Energy Efficiency Analysis for a Multi-Story Commercial Office Building

(LG Multi V™ Water II Heat Recovery VRF System)

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Executive Summary

LG Electronics U.S.A. Commercial Air-Conditioning (LG CAC) conducted an energy efficiency option analysis for a proposed office building design. To provide a concrete basis for analysis, the building would be built in Department of Energy (DOE) climate zones, 1A, 2B, 3A, 4A, and 5A. This study explores the energy and resulting cost savings of operating a LG Multi V™ Water II Heat Recovery Variable Refrigerant Flow (VRF) System as compared with various types of typical commercial 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 of which used the same floor plans, occupancy schedules, lighting power density, ventilation, and envelope types. Only the mechanical system types and associated efficiencies were different for each simulation.

The simulations demonstrated that the proposed designs using LG Multi V Water II VRF systems provided significant annual utility bill savings when compared to all LEED baseline building systems.

Table 1 Summary of LG Multi V Water II Heat Recovery

HVAC Energy Cost Savings and % Savings

Location (Climate zone)	Multi V Water II Heat Recovery	
	Savings*	Savings (%) *
Miami, FL(1A)	$57,757	41%
Phoenix, AZ (2B)	$36,718	31%
Atlanta, GA (3A)	$65,511	42%
New York, NY(4A)	$38,672	35%
Chicago, IL (5A)	$17,971	15%

[*Compared to the LEED baseline System 7, variable air volume (VAV) with Reheat.]

Note: ***Legal Disclaimer****: The models described in this report are intended to demonstrate the potential cost-effectiveness of possible energy improvements for the 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 implementation of a LG Multi V Water II Heat Recovery VRF system in a typical new construction multi-story commercial office building. Specifically, it compares the energy saving when compared to a baseline building as the United States Green Building Council (USGBC®'s) LEED[1]. The study was conducted using a building model with the same physical properties, and based on the exact same plans in five different climates—Miami, FL (1A), Phoenix, AZ (2B), Atlanta, GA (3A), New York, NY (4A), and Chicago, IL (5A). (See Figure 1)

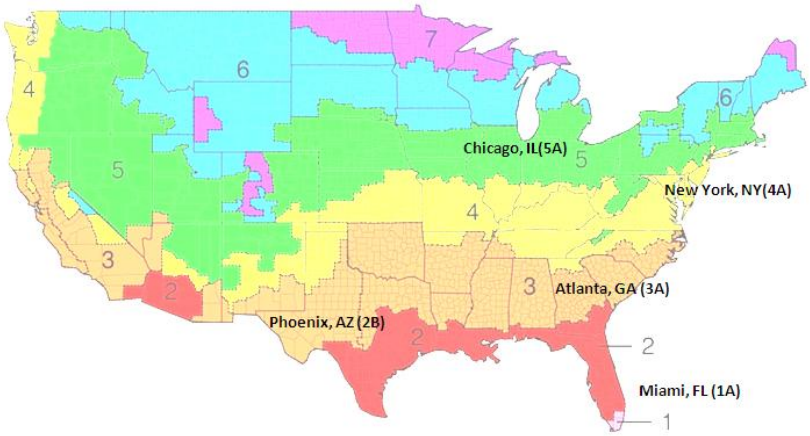

Figure 1: DOE Climate Zones (ASHRAE® Standard 90.1-2007).

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

The building consists of six stories with a total area of conditioned space at 133,595 ft^2. The types of conditioned space included varying sizes and miscellaneous spaces such as the office, lobbies, conference, break, and fitness rooms, as well as some mechanical/electrical rooms. (See Table 2) Outside air is introduced to the inlet of the heat recovery ventilators serving spaces of the building.

The buildings envelopes consisted of a mass wall with friction-fit insulation and roof with insulation entirely above a deck. The common spaces and offices were expected to operate from Monday through Friday (8am-7pm, 75 hours per week).

Table 2: Office Space Types and Sizes

Space Types	Size (ft^2)
Office Area	102,761
Corridor	20,109
Restrooms	2,464
Electrical/Mechanical	2,056
Dining Area	1,869
Lobby	1,388
Gymnasium/Exercise Center	1,272
Library	920
Museum	756
Total	133,595

Modeling Approach

Overview

EnergyPro version 5.1, computer-based building energy simulation software developed by EnergySoft® (www.energysoft.com), was used to model the building for this analysis. EnergyPro software contains the following accreditations:

- Employs the DOE-2.1E simulation engine
- Approved by California Energy Commission for use with California Title 24 code
- Approved by Internal Revenue Service (IRS) for use with Residential and Nonresidential Tax Credits
- Accepted by California Utilities for Savings by Design Incentive Program
- Accepted by USGBC to apply for LEED certification

To determine savings, the energy consumption was calculated using LEED baseline building requirements.

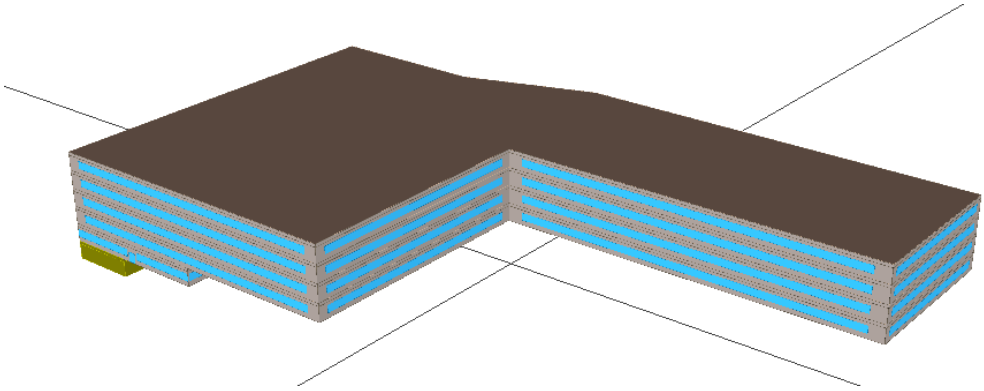

Figure 2: Sketch of Building Energy Model.[2]

[2]Rendering by eQUEST.

