Building Energy Efficiency Analysis for a High School

(LG Multi V™ III VRF System)

Contents

Executive Summary

LG Electronics U.S.A. Commercial Air-Conditioning (LG CAC) conducted an energy efficiency option analysis for a proposed high school building design. This analysis assumes the building is located in Department of Energy (DOE) climate zones, 1A, 2A, 3A, 3B, 4A, 4C, and 5A. This study explores the energy and cost savings of operating an LG Multi V™ III Heat Pump Variable Refrigerant Flow (VRF) System 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 V™ III Heat Pump VRF systems provide significant annual utility bill savings compared to all LEED® baseline and American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) minimum efficiency building systems.

Table 1 Summary of LG Multi V™ III Building Annual Energy Cost Savings and Percentage Savings

Location (Climate Zone)	Multi V III	
	Annual Savings ($) *	Annual Savings (%) *
Miami, FL (1A)	8,018	16
Houston, TX (2A)	14,353	27
Atlanta, GA (3A)	14,480	29
Los Angeles, CA (3B)	8,916	20
New York, NY (4A)	37,031	33
Seattle, WA (4C)	17,465	39
Chicago, IL (5A)	28,548	38

[*Compared to the LEED® baseline ASHRAE Standard 90.1-2007 System 6, packaged variable air volume (PVAV) with parallel fan powered (PFP) Boxes]

Note: *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.*

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 an LG Multi V™ III Heat Pump VRF system in a typical new construction high school building. This baseline building is defined by the United States Green Building Council's (USGBC®) LEED®[1]. This study calculates the energy saved by the LG Multi V™ III compared to typical HVAC systems meeting the baseline LEED requirements. The baseline building with identical physical properties and architectural plans is studied in seven different climates and eight cities—Miami, FL (1A), Houston, TX (2A), Atlanta, GA (3A), Los Angeles, CA (3B), New York, NY (4A), Seattle, WA (4C), and Chicago, IL (5A).

Table 2 Climate Conditions

Climate	Hot	Mild	Cold
Marine		Seattle-4C	
	Miami-1A		
Humid	Houston-2A	New York-4A	Chicago-5A
Dry	Atlanta-3A		
	Los Angeles-3B		

The building consists of a single story with 55,760 ft² of conditioned space. The building is of concrete masonry block construction and has a variety of space types including classrooms, lobby, gymnasium, corridors, offices, and kitchen and food preparation rooms. (See Table 3).

Table 3 Space Types and Sizes

Space Types	Size (ft²)
Classroom Area	43,720
Corridor	4,040
Lobby	313
Gymnasium	5,010
Kitchen and Food Prep	2,677
Total	**55,760**

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

Modeling Approach

Overview

LG CAC used the Quick Energy Simulation Tool (eQUEST) version 3.64 to model the baseline building with both typical HVAC and the proposed LG Multi V™ III Heat Pump VRF system. eQUEST is a 3-D building simulation program developed under funding from the U.S. Department of Energy (Developer: James J. Hirsch & Associates, http://www.doe2.com/). eQUEST performs energy and thermal calculations on an hour-by-hour basis for a typical one-year period, resulting in an energy consumption model for both designs.

LG CAC gathered the following building information from the building's owner and design team:

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

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

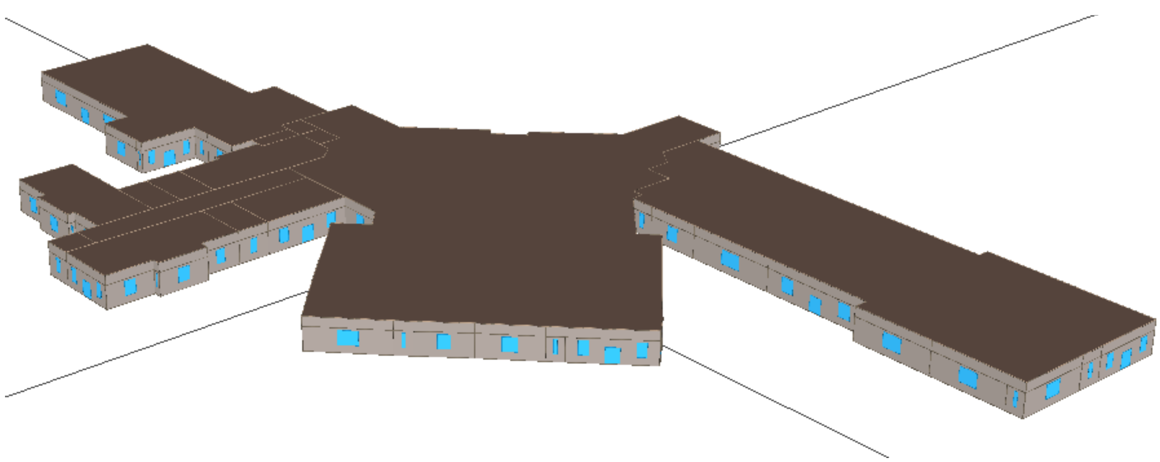

Figure 1: Sketch of Building Energy Model.[2]

[2] Rendering by eQUEST

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 variable air volume (PVAV) units with parallel fan powered (PFP) boxes composed of a central, variable-volume fan supplying conditioned air to each room. This system conforms to ASHRAE Standard 90.1-2007 System 6.
2. Baseline system two consists of a 4-pipe Fan Coil System with a chiller and boiler with minimum efficiency consistent with ASHRAE Standard 90.1-2007.

The high 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, avoiding mold and moisture is good practice. See Table 5 for specification details of the baseline and proposed LG Multi V™ III HVAC systems.

Proposed Building

The proposed building models use Multi V™ III Heat Pump VRF air-conditioning systems (Figure 2), designed for medium to large-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 Multi V™ VRF design, the building can achieve an average energy savings of 38% compared to an average baseline Energy Use Intensity (EUI) of 41.6 kBTU/sf/year.

The Multi V™ III Heat Pump system features superior energy efficiency and longer piping capabilities and is Air Conditioning, Heating, and Refrigeration Institute (ARHI) 1230 certified. Boosted by LG's high-side shell compressor, the system provides an increased inverter range for better load matching. The Multi V™ III Heat Pump system reduces operational costs while providing reliable heat in colder regions. The system's advanced rapid start feature enables the compressors to come on faster to meet startup load. The Multi V™ III Heat Pump system's compact space-saving design and industry leading piping capabilities provide the ultimate in design flexibility.

The following section discusses specifics of the design choices.

Figure 2: Multi V™ III and Indoor Units.

Component Comparison

This study considers and 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 follow the baseline values stipulated by LEED®, which adheres to ASHRAE Standard 90.1-2007:

Table 4: Building Envelope Characteristics

Components		Locations (Climate Zones)						
		Miami, FL (1A)	Houston, TX (2A)	Atlanta, GA (3A)	Los Angeles, CA (3B)	New York, NY (4A)	Seattle, WA (4C)	Chicago, IL (5A)
Windows: (14 % of Wall Area)	Assembly U-factor	1.20	0.70	0.60	0.60	0.50	0.50	0.45
	SHGC	0.25	0.25	0.25	0.25	0.40	0.40	0.40
Exterior Walls (Mass wall building)	Above Grade	0.580	0.151	0.123	0.123	0.104	0.104	0.090
Roofs (Entirely Insulated)		0.063	0.048	0.048	0.048	0.048	0.048	0.048
Floors (Mass)		0.322	0.107	0.107	0.107	0.087	0.087	0.074
Opaque doors		0.700	0.700	0.700	0.700	0.700	0.700	0.700
Standards		LEED® for New Construction & Major Renovations ASHRAE 62.1-2007 ASHRAE 90.1-2007						

Mechanical Systems

HVAC System

For this building size and type, ASHRAE std. 90.1 2007 defines the baseline as a packaged variable air volume system with electric reheat (ASHRAE std. 90.1 System 6 –Packaged VAV with PFP Boxes). This system is used in nonresidential buildings with 4 or 5 floors and less than 25,000 ft^2 or 5 floors or less and 25,000 ft^2 to 150,000 ft^2.

