Energy Efficiency Analysis for a Low-rise Office Building

(LG Multi V™ IV Heat Recovery System)

Contents

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.*

Note: ***Legal Disclaimer****: 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.*

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, 2A, 3A, 4A, and 5A. This study explores the energy and cost savings of operating an LG Multi V™ 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 using the same floor plans, occupancy schedules, lighting power density, ventilation, and envelopes types. Only the mechanical system types and associated efficiencies differed for each simulation.

The simulations demonstrated that the proposed designs using LG Multi V IV Heat Recovery VRF systems provide significant annual utility bill savings when compared to all LEED baseline building systems (Table 1).

Table 1 Summary of LG Multi V IV Heat Recovery HVAC Energy Cost % Savings

Location (Climate zone)	Multi V IV Heat Recovery Savings (%) *
Miami, FL(1A)	26.7
Houston, TX (2A)	29.1
Atlanta, GA (3A)	28.5
New York, NY(4A)	29.2
Chicago, IL (5A)	36.0

[*Compared to the LEED® baseline System 4: Packaged rooftop heat pump.]

Introduction

Overview

This engineering case study explores using an LG Multi V IV Heat Recovery VRF system in a typical new construction single-story medical office building. Specifically, it compares the energy saved by the LG system compared to two types of United States Green Building Council (USGBC®) LEED[1] baseline building systems. The study was conducted using a building model with the same physical properties and plan in five different climates—Miami, FL (1A), Houston, TX (2A), Atlanta, GA (3A), New York, NY (4A), and Chicago, IL (5A).

The building consisted of one story and a basement with a total of 26,245ft^2 of conditioned space (Table 2). The types of conditioned spaces included varying sizes and purposes such as offices, lobbies, conference rooms, mechanical rooms and corridors.

The building's envelope consisted of a mass wall with friction-fit insulation and a roof with insulation entirely above a deck. The common spaces and offices were expected to be occupied from Monday through Friday (8am-7pm, 55 hours per week).

Table 2 Office Space Types and Sizes

Space Types	Size (ft^2)
Conference	3,000
Physical Therapy	6,000
Corridor	2,125
Restrooms	435
Electrical/Mechanical	3,000
Offices, Pharmacy, and Exam	7,924
Lobby, Reception, and Waiting	2,724
Ancillary Support	1,037
Total	26,245

Table 3 Floor Areas and Window-to-Wall Ratios

Total Conditioned Floor Area (ft^2)	26,245
Window to Wall Ratio (%)	21
Gross Wall Area (ft^2)	49,920
Vertical Window Area (ft^2)	10,380

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

Modeling Approach

Overview

Carrier's Hourly Analysis Program (HAP) was used to estimate energy consumption. HAP software runs on an industry-standard computer and assists engineers in designing HVAC systems for commercial buildings. HAP software:

- employs the ASHRAE-endorsed transfer function method
- meets the minimum requirements for the Energy Cost Budget Compliance path for ASHRAE Standard 90.1
- is approved by Internal Revenue Service (IRS) for calculating Residential and Nonresidential Tax Credits
- is accepted by the U.S. Green Building Council in submissions for the LEED® (Leadership in Energy and Environmental Design) Rating System

Baseline Building

To determine savings, the energy consumption was calculated using LEED baseline building requirements. The LEED design guide uses envelope building material specifications defined by ASHRAE Standard 90.1-2007 for U-values of walls, roofs, floors, and windows.

Two different baseline systems were developed, each consisting of multiple heating, ventilating, and air-conditioning (HVAC) systems. The first system was an ASHRAE Standard 90.1-2007 System 4, Packaged Rooftop Heat Pump (PSZ-HP). This system was composed of a central, constant-volume fan that supplied conditioned air to each room. The second system was an ASHRAE Standard System 6, Packaged Rooftop VAV with Reheat (Packaged VAV with PFP Boxes).

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 programmed to cycle to maintain temperature and humidity requirements. Although humidity may not typically be controlled during unoccupied periods, avoiding mold and moisture is good practice.

Proposed Building

The proposed building model used LG Multi V IV Heat Recovery VRF commercial air-conditioning systems designed for large-scale facilities such as commercial office buildings, hotels, hospitals, and schools.

Multi V IV Heat Recovery systems feature superior energy efficiency, longer piping capabilities and are ARHI 1230 certified. The advanced rapid start feature of LG's high-side shell compressor quickly meets load demand and increased inverter range gives better response to load matching. With this increased efficiency, Multi V IV Heat Recovery systems could reduce operating costs while providing reliable heat in colder regions. Multi V IV Heat Recovery's compact, space-saving design and industry leading piping capabilities provide the ultimate in design flexibility.

Figure 1: Multi V IV Heat Recovery, Heat Recovery Unit, and a Ducted Indoor Unit.

The following section describes the specific design choices.

