3–11.8–17.0
	Heating (A)	4.9–15.5–17.8
Power Supply	**Ø / V / Hz**	1/208–230/60
Dimensions (W x H x D)	**Inches**	35 7/16 x 45 7/8 x 14 9/16
Min / Max. Number of Connectable Indoor Units		2/4
Refrigerant	**Charge (at 24.6 ft.)**	123.5 oz
	Type	R410A
	Control	Electronic Expansion Valve
Sound Level (H)	**Sound Pressure dB(A)**	57
Piping Connections (4 each)	**Liquid, diameter (inches)**	1/4
	Gas, diameter (inches)	3/8
Piping length spec. (ft.)	**Max. total piping**	246.1
	Max. ODU–IDU piping	82
	Piping length (no additional refrigerant)	98.4
Max. Elevation Difference (ft.)	**Outdoor Unit to Indoor Unit**	49.2
	Indoor Unit to Indoor Unit	24.6
Operation Range(Outdoor)	**Cooling (˚F)**	14 –114.8
	Heating (˚F)	5– 75.2

Component Comparison

This study analyzes several components in the building model:

- Modeled sizes and efficiencies (code minimum efficiencies)
- Baseline building envelope
- Lighting system
- Mechanical system
- Domestic hot-water system

Building Envelope

The model's building envelope characteristics (Table 5) follow the baseline values stipulated by LEED®, which adheres to ASHRAE Standard 90.1-2007.

Table 5: Building Envelope Characteristics

Components		Locations (Climate Zones)				
		Miami, FL (1A)	Austin, TX (2A)	Atlanta, GA (3A)	New York, NY (4A)	Chicago, IL (5A)
Windows: (25 % of Wall Area)	Assembly U-factor	1.20	0.70	0.60	0.50	0.45
	SHGC	0.25	0.25	0.25	0.40	0.40
Exterior Walls (Mass wall building)	Above Grade U-factor	0.580	0.151	0.123	0.104	0.090
Roof, U-factor (Entirely Insulated)		0.063	0.048	0.048	0.048	0.048
Floors (Mass) U-factor		0.322	0.107	0.107	0.087	0.074
Opaque doors U-factor		0.700	0.700	0.700	0.700	0.700
Standards		LEED® for New Construction & Major Renovations ASHRAE Standard 62.1-2007 ASHRAE Standard 90.1-2007				

Mechanical Systems

HVAC System

For this building size and type, ASHRAE Standard 90.1-2007 defines the baseline as a packaged rooftop heat pump (ASHRAE std. 90.1 System 4 – PSZ-HP). This system is used in non-residential buildings of one to three stories and less than 25,000 ft².

A Packaged rooftop VAV with reheat system with minimum efficient chiller and boiler (ASHRAE std. 90.1 System 7 – VAV with Reheat) is another typical choice for this middle school building. Chilled-water design supply temperature is modeled at 44 °F and return water temperature at 56°F. Chilled-water supply temperature is reset based on outdoor dry-bulb temperature using the following schedule: 44 °F at 80 °F and above, 54 °F at 60 °F and below, and ramped linearly between 44°F and 54°F at temperatures between 80°F and 60 °F. The chilled-water pump power is 22 W/gpm. Hot-water design supply temperature is modeled at 180 °F and design return temperature at 130 °F. Hot-water supply temperature is reset based on outdoor dry-bulb temperature using the following schedule: 180°F at 20°F and below, 150 °F at 50 °F and above, and ramped linearly between 180 °F and 150 °F at temperatures between 20 °F and 50 °F. The hot-water pump power is 19 W/gpm. The pumping system is modeled as primary-only with continuous variable flow. The heat rejection device is an axial fan cooling tower with two-speed fans. Condenser water design supply temperature is modeled at 85 °F or 10 °F, approaching design wet-bulb temperature, whichever is lower, with a design temperature rise of 10 °F. The design condenser-water pump power is 19 W/gpm.