A 4-pipe fan coil system with an ASHRAE Standard 90.1-2007 minimum efficient chiller and boiler is another typical choice for this high 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 5: Air-Handling Mechanical System Characteristics

Systems		LEED Baseline	4-pipe Fan Coil	
		ASHRAE Type6 PVAV with elec. Reheat	ASHRAE minimum efficiency	LG Multi-V III Heat Pump
Cooling	Cooling Tower	–	Two-Speed-Fan, 2.5 gpm/ton	–
	Chiller		2x(80~100) tons Screw type Chiller (0.718 kW/ton,3 gpm/ton)	–
	DX-Cooling	13×(10~20 RT), EER : 11.0	–	13×(10~20 RT) Heat Pump (EER : 14.0 : not include indoor unit fan power)
Heating	Gas-fired HW-Boiler		1,000~1500 Mbh, η = 80%	–
	Electricity	Electric resistance	–	–
	Heat pump	–	–	13×(10~20 RT) Heat Pump (COP: 4.6: not include indoor unit fan power)
Air Systems		13 × Built-Up VAVs	71 x FCU (0.0003kW/cfm, Constant speed)	71 x High Static Ducted or cassette type Indoor units (1~3 RT, 0.0004kW/cfm, Variable speed)

Domestic Hot Water

Baseline and proposed domestic hot-water systems are as follows:

Table 6: Domestic Hot-Water Characteristics

Baseline	Proposed	Notes
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 7: Interior-Lighting Energy Characteristics

	Baseline	Proposed	Notes
Interior Lighting	Lighting Power Density (Average: 1.1 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 8: Receptacle load Energy Characteristics

	Baseline	Proposed	Notes
Receptacle Load	Average : 0.338 w/ft^2	Same	ASHRAE 90.1-2007 *(TABLE G3.1 Modeling Requirements for Calculating Proposed and Baseline Building Performance)*

Average Utility Rates Source

The study uses the following sources for electrical and natural gas rates[3]:

Table 9 : Utility Rates

Energy Source	Miami, FL (1A)	Houston, TX (2A)	Atlanta, GA (3A)	Los Angeles, CA (3B)	New York, NY (4A)	Seattle, WA (4C)	Chicago, IL (5A)
Electricity ($/kWh)	0.149	0.148	0.089	0.121	0.155	0.070	0.086
Natural Gas ($/therm)	1.225	0.894	1.122	0.853	1.212	1.242	0.914

[3] 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 large high school buildings across the United States relative to one built to comply with the minimum requirements of ASHRAE Standard 90.1-2007.

Multi V III Heat Pump

The proposed building with Multi V™ III Heat Pump VRF systems uses an average of 26 kBtu per square foot of site energy each year.

The whole building energy cost savings realized with the Multi V III Heat Pump system is 35% on average compared to an ASHRAE standard 90.1-2007 System 6 PVAV. When comparing the energy cost of the HVAC systems alone, the Multi V™ III Heat Pump system is 55% less on average. (See Figure 3 and Figure 4) The whole building energy cost savings realized with the Multi V™ III Heat Pump system is 24% when compared to 4-pipe FCU with ASHRAE minimum efficiency and a 49% 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 5 through Figure 18) and Annual Energy Consumption by End Use Summaries (See Table 10 through Table 23).

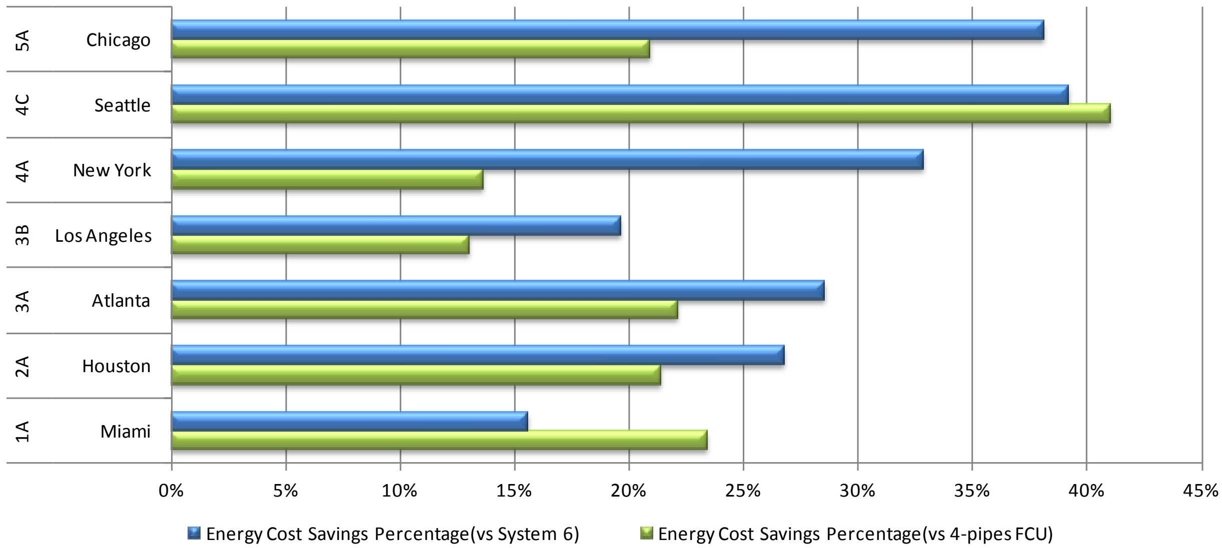

Figure 3 : LG Multi-V™ III VRF Systems Whole Building Energy Cost Savings (%).

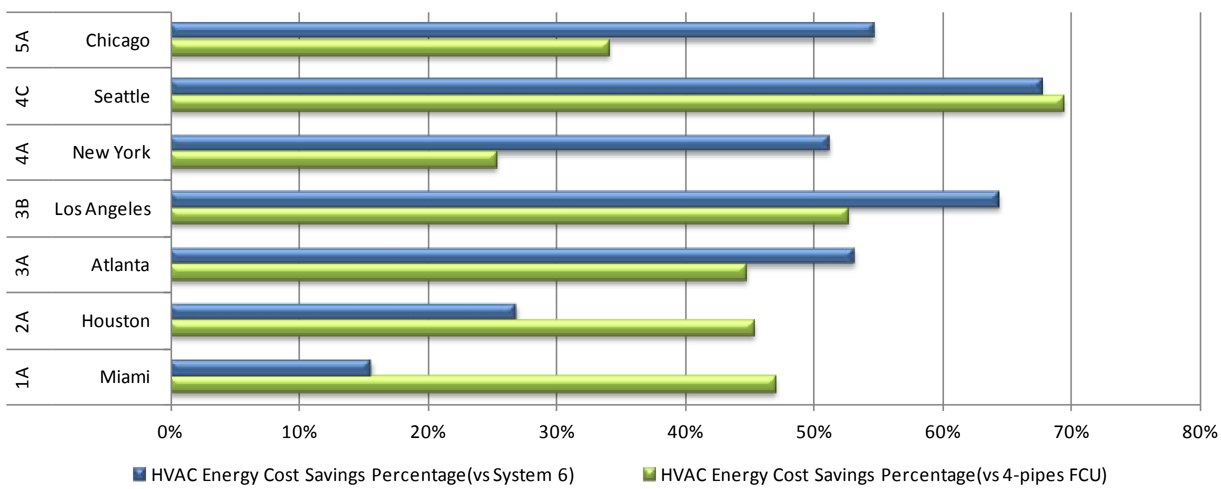

Figure 4 : LG Multi-V™ III VRF Systems HVAC Energy Cost Savings (%).