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

Building Envelope

Table 4 lists the model's building envelope characteristics followed the baseline values of 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)	New York, NY (4A)	Chicago, IL (5A)
Windows: (21 % of Wall Area)	Assembly U-factor	U-1.20	U-0.70	U-0.6	U-0.50	0.45
	SHGC	0.25	0.25	0.25	0.40	0.40
Exterior Walls (Mass wall building)	Above Grade	U-0.124	U-0.151	U-0.084	U-0.064	0.064
	Below Grade	U-0.084	U-0.084	U-0.084	U-0.084	0.084
Roof (Entirely Insulated)		U-0.063	U-0.048	U-0.048	U-0.048	0.048
Standards		LEED for New Construction & Major Renovations ASHRAE 62.1-2007 ASHRAE 90.1-2007				

Mechanical Systems

HVAC System

Three systems were studied:

- Packaged Rooftop Heat Pump System (ASHRAE std. 90.1 Sys-4)
- Packaged Rooftop VAV with Reheat (ASHRAE Standard 90.1 Sys-6)
- LG Multi V IV Heat Recovery System with Dedicated Outdoor Air System (DOAS)

A Packaged Rooftop Heat Pump System (ASHRAE std. 90.1 Sys-4) is the baseline defined by ASHRAE std. 90.1 2007 for this building size and type. This system is used in nonresidential buildings with less than three floors, or smaller than 25,000 ft^2. A Packaged Rooftop VAV with Reheat (ASHRAE Standard 90.1 Sys-6) is a typical HVAC system used in many building types. Table 5 describes the baseline and proposed HVAC systems.

Table 5: Air-Handling Mechanical System Characteristics

Systems		Packaged rooftop heat pump	Packaged rooftop VAV with reheat	Multi V IV Heat Recovery + DOAS
		ASHRAE System Type 4	ASHRAE System Type 6	
Cooling	DX-Cooling	EER 11.0	EER 11.0	EER 12.5
Heating	Electricity	-	Electric resistance	-
	Heat pump	COP: 3.2	-	COP 3.5
Air Systems		Packaged CAVs Total Static: 2.0 in wg.	Packaged VVTs Total Static: 2.0 in wg.	LG Multi V IV Heat Recovery (14 x 10 RT, ARUB121BTE4) + High Static Ducted Indoor Units (Total Static: 0.5 in wg.) DOAS(11.0 EER + Electric resistance)

Interior Lighting

Table 6 describes baseline and proposed interior lighting.

Table 6: Interior-Lighting Energy Characteristics

	Baseline	Proposed	Notes
Interior Lighting	Lighting Power Density (Average: 1.0 w/ft^2)	Same	ASHRAE 90.1-2007 (Table 9.5.1: *Lighting Power Densities Using the Building Area Method*)

Receptacle Load

Table 7 describes baseline and proposed receptacle equipment.

Table 7: Receptacle Equipment Characteristics

	Baseline	Proposed	Notes
Receptacle load	2.0 w/ft^2	Same	ASHRAE 90.1-2007 (TABLE G3.1 *Modeling Requirements for Calculating Proposed and Baseline Building Performance*)

Average Utility Rates Source

Table 8 lists the study's electricity rate in each city[2]:

Table 8: Average Utility Rates

Energy Source	Miami, FL (1A)	Houston, TX (2A)	Atlanta, GA (3A)	New York, NY (4A)	Chicago, IL (5A)
Electricity ($/kWh)	0.149	0.148	0.089	0.155	0.086

[2] 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 consume an estimated average of 93 kBtu of energy per square foot each year. Office buildings represent almost one-fifth of all delivered energy consumed by commercial buildings, and are, therefore, an important focus for improving energy efficiency (EIA 2005).[3] Our goal is to investigate the feasibility of reducing energy use in new construction large office buildings across the United States by using LG Multi V IV VRF systems instead of typical HVAC systems that comply with the minimum requirements of ASHRAE Standard 90.1-2007.

Multi V IV Heat Recovery

The Multi V IV Heat Recovery VRF systems studied used an average of 52.7 kBtu per square foot of site energy each year. Savings varied based on location and utility rates, but the Multi V IV Heat Recovery VRF systems averaged cost savings of 29.9% compared to Packaged RTU system-4. When compared to VAV system-6, Multi V IV Heat Recovery system resulted in 36.0%.energy cost savings.

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 thirteen LEED points. The savings are detailed in the following graphs and are further detailed in tables in the Annual Building Energy Consumption Comparisons and Annual Energy Consumption by End Use Summaries.

Table 9: Estimated LEED 2009 EA Credit 1 Points

New Construction % Cost Savings	Existing Building Renovations % Cost Savings	LEED 2009 Points Awarded
12%	8%	1 pt
14%	10%	2 pt
16%	12%	3 pts
18%	14%	4 pts
20%	16%	5 pts
22%	18%	6 pts
24%	20%	7 pts
26% (Miami)	22%	8 pts
28% (Houston, Atlanta, New York)	24%	9 pts
30 %	26% (Miami)	10 pts
32 %	28% (Houston, Atlanta, New York)	11 pts
34%	30%	12 pts
36% (Chicago)	32%	13 pts
38%	34%	14 pts
40%	36%(Chicago)	15 pts

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

Table 10: LG Multi V IV VRF Systems Whole Building Energy Use and Energy Cost.

