Energy Efficiency Analysis
for a Multi-Story Research Office Building

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

(* Source: http://kr.lgeaircon.com/)

Contents

Executive Summary

LG Electronics U.S.A. Commercial Air-Conditioning (LG CAC) conducted an energy efficiency option analysis for a proposed research office building design. To provide a concrete basis for analysis, the building was built in Department of Energy (DOE) climate zones, 1A, 2A, 3A, 3B, 4A, and 5A. This study explores the energy and potential cost savings of operating a LG Multi V™ Water IV 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 IV VRF systems provided significant annual utility bill savings when compared to all LEED baseline building systems.

Table 1 Summary of LG Multi V Water IV Heat Recovery

HVAC Energy Cost Savings and % Savings

Location (Climate zone)	Multi V Water IV Heat Recovery	
	Savings ($)*	Savings (%)*
Miami, FL(1A)	67,558	60%
Houston, TX (2A)	47,000	54%
Atlanta, GA (3A)	46,232	54%
Los Angeles, CA (3B)	48,341	66%
New York, NY(4A)	79,498	55%
Chicago, IL (5A)	36,835	41%

[*Compared to the LEED baseline, ASHRAE STD 90.1 Sys 5: Packaged 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 explored the implementation of an LG Multi V Water IV Heat Recovery VRF system in a typical new construction multi-story commercial Research office building. Specifically, it compared the energy saving when compared to a baseline building as the United States Green Building Council (USGBC's®) LEED 2009[1]. The study was conducted using a building model with the same physical properties, and based on the exact same plans in six different climates—Miami, FL (1A), Houston, TX (2A), Atlanta, GA (3A), Los Angeles, CA (3B), New York, NY (4A), and Chicago, IL (5A).

The building consisted of four stories with a total area of conditioned space at 70,128 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 was introduced to the inlet of the dedicated outdoor air system serving spaces of the building.

The building 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, 55 hours per week).

Table 2: Research Office Space Types and Sizes

Space Types	Size (ft^2)
Office Area	23,393
Atrium	21,484
Laboratory	20,994
Conference/Meeting/Multipurpose	4,246
ETC	11
Total	70,128

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 (Residential Building)
- 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.

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.

The conditioned areas were served by ASHRAE Standard 90.1-2007 a System 5 packaged variable air volume (VAV) rooftop with reheat, and a chilled water which included 4-pipe fan coil unit that supplied conditioned air to each room. In addition, an ASHRAE Standard 90.1-2007 minimum efficient water-source heat pump (WSHP) was also considered as a baseline HVAC system.

The office building was assumed to be fully heated and cooled. Setup and setback schedules were implemented during unoccupied hours (nighttime), when the HVAC system was 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 was 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 IV 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 1)

Multi V Water IV system features superior energy efficiency and longer piping capabilities and is AHRI 1230 certified. Multi V Water IV system could reduce operational costs while providing reliable heat in colder regions. Multi V Water IV system's advanced rapid start feature enables the compressors to come on faster to meet startup load. LG Multi V Water IV 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 1: Multi V Water IV Heat Recovery Units, Heat Recovery Unit, and Ducted / Non-Ducted Indoor Units.

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)	Houston, TX (2A)	Atlanta, GA (3A)	Los Angeles, CA (3B)	New York, NY (4A)	Chicago, IL (5A)
Windows: (36% of Wall Area)	Assembly U-factor	U-1.20	U-0.55	U-0.6	U-0.6	U-0.50	0.45
	SHGC	0.25	0.25	0.25	0.25	0.40	0.40
Exterior Walls (Mass wall building)	Above Grade	U-0.124	U-0.124	U-0.084	U-0.084	U-0.064	0.064
	Below Grade	U-0.084	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	U-0.048	0.048
Floors		U-0.253	U-0.052	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	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 System 5, packaged rooftop variable air volume [VAV] with reheat) was the baseline defined by ASHRAE Standard. 90.1 2007 for the building size and type (nonresidential with four or five floors or more than 25,000 ft², or five floors or less and 25,000 ft² to 150,000 ft²). A 4-pipe chiller/boiler system is a typical HVAC system used in many commercial building types, however, 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		ASHRAE Baseline System5: Packaged VAV with Reheat	4-Pipe	WSHP: ASHRAE minimum efficiency	Multi V Water IV Heat Recovery
Cooling	Cooling Tower		200 tons, Two-Speed-Fan	200 tons, Two-Speed-Fan	200 tons, Two-Speed-Fan
	Chiller		200 tons, 4.90 COP (150~300 Ton)	-	-
	DX-Cooling	EER 9.5 (240,000~760,000 Btu/h)		EER 12.0 (65,000~135,000 Btu/h)	EER *13.0~16.1 (65,000~135,000 Btu/h)
Heating	HW-Boiler (Natural Gas)	η = 80%	η = 80%	η = 80%	η = 80%
	Heat pump	-	-	COP: 4.2	COP*: 4.4~5.1
OA Processing		DOAS (ASHRAE minimum efficiency)	DOAS (ASHRAE minimum efficiency)	DOAS (ASHRAE minimum efficiency)	DOAS (ASHRAE minimum efficiency)
Air Systems		8 × Packaged VAV (variable air volume)	213 Fan coil units (2-speed air volume)	33 × Built-Up WSHP (5~6 RT)	8 × LG Multi V Water IV Heat Recovery (16~30 RT)+ Concealed Ducted/ Non-Ducted Indoor Units

(*https://www.ahridirectory.org/ahridirectory/pages/vrfhp/defaultSearch.aspx)

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, Peak Hot Water Demand: 7.966 gpm)	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: 0.945 w/ft²)	Same	ASHRAE 90.1-2007 Table 9.5.1: *Lighting Power Densities Using the Building Area Method*

Receptacle Load

Baseline and proposed receptacle equipment were as follows:

Table 7: Interior-Lighting Energy Characteristics

	Baseline	Proposed	Notes
Receptacle load	2.27 w/ft² -Total Power Modeled Using Space-by-Space Method (kW):159.2	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[1]:

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

[1]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 roughly consume an average of 93 kBtu per square foot of site energy each year. Office buildings represent nearly one-fifth of all energy consumed by commercial buildings, and are, therefore, an important focus for energy efficiency improvements (EIA 2005).[2] The goal for the case study was to to investigate the feasibility of reducing energy use in newly constructed 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 IV Heat Recovery

The whole building energy cost savings realized with the Multi V Water IV Heat Recovery VRF systems was 28% when compared to ASHRAE Baseline system-5, and 55% average HVAQC energy cost savings when comparing the baseline HVAC systems. The whole building energy cost savings realized with the Multi V Water IV Heat Recovery system was 32% when compared to a 4-pipe system, and a 60% average HVAC savings when comparing HVAC energy cost. The whole building energy cost savings realized with the Multi V Water IV Heat Recovery system was 21% 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 IV Heat Recovery system was 45% less on average. (See Figure 2 and Figure 3)

Based on the average energy cost savings from the models, future projects would meet the LEED 2009 EA prerequisite, and qualify for LEED EA credit 1 points. The savings are detailed in Figure 4 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 25).