Miami Results

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

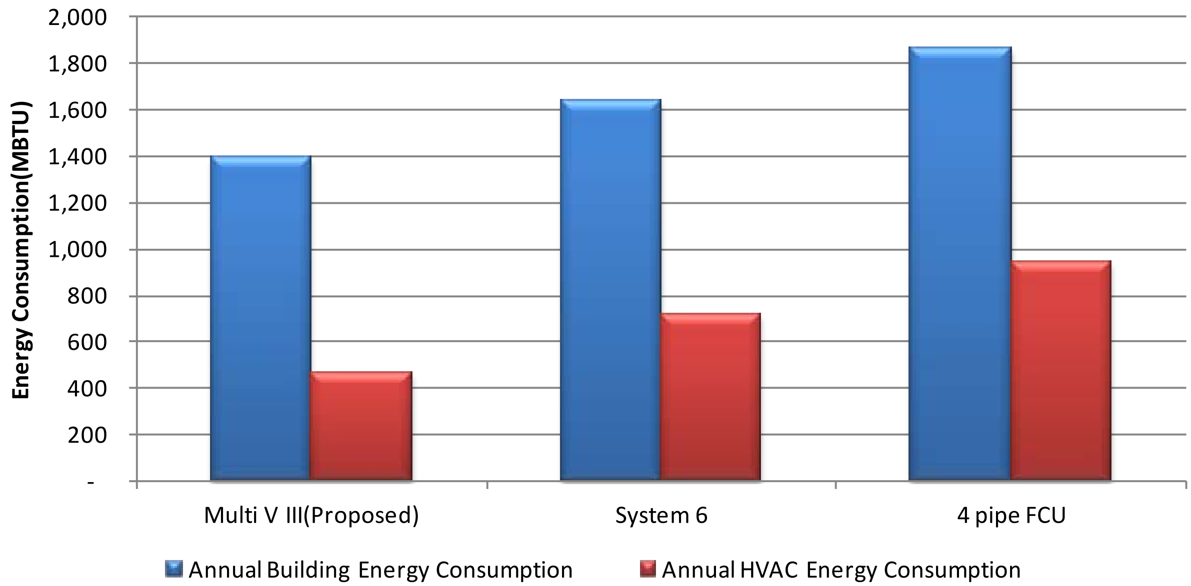

Figure 5: Miami Annual Energy Consumption Comparisons.

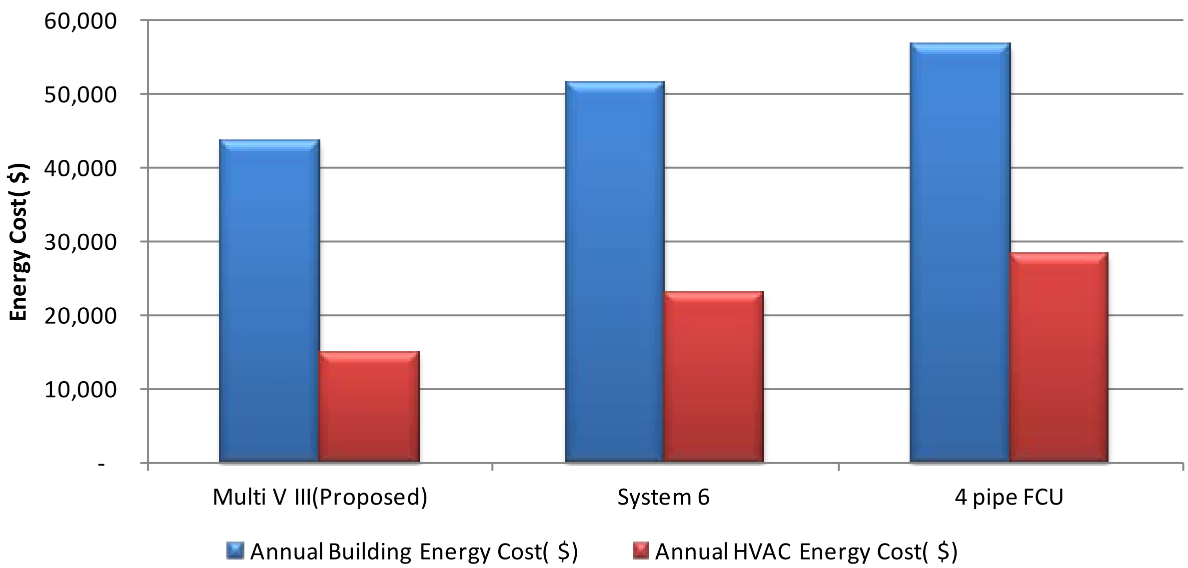

Figure 6: Miami Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 6—Packaged VAV with PFP Boxes) for the Multi V™ III Heat Pump VRF systems was 16%.

Table 10: Miami Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Area Lights	kWh	154,200	154,200	154,200
Equipment	kWh	102,600	102,600	102,600
Hot Water	therms	459	459	459
Space Cooling	kWh	129,000	186,300	150,560
Space Heating	kWh	3,570	9,530	0
	therms	0	0	967
Fans	kWh	4,770	15,070	8,030
Pumps	kWh	0	0	89,880
Totals	kBtux000	1,391	1,642	1,867

Table 11: Miami Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	394,140	467,700	505,270
	Gas(therms)	459	459	1,426
	Total (kBtu x000)	1,391	1,642	1,867
Whole Building Energy Cost	($)	43,522	51,540	56,818
	($/ft²)	0.78	0.92	1.02
HVAC Energy Usage	Electricity(kWh)	137,340	210,900	248,470
	Gas(therms)	0	0	967
	Total (kBtu x000)	469	720	945
HVAC Energy Cost	($)	14,970	22,988	28,267
	($/ft²)	0.27	0.41	0.51

Houston Results

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

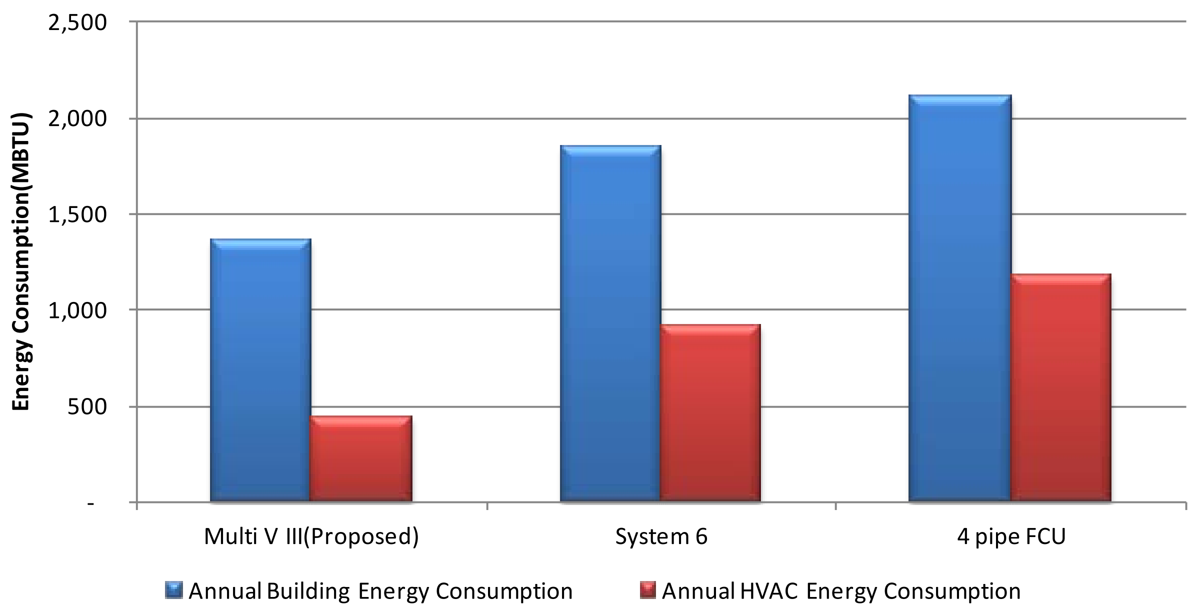

Figure 7: Houston Annual Energy Consumption Comparisons.

