Building Energy Efficiency Analysis for a High School

(LG Multi V™ Water II 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™ Water II 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™ Water II 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™ Water II Building Annual Energy Cost Savings and Percentage Savings

Location (Climate Zone)		Multi V™ II	
		Annual Savings *	Annual Savings *
Miami, FL	(1A)	$ 6,510	13%
Houston, TX	(2A)	$ 5,287	11%
Atlanta, GA	(3A)	$ 4,308	9%
Los Angeles, CA	(3B)	$ 3,173	8%
New York, NY	(4A)	$ 5,442	7%
Seattle, WA	(4C)	$ 3,320	8%
Chicago, IL	(5A)	$ 1,459	3%

[*Compared to the LEED® baseline ASHRAE Standard 90.1-2007 System 5, packaged variable air volume (PVAV) with parallel fan powered (PFP) Boxes]

***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.*

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

Introduction

Overview

This engineering case study explores the benefits of using an LG Multi V™ Water II 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™ Water II 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 ft^2 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 (ft^2)
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™ Water II 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 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™ Water II design is compared to a building meeting (but not exceeding) the LEED® 2009 building baseline requirements.

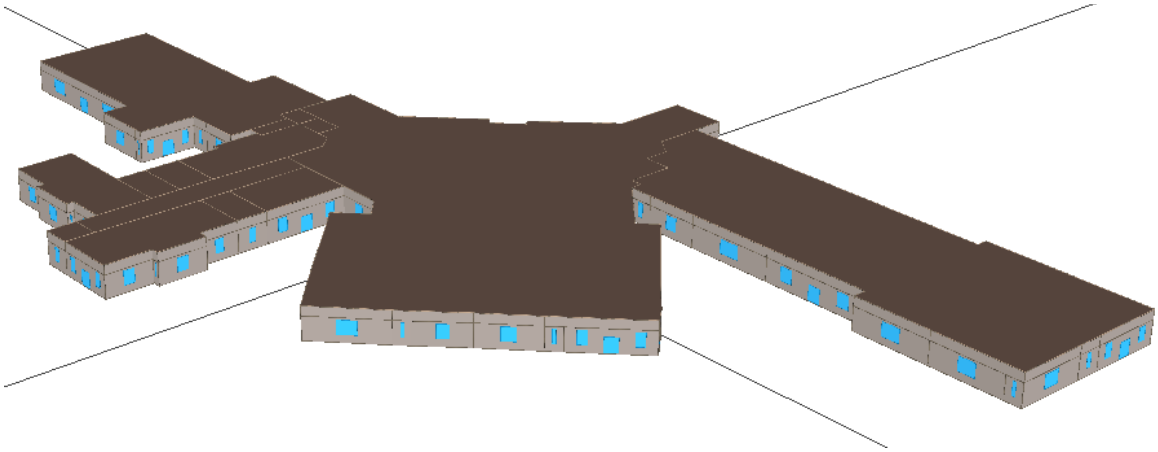

Figure 1: Sketch of Building Energy Model.[2]

[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 5.
2. Baseline system two consists of a 4-pipe fan coil system (FCS) 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™ Water II HVAC systems.

Proposed Building

The proposed building models use Multi V™ Water II 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 8% compared to an average baseline Energy Use Intensity (EUI) of 41.6 kBTU/sf/year.

The Multi V™ Water II 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™ Water II 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™ Water II 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™ Water II 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 hot-water reheat (ASHRAE std. 90.1 System 5 –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 Sys 5 PVAV with hot-water reheat	ASHRAE minimum efficiency	LG Multi-V™ Water II Heat Pump
Cooling	Cooling Tower	–	Two-Speed-Fan, 2.5 gpm/ton	Two-Speed-Fan, 2.5 gpm/ton
	Chiller		2 x (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) Water source Heat Pump (EER : 16.0 : not include indoor unit fan power)
Heating	Gas-fired HW-Boiler	1,000~1500 Mbh, η = 80%	1,000~1500 Mbh, η = 80%	1,000~1500 Mbh, η = 80%
	Electricity	Electric resistance	–	–
	Heat pump	–	–	13×(10~20 RT) Water source Heat Pump (COP: 4.8: not in-cluding indoor unit fan power)
Air Systems		13 × Built-Up VAVs	71 x FCU (0.0003kW/cfm, Constant speed)	71 x High Static Ducted or cas-sette 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™ II Water Heat Pump

The proposed building with Multi V™ Water II 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™ II Water Heat Pump system is 10% on average compared to an ASHRAE standard 90.1-2007 System 5 PVAV. When comparing the energy cost of the HVAC systems alone, the Multi V™ Water II Heat Pump system is 20% less on average. (See Figure 3 and Figure 4) The whole building energy cost savings realized with the Multi V™ Water II Heat Pump system is 15% when compared to 4-pipe FCU with ASHRAE minimum efficiency and a 32% 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).