Baseline Building

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

Three different baseline systems were developed consisting of multiple heating, ventilating, and air-conditioning (HVAC) systems each. The conditioned areas were served by ASHRAE Standard 90.1-2007 System 7, variable air volume (VAV) with reheat, and chilled water which included a central, variable-volume fan that supplied conditioned air to each room. In addition, ASHRAE Standard System 3, packaged rooftop air conditioner (PSZ-AC) and ASHRAE Standard 90.1-2007 minimum efficient water-source heat pump (WSHP) were also considered as baseline HVAC systems.

The office 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 4 for details about the specification of the baseline and proposed HVAC systems, respectively.)

Proposed Building

The proposed building models used Multi V Water II Heat Recovery VRF commercial air-conditioning systems, which are designed for large-scale facilities, such as commercial office buildings, hotels, hospitals, and schools (See Figure 3)

Multi V Water II system features superior energy efficiency and longer piping capabilities and is AHRI 1230 certified. Multi V Water II system could reduce operational costs while providing reliable heat in colder regions. Multi V Water II system's advanced rapid start feature enables the compressors to come on faster to meet startup load. LG Multi V Water II Heat Recovery systems permit synchronous cooling and heating in different zones. The benefit of zoning for heating and cooling at the same time provides the ultimate in VRF technology, moving heat from one zone to another, in addition to water side heat recovery.

Figure 3: Multi V Water II Heat Recovery Units, Heat Recovery Unit, and a Ducted Indoor Unit.

Component Comparison

Several components were considered and analyzed in the building model:

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

Baseline Building Envelope

The model's building envelope characteristics followed the baseline values stipulated by LEED, which adheres to ASHRAE Standard 90.1-2007:

Table 3: Building Envelope Characteristics

Components		Locations (Climate Zones)				
		Miami, FL (1A)	Phoenix, AZ (2B)	Atlanta, GA (3A)	New York, NY (4A)	Chicago, IL (5A)
Windows: (32.78% of Wall Area)	Assembly U-factor	U-1.20	U-0.55	U-0.6	U-0.50	0.45
	SHGC	0.25	0.25	0.25	0.40	0.40
Skylights		None	None	None	None	None
Exterior Walls (Mass wall building)	Above Grade	U-0.124	U-0.124	U-0.084	U-0.064	0.064
	Below Grade	U-0.084	U-0.084	U-0.084	U-0.084	0.084
Roofs (Entirely Insulated)		U-0.063	U-0.048	U-0.048	U-0.048	0.048
Floors		U-0.253	U-0.052	U-0.052	U-0.038	0.038
Opaque doors		U-0.700	U-0.700	U-0.700	U-0.700	0.700
Standards		• LEED for New Construction & Major Renovations • ASHRAE 62.1-2004 • ASHRAE 90.1-2007				

Mechanical Systems

HVAC System

A VAV system (ASHRAE Standard 90.1 Type 7 VAV with HW-Reheat) is the baseline defined by ASHRAE std. 90.1 2007 for this building size and type. This system is used in the building types of nonresidential and more than five floors or more than 150,000 ft². A RTU-Gas Furnace (ASHRAE Standard 90.1 Sys-3) is a typical HVAC package used in many building types. ASHRAE Standard 90.1-2007 minimum efficient WSHP systems have recently become a popular choice to replace outdated HVAC systems. Baseline and proposed HVAC systems were as follows:

Table 4: Air-Handling Mechanical System Characteristics

Systems		VAV with HW-Reheat	RTU-Gas Furnace	WSHP	Multi-V water II Heat Recovery
		ASHRAE Type 7	ASHRAE Type 3	ASHRAE minimum efficiency	
Cooling	Cooling Tower	2 x (250~300 tons), Two-Speed-Fan	-	2 x (250~300 tons), Two-Speed Fan	2 x (250~300 tons), Two-Speed Fan
	Chiller	2 x (250~300 tons), 0.718 kW/ton	-	-	-
	DX-Cooling	-	EER 11.0	EER 12.0	EER 12.0~16.0
Heating	HW-Boiler (Natural Gas)	η = 80%	-	η = 80%	η = 80%
	Electricity	-	-	-	-
	Gas-fired furnace (Natural Gas)	-	η = 80%	-	-
	Heat pump	-	-	COP: 4.2	COP: 4~6
Air Systems		11 × Built-Up VAVs	11 × Packaged VVTs	11 × Built-Up VAVs /WSHP (16~30 RT)	11 × LG Multi V Water II Heat Recovery (16~30 RT)+ Concealed Ducted Indoor Units

Domestic Hot Water

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

Table 5: Domestic Hot-Water Characteristics

Baseline	Proposed	Notes
Gas-fired storage water heater (50.0 gallons , 40,000 Btu/hr , 0.575 Energy Factor	Same	ASHRAE 90.1-2007 Table 7.8: *Performance Requirements for Water Heating Equipment*

Interior Lighting

Baseline and proposed interior lighting were as follows:

Table 6: Interior-Lighting Energy Characteristics

	Baseline	Proposed	Notes
Interior Lighting	Lighting Power Density (Average: 0.918 w/ft²)	Same	ASHRAE 90.1-2007 (Table 9.5.1: *Lighting Power Densities Using the Building Area Method*)
Exterior Lighting (Tradable)	1,680 watts	Same	ASHRAE 90.1-2007 (Table 9.4.5 *Lighting Power Densities for Building Exteriors*)

Receptacle Load

Baseline and proposed Receptacle equipment were as follows:

Table 7: Interior-Lighting Energy Characteristics

	Baseline	Proposed	Notes
Receptacle load	1.509 w/ft²	Same	ASHRAE 90.1-2007 (TABLE G3.1 *Modeling Requirements for Calculating Proposed and Baseline Building Performance*)

Average Utility Rates Source

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

Energy Source	Miami, FL (1A)	Phoenix, AZ (2B)	Atlanta, GA (3A)	New York, NY (4A)	Chicago, IL (5A)
Electricity ($/kWh)	0.109	0.085	0.089	0.155	0.091
Natural Gas($/therm)	1.224	1.206	1.122	1.212	1.160

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

Results

Overview

According to the Commercial Building Energy Consumption Survey (CBECS), office buildings in the United States comprise roughly consume an average of 93 kBtu per square foot of site energy each year. Office buildings represent nearly one-fifth of all delivered energy consumed by commercial buildings, and are, therefore, an important focus for energy efficiency improvements (EIA 2005).[4] Our goal is to investigate the feasibility of reducing energy use in newly constructed large office buildings across the United States relative to one built to comply with the minimum requirements of ASHRAE Standard 90.1-2007.