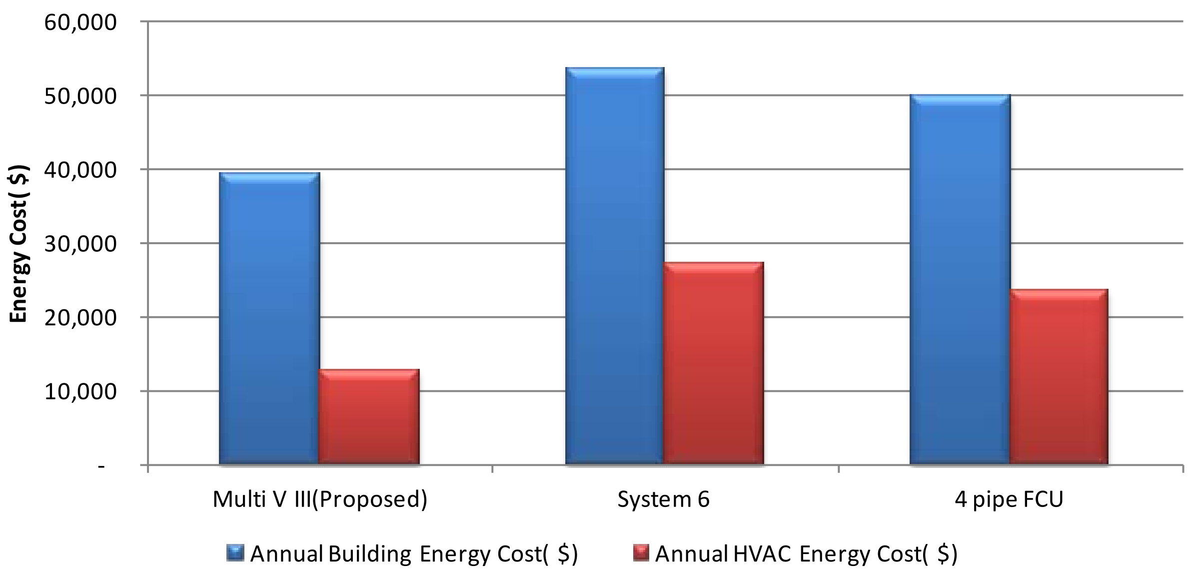

Figure 8: Houston Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 6—Packaged VAV with PFP Boxes) for the Multi V™ III Heat Pump VRF systems was 27%.

Table 12: Houston Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Area Lights	kWh	154,200	154,200	154,200
Equipment	kWh	102,600	102,600	102,600
Hot Water	therms	519	519	519
Space Cooling	kWh	86,400	142,940	111,780
Space Heating	kWh	36,800	114,510	0
	therms	0	0	5,505
Fans	kWh	4,500	12,350	6,790
Pumps	kWh	0	0	66,180
Totals	kBtux000	1,361	1,973	2,097

Table 13: Houston Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	384,500	526,600	441,550
	Gas(therms)	519	519	6,024
	Total (kBtu x000)	1,364	1,849	2,109
Whole Building Energy Cost	($)	39,298	53,651	49,981
	($/ft²)	0.70	0.96	0.90
HVAC Energy Usage	Electricity(kWh)	127,700	269,800	184,750
	Gas(therms)	0	0	5,505
	Total (kBtu x000)	436	921	1,181
HVAC Energy Cost	($)	12,898	27,250	23,581
	($/ft²)	0.23	0.49	0.42

Atlanta Results

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

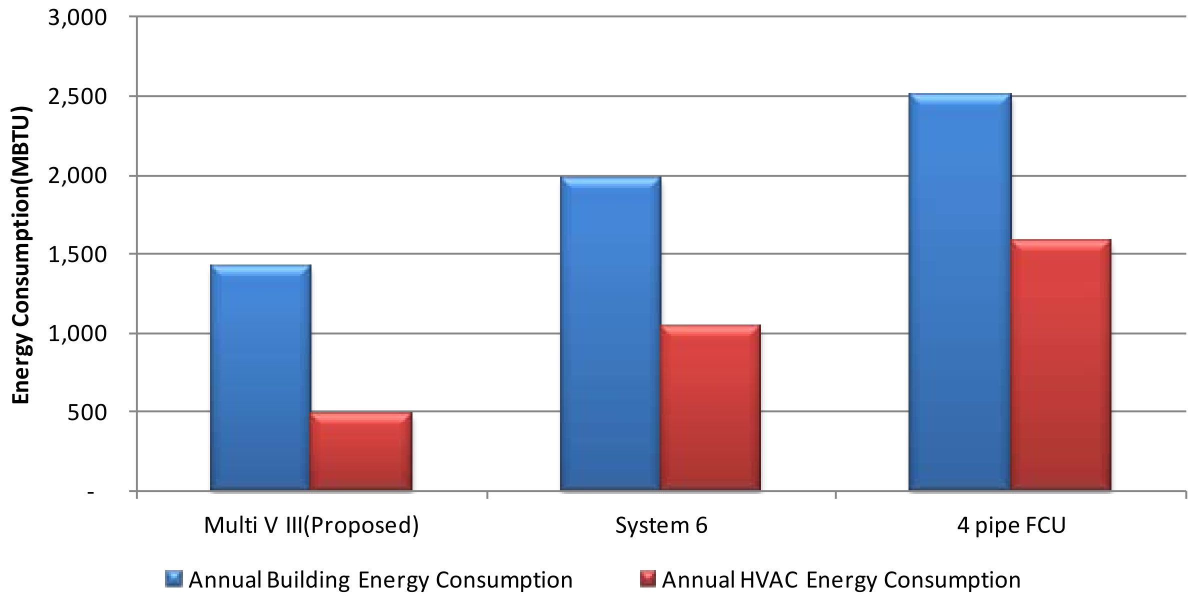

Figure 9: Annual Energy Consumption Comparisons.