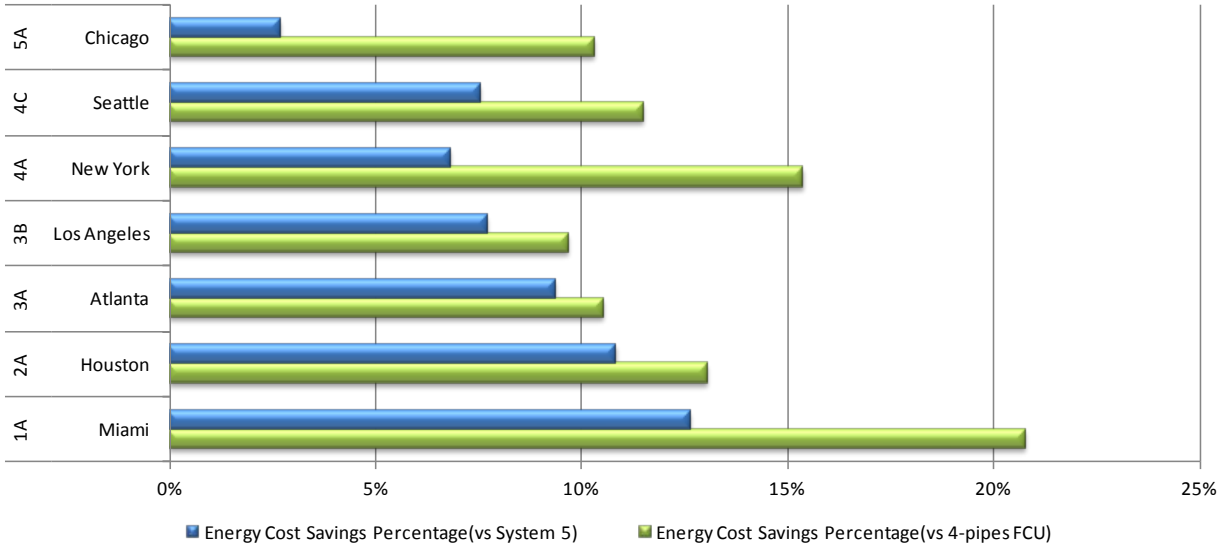

Figure 3 : LG Multi-V™ Water II VRF Systems Whole Building Energy Cost Savings (%).

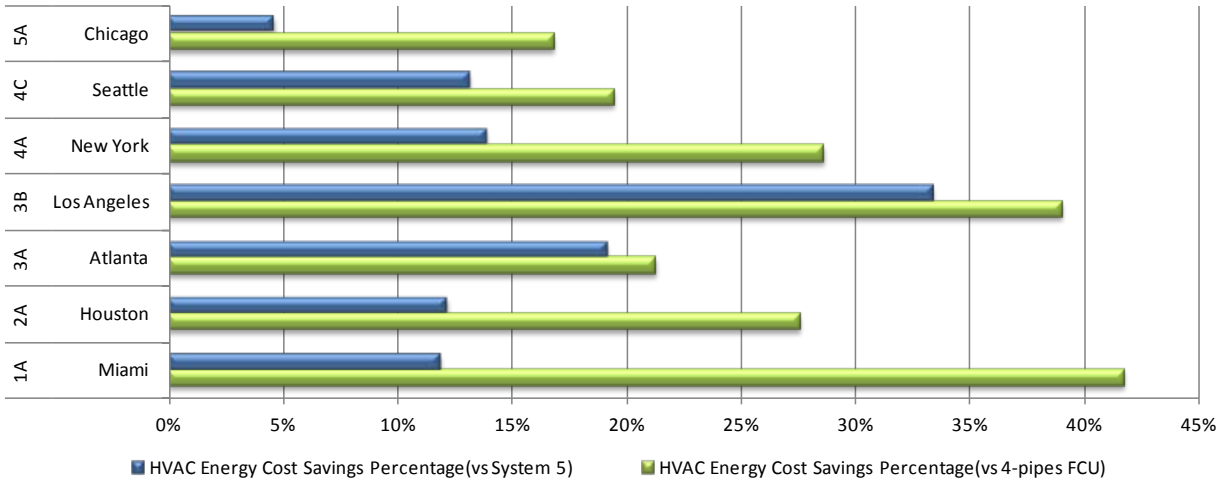

Figure 4 : LG Multi-V™ Water II VRF Systems HVAC Energy Cost Savings (%).

Miami Results

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

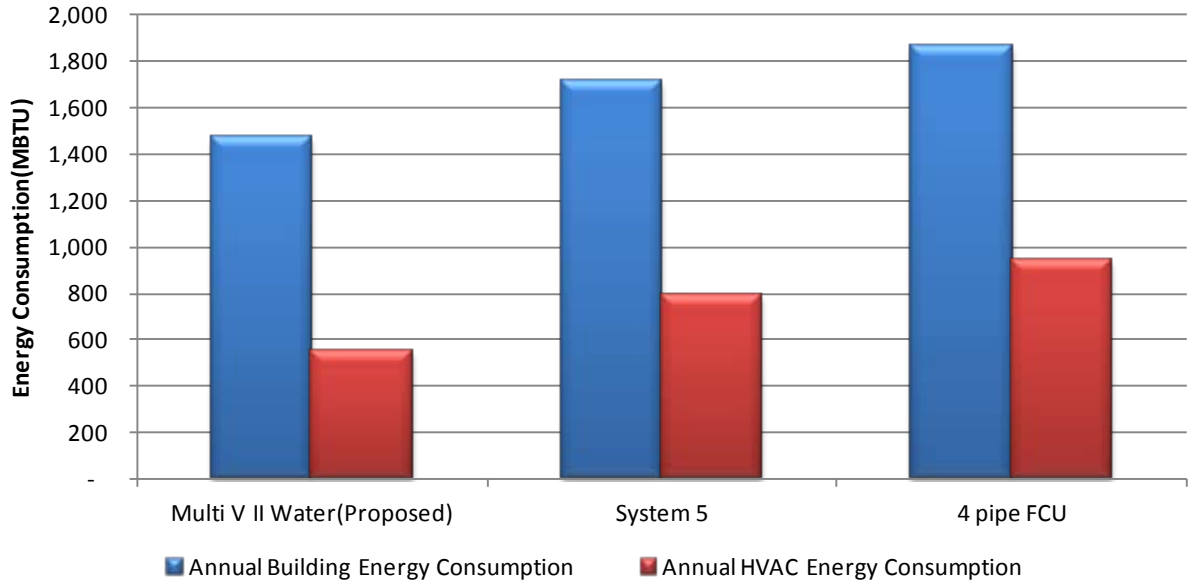

Figure 5: Miami Annual Energy Consumption Comparisons.