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

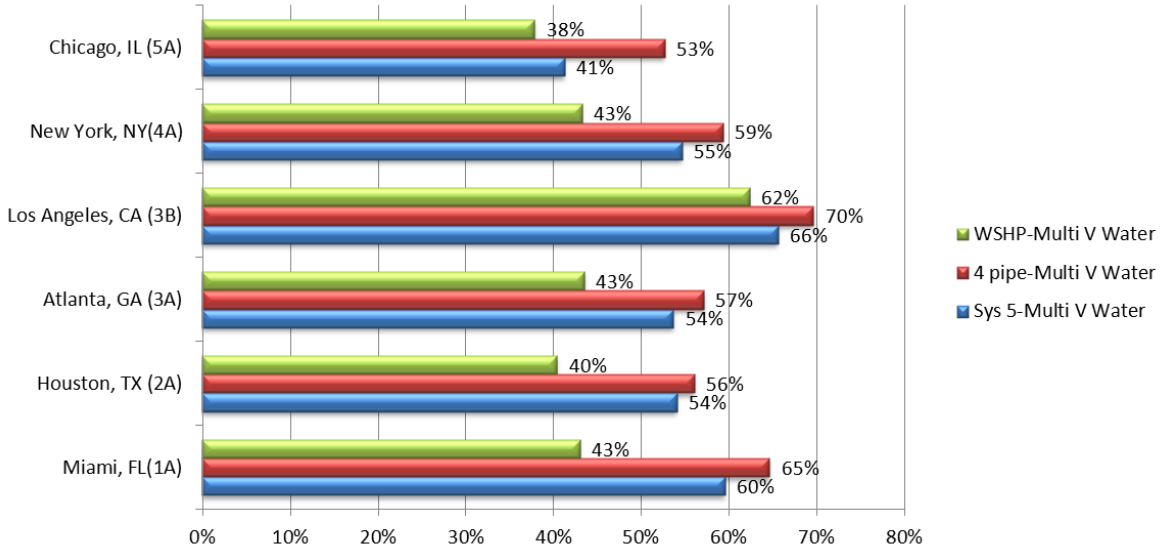

Figure 2 : LG Multi V Water IV VRF systems Whole Building Energy Cost (%) Savings.

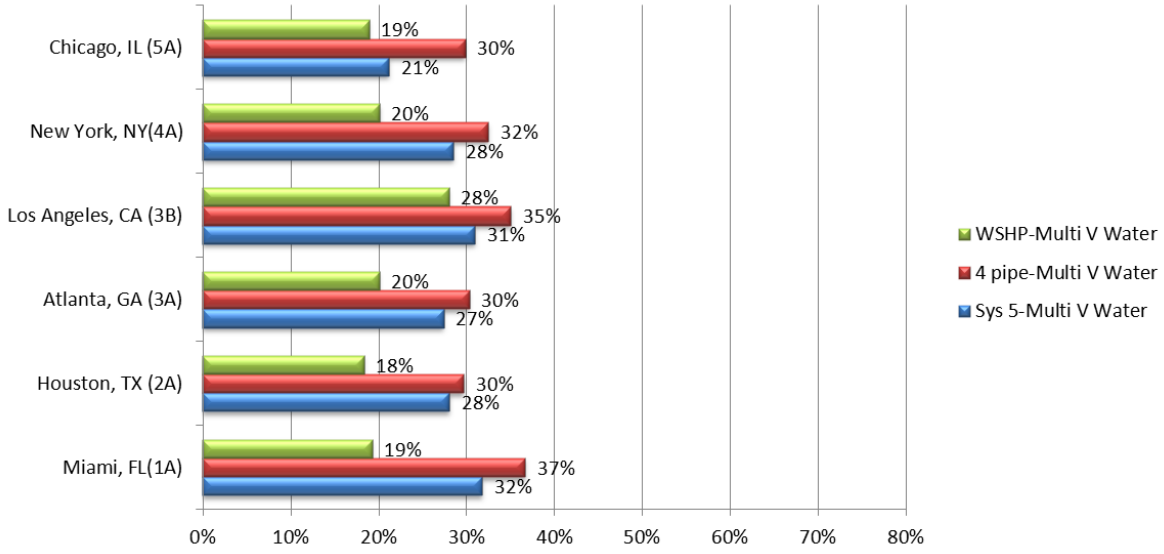

Figure 3 : LG Multi V Water IV VRF systems HVAC Energy Cost (%) Savings.