	Proposed Design(Multi V IV)			Baseline Design(Sys 4)		
	Energy Use		Cost ($)	Energy Use		Cost ($)
	Electric (kWh)	kBTU		Electric	kBTU	
Miami	454,971	1,552,361	45,497	621,097	2,119,182	62,110
Houston	377,363	1,287,562	55,850	532,337	1,816,333	78,786
Atlanta	375,596	1,281,535	33,428	525,628	1,793,444	46,781
New York	398,240	1,358,795	35,443	562,536	1,919,371	50,066
Chicago	422,002	1,439,872	36,292	658,966	2,248,392	56,671

Table 11 : LG Multi V IV VRF Systems Energy Use Intensity and (%) Savings.

		Proposed Design (Multi V IV)	Baseline Design (Sys 4)
Miami	Energy Use Intensity(kBTU/ft^2)	59.15	80.75
	Percent Savings	26.7%	
Houston	Energy Use Intensity(kBTU/ft^2)	49.06	69.21
	Percent Savings	29.1%	
Atlanta	Energy Use Intensity(kBTU/ft^2)	48.83	68.33
	Percent Savings	28.5%	
New York	Energy Use Intensity(kBTU/ft^2)	51.77	73.13
	Percent Savings	29.2%	
Chicago	Energy Use Intensity(kBTU/ft^2)	54.86	85.67
	Percent Savings	36.0%	

Miami Results

Table 12 through Table 20 summarize energy usage and cost savings for the Miami location (climate zone 1A). The whole building energy cost savings over the baseline (Sys 4, Packaged rooftop heat pump system) for the Multi V IV Heat Recovery VRF systems was 26.7%.

Table 12: Miami Estimated Annual Energy Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	14,867	20,112	4,888
Cooling	23,454	30,976	17,032
Heating	779	1,233	567
HVAC Sub-Total	39,100	52,321	22,488
Lights	7,670	7,670	7,670
Electric Equipment	15,340	15,340	15,340
Non-HVAC Sub-Total	23,009	23,009	23,009
Grand Total	62,110	75,331	45,497

Table 13: Miami Estimated Annual Cost per Unit Floor Area ($/ft²)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	0.567	0.766	0.186
Cooling	0.894	1.180	0.649
Heating	0.030	0.047	0.022
HVAC Sub-Total	1.490	1.994	0.857
Lights	0.292	0.292	0.292
Electric Equipment	0.585	0.585	0.585
Non-HVAC Sub-Total	0.877	0.877	0.877
Grand Total	2.367	2.870	1.734
Conditioned Floor Area (ft^2)	26245.0	26245.0	26245.0

Table 14: Miami Estimated Component Cost as a Percentage of Total Cost (%)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	23.9	26.7	10.7
Cooling	37.8	41.1	37.4
Heating	1.3	1.6	1.2
HVAC Sub-Total	**63.0**	**69.5**	**49.4**
Lights	12.3	10.2	16.9
Electric Equipment	24.7	20.4	33.7
Non-HVAC Sub-Total	**37.0**	**30.5**	**50.6**
Grand Total	**100.0**	**100.0**	**100.0**

Table 15: Miami Estimated Annual Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
HVAC Components			
Electric	39,100	52,321	22,488
Non-HVAC Components			
Electric	23,009	23,009	23,009
Grand Total	62,109	75,331	45,497

Table 16: Miami Estimated Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance

	Proposed Design(Multi V IV)		Baseline Design(sys 4)	
Energy Type	**Energy Use**	**Cost ($)**	**Energy Use**	**Cost ($)**
Electric	454,971 kWh	45,497	621,097 kWh	62,110
Subtotal (Model Outputs)	1,552,361 kBTU	45,497	2,119,182 kBTU	62,110
	Percent Savings		**Energy Use Intensity(kBTU/ft²)**	
	Energy	**Cost**	**Proposed Design**	**Baseline Design**
Summary Data	26.7%	26.7%	59.15	80.75