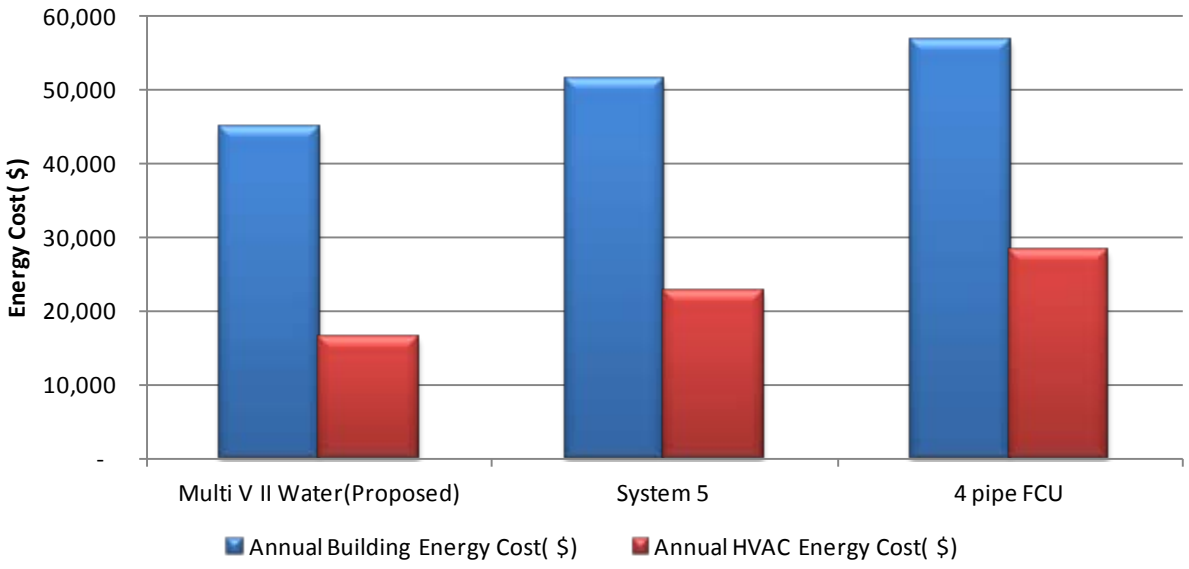

Figure 6: Miami Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 5—Packaged VAV with PFP Boxes) for the Multi V™ Water II Heat Pump VRF systems was 13%.

Table 10: Miami Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (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	122,010	187,960	150,560
Space Heating	kWh	2,830	0	0
	therms	545	986	967
Fans	kWh	5,010	15,070	8,030
Pumps	kWh	15,190	390	89,880
Totals	kBtux000	1,472	1,715	1,867

Table 11: Miami Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	401,840	460,220	505,270
	Gas(therms)	1,004	1,445	1,426
	Total (kBtu x000)	1,472	1,715	1,867
Whole Building Energy Cost	($)	45,030	51,540	56,818
	($/ft²)	0.81	0.92	1.02
HVAC Energy Usage	Electricity(kWh)	145,040	203,420	248,470
	Gas(therms)	545	986	967
	Total (kBtu x000)	549	793	945
HVAC Energy Cost	($)	16,477	22,917	28,267
	($/ft²)	0.30	0.41	0.51

Houston Results

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

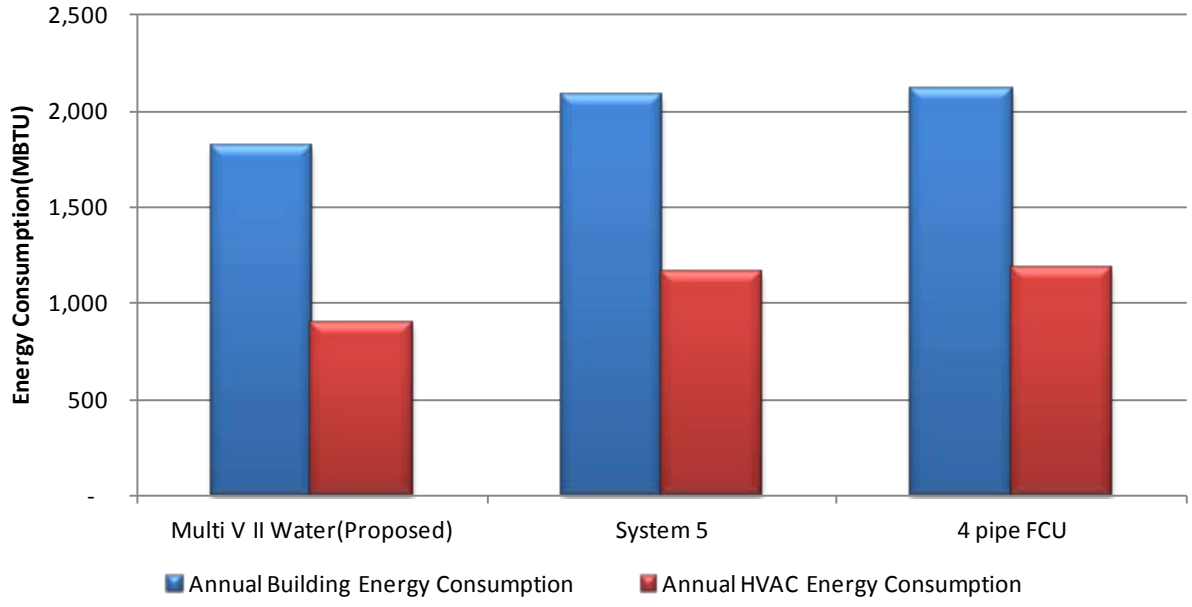

Figure 7: Houston Annual Energy Consumption Comparisons.