Multi V Water II Heat Recovery

The Multi V Water II Heat Recovery VRF systems used an average of 59 kBtu per square foot of site energy each year. The savings varied based on the location and the utility rates, but the Multi V Water II Heat Recovery VRF systems averaged about 17% of cost savings. (See Figure 4 and Figure 5)

The whole building energy cost savings realized with the Multi V Water II Heat Recovery VRF systems was 32% when compared to RTU system-3, and 45% average savings when comparing HVAC energy cost. The whole building energy cost savings realized with the Multi V Water II Heat Recovery system was 17% when compared to VAV system-7, and a 31% average savings when comparing HVAC energy cost.

The whole building energy cost savings realized with the Multi V Water II Heat Recovery system was 8% on average compared to an ASHRAE Standard 90.1-2007 WSHP system. When comparing the energy cost used by the HVAC systems alone, Multi V Water II Heat Recovery system was 10% less on average.

Based on the average energy cost savings from the models, future projects would meet the LEED EA credit 1 prerequisite, and qualify for about up to nine LEED points. The savings are detailed in Figure 6 to Figure 15, and are further detailed in tables in the Annual Building Energy Consumption Comparisons and Annual Energy Consumption by End Use Summaries (See Table 8 to Table 17).

[4] NREL, Technical Support Document: Strategies for 50% Energy Savings in Large Office Buildings, 2010.

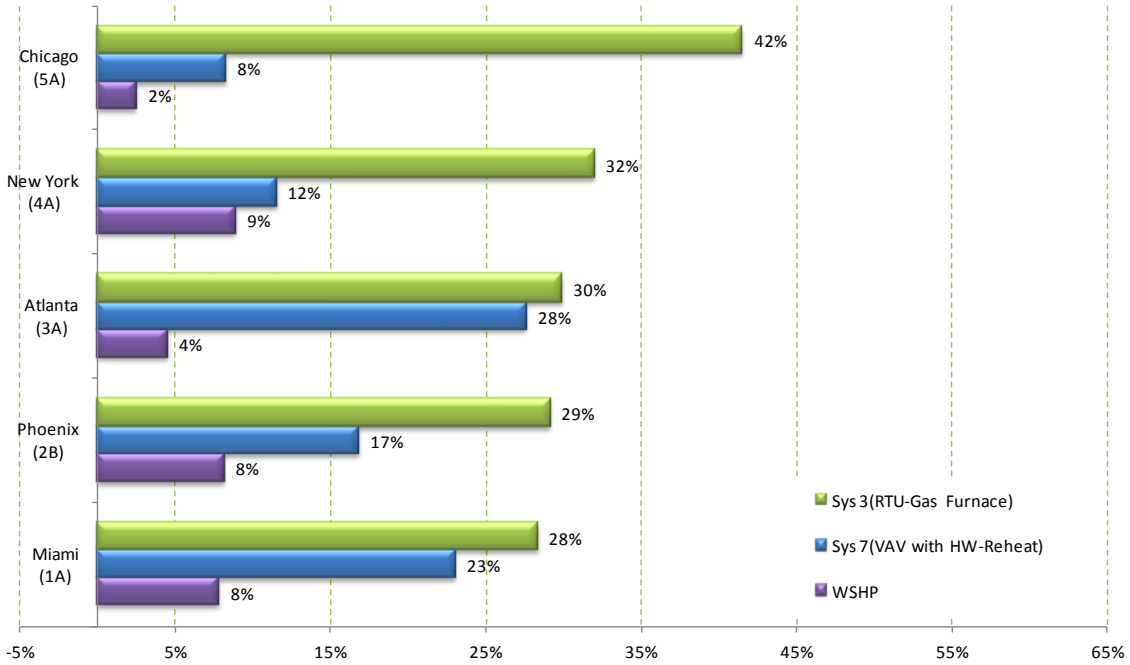

Figure 4 : LG Multi V Water II VRF systems Whole Building Energy Cost (%) Savings.

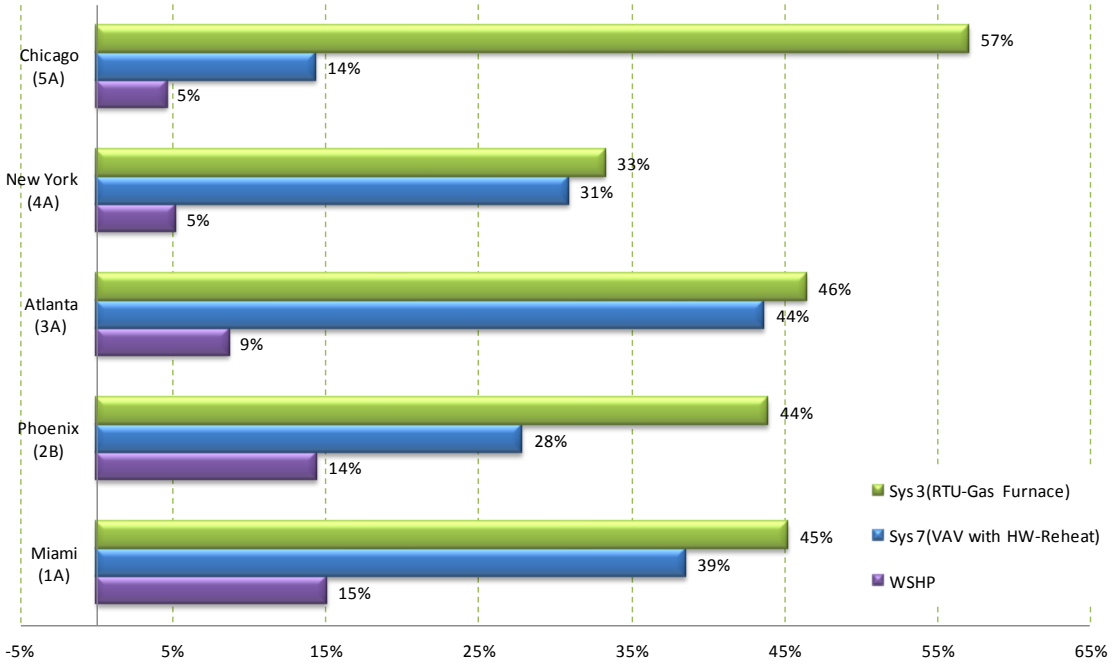

Figure 5 : LG Multi V Water II VRF systems HVAC Energy Cost (%) Savings.