Miami Results

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

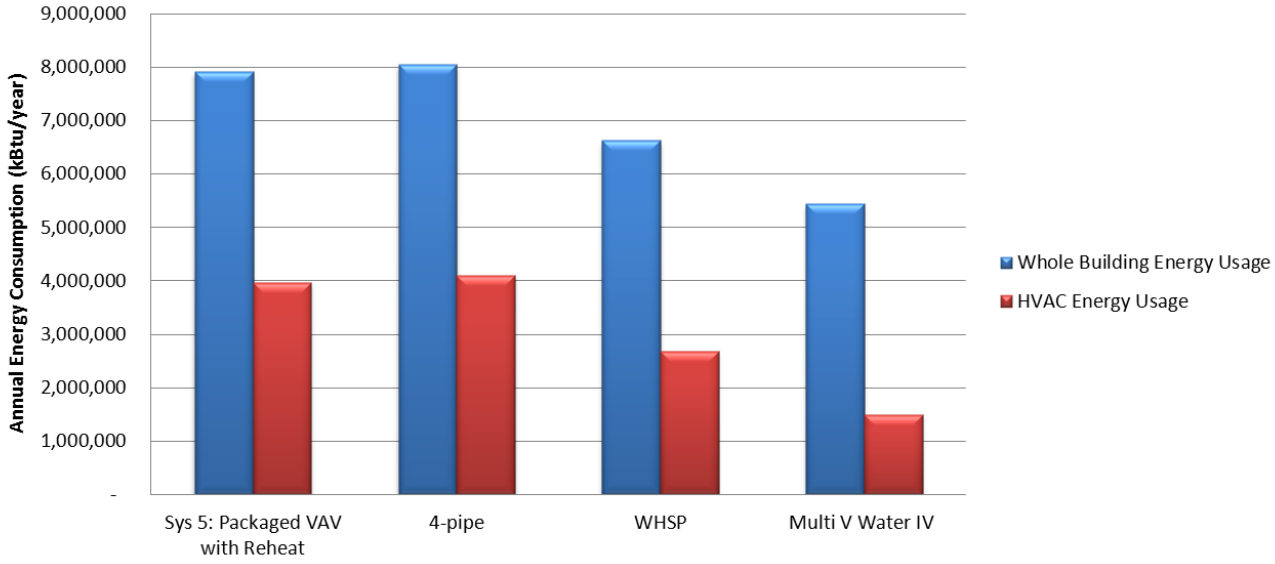

Figure 4: Miami Annual Energy Consumption Comparisons.

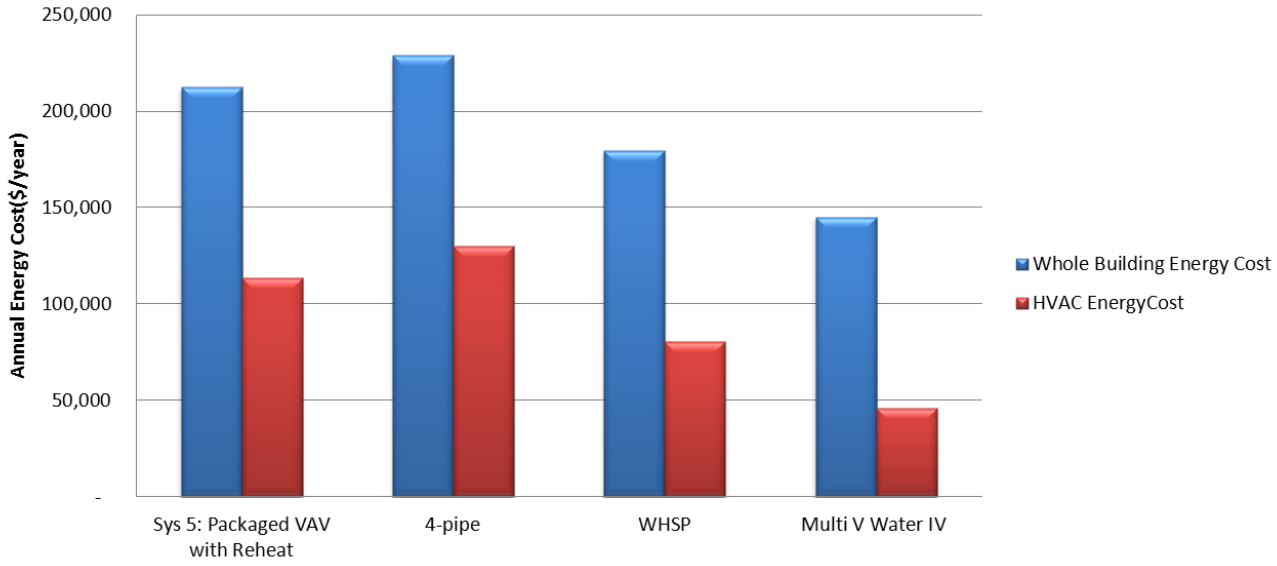

Figure 5: Miami Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (System 5, Packaged Rooftop VAV with Reheat) for the Multi V Water IV Heat Recovery VRF systems was 32%.

Table 8: Miami Annual Energy Consumption by End Use

		Baseline (ASHRAE Standard 90.1-2007)			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Area Lights	kWh	221,961	221,961	221,961	221,961
Equipment	kWh	533,811	533,811	533,811	533,811
Hot Water	therms	13,598	13,598	13,598	13,598
Space Cooling	kWh	826,492	776,714	430,739	263,635
Space Heating	therms	6,698	535	2,519	914
	kWh	-	-	1,846	174
Fans	kWh	134,004	384,465	228,014	106,091
Pumps	kWh	5,541	23,644	50,177	41,292
Totals	kBtu	7,907,856	8,038,491	6,618,495	5,435,215

Table 9: Miami Estimated Annual Energy Use and Cost

		Baseline (ASHRAE Standard 90.1-2007)			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	1,721,809	1,940,595	1,466,548	1,166,964
	Gas (therms)	20,296	14,133	16,117	14,512
	Total (kBtu)	7,907,856	8,038,491	6,618,495	5,435,215
Whole Building Energy Cost	($)	212,519	228,824	179,581	144,962
	($/ft^2)	3.03	3.26	2.56	2.07

Table 10: Miami Estimated Annual HVAC Energy Use and Cost

		Baseline (ASHRAE Standard 90.1-2007)			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
HVAC Energy Usage	Electricity (kWh)	966,037	1,184,823	710,776	411,192
	Gas (therms)	6,698	535	2,519	914
	Total (kBtu)	3,967,850	4,098,486	2,678,489	1,495,209
HVAC Energy Cost ($/ft^2)	($)	113,496	129,801	80,558	45,939
	($/ft^2)	1.62	1.85	1.15	0.66