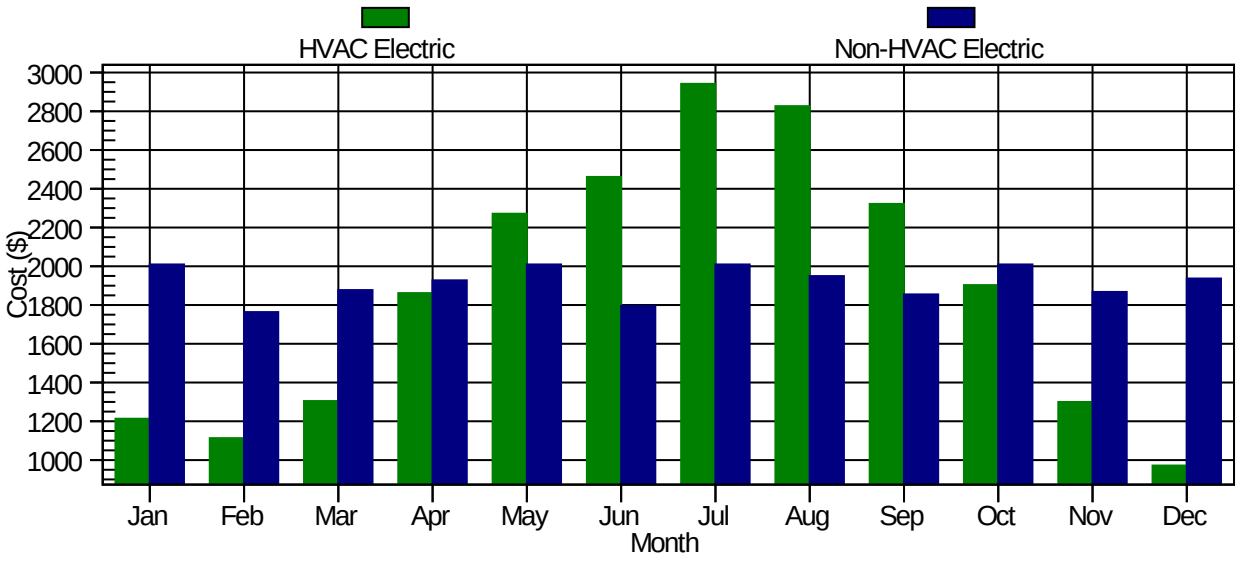

Table 17: Monthly HVAC and Non-HVAC Costs – Proposed Building (Multi V IV)

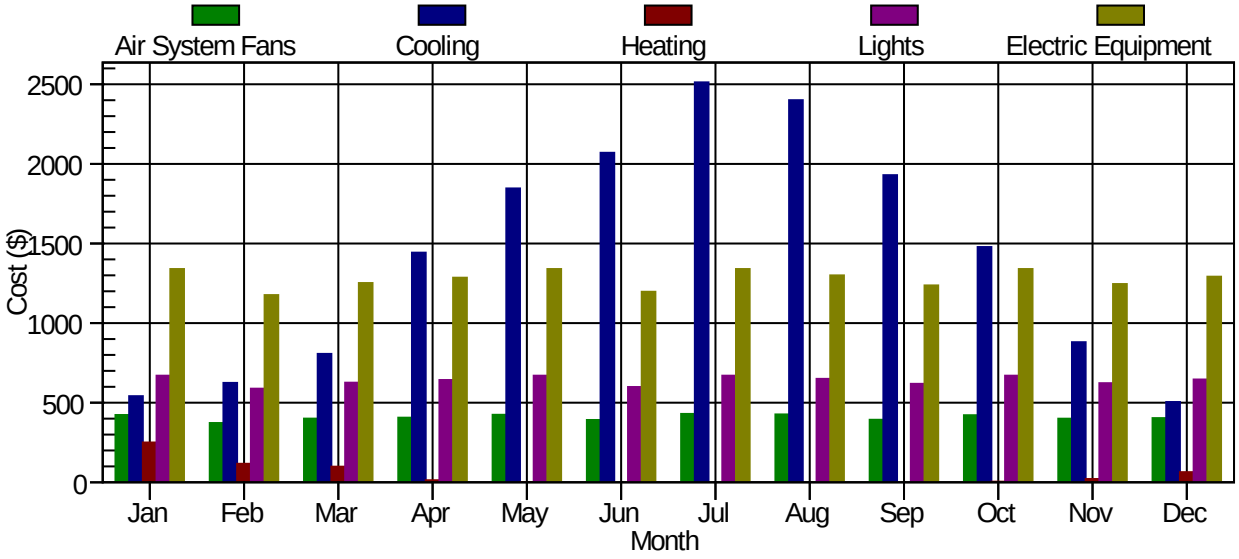

Table 18: Monthly Component Costs – Proposed Building (Multi V IV)

Table 19: Miami Estimated Performance Rating Table - Performance Rating Method Compliance

End Use	Energy Type	Baseline Building		Proposed Building		Percent Savings
		Units	Results	Units	Results	
Interior Lighting	Electric	Energy kWh	76,698	Energy kWh	76,698	0 %
		Demand kW	23.6	Demand kW	23.6	0 %
Space Heating	Electric	Energy kWh	7,794	Energy kWh	5,674	27 %
		Demand kW	297.4	Demand kW	106.6	64 %
Space Cooling	Electric	Energy kWh	234,537	Energy kWh	170,322	27 %
		Demand kW	109.0	Demand kW	101.0	7 %
Fans - Interior	Electric	Energy kWh	148,671	Energy kWh	48,880	67 %
		Demand kW	29.1	Demand kW	10.1	65 %
Receptacle Equipment	Electric	Energy kWh	153,397	Energy kWh	153,397	0 %
		Demand kW	47.2	Demand kW	47.2	0 %
Energy Totals		Baseline Total Energy Use (kBTU)	2,119,182	Proposed Total Energy Use (kBTU)	1,552,361	27 %
		Baseline Annual Process Energy (kBTU)	523,390	Proposed Annual Process Energy (kBTU)	523,390	0 %