Miami Results

Energy consumption by end use for the Miami location (climate zone 1A) was as follows:

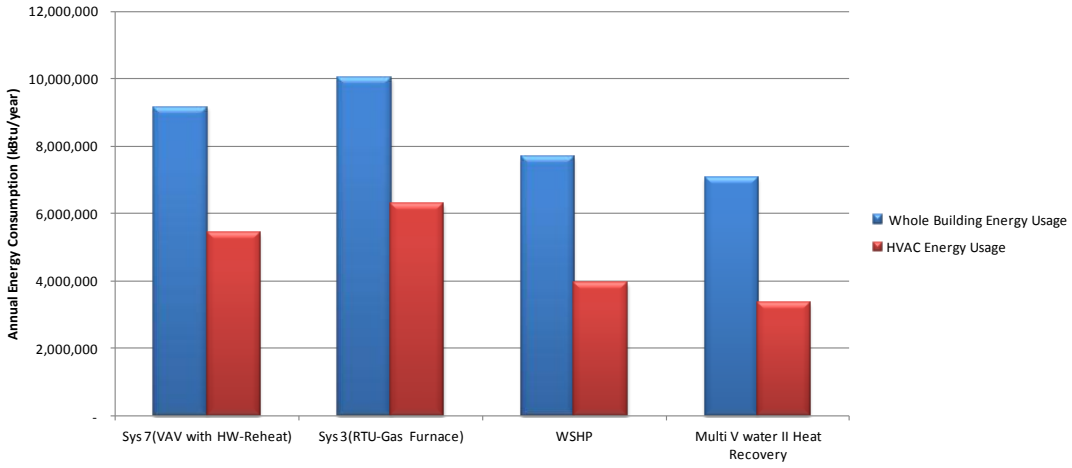

Figure 6: Miami Annual Energy Consumption Comparisons.

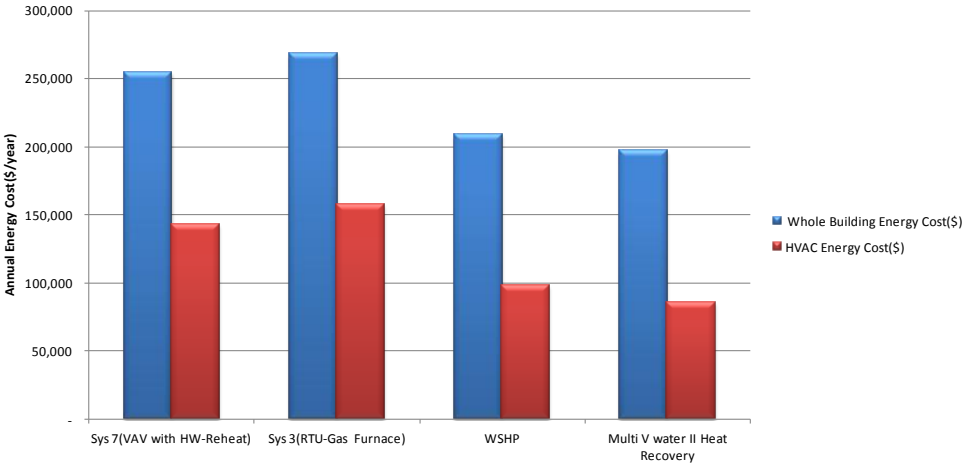

Figure 7: Miami Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (Sys 7, VAV with HW-Reheat) for the Multi V Water II Heat Recovery VRF systems was 23%.

Table 8: Miami Annual Energy Consumption by End Use

		Baseline (ASHRAE Standard 90.1-2007)			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Area Lights	kWh	350,047	350,047	350,047	350,047
Equipment	kWh	663,385	663,385	663,385	663,385
Hot Water	therms	2,638	2,638	2,638	2,638
Space Cooling	**kWh**	**650,119**	**551,284**	**308,047**	**244,333**
Space Heating	**kWh**	**-**	**-**	**6,060**	**1,343**
	therms	**3,578**	**4,383**	**1,608**	**1,183**
Fans	**kWh**	**814,962**	**1,169,667**	**771,227**	**677,860**
Pumps	**kWh**	**20,674**	**-**	**25,883**	**19,233**
Totals	**kBtu**	**9,149,180**	**10,032,202**	**7,674,203**	**7,056,935**

Table 9: Miami Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Whole Building Energy Consumption	**Electricity(kWh)**	**2,499,187**	**2,734,383**	**2,124,649**	**1,956,201**
	Gas(therms)	**6,216**	**7,021**	**4,246**	**3,821**
	Total(kBtu)	**9,149,180**	**10,032,202**	**7,674,203**	**7,056,935**
Whole Building Energy Cost	**($)**	**250,568**	**268,924**	**209,110**	**192,811**
	($/ft²)	**1.88**	**2.01**	**1.57**	**1.44**
HVAC Energy Usage	**Electricity(kWh)**	**1,485,755**	**1,720,951**	**1,111,217**	**942,769**
	Gas(therms)	**3,578**	**4,383**	**1,608**	**1,183**
	Total(kBtu)	**5,427,407**	**6,310,429**	**3,952,430**	**3,335,161**
HVAC Energy Cost ($/ft²)	**($)**	**139,297**	**157,653**	**97,839**	**81,540**
	($/ft²)	**1.04**	**1.18**	**0.73**	**0.61**

Phoenix Results

Energy consumption by end use for the Phoenix location (climate zone 2B) was as follows:

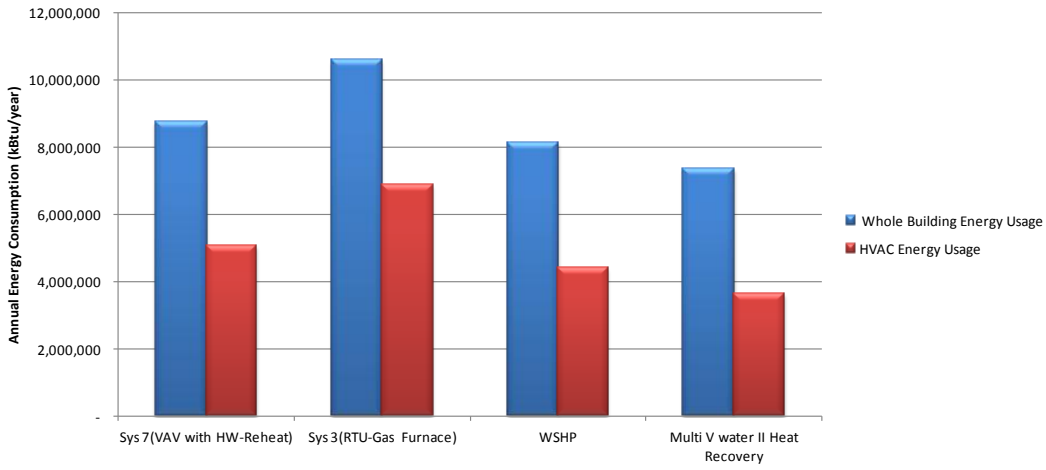

Figure 8: Phoenix Annual Energy Consumption Comparisons.

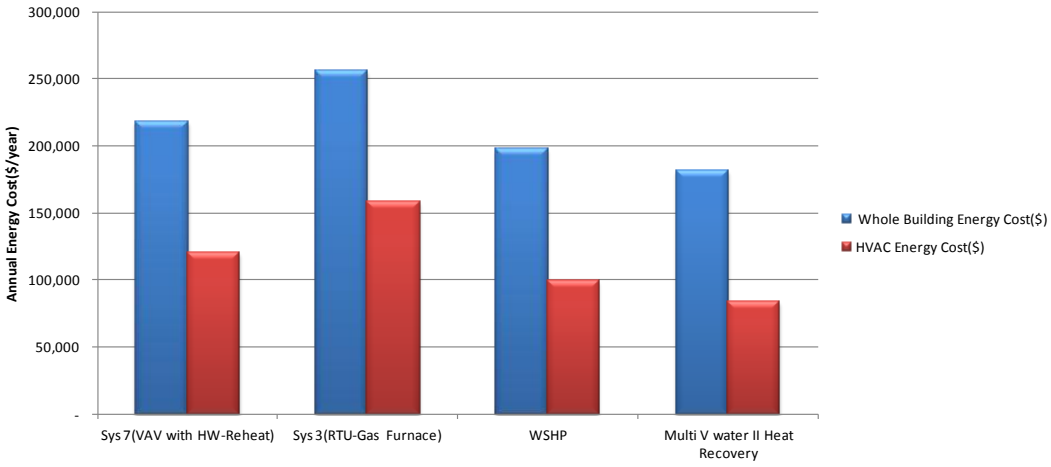

Figure 9: Phoenix Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (Sys 7, VAV with HW-Reheat) for the Multi V Water II Heat Recovery VRF systems was 17%.

Table 10: Phoenix Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Area Lights	kWh	350,047	350,047	350,047	350,047
Equipment	kWh	663,385	663,385	663,385	663,385
Hot Water	therms	2,638	2,638	2,638	2,638
Space Cooling	**kWh**	**471,986**	**573,059**	**349,147**	**256,897**
Space Heating	**kWh**	**-**	**-**	**9,849**	**1,970**
	therms	**4,343**	**8,334**	**2,898**	**1,862**
Fans	**kWh**	**854,011**	**1,202,129**	**809,521**	**732,877**
Pumps	**kWh**	**23,733**	**265**	**33,515**	**22,652**
Totals	**kBtu**	**8,761,544**	**10,613,271**	**8,113,077**	**7,369,236**

Table 11: Phoenix Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Whole Building Energy Consumption	**Electricity (kWh)**	**1,349,730**	**1,775,453**	**1,202,032**	**1,014,396**
	Gas (therms)	**6,981**	**10,972**	**5,536**	**4,500**
	Total(kBtu)	**8,761,544**	**10,613,271**	**8,113,077**	**7,369,236**
Whole Building Energy Cost	**($)**	**218,097**	**255,883**	**197,387**	**181,379**
	($/ft²)	**1.63**	**1.92**	**1.48**	**1.36**
HVAC Energy Usage	**Electricity (kWh)**	**1,349,730**	**1,775,453**	**1,202,032**	**1,014,396**
	Gas (therms)	**4,343**	**8,334**	**2,898**	**1,862**
	Total (kBtu)	**5,039,770**	**6,891,497**	**4,172,450**	**3,674,999**
HVAC Energy Cost ($/ft²)	**($)**	**119,867**	**157,653**	**99,157**	**83,149**
	($/ft²)	**0.90**	**1.18**	**0.74**	**0.62**

Atlanta Results

Energy consumption by end use for the Atlanta location (climate zone 3A) was as follows:

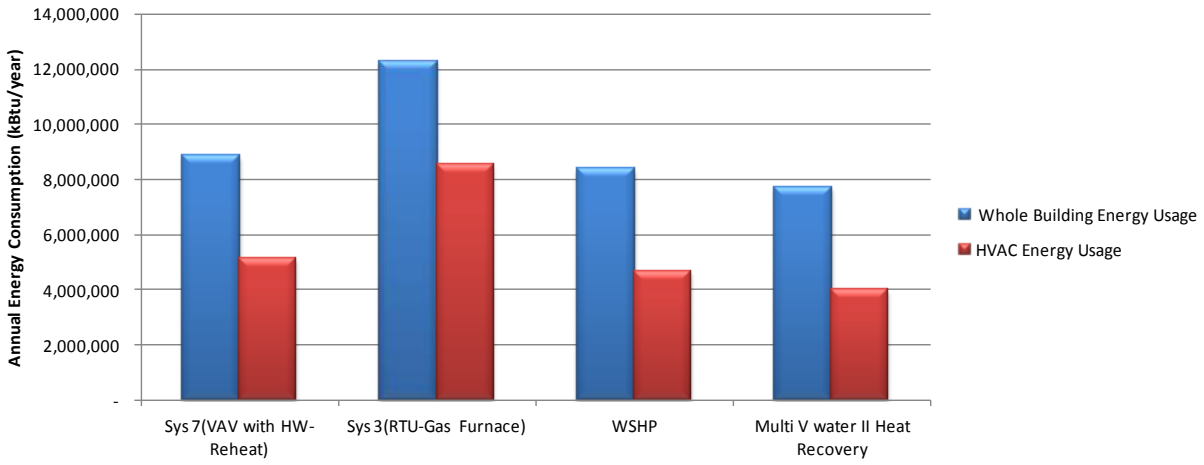

Figure 10: Annual Energy Consumption Comparisons.