Table 6: Air-Handling Mechanical System Characteristics

<table>
<tr><th colspan="2" rowspan="2">Systems</th><th>LEED Baseline</th><th>ASHRAE</th><th rowspan="2">LG Multi F
Heat Pump</th></tr>
<tr><th>ASHRAE System 4
(Packaged Rooftop Heat Pump)</th><th>ASHRAE System 7
(VAV with Reheat)</th></tr>
<tr><td rowspan="3">Cooling</td><td>Cooling Tower</td><td>–</td><td>Two-Speed-Fan,
2.5 gpm/ton</td><td>–</td></tr>
<tr><td>Chiller</td><td>–</td><td>1 x 150 tons centrifugal type chiller
(COP: 5.0, IPLV : 5.90,
3 gpm/ton)</td><td>–</td></tr>
<tr><td>DX-Cooling</td><td>6×(10–15 RT),
EER : 11.0</td><td>–</td><td>28 ×LMU369HV
(34 Mbh heat pump,
SEER: 17.5, EER 12.5)</td></tr>
<tr><td rowspan="2">Heating</td><td>Gas-Fired HW-Boiler</td><td>–</td><td>1500 Mbh, η = 80%</td><td>–</td></tr>
<tr><td>Heat Pump</td><td>COP : 3.3</td><td>–</td><td>28 × LMU369HV
(41 Mbh heat pump
COP: 3.3, HSPF: 10.0)</td></tr>
<tr><td colspan="2">Air Systems</td><td>6× Built-Up CAVs</td><td>2 × Built-Up VAVs</td><td>Ducted, wall-mounted, or cassette type Indoor units
(1–2 RT, 0.0002kW/cfm)</td></tr>
</table>

Domestic Hot Water

Baseline and proposed domestic hot water systems are as follows:

Table 7: Domestic Hot Water Characteristics

	Baseline	Proposed	Notes
Domestic Hot-Water	Gas-fired storage water heater (20 kBtu/hr , 0.8 Energy Factor)	Same	ASHRAE 90.1-2007 Table 7.8: *Performance Requirements for Water Heating Equipment*

Interior Lighting

Baseline and proposed interior lighting are as follows:

Table 8: Interior Lighting Energy Characteristics

	Baseline	Proposed	Notes
Interior Lighting	Lighting Power Density (Average: 1.2 W/ft^2)	Same	ASHRAE 90.1-2007 *(Table 9.5.1: Lighting Power Densities Using the Building Area Method)*

Receptacle Load

Baseline and proposed receptacle equipment are as follows:

Table 9: Receptacle Load Energy Characteristics

	Baseline	Proposed	Notes
Receptacle Load	25% of total energy cost	Same	1. ASHRAE 90.1-2007 *(TABLE G3.1 Modeling Requirements for Calculating Proposed and Baseline Building Performance)* 2. U.S. Green Building Council, LEED® for New Construction & Major Renovations

Ventilation

Minimum outdoor air ventilation rates shall be the same for the proposed and baseline building designs.

Table 10: Ventilation Rates for Classrooms

	Baseline	Proposed	Notes
People Outdoor Air Rate	10 cfm/person	Same	ASHRAE 62.1-2007 *(Table 6-1 Minimum Ventilation Rates in Breathing Zone)*
Area Outdoor Air Rate	0.12 cfm/ft^2		
Occupant Density	35/1000 ft^2		
Combined Outdoor Air Rate	13 cfm/person		

Average Utility Rates Source

The study uses the following sources for electrical and natural gas rates[5]:

Table 11 : Utility Rates

Energy Source	Miami, FL (1A)	Austin, TX (2A)	Atlanta, GA (3A)	New York, NY (4A)	Chicago, IL (5A)
Electricity ($/kWh)	0.109	0.101	0.089	0.155	0.086
Natural Gas ($/therm)	1.216	0.894	1.122	1.212	0.914

[5] Source: Data adapted from DOE-EIA and local utility companies

Results

Overview

According to the Commercial Building Energy Consumption Survey (CBECS), the average annual energy consumption of education buildings in the United States is 83.1 kBtu per square foot. This engineering study investigates reducing energy use in newly constructed middle school buildings across the United States relative to one built to comply with the minimum requirements of ASHRAE Standard 90.1-2007. All results are estimated based on this comparison of LG Multi F heat pump systems and traditional HVAC systems.

LG Multi F Heat Pump

The proposed building with LG Multi F heat pump systems uses an estimated average of 24 kBtu per square foot of site energy each year. The same building with an ASHRAE standard 90.1-2007 System 4 PSZ-HP system uses an average of 30.8 kBtu per square foot each year. The whole building energy cost savings realized with the LG Multi F heat pump system is 22% on average compared to the ASHRAE standard system.

When comparing the estimated energy cost of the HVAC systems alone, the LG Multi F heat pump system is 43% less on average. (See Figure 2 and Figure 3) The whole building energy cost savings realized with the LG Multi F heat pump system is 40% when compared to ASHRAE standard 90.1-2007 System 7 VAV with reheat and a 62% average savings when comparing HVAC-only energy cost. Based on the average energy cost savings from the models, future projects would meet the LEED® EA credit 1 prerequisite and qualify for up to nine LEED® points. The savings are detailed in the following graphs and are further detailed in tables in the Annual Building Energy Consumption Comparisons (See Figure 4 through Figure 13) and Annual Energy Consumption by End Use Summaries (See Table 12 through Table 16).