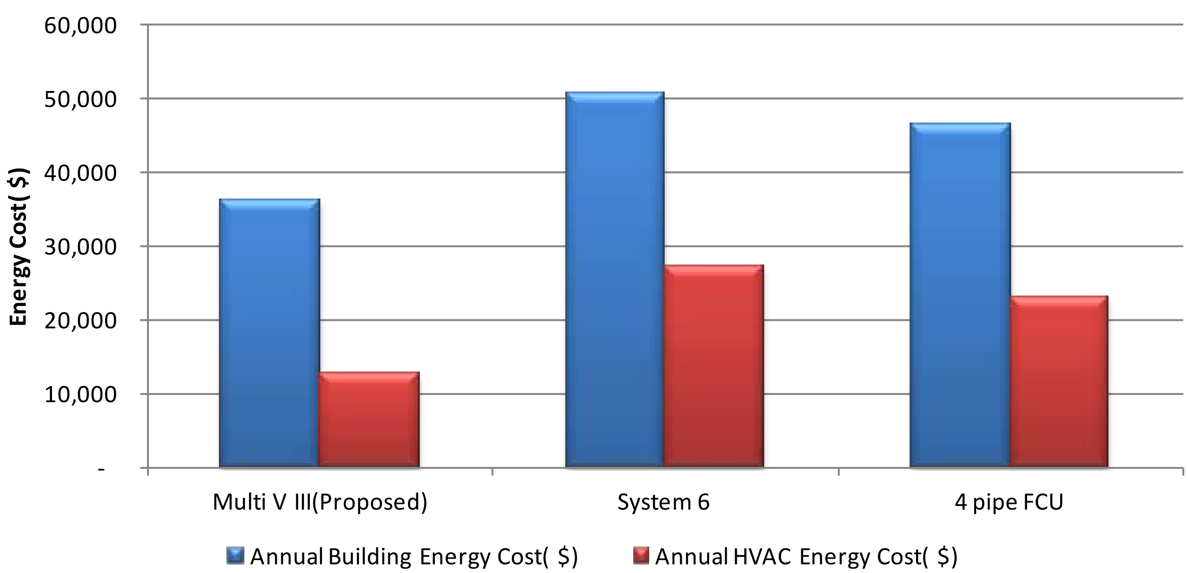

Figure 10: Atlanta Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 6—Packaged VAV with PFP Boxes) for the Multi V™ III Heat Pump VRF systems was 29%.

Table 14: Atlanta Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Area Lights	kWh	154,200	154,200	154,200
Equipment	kWh	102,600	102,600	102,600
Hot Water	therms	577	577	577
Space Cooling	kWh	46,730	66,860	43,830
Space Heating	kWh	92,520	228,120	0
	therms	0	0	12,210
Fans	kWh	3,970	10,940	6,840
Pumps	kWh	0	0	53,530
Totals	kBtu x000	1,423	1,978	2,511

Table 15: Atlanta Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	400,020	562,720	361,000
	Gas(therms)	577	577	12,787
	Total (kBtu x000)	1,423	1,978	2,511
Whole Building Energy Cost	($)	36,249	50,729	46,566
	($/ft²)	0.65	0.91	0.84
HVAC Energy Usage	Electricity(kWh)	143,220	305,920	104,200
	Gas(therms)	0	0	12,210
	Total (kBtu x000)	489	1,044	1,577
HVAC Energy Cost	($)	12,747	27,227	23,059
	($/ft²)	0.23	0.49	0.41

Los Angeles Results

Los Angeles location (climate zone 3B) energy consumption by end use:

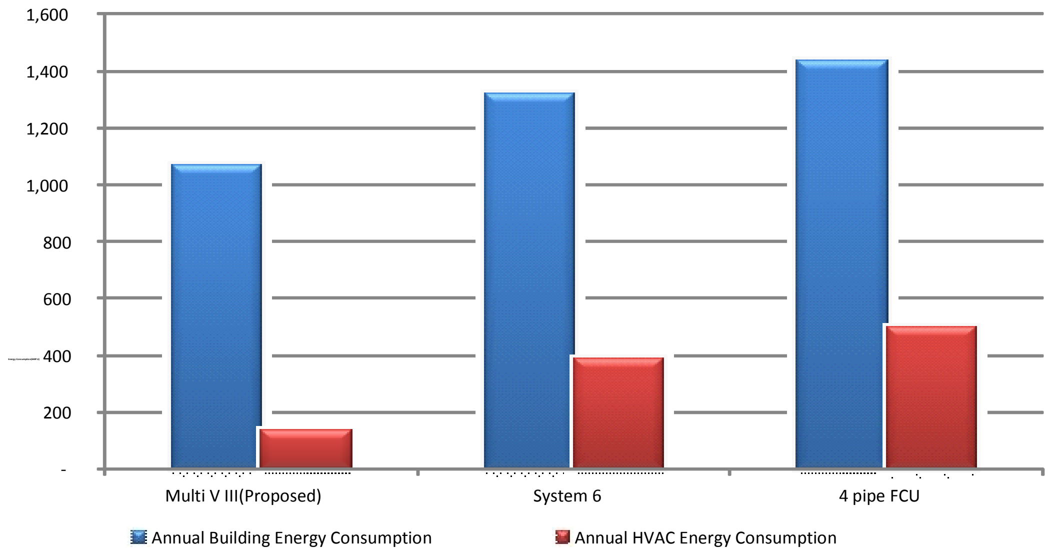

Figure 11: Annual Energy Consumption Comparisons.

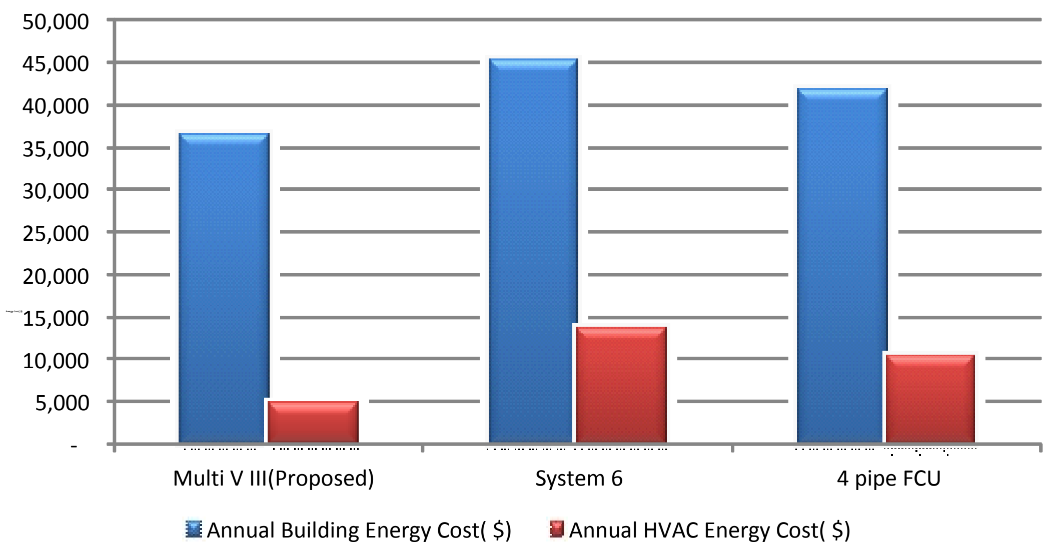

Figure 12: Los Angeles Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 6—Packaged VAV with PFP Boxes) for the Multi V™ III Heat Pump VRF systems was 20%.

Table 16: Los Angeles Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Area Lights	kWh	154,200	154,200	154,200
Equipment	kWh	102,600	102,600	102,600
Hot Water	therms	565	565	565
Space Cooling	kWh	28,790	49,620	21,130
Space Heating	kWh	10,000	59,390	0
	therms	0	0	2,756
Fans	kWh	1,840	5,290	3,870
Pumps	kWh	0	0	41,340
Totals	kBtu x000	1,072	1,323	1,435

Table 17: Los Angeles Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	297,430	371,100	323,140
	Gas(therms)	565	565	3,321
	Total (kBtu x000)	1,072	1,323	1,435
Whole Building Energy Cost	($)	36,469	45,385	41,933
	($/ft²)	0.65	0.81	0.75
HVAC Energy Usage	Electricity(kWh)	40,630	114,300	66,340
	Gas(therms)	0	0	2,756
	Total (kBtu x000)	139	390	502
HVAC Energy Cost	($)	4,916	13,830	10,378
	($/ft²)	0.09	0.25	0.19