Houston Results

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

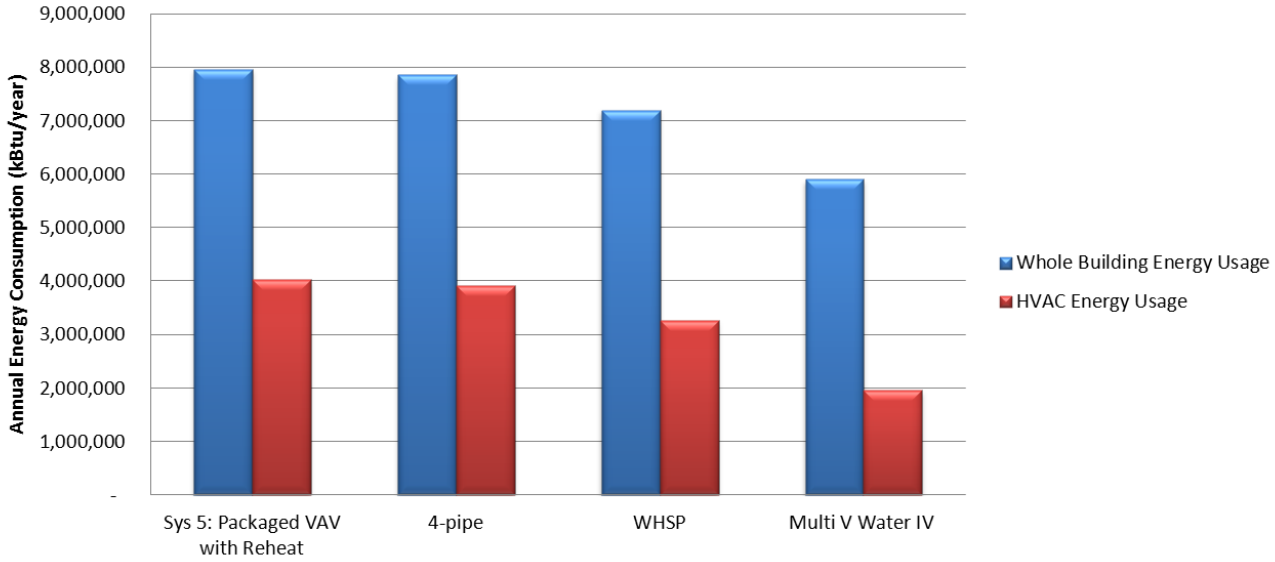

Figure 6: Houston Annual Energy Consumption Comparisons.

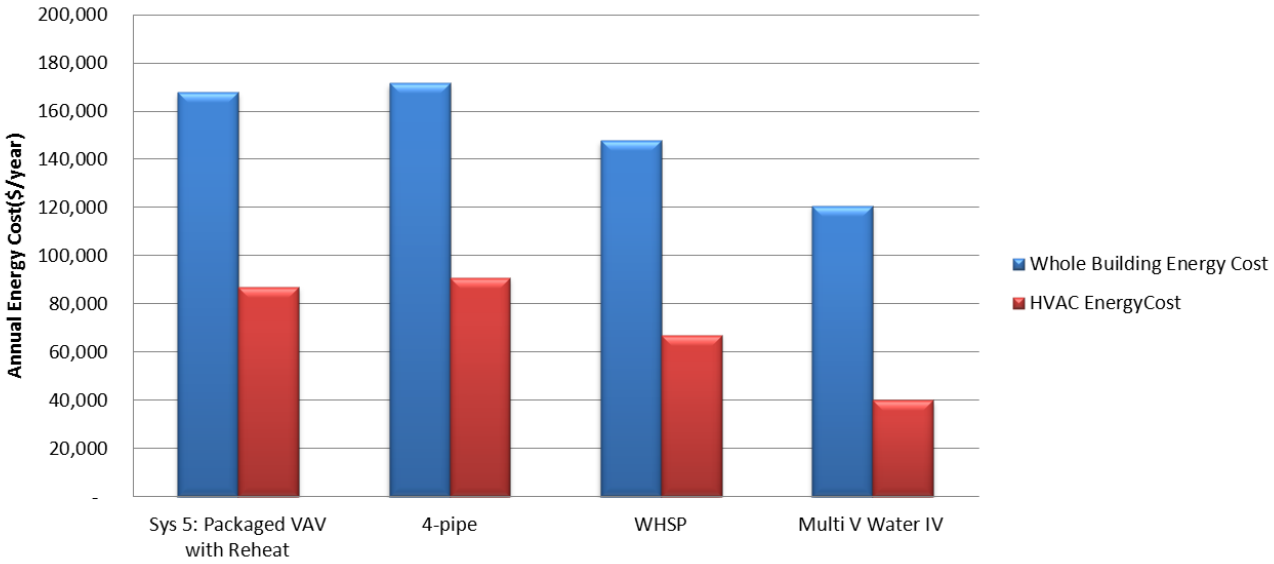

Figure 7: Houston Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (System 5, packaged rooftop VAV with Reheat) for the Multi V Water IV Heat Recovery VRF systems was 28%.

Table 11: Houston Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Area Lights	kWh	221,961	221,961	221,961	221,961
Equipment	kWh	533,811	533,811	533,811	533,811
Hot Water	therms	13,598	13,598	13,598	13,598
Space Cooling	kWh	737,024	612,251	343,769	227,971
Space Heating	therms	10,298	5,174	10,878	6,842
	kWh	-	-	7,356	1,168
Fans	kWh	134,021	357,132	240,067	106,574
Pumps	kWh	5,905	26,199	43,011	37,335
Totals	kBtu	7,963,713	7,856,323	7,192,975	5,897,791

Table 12: Houston Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5,: Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	1,632,722	1,751,354	1,389,975	1,128,820
	Gas (therms)	23,896	18,772	24,476	20,440
	Total (kBtu)	7,963,713	7,856,323	7,192,975	5,897,791
Whole Building Energy Cost	($)	167,600	171,504	147,666	120,600
	($/ft^2)	2.39	2.45	2.11	1.72

Table 13: Houston Estimated Annual HVAC Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
HVAC Energy Usage	Electricity (kWh)	876,950	995,582	634,203	373,048
	Gas (therms)	10,298	5,174	10,878	6,842
	Total (kBtu)	4,023,707	3,916,317	3,252,969	1,957,786
HVAC Energy Cost ($/ft^2)	($)	86,960	90,864	67,026	39,961
	($/ft^2)	1.24	1.30	0.96	0.57