Table 20: Miami Estimated LEED 2009 EA Credit 1 Points Reference Table

New Construction % Cost Savings	Existing Building Renovations % Cost Savings	LEED 2009 Points Awarded
12%	8%	1 pt
14%	10%	2 pt
16%	12%	3 pts
18%	14%	4 pts
20%	16%	5 pts
22%	18%	6 pts
24%	20%	7 pts
26%	22%	8 pts
28%	24%	9 pts
30%	26%	10 pts
32%	28%	11 pts
34%	30%	12 pts
36%	32%	13 pts
38%	34%	14 pts
40%	36%	15 pts
42%	38%	16 pts
44%	40%	17 pts
46%	42%	18 pts
48%	44%	19 pts

Houston Results

Table 21 through Table 29 summarize the energy usage and cost savings for the Houston location (climate zone 2A). The whole building energy cost savings over the baseline (Sys 4, Packaged rooftop heat pump system) for the Multi V IV Heat Recovery VRF systems was 29.1%.

Table 21: Houston Estimated Annual Energy Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	13,478	17,141	4,406
Cooling	20,647	23,197	12,072
Heating	10,608	11,277	5,318
HVAC Sub-Total	**44,732**	**51,615**	**21,796**
Lights	11,351	11,351	11,351
Electric Equipment	22,703	22,703	22,703
Non-HVAC Sub-Total	**34,054**	**34,054**	**34,054**
Grand Total	78,786	85,670	55,850

Table 22: Houston Estimated Annual Cost per Unit Floor Area ($/ft²)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	0.514	0.653	0.168
Cooling	0.787	0.884	0.460
Heating	0.404	0.430	0.203
HVAC Sub-Total	**1.704**	**1.967**	**0.831**
Lights	0.433	0.433	0.433
Electric Equipment	0.865	0.865	0.865
Non-HVAC Sub-Total	**1.298**	**1.298**	**1.298**
Grand Total	**3.002**	**3.264**	**2.128**
Conditioned Floor Area (ft²)	**26245.0**	**26245.0**	**26245.0**

Table 23: Houston Estimated Component Cost as a Percentage of Total Cost (%)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	17.1	20.0	7.9
Cooling	26.2	27.1	21.6
Heating	13.5	13.2	9.5
HVAC Sub-Total	**56.8**	**60.2**	**39.0**
Lights	14.4	13.3	20.3
Electric Equipment	28.8	26.5	40.6
Non-HVAC Sub-Total	**43.2**	**39.8**	**61.0**
Grand Total	**100.0**	**100.0**	**100.0**

Table 24: Houston Estimated Annual Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
HVAC Components			
Electric	44,732	51,616	21,796
Non-HVAC Components			
Electric	34,054	34,054	34,054
Grand Total	**78,785**	**85,670**	**55,849**

Table 25: Houston Estimated Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance

	Proposed Design(Multi V IV)		Baseline Design(sys 4)	
Energy Type	**Energy Use**	**Cost ($)**	**Energy Use**	**Cost ($)**
Electric	377,363 kWh	55,850	532,337 kWh	78,786
Subtotal (Model Outputs)	**1,287,562 kBTU**	**55,850**	**1,816,333 kBTU**	**78,786**
	Percent Savings		**Energy Use Intensity(kBTU/ft²)**	
	Energy	**Cost**	**Proposed Design**	**Baseline Design**
Summary Data	29.1 %	29.1 %	49.06	69.21

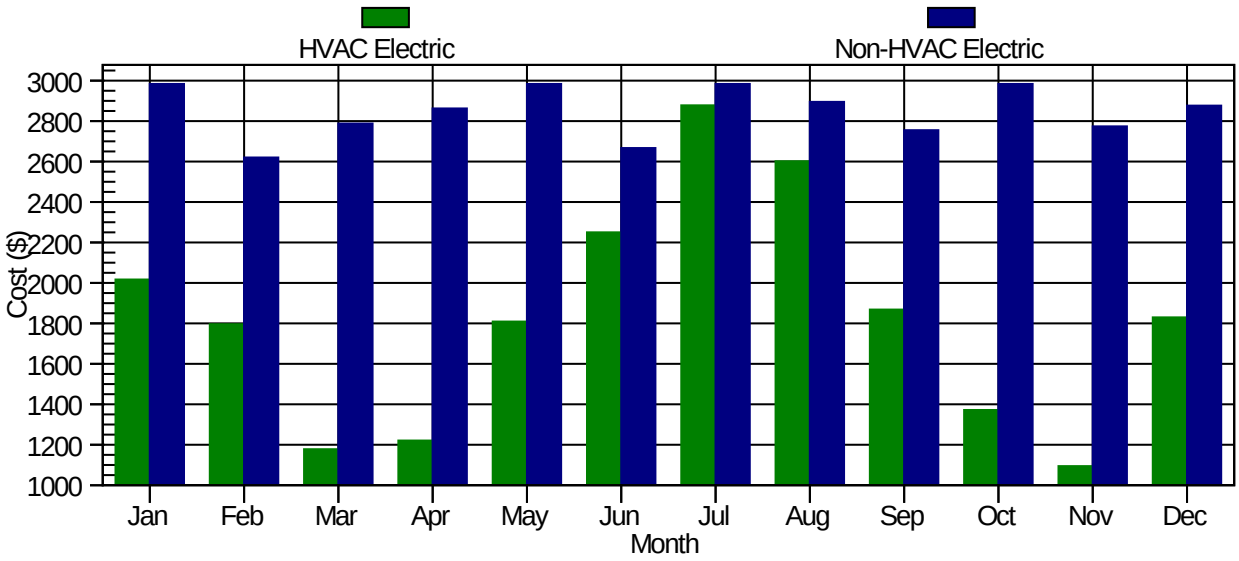

Table 26: Monthly HVAC and Non-HVAC Costs – Proposed Building (Multi V IV)