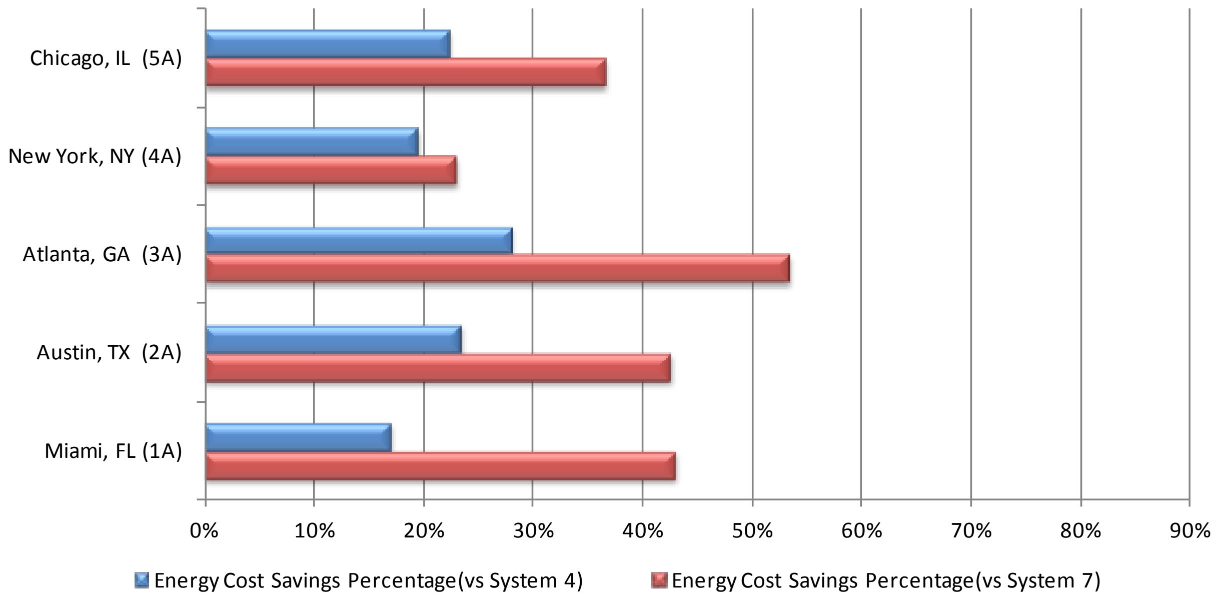

Figure 2 : Whole Building Estimated Energy Cost Savings (%) - LG Multi F Systems.

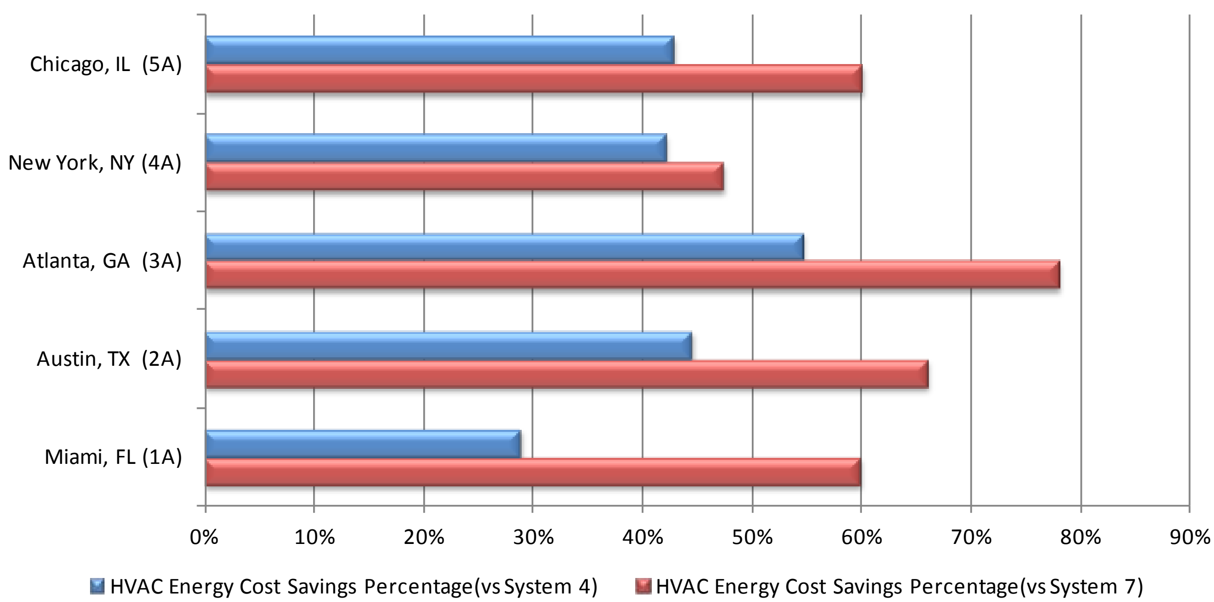

Figure 3 : HVAC Estimated Energy Cost Savings (%) - LG Multi F Systems.