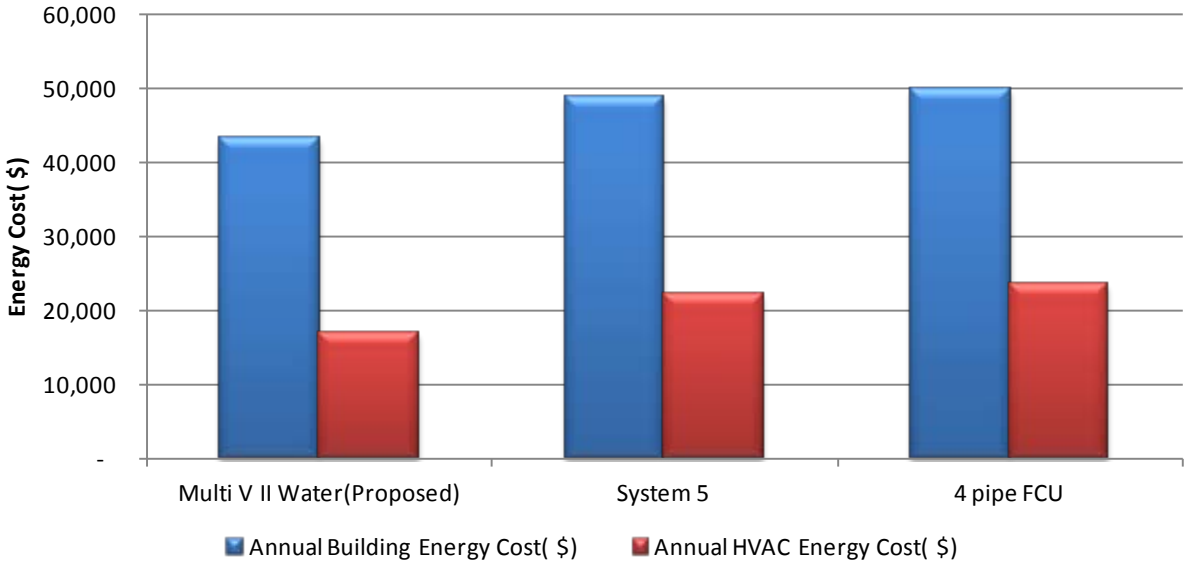

Figure 8: Houston Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 5—Packaged VAV with PFP Boxes) for the Multi V™ Water II Heat Pump VRF systems was 11%.

Table 12: Houston Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (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	89,180	151,610	111,780
Space Heating	kWh	34,480	0	0
	therms	4,544	5,756	5,505
Fans	kWh	5,080	13,730	6,790
Pumps	kWh	8,140	5,020	66,180
Totals	kBtux000	1,822	2,085	2,109

Table 13: Houston Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	393,680	427,160	441,550
	Gas(therms)	5,063	6,275	6,024
	Total (kBtu x000)	1,822	2,085	2,109
Whole Building Energy Cost	($)	43,466	48,753	49,981
	($/ft²)	0.78	0.87	0.90
HVAC Energy Usage	Electricity(kWh)	136,880	170,360	184,750
	Gas(therms)	4,544	5,756	5,505
	Total (kBtu x000)	894	1,157	1,181
HVAC Energy Cost	($)	17,065	22,352	23,581
	($/ft²)	0.31	0.40	0.42

Atlanta Results

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

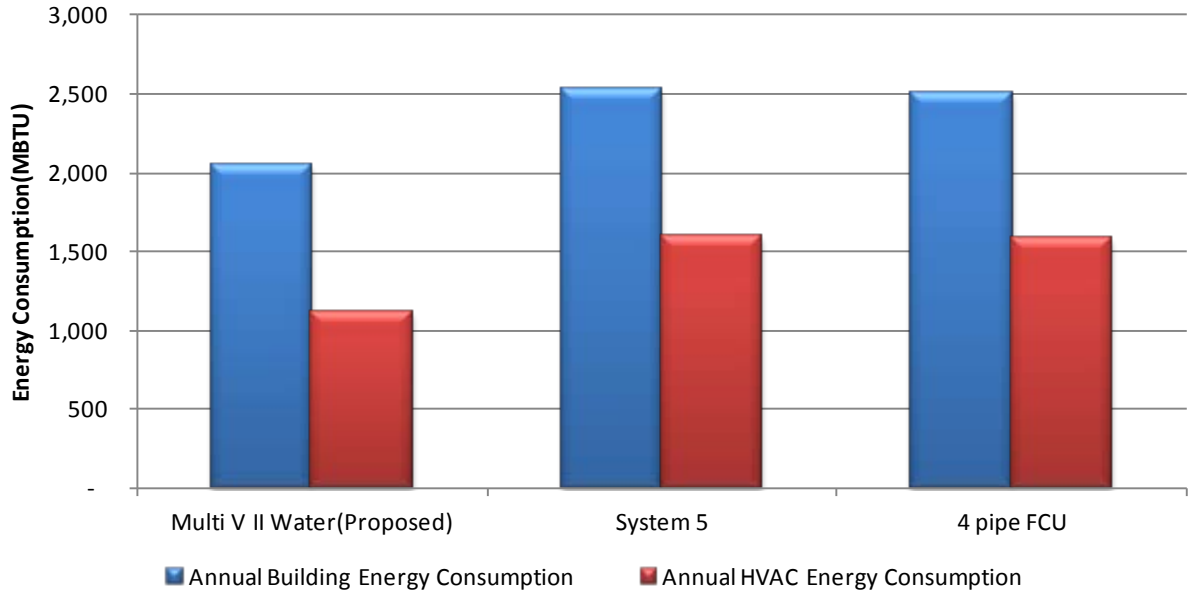

Figure 9: Annual Energy Consumption Comparisons.

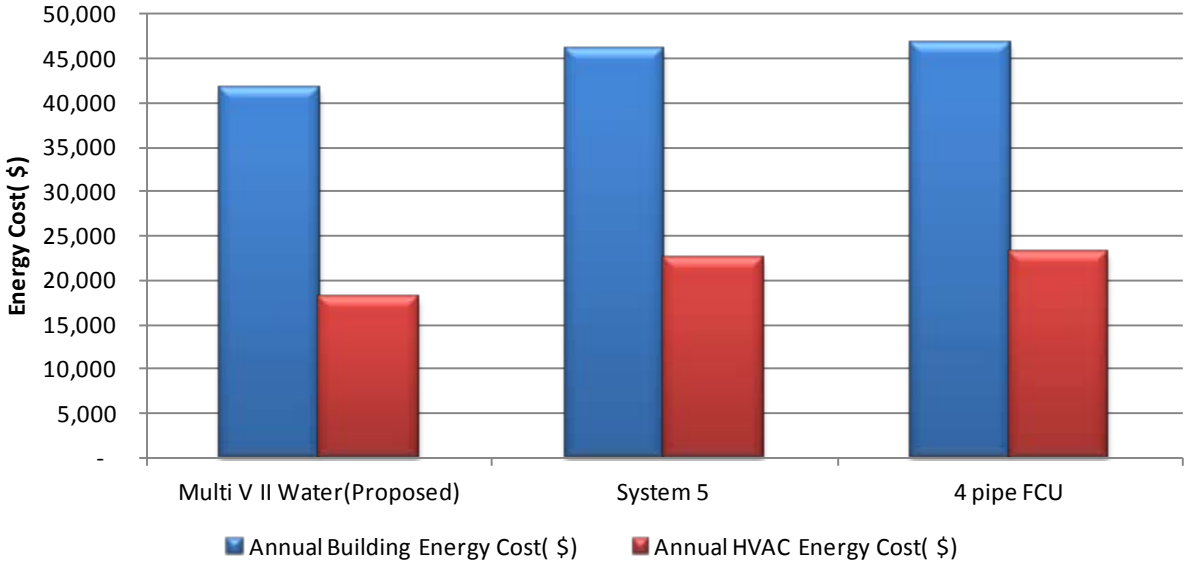

Figure 10: Atlanta Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 5—Packaged VAV with PFP Boxes) for the Multi V™ Water II Heat Pump VRF systems was 9%.