New York Results

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

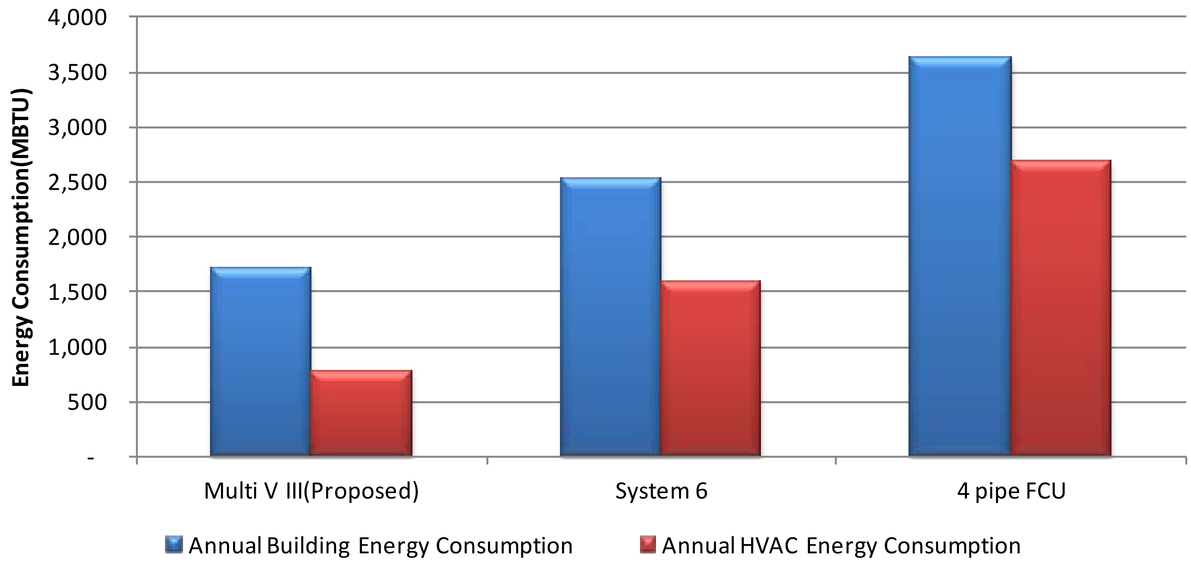

Figure 13: New York Annual Energy Consumption Comparisons.

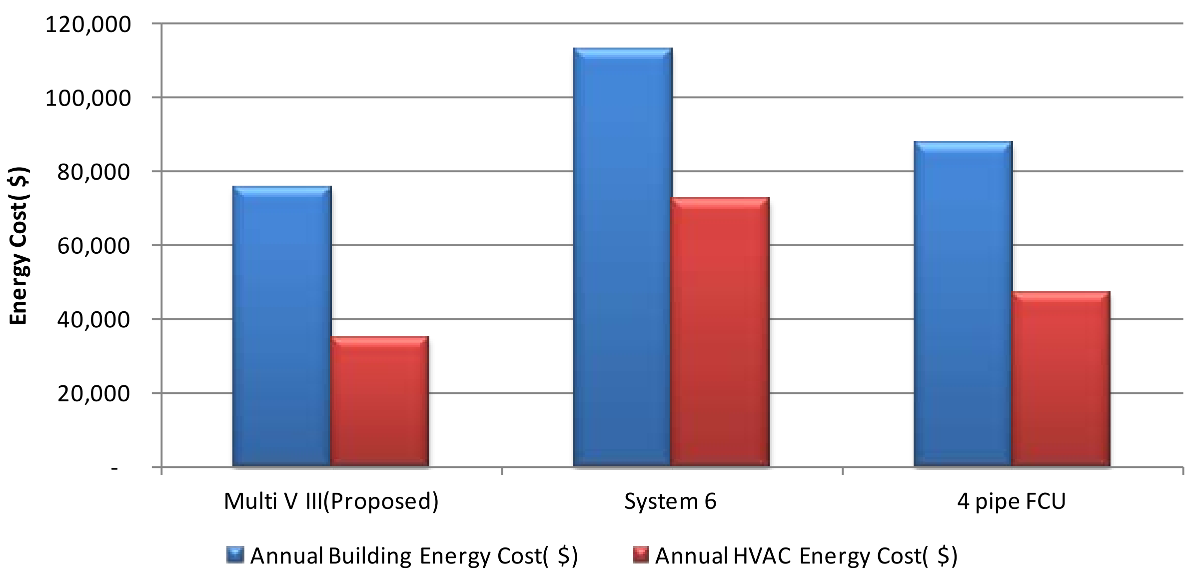

Figure 14: New York Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 6–Packaged VAV with PFP Boxes) for the Multi V™ III Heat Pump VRF systems was 33%.

Table 18: New York Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type6 (LEED® Baseline)	4-pipe Fan Coil Unit
Area Lights	kWh	154,200	154,200	154,200
Equipment	kWh	102,600	102,600	102,600
Hot Water	therms	630	630	630
Space Cooling	kWh	27,330	40,120	25,850
Space Heating	kWh	196,110	414,310	0
	therms	0	0	22,573
Fans	kWh	3,790	11,700	8,570
Pumps	kWh	0	0	93,440
Totals	kBtu x000	1,715	2,530	3,633

Table 19: New York Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE Type 6 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	484,030	722,930	384,660
	Gas(therms)	630	630	23,203
	Total (kBtu x000)	1,715	2,530	3,633
Whole Building Energy Cost	($)	75,788	112,819	87,744
	($/ft²)	1.36	2.02	1.57
HVAC Energy Usage	Electricity(kWh)	227,230	466,130	127,860
	Gas(therms)	0	0	22,573
	Total (kBtu x000)	776	1,591	2,694
HVAC Energy Cost	($)	35,221	72,250	47,177
	($/ft²)	0.63	1.30	0.85

Seattle Results

Seattle location (climate zone 4C) energy consumption by end use:

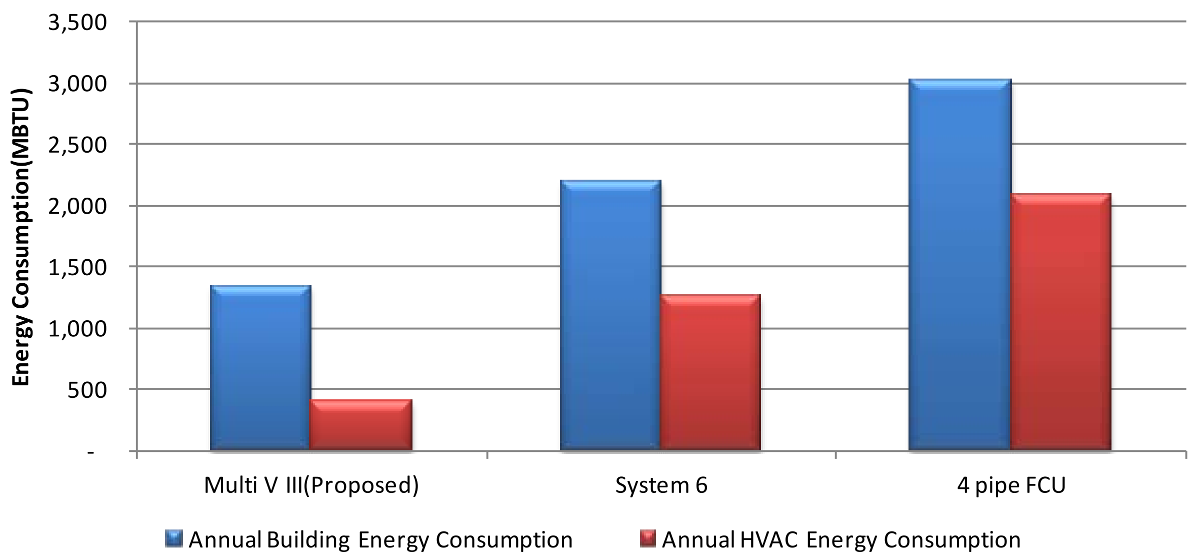

Figure 15: Seattle Annual Energy Consumption Comparisons.