Miami Results

Miami location (climate zone 1A) estimated energy consumption by end use:

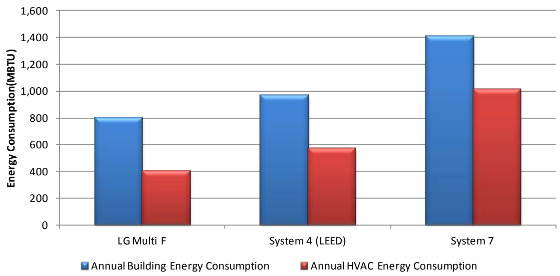

Figure 4: Miami Estimated Annual Energy Consumption Comparisons.

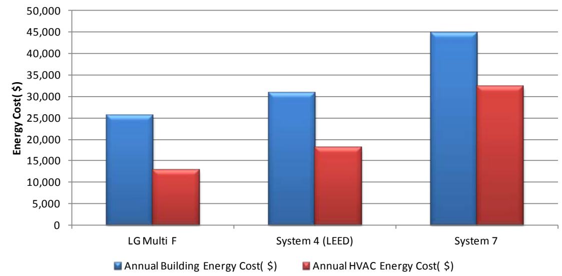

Figure 5: Miami Estimated Annual Building Energy Cost Comparisons.

The following tables summarize energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 4—Packaged rooftop heat pump) for the LG Multi F heat pump systems was 17%.

Table 12: Miami: Estimated Annual Energy Consumption and Cost by End Use

			Proposed	ASHRAE Standard 90.1-2007	
			Multi-F Heat Pump	System 4 (LEED® Baseline)	System 7 (VAV with reheat)
Energy Consump-tion by End Use	Area Lights	Electricity	172.5	172.5	172.5
	Space Heating	Electricity	0.1	1.5	0.2
		Gas	0	0	7.4
	Space Cooling	Electricity	376.8	504.4	565.1
	Pumps	Electricity	0	0	231.4
	Heat Rejection	Electricity	0	0	148.5
	Fans	Electricity	28.8	64.6	63.1
	Equipment	Electricity	224.8	224.8	224.8
	Totals	kBtu x000	803.1	967.9	1413
Energy Use and Cost	Whole Building Energy Consumption	Electricity(kWh)	235,365	283,663	411,941
		Gas(therms)	0	0	74
		Total (kBtu x000)	803	968	1,413
	Whole Building Energy Cost	($)	25,647	30,910	44,982
		($/ft²)	1.04	1.25	1.82
	HVAC Energy Usage	Electricity(kWh)	118,899	167,197	295,504
		Gas(therms)	0	0	74
		Total (kBtu x000)	406	571	1,016
	HVAC Energy Cost	($)	12,957	18,221	32,293
		($/ft²)	0.52	0.74	1.30

Austin Results

Austin location (climate zone 2A) estimated energy consumption by end use:

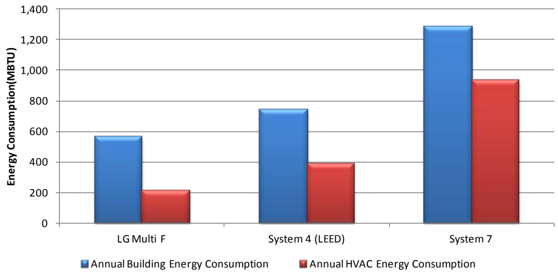

Figure 6: Austin Estimated Annual Energy Consumption Comparisons.

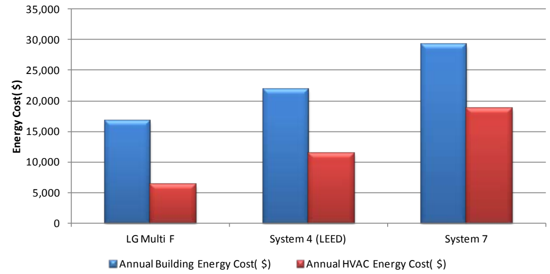

Figure 7: Austin Estimated Annual Building Energy Cost Comparisons.

The following tables summarize energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 4—Packaged rooftop heat pump) for the LG Multi F heat pump systems was 23%.