Table 14: Atlanta Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (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	45,010	73,550	43,830
Space Heating	kWh	59,790	0	0
	therms	7,302	12,964	12,210
Fans	kWh	7,110	10,460	6,840
Pumps	kWh	7,890	4,920	53,530
Totals	kBtu x000	2,046	2,534	2,511

Table 15: Atlanta Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	376,600	345,730	361,000
	Gas (therms)	7,879	13,541	12,787
	Total (kBtu x000)	2,046	2,534	2,511
Whole Building Energy Cost	($)	41,655	45,963	46,566
	($/ft²)	0.75	0.82	0.84
HVAC Energy Usage	Electricity(kWh)	119,800	88,930	104,200
	Gas (therms)	7,302	12,964	12,210
	Total (kBtu x000)	1,112	1,600	1,577
HVAC Energy Cost	($)	18,153	22,460	23,059
	($/ft²)	0.33	0.40	0.41

Los Angeles Results

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

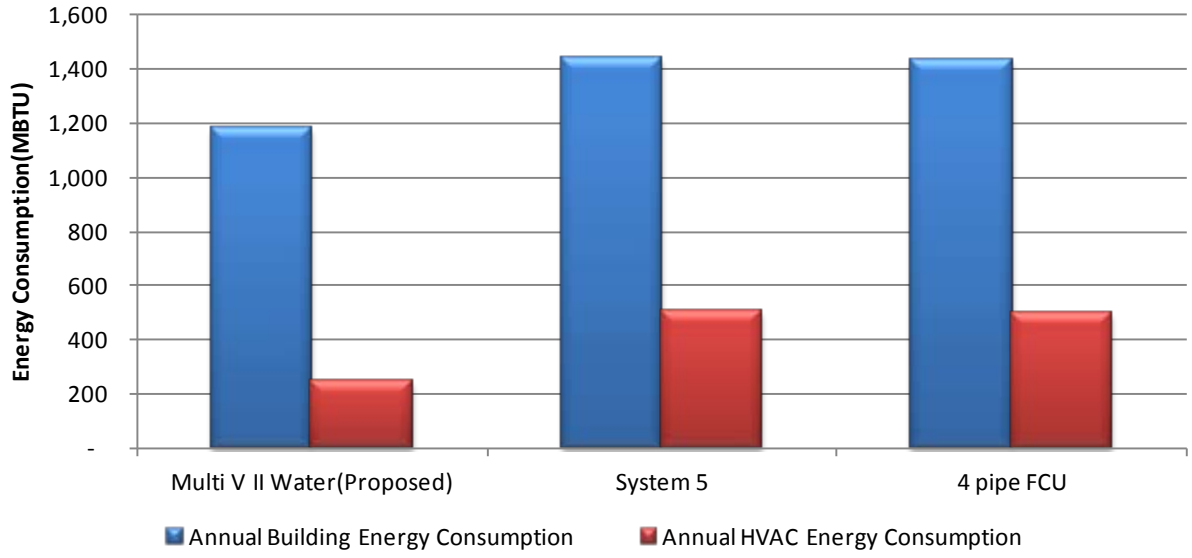

Figure 11: Annual Energy Consumption Comparisons.

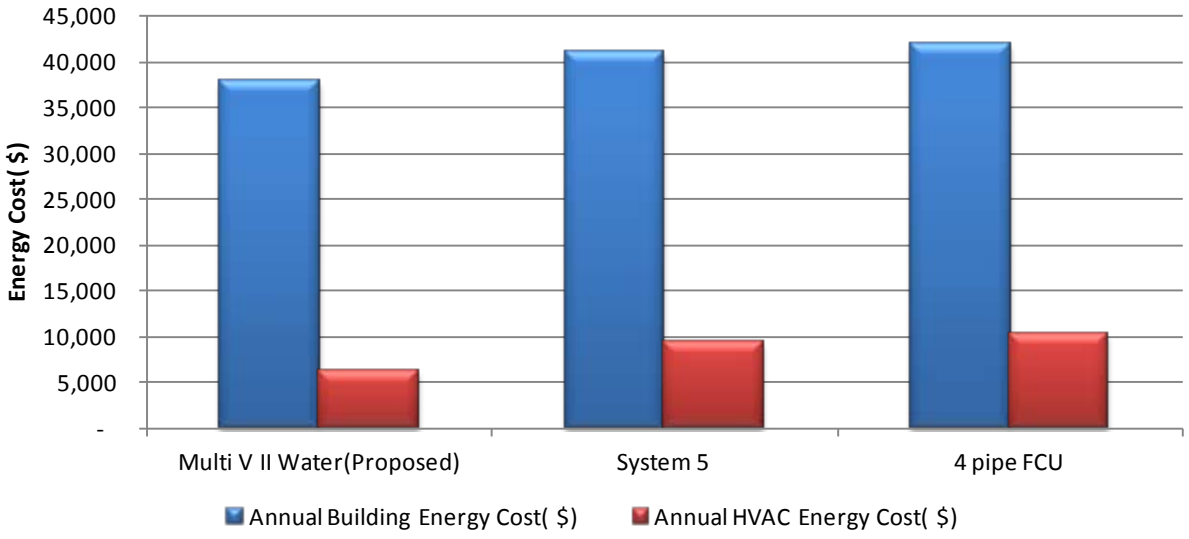

Figure 12: Los Angeles Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 5—Packaged VAV with PFP Boxes) for the Multi V™ Water II Heat Pump VRF systems was 8%.