Atlanta Results

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

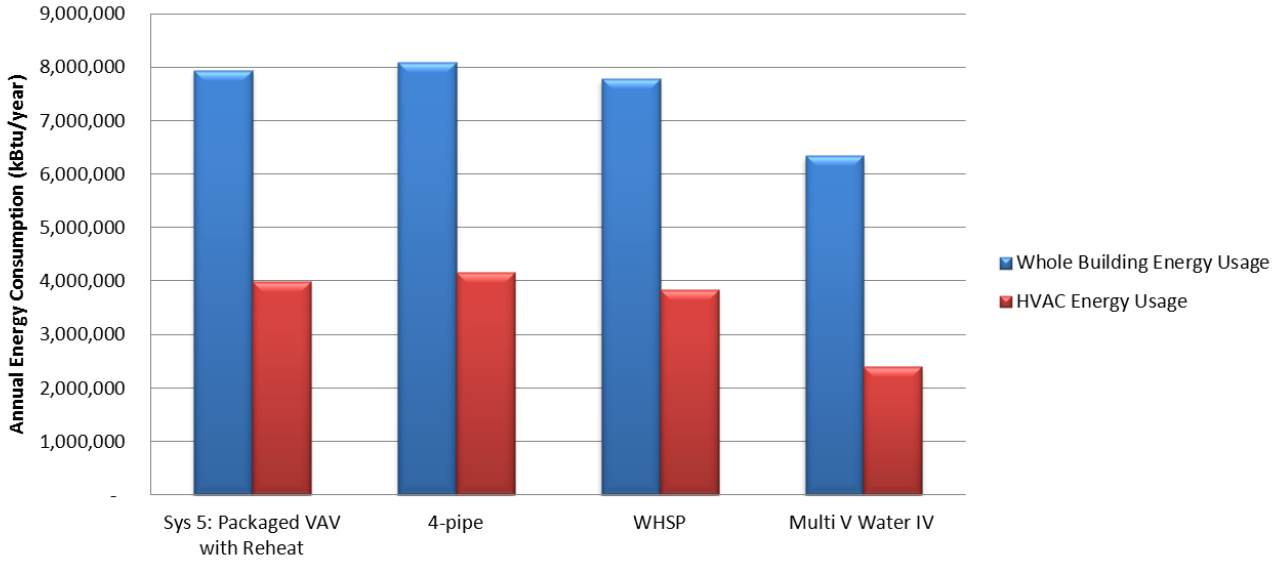

Figure 8: Annual Energy Consumption Comparisons.

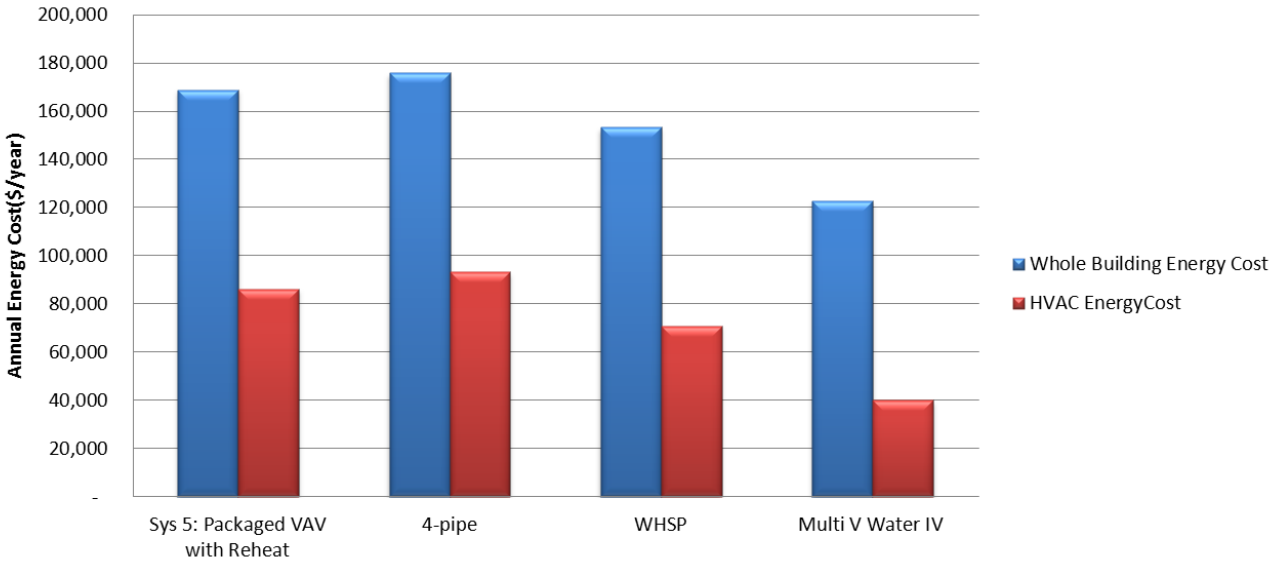

Figure 9: Atlanta Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (System 5, Packaged Rooftop VAV with Reheat) for the Multi V Water IV Heat Recovery VRF systems was 27%.

Table 14: Atlanta Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Area Lights	kWh	221,961	221,961	221,961	221,961
Equipment	kWh	533,811	533,811	533,811	533,811
Hot Water	therms	13,598	13,598	13,598	13,598
Space Cooling	kWh	676,770	544,880	267,373	132,608
Space Heating	therms	12,167	10,268	19,858	15,310
	kWh	-	-	12,737	4,363
Fans	kWh	132,496	345,503	233,545	93,773
Pumps	kWh	5,829	27,269	30,701	25,265
Totals	kBtu	7,939,440	8,099,670	7,784,237	6,345,020

Table 15: Atlanta Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	1,570,867	1,673,424	1,300,128	1,011,781
	Gas (therms)	25,765	23,866	33,456	28,908
	Total (kBtu)	7,939,440	8,099,670	7,784,237	6,345,020
Whole Building Energy Cost	($)	168,715	175,712	153,249	122,483
	($/ft^2)	2.41	2.51	2.19	1.75

Table 16: Atlanta Estimated Annual HVAC Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
HVAC Energy Usage	Electricity (kWh)	815,095	917,652	544,356	256,009
	Gas (therms)	12,167	10,268	19,858	15,310
	Total (kBtu)	3,999,434	4,159,664	3,844,231	2,405,015
HVAC Energy Cost ($/ft^2)	($)	86,195	93,192	70,728	39,963
	($/ft^2)	1.23	1.33	1.01	0.57

Los Angeles Results

Energy consumption by end use for the Los Angeles location (climate zone 3B) was as follows:

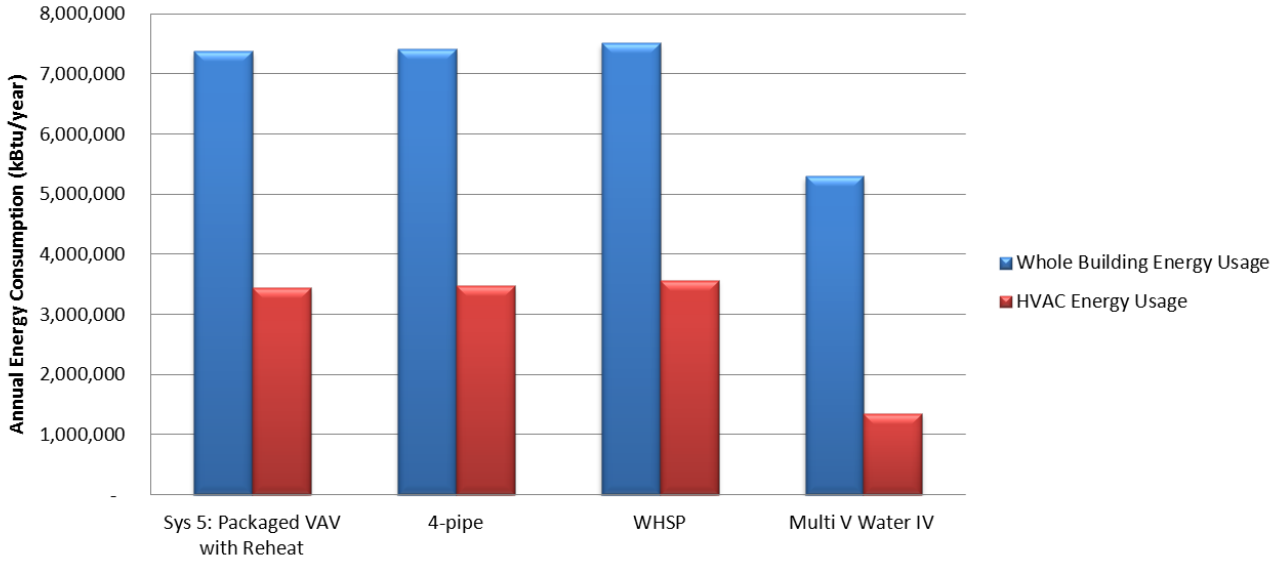

Figure 10: Annual Energy Consumption Comparisons.

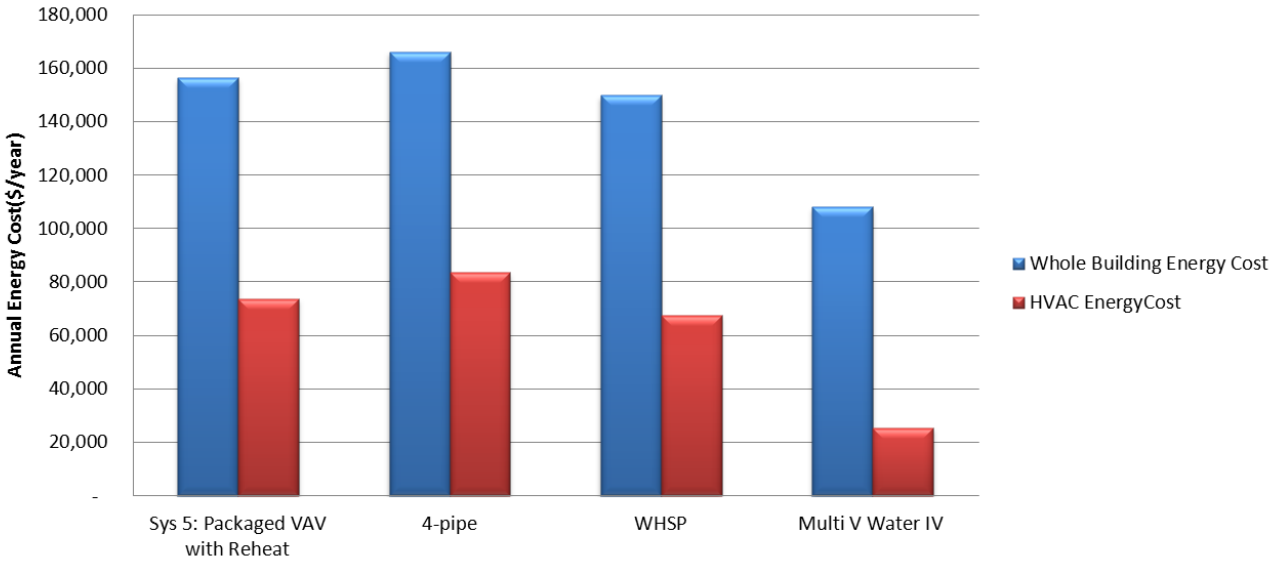

Figure 11: Atlanta Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (System 5, Packaged Rooftop VAV with Reheat) for the Multi V Water IV Heat Recovery VRF systems was 31%.

Table 17: Los Angeles Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Area Lights	kWh	221,961	221,961	221,961	221,961
Equipment	kWh	533,811	533,811	533,811	533,811
Hot Water	therms	13,598	13,598	13,598	13,598
Space Cooling	kWh	555,359	509,237	288,166	88,384
Space Heating	therms	10,695	4,854	17,334	6,753
	kWh	-	-	4,479	404
Fans	kWh	133,290	342,030	220,458	90,323
Pumps	kWh	4,703	25,372	24,890	20,783
Totals	kBtu	7,376,609	7,418,251	7,510,114	5,297,744

Table 18: Los Angeles Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	1,449,124	1,632,411	1,293,765	955,666
	Gas (therms)	24,293	18,452	30,932	20,351
	Total (kBtu)	7,376,609	7,418,251	7,510,114	5,297,744
Whole Building Energy Cost	($)	156,229	165,988	149,851	107,888
	($/ft^2)	2.23	2.37	2.14	1.54

Table 19: Los Angeles Estimated Annual HVAC Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
HVAC Energy Usage	Electricity (kWh)	693,352	876,639	537,993	199,894
	Gas (therms)	10,695	4,854	17,334	6,753
	Total (kBtu)	3,436,604	3,478,246	3,570,108	1,357,738
HVAC Energy Cost ($/ft^2)	($)	73,708	83,467	67,330	25,367
	($/ft^2)	1.05	1.19	0.96	0.36