Table 13: Austin: Estimated Annual Energy Consumption and Cost by End Use

			Proposed	ASHRAE Standard 90.1-2007	
			Multi-F Heat Pump	System 4 (LEED® Baseline)	System 7 (VAV with reheat)
Energy Consumption by End Use	Area Lights	Electricity	172.5	172.5	172.5
	Space Heating	Electricity	25.6	71.6	1.7
		Gas	0	0	431.1
	Space Cooling	Electricity	166.6	270.6	250.1
	Pumps	Electricity	0	0	137.5
	Heat Rejection	Electricity	0	0	67.1
	Fans	Electricity	23.9	47.4	49.2
	Equipment	Electricity	178	178	178
	Totals	kBtu x000	566.6	740	1287.2
Energy Use and Cost	Whole Building Energy Consumption	Electricity(kWh)	166,054	216,873	250,898
		Gas(therms)	0	0	4,312
		Total (kBtu x000)	567	740	1,287
	Whole Building Energy Cost	($)	16,767	21,900	29,189
		($/ft²)	0.68	0.88	1.18
	HVAC Energy Usage	Electricity(kWh)	63,333	114,180	148,177
		Gas(therms)	0	0	4,312
		Total (kBtu x000)	216	390	937
	HVAC Energy Cost	($)	6,395	11,530	18,816
		($/ft²)	0.26	0.47	0.76

Atlanta Results

Atlanta location (climate zone 3A) estimated energy consumption by end use:

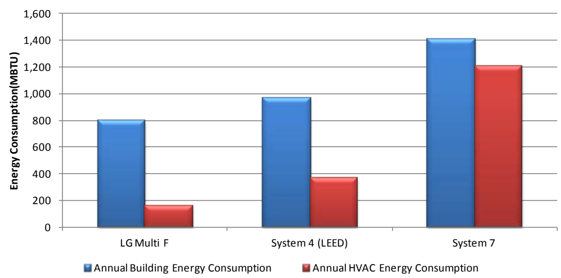

Figure 8: Atlanta Estimated Annual Energy Consumption Comparisons.

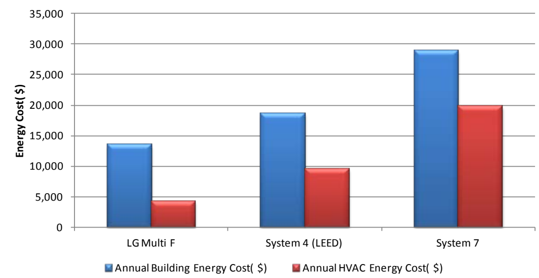

Figure 9: Atlanta Estimated Annual Building Energy Cost Comparisons.

The following tables summarize energy usage and cost savings for each case. The whole building energy cost savings over baseline (System 4—Packaged rooftop heat pump) for the LG Multi F heat pump systems was 28%.

Table 14: Atlanta: Estimated Annual Energy Consumption and Cost by End Use

			Proposed	ASHRAE Standard 90.1-2007	
			Multi-F Heat Pump	System 4 (LEED® Baseline)	System 7 (VAV with reheat)
Energy Consump-tion by End Use	Area Lights	Electricity	172.5	172.5	172.5
	Space Heating	Electricity	47.1	129.8	2.8
		Gas	0	0	785.3
	Space Cooling	Electricity	97.5	196.9	179.4
	Pumps	Electricity	0	0	136.4
	Heat Rejection	Electricity	0	0	55.8
	Fans	Electricity	22.7	42	47.9
	Equipment	Electricity	178	178	178
	Totals	kBtu x000	517.8	719.1	1558.1
Energy Use and Cost	Whole Building Energy Consumption	Electricity(kWh)	151,752	210,747	226,485
		Gas(therms)	0	0	7,855
		Total (kBtu x000)	518	719	1,558
	Whole Building Energy Cost	($)	13,503	18,753	28,963
		($/ft²)	0.55	0.76	1.17
	HVAC Energy Usage	Electricity(kWh)	49,031	108,055	123,764
		Gas(therms)	0	0	7,855
		Total (kBtu x000)	167	369	1,208
	HVAC Energy Cost	($)	4,362	9,614	19,823
		($/ft²)	0.18	0.39	0.80

New York Results

New York location (climate zone 4A) estimated energy consumption by end use:

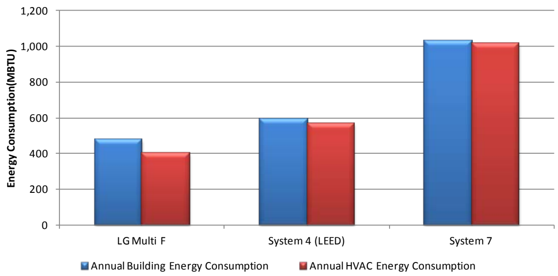

Figure 10: New York Estimated Annual Energy Consumption Comparisons.