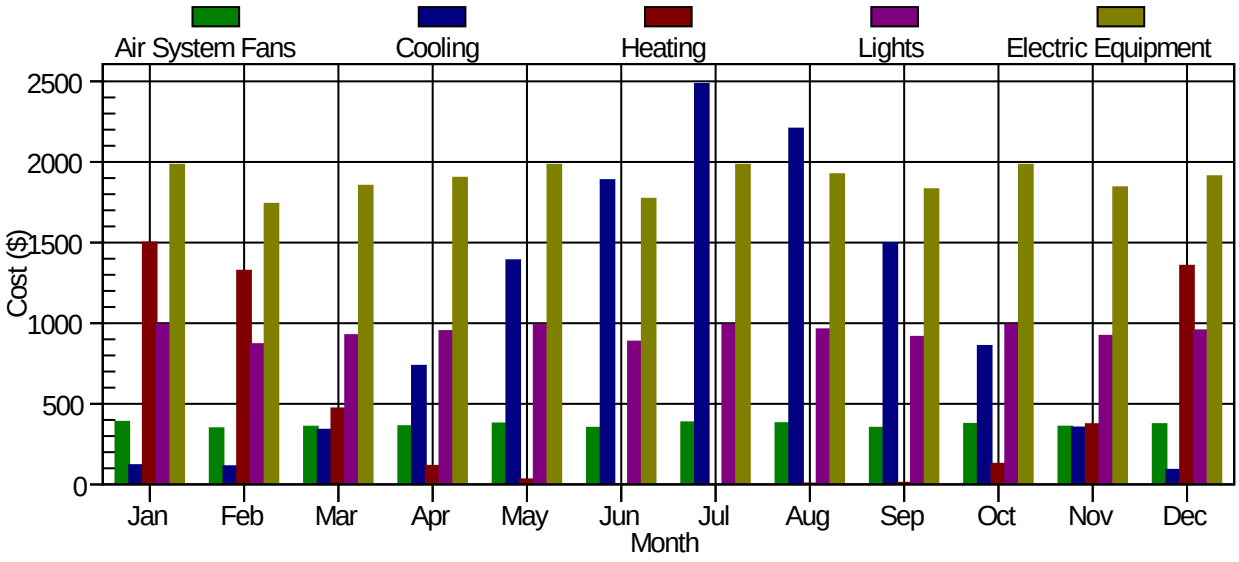

Table 27: Monthly Component Costs – Proposed Building (Multi V IV)

Table 28: Houston Estimated Performance Rating Table - Performance Rating Method Compliance

		Baseline Building		Proposed Building		Percent Savings
End Use	Energy Type	Units	Results	Units	Results	
Interior Lighting	Electric	Energy kWh	76,698	Energy kWh	76,698	0 %
		Demand kW	23.6	Demand kW	23.6	0 %
Space Heating	Electric	Energy kWh	71,674	Energy kWh	35,931	50 %
		Demand kW	264.2	Demand kW	154.8	41 %
Space Cooling	Electric	Energy kWh	139,504	Energy kWh	81,565	42 %
		Demand kW	85.7	Demand kW	65.3	24 %
Fans - Interior	Electric	Energy kWh	91,064	Energy kWh	29,772	67 %
		Demand kW	17.2	Demand kW	6.1	65 %
Receptacle Equipment	Electric	Energy kWh	153,397	Energy kWh	153,397	0 %
		Demand kW	47.2	Demand kW	47.2	0 %
Energy Totals		Baseline Total Energy Use (kBTU)	1,816,333	Proposed Total Energy Use (kBTU)	1,287,562	29 %
		Baseline Annual Process Energy (kBTU)	523,390	Proposed Annual Process Energy (kBTU)	523,390	0 %

Table 29: Houston Estimated LEED 2009 EA Credit 1 Points Reference Table

New Construction % Cost Savings	Existing Building Renovations % Cost Savings	LEED 2009 Points Awarded
12%	8%	1 pt
14%	10%	2 pt
16%	12%	3 pts
18%	14%	4 pts
20%	16%	5 pts
22%	18%	6 pts
24%	20%	7 pts
26%	22%	8 pts
28%	24%	9 pts
30%	26%	10 pts
32%	28%	11 pts
34%	30%	12 pts
36%	32%	13 pts
38%	34%	14 pts
40%	36%	15 pts
42%	38%	16 pts
44%	40%	17 pts
46%	42%	18 pts
48%	44%	19 pts

Atlanta Results

Table 30 through Table 38 summarize the energy usage and cost savings for the Atlanta location (climate zone 3A). The whole building energy cost savings over the baseline (Sys 4, Packaged rooftop heat pump system) for the Multi V IV Heat Recovery VRF systems was 28.5%.