Table 16: Los Angeles Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (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	31,300	48,890	21,130
Space Heating	kWh	12,400	0	0
	therms	943	3,131	2,756
Fans	kWh	1,920	5,300	3,870
Pumps	kWh	7,640	2,210	41,340
Totals	kBtu x000	1,183	1,439	1,435

Table 17: Los Angeles Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	310,060	313,200	323,140
	Gas(therms)	1,508	3,696	3,321
	Total (kBtu x000)	1,183	1,439	1,435
Whole Building Energy Cost	($)	37,876	41,049	41,933
	($/ft²)	0.68	0.74	0.75
HVAC Energy Usage	Electricity(kWh)	53,260	56,400	66,340
	Gas(therms)	943	3,131	2,756
	Total (kBtu x000)	250	506	502
HVAC Energy Cost	($)	6,324	9,495	10,378
	($/ft²)	0.11	0.17	0.19

New York Results

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

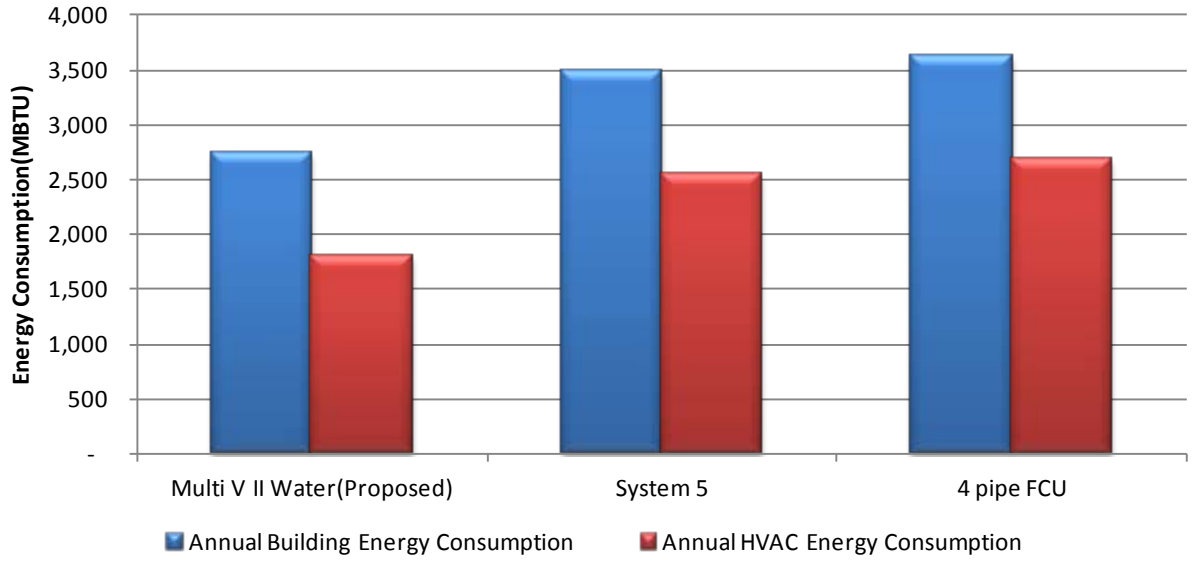

Figure 13: New York Annual Energy Consumption Comparisons.

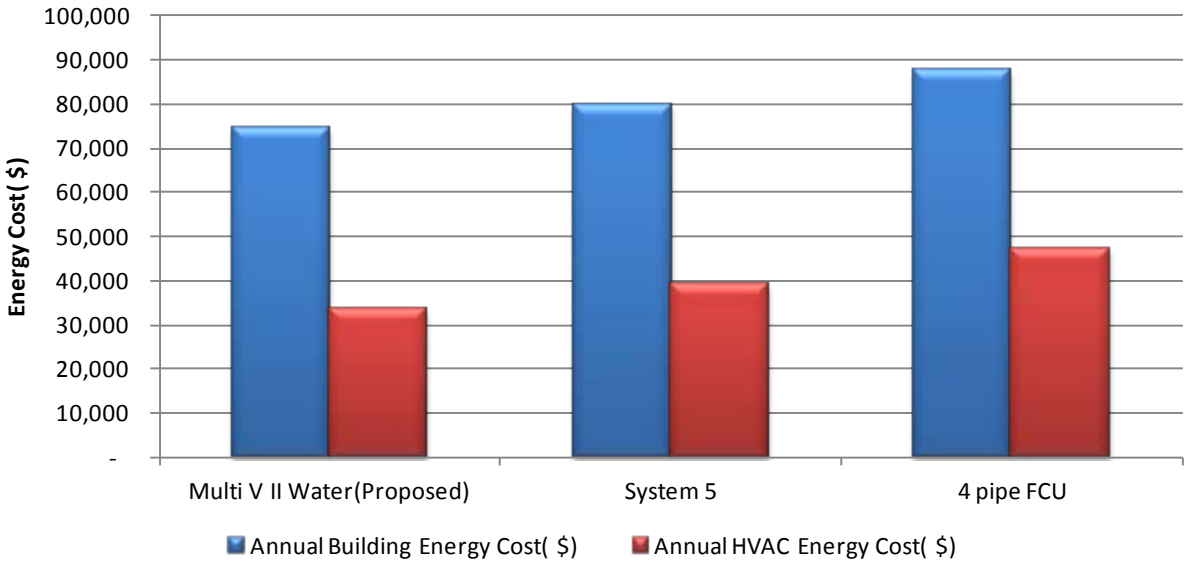

Figure 14: New York Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 5–Packaged VAV with PFP Boxes) for the Multi V™ Water II Heat Pump VRF systems was 7%.