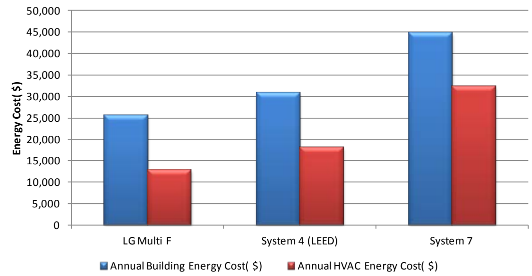

Figure 11: New York Estimated Annual Building Energy Cost Comparisons.

The following tables summarize energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 4—Packaged rooftop heat pump) for the LG Multi F heat pump systems was 19%.

Table 15: New York: Estimated Annual Energy Consumption and Cost by End Use

			Proposed	ASHRAE Standard 90.1-2007	
			Multi-F Heat Pump	System 4 (LEED® Baseline)	System 7 (VAV with reheat)
Energy Consump-tion by End Use	Area Lights	Electricity	172.5	172.5	172.5
	Space Heating	Electricity	110.3	181.3	3.7
		Gas	0	0	560.5
	Space Cooling	Electricity	30.9	71.2	58.6
	Pumps	Electricity	0	0	49.5
	Heat Rejection	Electricity	0	0	19.8
	Fans	Electricity	18.2	22.9	21.7
	Equipment	Electricity	148.4	148.4	148.4
	Totals	kBtu x000	480.3	596.4	1034.7
Energy Use and Cost	Whole Building Energy Consumption	Electricity(kWh)	140,762	174,788	138,974
		Gas(therms)	0	0	5,606
		Total (kBtu x000)	480	596	1,035
	Whole Building Energy Cost	($)	21,814	27,085	28,328
		($/ft²)	0.88	1.09	1.14
	HVAC Energy Usage	Electricity(kWh)	46,716	80,712	44,928
		Gas(therms)	0	0	5,606
		Total (kBtu x000)	159	275	714
	HVAC Energy Cost	($)	7,239	12,507	13,755
		($/ft²)	0.29	0.51	0.56

Chicago Results

Chicago location (climate zone 5A) estimated energy consumption by end use:

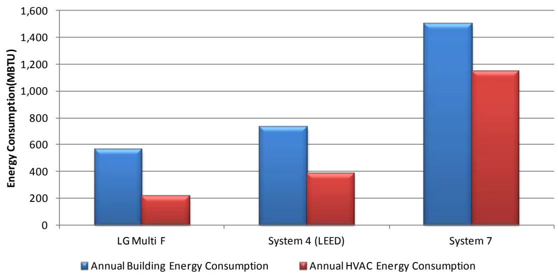

Figure 12: Chicago Estimated Annual Energy Consumption Comparisons.

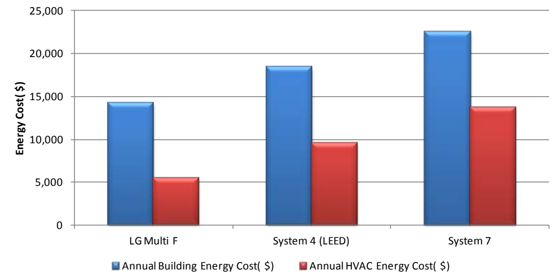

Figure 13: Chicago Estimated Annual Building Energy Cost Comparisons.

The following tables summarize energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 4—Packaged rooftop heat pump) for the LG Multi F heat pump systems was 22%.

Table 16: Chicago: Estimated Annual Energy Consumption and Cost by End Use

			Proposed	ASHRAE Standard 90.1-2007	
			Multi-F Heat Pump	System 4 (LEED® Baseline)	System 7 (VAV with reheat)
Energy Consump-tion by End Use	Area Lights	Electricity	172.5	172.5	172.5
	Space Heating	Electricity	159.1	265	4.1
		Gas	0	0	950.4
	Space Cooling	Electricity	39	91.4	78
	Pumps	Electricity	0	0	67.1
	Heat Rejection	Electricity	0	0	26.2
	Fans	Electricity	20.4	25.7	26.8
	Equipment	Electricity	178	178	178
	Totals	kBtu x000	569	732.7	1503.1
Energy Use and Cost	Whole Building Energy Consumption	Electricity(kWh)	166,757	214,733	161,980
		Gas(therms)	0	0	9,506
		Total (kBtu x000)	569	733	1,503
	Whole Building Energy Cost	($)	14,338	18,461	22,614
		($/ft²)	0.58	0.75	0.91
	HVAC Energy Usage	Electricity(kWh)	64,036	111,982	59,259
		Gas(therms)	0	0	9,506
		Total (kBtu x000)	219	382	1,153
	HVAC Energy Cost	($)	5,506	9,628	13,782
		($/ft²)	0.22	0.39	0.56

Emissions Rate Comparison

With the LG Multi F heat pump systems, estimated carbon emissions are an average 22% lower than the baseline building, reducing emissions by an average of 33,114 tons of carbon each year.