Table 30: Atlanta Estimated Annual Energy Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	7,761	9,735	2,537
Cooling	7,009	8,305	4,487
Heating	11,532	12,275	5,926
HVAC Sub-Total	**26,302**	**30,315**	**12,950**
Lights	6,826	6,826	6,826
Electric Equipment	13,652	13,652	13,652
Non-HVAC Sub-Total	**20,478**	**20,478**	**20,478**
Grand Total	**46,781**	**50,793**	**33,428**

Table 31: Atlanta Estimated Annual Cost per Unit Floor Area ($/ft²)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	0.296	0.371	0.097
Cooling	0.267	0.316	0.171
Heating	0.439	0.468	0.226
HVAC Sub-Total	**1.002**	**1.155**	**0.493**
Lights	0.260	0.260	0.260
Electric Equipment	0.520	0.520	0.520
Non-HVAC Sub-Total	**0.780**	**0.780**	**0.780**
Grand Total	**1.783**	**1.935**	**1.274**
Conditioned Floor Area (ft²)	**26245.0**	**26245.0**	**26245.0**

Table 32: Atlanta Estimated Component Cost as a Percentage of Total Cost (%)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	16.6	19.2	7.6
Cooling	15.0	16.4	13.4
Heating	24.7	24.2	17.7
HVAC Sub-Total	**56.2**	**59.7**	**38.7**
Lights	14.6	13.4	20.4
Electric Equipment	29.2	26.9	40.8
Non-HVAC Sub-Total	**43.8**	**40.3**	**61.3**
Grand Total	**100.0**	**100.0**	**100.0**

Table 33: Atlanta Estimated Annual Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
HVAC Components			
Electric	26,303	30,315	12,950
Non-HVAC Components			
Electric	20,478	20,478	20,478
Grand Total	**46,781**	**50,793**	**33,428**

Table 34: Atlanta Estimated Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance

	Proposed Design (Multi V IV)		Baseline Design (Sys 4)	
Energy Type	**Energy Use**	**Cost ($)**	**Energy Use**	**Cost ($)**
Electric	375,596 kWh	33,428	525,628 kWh	46,781
Subtotal (Model Outputs)	**1,281,535 kBTU**	**33,428**	**1,793,444 kBTU**	**46,781**
	Percent Savings		**Energy Use Intensity(kBTU/ft²)**	
	Energy	**Cost**	**Proposed Design**	**Baseline Design**
Summary Data	**28.5 %**	**28.5 %**	**48.83**	**68.33**

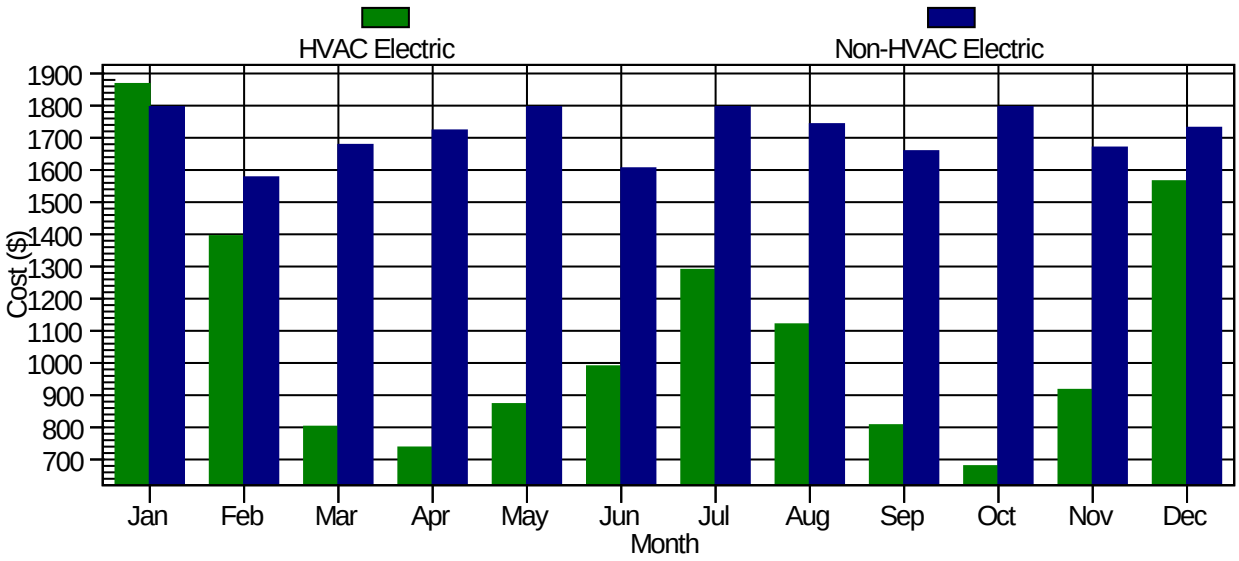

Table 35: Monthly HVAC and Non-HVAC Costs – Proposed Building (Multi V IV)