Table 18: New York Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (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	25,350	52,730	25,850
Space Heating	kWh	73,230	0	0
	therms	14,378	22,938	22,573
Fans	kWh	6,310	13,140	8,570
Pumps	kWh	6,810	7,200	93,440
Totals	kBtu x000	2,735	3,483	3,633

Table 19: New York Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	368,500	329,870	384,660
	Gas(therms)	15,008	23,568	23,203
	Total (kBtu x000)	2,735	3,483	3,633
Whole Building Energy Cost	($)	74,252	79,694	87,744
	($/ft²)	1.33	1.43	1.57
HVAC Energy Usage	Electricity(kWh)	111,700	73,070	127,860
	Gas(therms)	14,378	22,938	22,573
	Total (kBtu x000)	1,796	2,543	2,694
HVAC Energy Cost	($)	33,683	39,126	47,177
	($/ft²)	0.60	0.70	0.85

Seattle Results

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

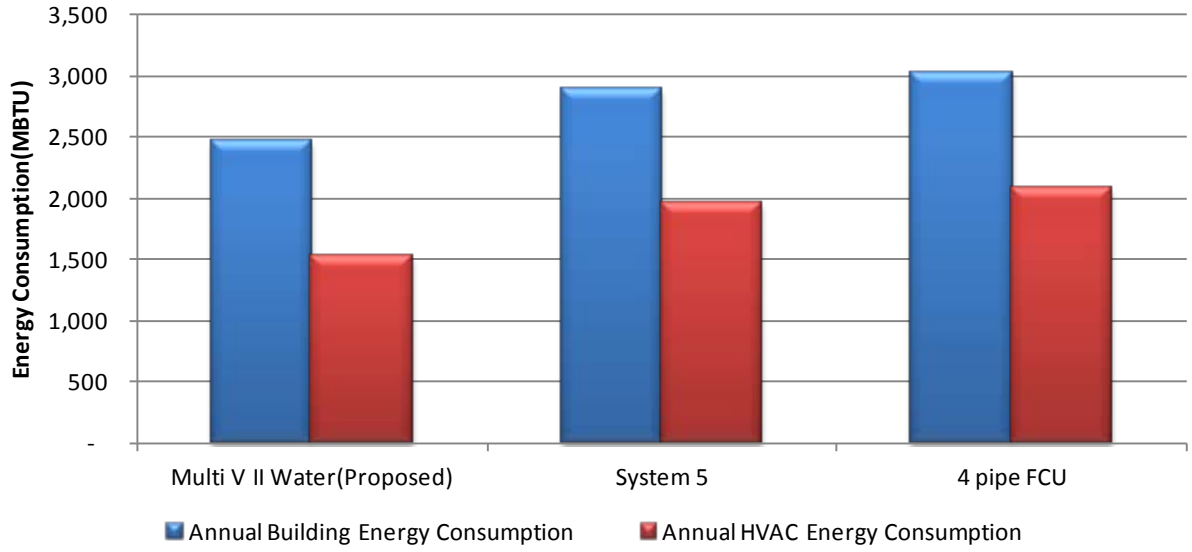

Figure 15: Seattle Annual Energy Consumption Comparisons.

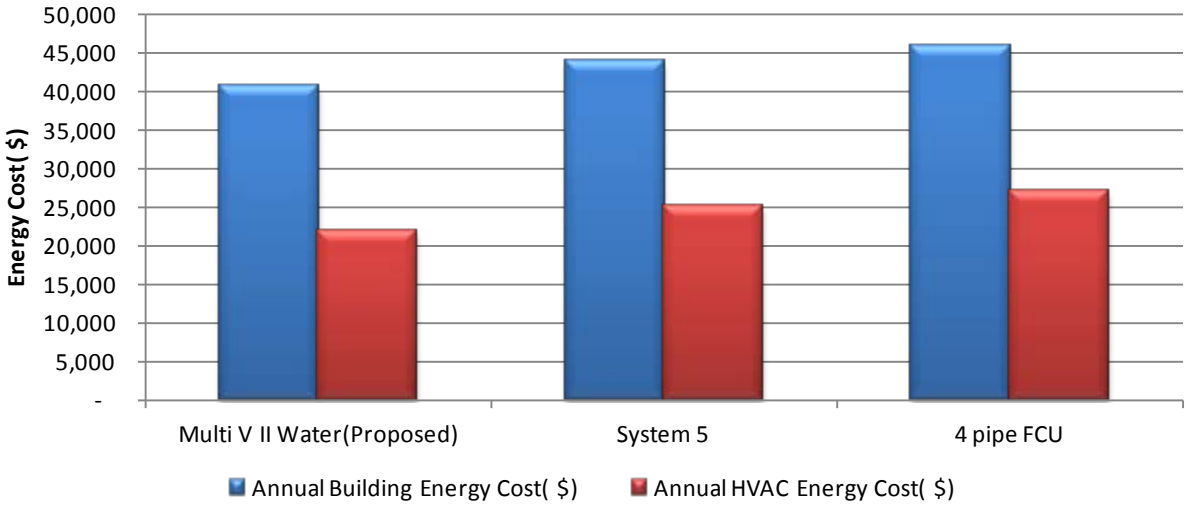

Figure 16: Seattle Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 5—Packaged VAV with PFP Boxes) for the Multi V™ Water II Heat Pump VRF systems was 8%.

Table 20: Seattle Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (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	9,010	15,360	8,610
Space Heating	kWh	89,570	0	0
	therms	11,734	18,504	19,251
Fans	kWh	5,760	9,410	6,080
Pumps	kWh	7,320	6,780	31,840
Totals	kBtu x000	2,471	2,899	3,025

Table 21: Seattle Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	368,460	288,350	303,330
	Gas(therms)	12,380	19,150	19,897
	Total (kBtu x000)	2,471	2,899	3,025
Whole Building Energy Cost	($)	40,669	43,989	45,965
	($/ft²)	0.73	0.79	0.82
HVAC Energy Usage	Electricity(kWh)	111,660	31,550	46,530
	Gas(therms)	11,734	18,504	19,251
	Total (kBtu x000)	1,530	1,958	2,084
HVAC Energy Cost	($)	21,890	25,210	27,186
	($/ft²)	0.39	0.45	0.49