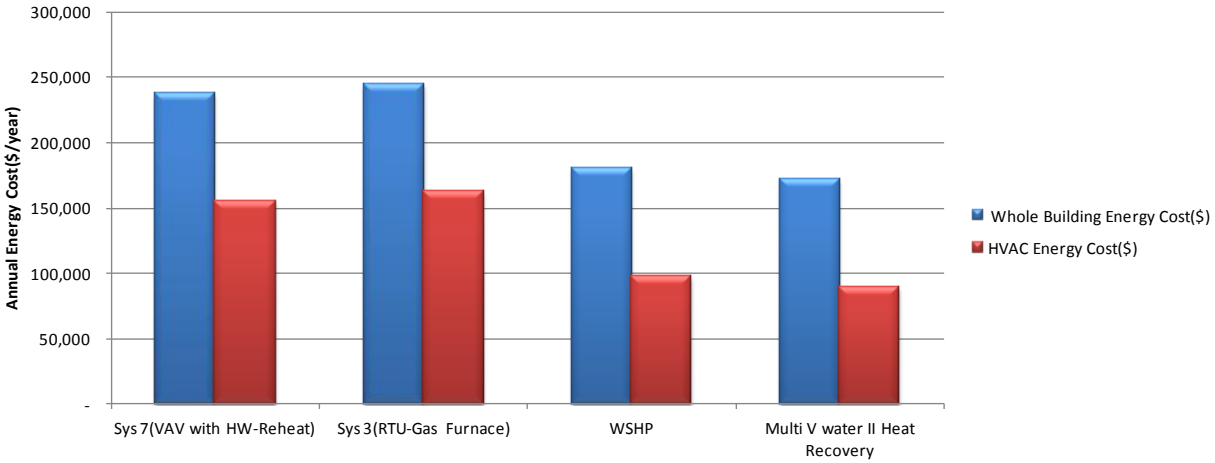

Figure 11: Atlanta Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (Sys 7, VAV with HW-Reheat) for the Multi V Water II Heat Recovery VRF systems was 21%.

Table 12: Atlanta Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Area Lights	kWh	350,047	350,047	350,047	350,047
Equipment	kWh	663,385	663,385	663,385	663,385
Hot Water	therms	2,638	2,638	2,638	2,638
Space Cooling	kWh	320,554	332,061	216,859	158,688
Space Heating	kWh	-	-	39,435	10,004
	therms	13,723	32,332	11,054	10,096
Fans	kWh	771,982	1,228,191	772,301	690,594
Pumps	kWh	15,345	-	15,396	15,496
Totals	kBtu	8,874,321	12,278,775	8,389,419	7,716,254

Table 13: Atlanta Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	2,121,313	2,573,684	2,057,423	1,888,214
	Gas (therms)	16,361	34,970	13,692	12,734
	Total(kBtu)	8,874,321	12,278,775	8,389,419	7,716,254
Whole Building Energy Cost	($)	237,173	244,851	179,675	171,662
	($/ft²)	1.78	1.83	1.34	1.28
HVAC Energy Usage	Electricity (kWh)	1,107,881	1,560,252	1,043,991	985,468
	Gas (therms)	13,723	32,332	11,054	-
	Total (kBtu)	5,152,547	8,557,001	4,667,645	3,362,556
HVAC Energy Cost ($/ft²)	($)	154,990	162,668	97,492	89,479
	($/ft²)	1.16	1.22	0.73	0.67

New York Results

Energy consumption by end use for the New York location (climate zone 4A) was as follows:

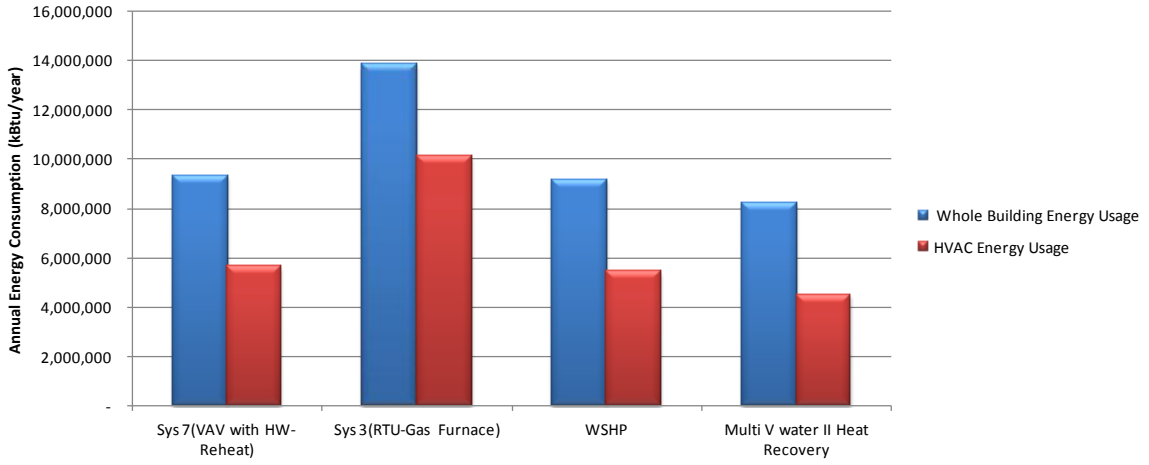

Figure 12: New York Annual Energy Consumption Comparisons.