New York Results

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

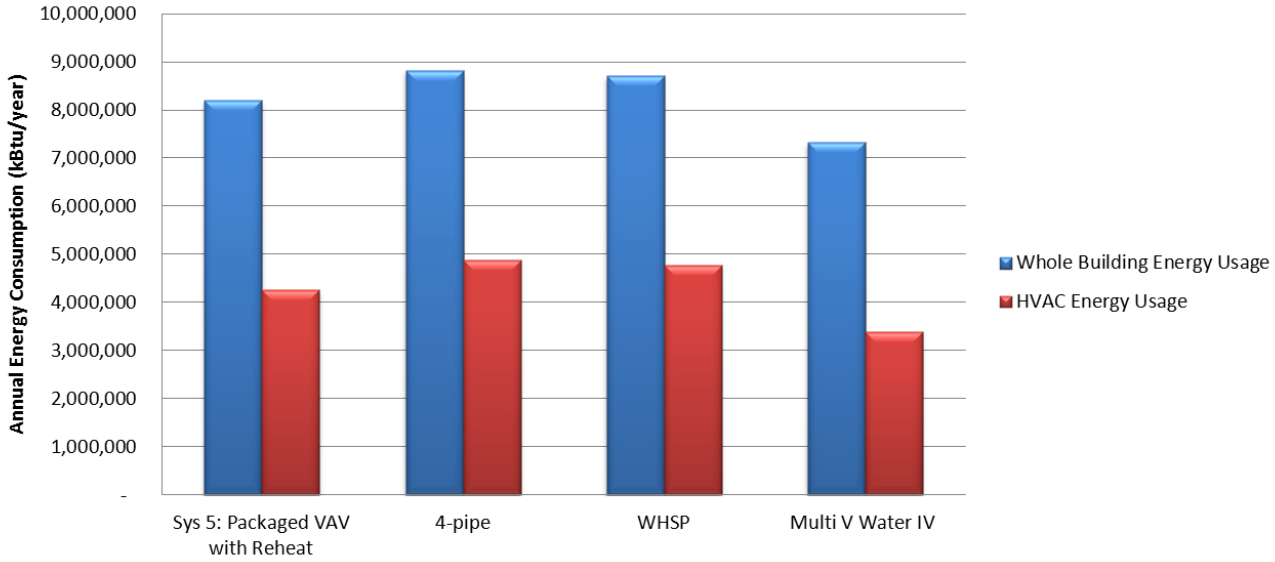

Figure 12: New York Annual Energy Consumption Comparisons.

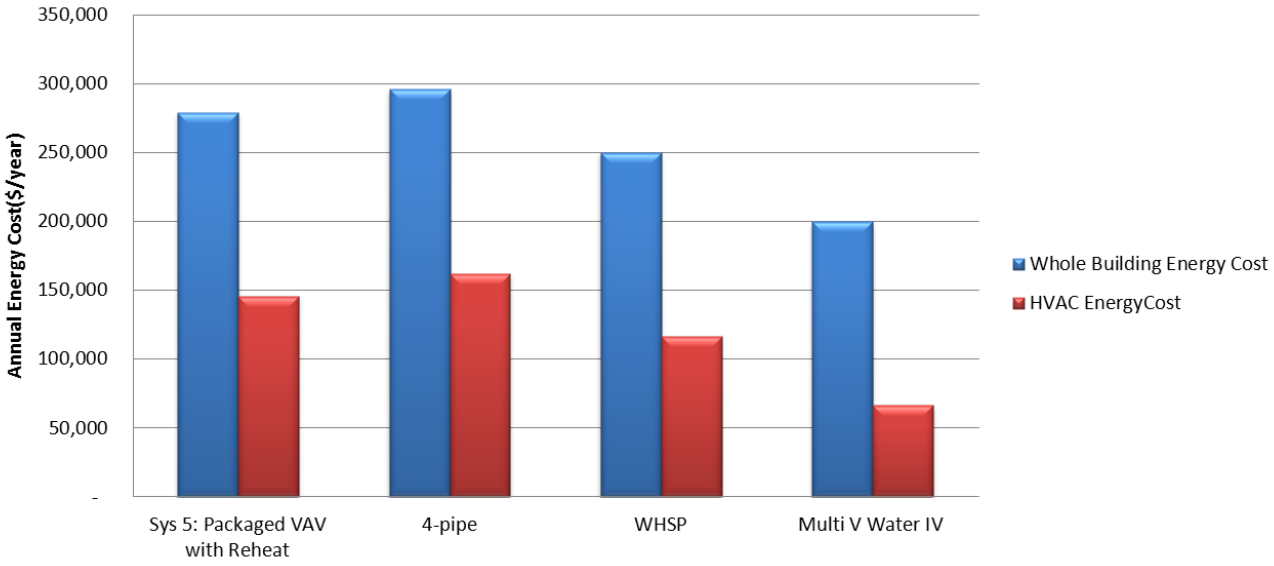

Figure 13: New York Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (System 5, Packaged Rooftop VAV with Reheat) for the Multi V Water IV Heat Recovery VRF systems was 28%.

Table 20: New York Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Area Lights	kWh	221,961	221,961	221,961	221,961
Equipment	kWh	533,811	533,811	533,811	533,811
Hot Water	therms	13,598	13,598	13,598	13,598
Space Cooling	kWh	693,475	512,904	232,011	98,951
Space Heating	therms	14,320	17,984	30,133	26,308
	kWh	-	-	17,186	7,667
Fans	kWh	126,958	366,679	240,125	92,345
Pumps	kWh	6,029	25,082	24,467	20,870
Totals	kBtu	8,193,547	8,826,932	8,707,381	7,321,315

Table 21: New York Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	1,582,234	1,660,437	1,269,561	975,605
	Gas (therms)	27,918	31,582	43,731	39,906
	Total(kBtu)	8,193,547	8,826,932	8,707,381	7,321,315
Whole Building Energy Cost	($)	279,083	295,645	249,784	199,585
	($/ft^2)	3.98	4.22	3.56	2.85

Table 22: New York Estimated Annual HVAC Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
HVAC Energy Usage	Electricity (kWh)	826,462	904,665	513,789	219,833
	Gas (therms)	14,320	17,984	30,133	26,308
	Total (kBtu)	4,253,541	4,886,926	4,767,376	3,381,310
HVAC Energy Cost ($/ft^2)	($)	145,457	162,020	116,158	65,959
	($/ft^2)	2.07	2.31	1.66	0.94