Chicago Results

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

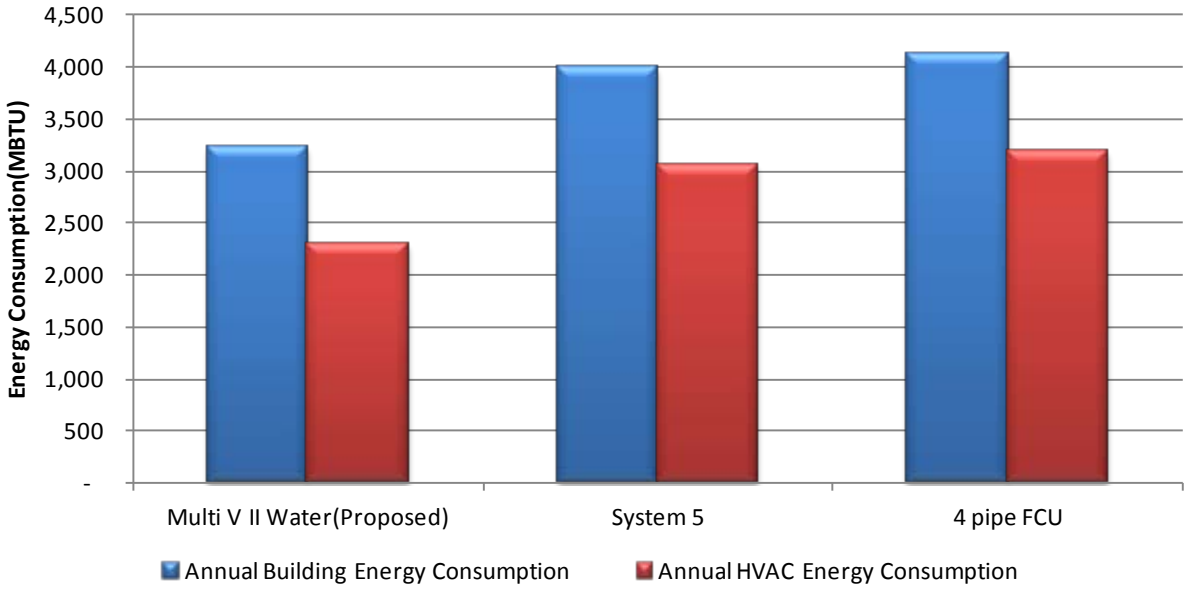

Figure 17: Chicago Annual Energy Consumption Comparisons.

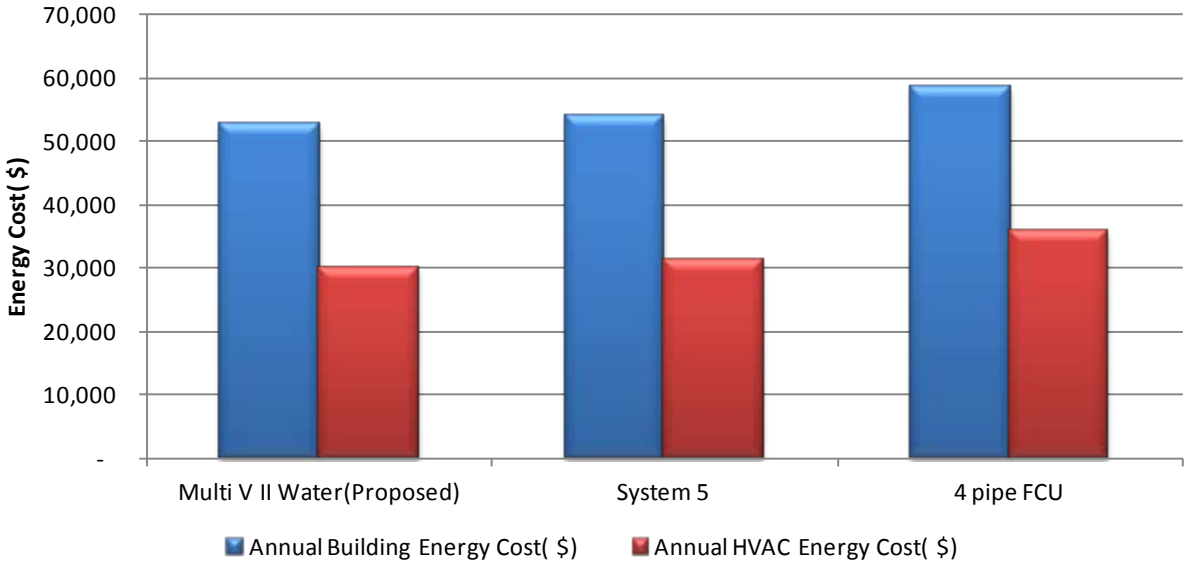

Figure 18: Chicago Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for each case. The whole building energy cost savings over the baseline (System 5—Packaged VAV with PFP Boxes) for the Multi V™ Water II Heat Pump VRF systems was 3%.

Table 22: Chicago Annual Energy Consumption by End Use

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (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	23,150	44,730	31,280
Space Heating	kWh	131,420	0	0
	therms	17,292	28,465	27,574
Fans	kWh	8,860	12,020	9,380
Pumps	kWh	7,900	5,260	84,010
Totals	kBtu x000	3,230	4,001	4,126

Table 23: Chicago Estimated Annual Energy Use and Cost

		Proposed	ASHRAE Standard 90.1-2007	
		Multi-V™ Water II Heat Pump	ASHRAE System 5 (LEED® Baseline)	4-pipe Fan Coil Unit
Whole Building Energy Consumption	Electricity(kWh)	428,130	318,810	381,470
	Gas(therms)	17,955	29,128	28,237
	Total (kBtu x000)	3,230	4,001	4,126
Whole Building Energy Cost	($)	52,581	54,040	58,614
	($/ft²)	0.94	0.97	1.05
HVAC Energy Usage	Electricity(kWh)	171,330	62,010	124,670
	Gas(therms)	17,292	28,465	27,574
	Total (kBtu x000)	2,287	3,058	3,183
HVAC Energy Cost	($)	29,889	31,350	35,925
	($/ft²)	0.54	0.56	0.64

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.

A building can be awarded from 1 to 19 points in the Energy and Atmosphere Credit 1, Optimize Energy Performance LEED® category. Table 24 lists 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™ Water II 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