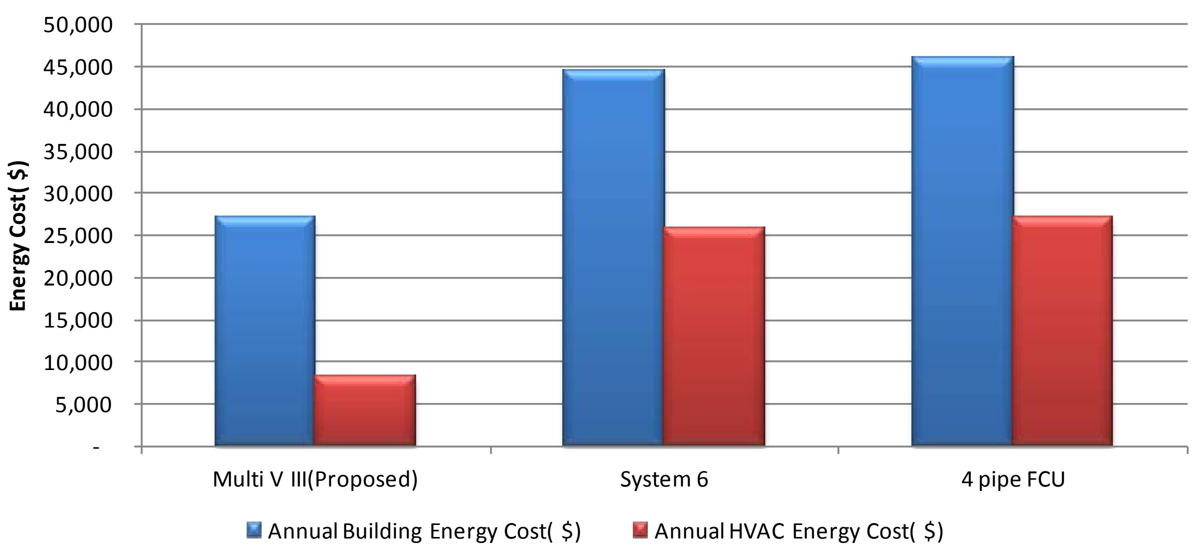

Figure 16: Seattle Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 6—Packaged VAV with PFP Boxes) for the Multi V™ III Heat Pump VRF systems was 39%.

Table 20: Seattle Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE System 6 (LEED® Baseline)	4-pipe Fan Coil Unit
Area Lights	kWh	154,200	154,200	154,200
Equipment	kWh	102,600	102,600	102,600
Hot Water	therms	646	646	646
Space Cooling	kWh	9,520	11,200	8,610
Space Heating	kWh	106,970	347,600	0
	therms	0	0	19,251
Fans	kWh	2,430	9,630	6,080
Pumps	kWh	0	0	31,840
Totals	kBtu x000	1,347	2,198	3,025

Table 21: Seattle Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE System 6 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	375,720	625,230	303,330
	Gas(therms)	646	646	19,897
	Total (kBtu x000)	1,347	2,198	3,025
Whole Building Energy Cost	($)	27,103	44,568	45,965
	($/ft²)	0.49	0.80	0.82
HVAC Energy Usage	Electricity(kWh)	118,920	368,430	46,530
	Gas(therms)	0	0	19,251
	Total (kBtu x000)	406	1,257	2,084
HVAC Energy Cost	($)	8,324	25,790	27,186
	($/ft²)	0.15	0.46	0.49

Chicago Results

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

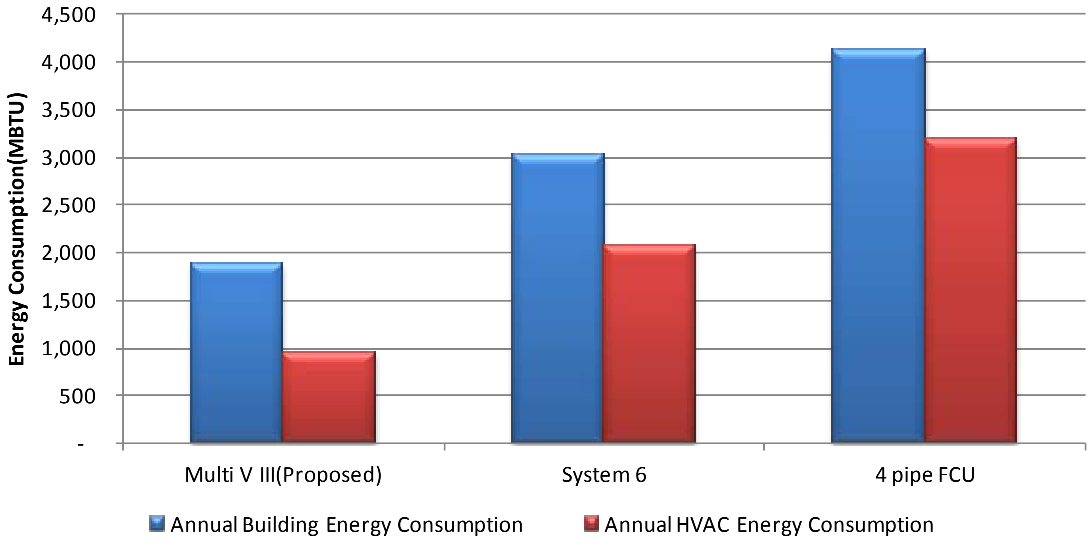

Figure 17: Chicago Annual Energy Consumption Comparisons.

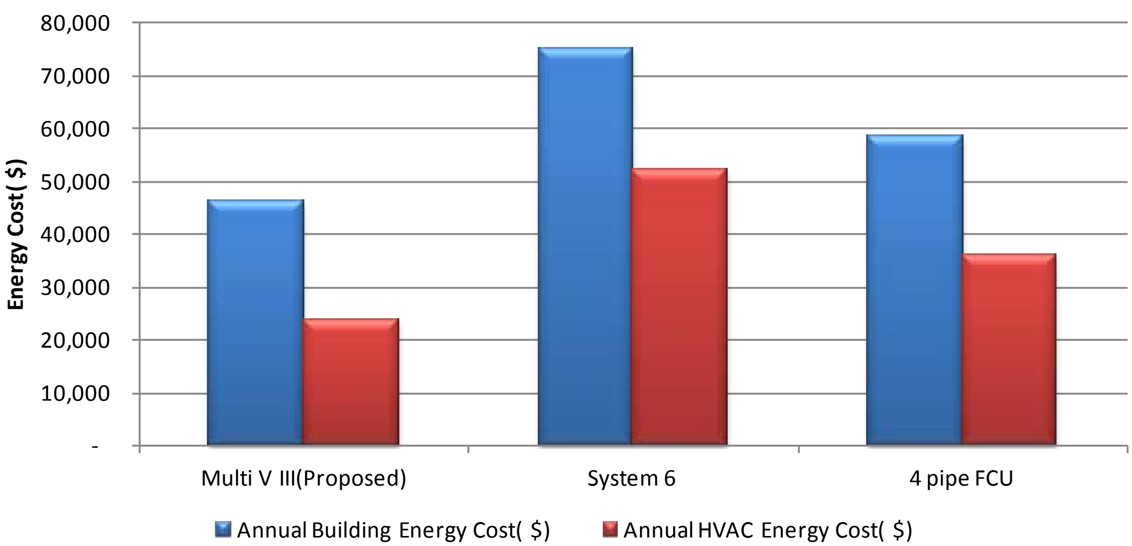

Figure 18: Chicago Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 6—Packaged VAV with PFP Boxes) for the Multi V™ III Heat Pump VRF systems was 38%.