Chicago Results

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

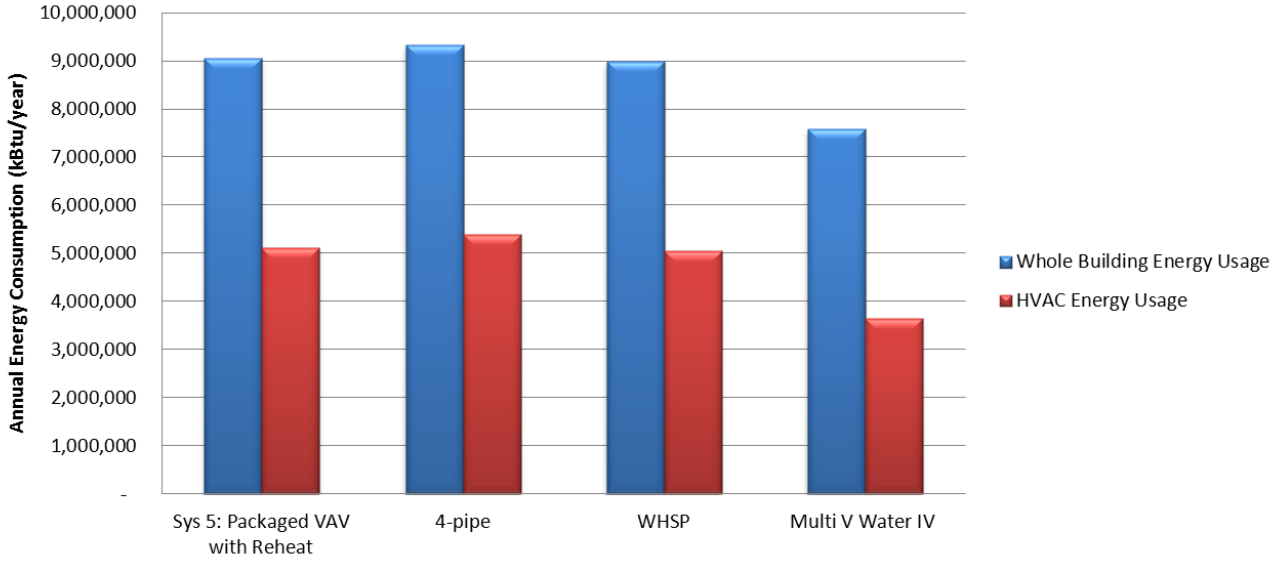

Figure 14: Chicago Annual Energy Consumption Comparisons.

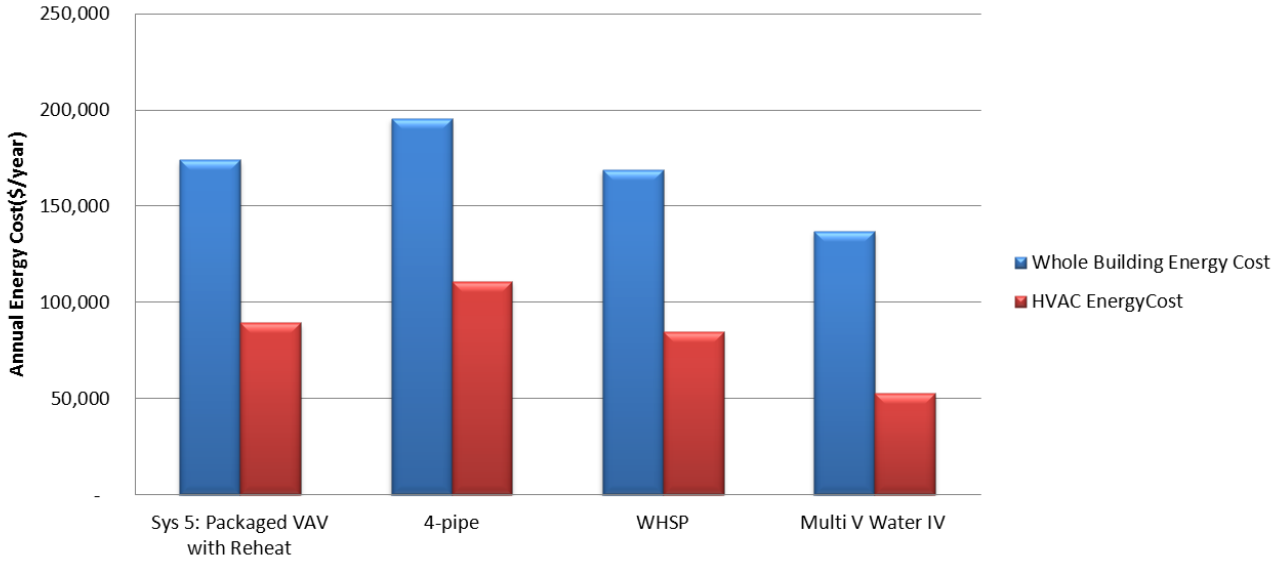

Figure 15: Chicago Annual Building Energy Cost Comparisons.

The following tables summarize the energy usage and cost savings for the different cases. The whole building energy cost savings over the baseline (System 5, Packaged Rooftop VAV with Reheat) for the Multi V Water IV Heat Recovery VRF systems was 21%.

Table 23: Chicago Annual Energy Consumption by End Use

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Area Lights	kWh	221,961	221,961	221,961	221,961
Equipment	kWh	533,811	533,811	533,811	533,811
Hot Water	therms	13,598	13,598	13,598	13,598
Space Cooling	kWh	259,899	523,759	223,498	99,390
Space Heating	therms	31,268	21,967	33,285	29,626
	kWh	-	-	22,895	9,881
Fans	kWh	305,590	390,368	233,722	64,077
Pumps	kWh	17,716	24,436	23,695	26,012
Totals	kBtu	9,057,867	9,340,960	8,988,513	7,583,221

Table 24: Chicago Estimated Annual Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
Whole Building Energy Consumption	Electricity (kWh)	1,338,977	1,694,335	1,259,582	955,132
	Gas (therms)	44,866	35,565	46,883	43,224
	Total(kBtu)	9,057,867	9,340,960	8,988,513	7,583,221
Whole Building Energy Cost	($)	173,891	195,440	169,006	137,057
	($/ft^2)	2.48	2.79	2.41	1.95

Table 25: Chicago Estimated Annual HVAC Energy Use and Cost

		ASHRAE Standard 90.1-2007			Proposed
		System 5, Packaged VAV with Reheat	4-Pipe	WSHP	Multi V Water IV Heat Recovery
HVAC Energy Usage	Electricity (kWh)	583,205	938,563	503,810	199,360
	Gas (therms)	31,268	21,967	33,285	29,626
	Total (kBtu)	5,117,862	5,400,954	5,048,507	3,643,215
HVAC Energy Cost ($/ft^2)	($)	89,343	110,891	84,457	52,508
	($/ft^2)	1.27	1.58	1.20	0.75

LEED for New Construction & Major Renovations

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 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.

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 was calculated using a simulation model for the whole building project. The minimum energy cost savings percentage for each point threshold was as follows:

Table 26 EA Credit 1: Optimize Energy Performance (1–19 points)

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

Multi V VRF air conditioning systemsmay provide 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 27 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. ○ All LG Electronics' products use R410A refrigerant. ○ Multi V offers energy performance by using state of the art controls, 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	
	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 zone. ○ 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 6.8.1E: 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

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

- 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