Emission Factor[6]

- **6.8956×10^{-4} metric tons CO_2 / kWh**
- **0.005 metric tons CO_2 / therm**

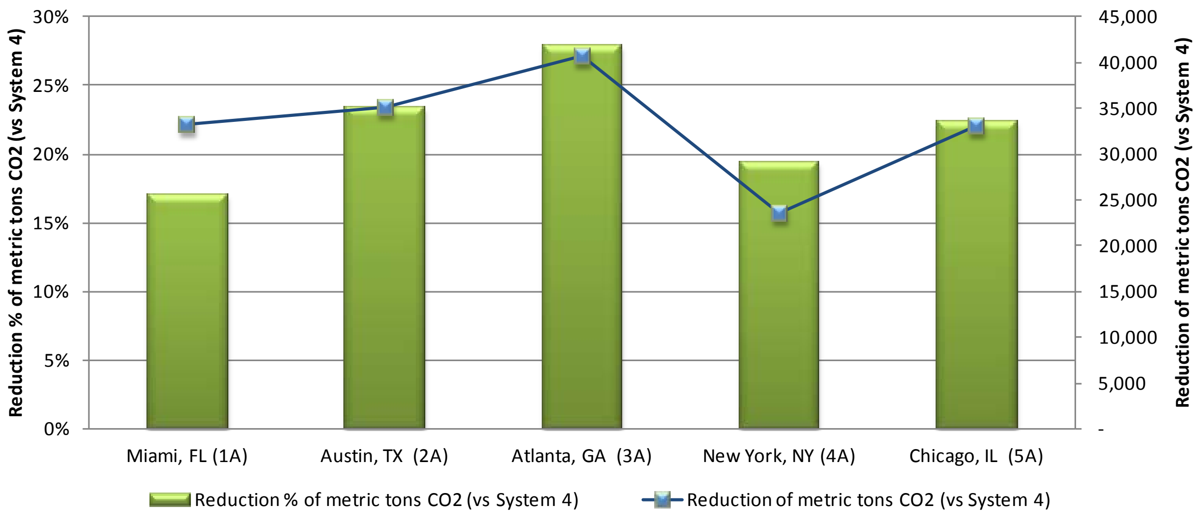

Figure 14 Estimated Reduction (%) of Carbon emissions of Proposed LG Multi-F Heat Pump Building vs. LEED baseline Building

[6] http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

- The Greenhouse Gas Equivalencies Calculator

LEED for New Construction & Major Renovations

The Leadership in Energy and Environmental Design (LEED®) 2009 Green Building Rating Systems are voluntary, consensus-based, and market-driven. Based on proven technology, they evaluate environmental performance from a whole building perspective over a building's life cycle, providing a standard for what constitutes a green building in design, construction, and operation. The LEED® rating system provides a complete framework for assessing building performance and meeting sustainability goals. Based on a system of prerequisites and credits, referring to ASHRAE standards, LEED® projects earn points during the certification process, and are then awarded certification levels.