Table 22: Chicago Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	ASHRAE System 6 (LEED® Baseline)	4-pipe Fan Coil Unit
Area Lights	kWh	154,200	154,200	154,200
Equipment	kWh	102,600	102,600	102,600
Hot Water	therms	663	663	663
Space Cooling	kWh	25,340	37,740	31,280
Space Heating	kWh	244,880	557,040	0
	therms	0	0	27,574
Fans	kWh	4,850	12,250	9,380
Pumps	kWh	0	0	84,010
Totals	kBtu x000	1,882	3,014	4,126

Table 23: Chicago Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ III Heat Pump	System 6 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	531,870	863,830	381,470
	Gas(therms)	663	663	28,237
	Total (kBtu x000)	1,882	3,014	4,126
Whole Building Energy Cost	($)	46,347	74,895	58,614
	($/ft²)	0.83	1.34	1.05
HVAC Energy Usage	Electricity(kWh)	275,070	607,030	124,670
	Gas(therms)	0	0	27,574
	Total (kBtu x000)	939	2,072	3,183
HVAC Energy Cost	($)	23,656	52,204	35,925
	($/ft²)	0.42	0.94	0.64

Emissions Rate Comparison

With the LG Multi V™ III, carbon emissions are an average 36% lower than the baseline building, reducing emissions by an average of 125,342 tons of carbon each year.

Emission Factor[4]

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

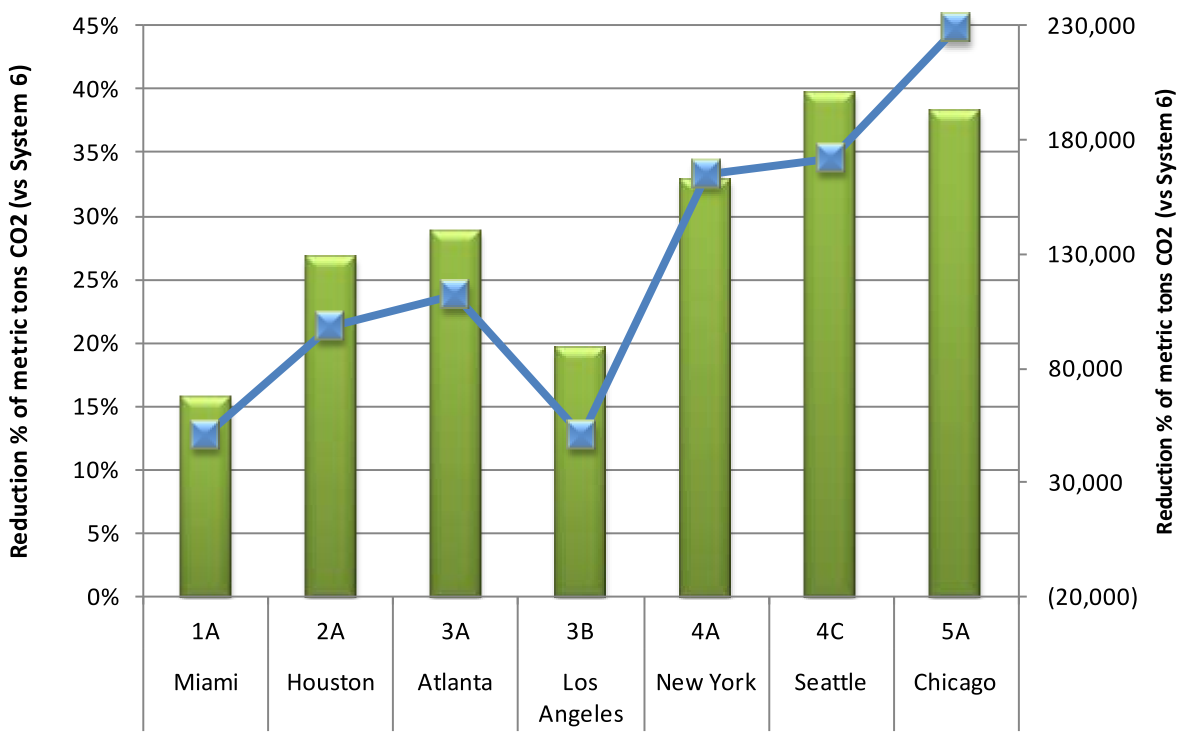

Figure 19 Reduction (%) of Carbon emissions of Proposed LG Multi-V™ III Heat Pump VRF Building vs LEED baseline Building

[4] 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.

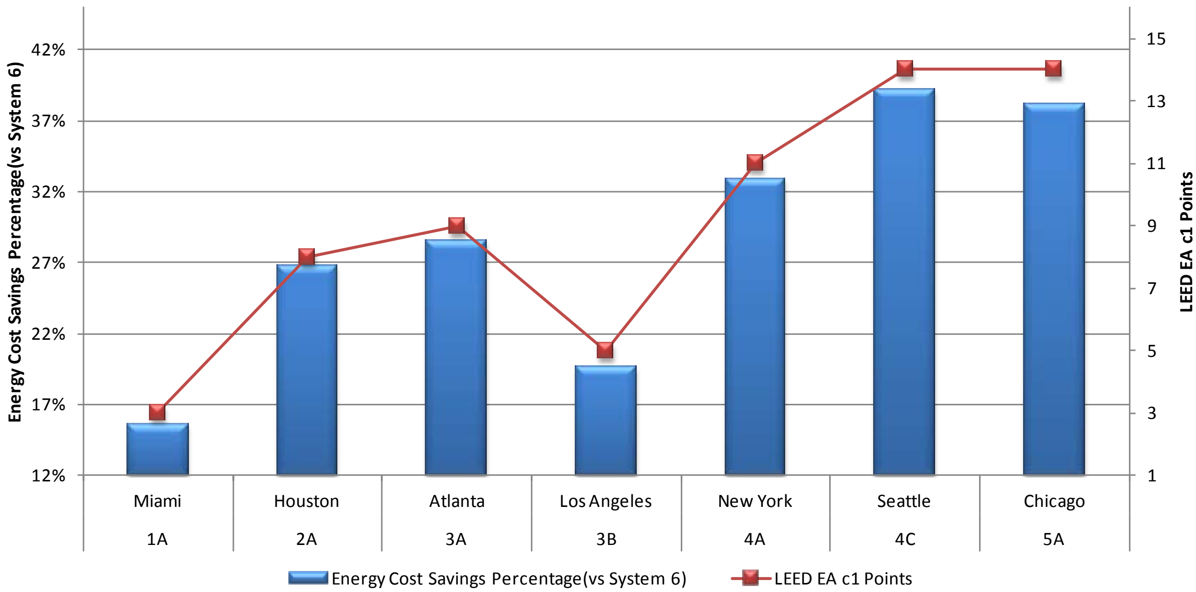

Figure 20 LG Multi-V™ III Heat Pump VRF Building Energy Cost Savings (%) and Potential LEED Points

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

Table 24 shows the 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 24 also shows the minimum energy cost savings percentage for each renovation point.

Table 24: Percentage Cost Savings and Renovation Points

New Buildings	Baseline Building	Renovation 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 Multi V™ III VRF air conditioning system provides opportunities for designers to claim many LEED® prerequisites and credit points. Below are LG Electronics' recommendations and strategies to earn points towards LEED® for new construction certification using Multi V™ VRF systems.

Table 25 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. • Multi V™ 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 Multi V™ heat recovery systems and ERV (Heat 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 Multi V™ 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 Multi V™ system operations based on building usage or indoor air quality. • All LG Electronics' products have tested sound data in accordance with standards. • Use ERV (Heat 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 Zone 1~5.
- 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

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 SF), 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