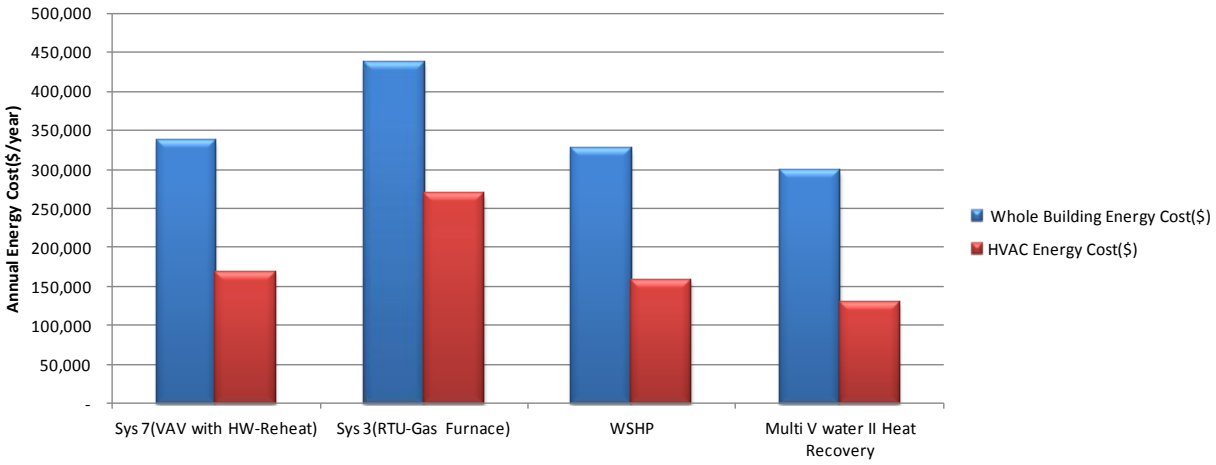

Figure 13: New York Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (Sys 7, VAV with HW-Reheat) for the Multi V Water II Heat Recovery VRF systems was 12%.

Table 14: New York Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Area Lights	kWh	350,047	350,047	350,047	350,047
Equipment	kWh	663,385	663,385	663,385	663,385
Hot Water	therms	2,638	2,638	2,638	2,638
Space Cooling	kWh	**304,455**	**233,656**	**216,141**	**144,071**
Space Heating	kWh	-	-	**68,036**	**16,704**
	therms	**18,878**	**45,833**	**18,265**	**14,697**
Fans	kWh	**773,852**	**1,382,056**	**754,439**	**710,437**
Pumps	kWh	**15,645**	**735**	**14,934**	**14,111**
Totals	kBtu	**9,342,293**	**13,820,620**	**9,143,136**	**8,212,321**

Table 15: New York Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	**2,107,384**	**2,629,879**	**2,066,982**	**1,898,755**
	Gas (therms)	**21,516**	**48,471**	**20,903**	**17,335**
	Total(kBtu)	**9,342,293**	**13,820,620**	**9,143,136**	**8,212,321**
Whole Building Energy Cost	($)	**336,255**	**437,401**	**326,518**	**297,583**
	($/ft²)	**2.52**	**3.27**	**2.44**	**2.23**
HVAC Energy Usage	Electricity (kWh)	**1,093,952**	**1,616,447**	**1,053,550**	**885,323**
	Gas (therms)	**18,878**	**45,833**	**18,265**	**14,697**
	Total (kBtu)	**5,620,519**	**10,098,847**	**5,421,362**	**4,490,548**
HVAC Energy Cost ($/ft²)	($)	**167,439**	**268,585**	**157,702**	**128,767**
	($/ft²)	**1.25**	**1.73**	**1.15**	**0.96**

Chicago Results

Energy consumption by end use for the Chicago location (climate zone 5A) was as follows:

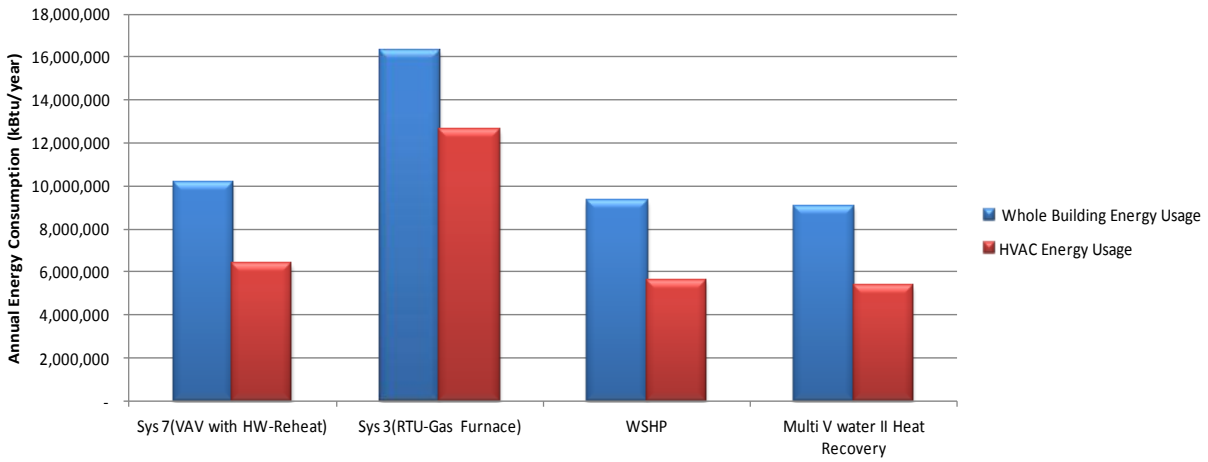

Figure 14: Chicago Annual Energy Consumption Comparisons.