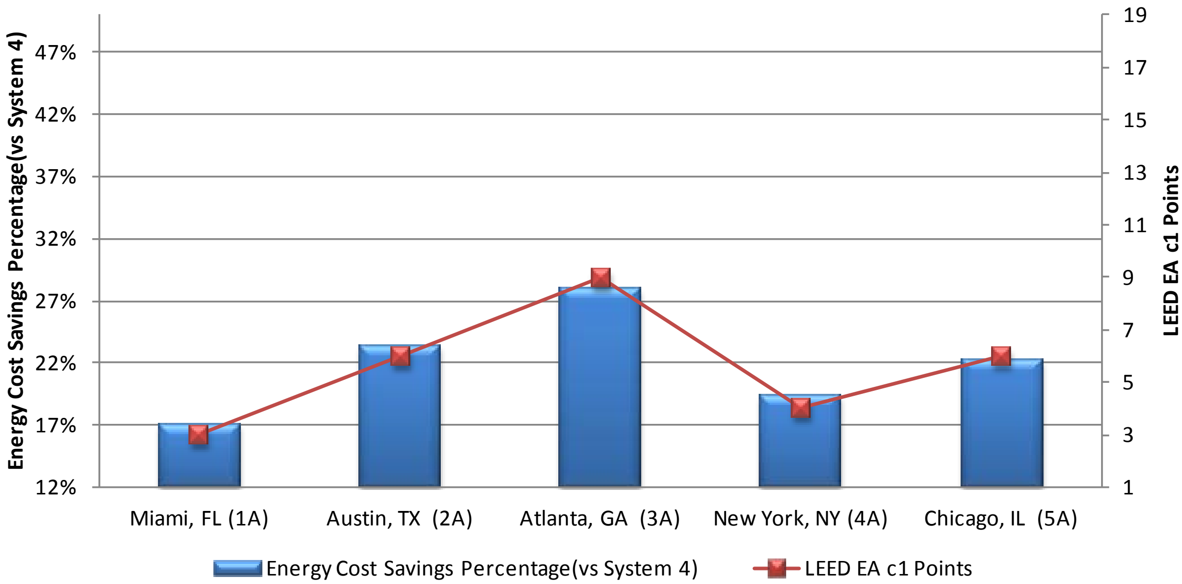

Figure 15 Estimated Building Energy Cost Savings (%) and Potential LEED Points - LG Multi-F Heat Pump

A building can be awarded from 1 to 19 points in the Energy and Atmosphere Credit 1, Optimize Energy Performance LEED® category.

Table 17 shows the estimated percentage energy cost saving in the proposed building performance rating compared with the baseline building performance rating. The baseline building performance according to ASHRAE Standard 90.1-2007 is calculated using a simulation model for the whole building project. Table 17 also shows the minimum energy cost savings percentage for each point.

Table 17: Percentage Cost Savings and Points

New Buildings	Renovation Buildings	Points
12%	8%	1
14%	10%	2
16%	12%	3
18%	14%	4
20%	16%	5
22%	18%	6
24%	20%	7
26%	22%	8
28%	24%	9
30%	26%	10
32%	28%	11
34%	30%	12
36%	32%	13
38%	34%	14
40%	36%	15
42%	38%	16
44%	40%	17
46%	42%	18
48%	44%	19

The LG Multi F air conditioning system provides opportunities for designers to claim many LEED® prerequisites and points. Below are LG Electronics' recommendations and strategies to earn points towards LEED® for new construction certification using LG Multi F heat pump systems.

Table 18 LG Electronics’ Recommendations and Strategies for LEED® Certification

Section Title	Credit	Intent of Credit	Points	LG Electronics’ Recommendations
EA(Energy and Atmosphere)	Prereq 2	Minimum Energy Performance	Required	• All LG Electronics’ products meet or exceed ASHRAE Standard 90.1-2007. • All LG Electronics’ products use R410A refrigerant. • LG Multi F system offers exceptional energy performance by using state of the art controls, high efficiency variable speed fan assemblies, and a combination of variable and constant speed compressors. • Select heat recovery equipment options. • Use LG Multi F systems and ERV (Energy Recovery Ventilator).
	Prereq 3	Fundamental Refrigerant Management	Required	
	Credit 1	Optimize Energy Performance	1 to 19	
IEQ (Indoor Environmental Quality)	Prereq 1	Minimum IAQ Performance	Required	• The modular design of LG Multi F system uses multiple indoor units, allowing the designer to provide individualized control for each occupant. • LG’s building management controllers and communication gateways make it easy to monitor energy usage and control the LG Multi F system operations based on building usage or indoor air quality. • All LG Electronics’ products have tested sound data in accordance with standards. • Use ERV (Energy Recovery Ventilator).
	Prereq 3	Minimum Acoustical Performance	Required	
	Credit 1	Outdoor Air Delivery Monitoring	1	
	Credit 2	Increased Ventilation	1	
	Credit 3.2	Construction Indoor Air Quality Management Plan	1	

References

ANSI/ASHRAE/IESNA Standard 90.1-2007

- Table 5.5-1 Building Envelope Requirements for Climate Zones 1 through 5.
- Table 6.8.1A: Electronically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements
- Table 6.8.1B Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements
- Table 6.8.1C Water Chilling Packages–Minimum Efficiency Requirements
- Table 6.8.1G Performance Requirements for Heat Rejection Equipment
- Table 7.8: Performance Requirements for Water Heating Equipment.
- Table 9.5.1: Lighting Power Densities Using the Building Area Method

ANSI/ASHRAE/IESNA Standard 62.1-2007

- Table 6-1 Minimum Ventilation Rates In Breathing Zone

2003 Commercial Buildings Energy Consumption Survey: Energy End-Use Consumption Tables

- Table 3.1.13. Commercial Buildings Delivered Energy End-Use Intensities by Building Activity (kBtu per F^2), 2003

The Emissions & Generation Resource Integrated Database (eGRID)

- http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
- The Greenhouse Gas Equivalencies Calculator

Electricity and Natural Gas Rates

- EPA EnergyStar (Portfolio Manager Overview), www.energystar.gov, http://www.eia.gov/electricity/data.cfm, http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_prices

Background and General Information

- U.S. Green Building Council, LEED® for New Construction & Major Renovations™
- Energy Star® Multifamily High Rise Program