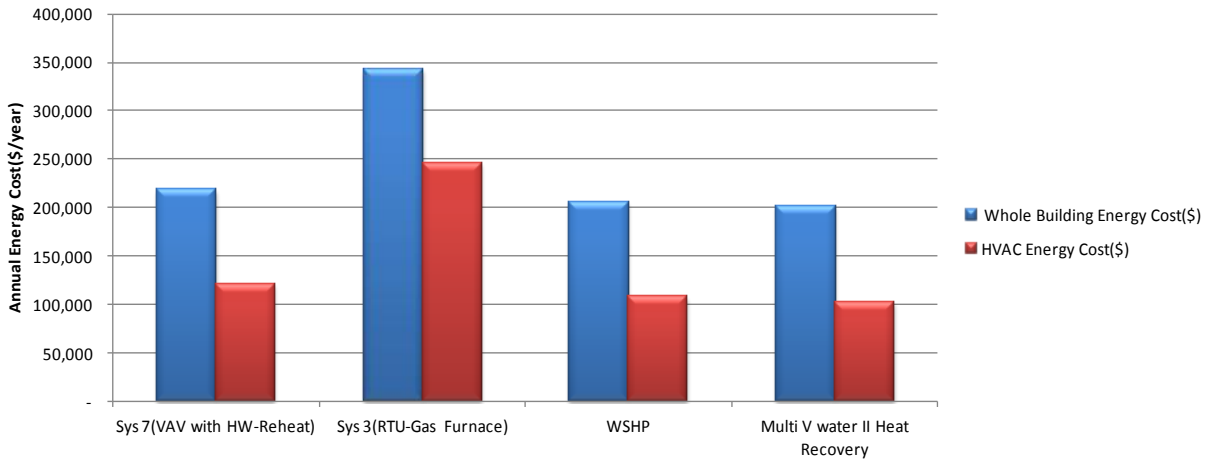

Figure 15: Chicago Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (Sys 7, VAV with HW-Reheat) for the Multi V Water II Heat Recovery VRF systems was 8%.

Table 16: Chicago Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Area Lights	kWh	350,047	350,047	350,047	350,047
Equipment	kWh	663,385	663,385	663,385	663,385
Hot Water	therms	2,638	2,638	2,638	2,638
Space Cooling	kWh	216,407	216,878	155,835	121,992
Space Heating	kWh	-	-	114,861	32,383
	therms	29,226	56,029	20,190	20,813
Fans	kWh	793,323	1,833,552	768,064	793,072
Pumps	kWh	10,767	-	8,153	9,049
Totals	kBtu	10,126,454	16,327,092	9,312,989	9,066,774

Table 17: Chicago Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		Sys 7 (VAV with HW-Reheat)	Sys 3 (RTU-Gas Furnace)	WSHP	Multi-V water II Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	2,033,929	3,065,638	2,060,345	1,969,928
	Gas (therms)	31,864	58,667	22,828	23,451
	Total(kBtu)	10,126,454	16,327,092	9,312,989	9,066,774
Whole Building Energy Cost	($)	218,808	343,420	205,967	200,837
	($/ft²)	1.64	2.57	1.54	1.5
HVAC Energy Usage	Electricity (kWh)	1,020,497	2,050,430	1,046,913	1,060,151
	Gas (therms)	29,226	56,029	20,190	-
	Total (kBtu)	6,404,681	12,599,258	5,591,216	3,617,385
HVAC Energy Cost ($/ft²)	($)	120,797	245,409	107,956	102,826
	($/ft²)	0.90	1.84	0.81	0.77

LEED for New Construction & Major Renovations

The LEED (Leadership in Energy and Environmental Design) 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 then are awarded certification levels.

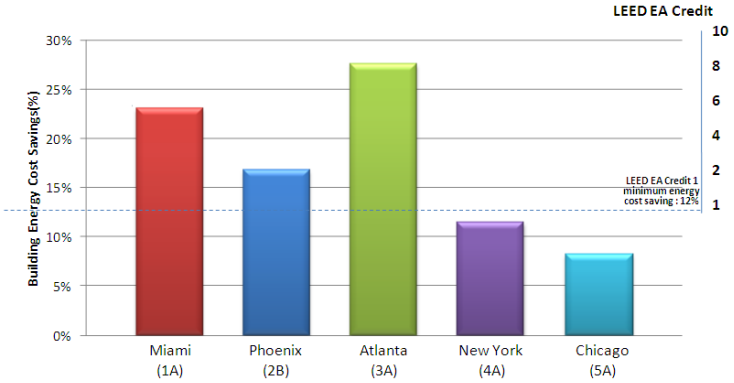

Figure 16 LG Multi V Water II Heat Recovery VRF systems Building Energy Cost Savings (%) and Potential LEED Points.

* EA Credit 1: Optimize Energy Performance (1–19 points)

Percentage energy cost saving in the proposed building performance rating was 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. The minimum energy cost savings percentage for each point threshold is as follows:

New Buildings	Existing Building	Renovations 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 is engineered for sustainable green building and 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 18 LG Electronics' recommendations and strategies towards 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/exceed ASHRAE Standard 90.1-2007. • All LG Electronics' products use environmentally friendly refrigerant R410A. • 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 eco V (Heat Recovery Ventilator).
	Prereq 3	Fundamental Refrigerant Management	Required	
	Credit 1	Optimize Energy Performance	1 to 19	
	Credit 4	Enhanced Refrigerant Management	2	
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 eco V (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 6.8.1E: Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm Air Duct Furnaces and Unit Heaters.
- 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.

Electricity 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
- Miami: FLORIDA POWER & LIGHT COMPANY, General Service Demand - Time of Use GSDT-1, www.fpl.com/rates/pdf/electric_tariff_section8.pdf
- Phoenix: ARIZONA PUBLIC SERVICE COMPANY, E-32 Large Plan, www.aps.com/main/services/business/rates/BusRatePlans_19.html
- Atlanta: Georgia Power -TOU-GSD-5 >500kW Primary, www.georgiapower.com/pricing/business/medium-business.asp
- New York: NY-ConEd- Rate II - General - Large, http://www.coned.com/rates/
- Chicago: ComED-Non-Residential, www.comed.com/sites/customerservice/Pages/RateInformation.aspx

Natural Gas Rates

- Miami: Peoples Gas, General Service,GS-2, www.peoplesgas.com/data/files/tariff/TariffSect7.pdf
- Phoenix: Southwest Gas, G-25 General Gas Service, www.swgas.com/tariffs/aztariff/schedules/g25.pdf
- Atlanta: Georgia Natural Gas - Standard Plan, www.gasgeorgia.com/fixed.html
- New York: NY Coned-Rate II - General - Heating, www.coned.com/rates/
- Chicago: People Gas Rate-2 , www.peoplesgasdelivery.com/business/gas_rates.aspx

Background and General Information

- NREL, Strategies for 50% Energy Savings in Large Office Buildings, 2009. www.nrel.gov/docs/fy10osti/49213.pdf.
- U.S. Green Building Council, LEED for New Construction & Major Renovations