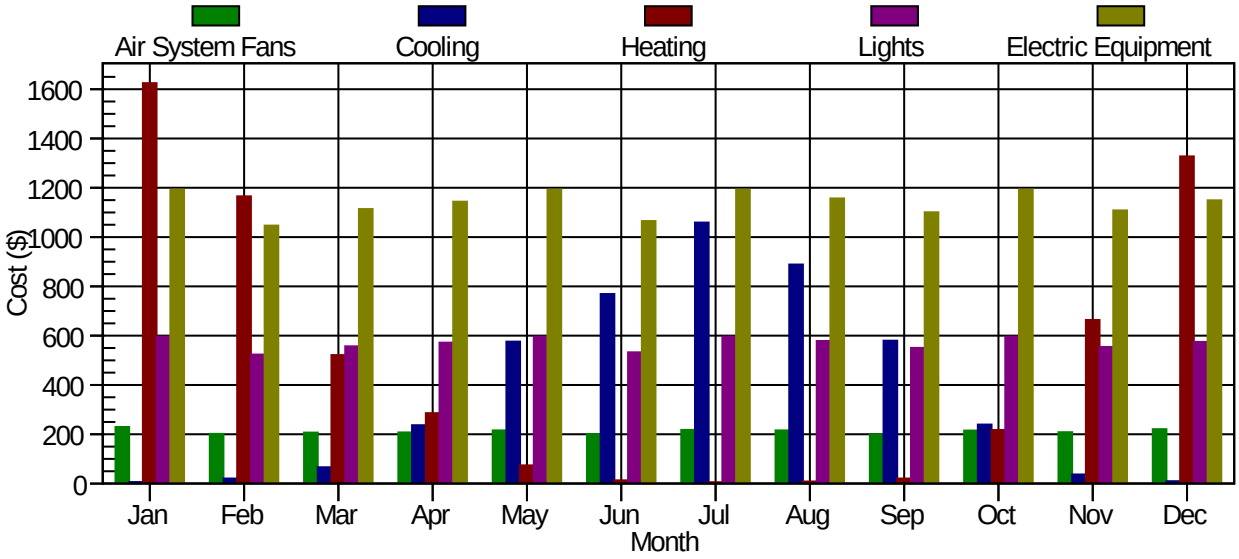

Table 36: Monthly Component Costs – Proposed Building (Multi V IV)

Table 37: Atlanta Estimated Performance Rating Table - Performance Rating Method Compliance

		Baseline Building		Proposed Building		
End Use	Energy Type	Units	Results	Units	Results	Percent Savings
Interior Lighting	Electric	Energy kWh	76,698	Energy kWh	76,698	0 %
		Demand kW	23.6	Demand kW	23.6	0 %
Space Heating	Electric	Energy kWh	129,578	Energy kWh	66,584	49 %
		Demand kW	253.1	Demand kW	161.0	36 %
Space Cooling	Electric	Energy kWh	78,753	Energy kWh	50,416	36 %
		Demand kW	77.4	Demand kW	62.8	19 %
Fans - Interior	Electric	Energy kWh	87,203	Energy kWh	28,501	67 %
		Demand kW	16.5	Demand kW	5.8	65 %
Receptacle Equipment	Electric	Energy kWh	153,397	Energy kWh	153,397	0 %
		Demand kW	47.2	Demand kW	47.2	0 %
Energy Totals		Baseline Total Energy Use (kBTU)	1,793,444	Proposed Total Energy Use (kBTU)	1,281,535	29 %
		Baseline Annual Process Energy (kBTU)	523,390	Proposed Annual Process Energy (kBTU)	523,390	0 %

Table 38: Atlanta Estimated LEED 2009 EA Credit 1 Points Reference Table

New Construction % Cost Savings	Existing Building Renovations % Cost Savings	LEED 2009 Points Awarded
12%	8%	1 pt
14%	10%	2 pt
16%	12%	3 pts
18%	14%	4 pts
20%	16%	5 pts
22%	18%	6 pts
24%	20%	7 pts
26%	22%	8 pts
28%	24%	9 pts
30%	26%	10 pts
32%	28%	11 pts
34%	30%	12 pts
36%	32%	13 pts
38%	34%	14 pts
40%	36%	15 pts
42%	38%	16 pts
44%	40%	17 pts
46%	42%	18 pts
48%	44%	19 pts

New York Results

Table 39 through Table 47 summarize the energy usage and cost savings for the New York location (climate zone 4A). The whole building energy cost savings over the baseline (Sys 4, Packaged rooftop heat pump system) for the Multi V IV Heat Recovery VRF systems was 29.2%.

Table 39: New York Estimated Annual Energy Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	7,422	9,100	2,404
Cooling	4,733	5,440	3,128
Heating	17,432	18,162	9,433
HVAC Sub-Total	29,587	32,702	14,965
Lights	6,826	6,826	6,826
Electric Equipment	13,652	13,652	13,652
Non-HVAC Sub-Total	20,478	20,478	20,478
Grand Total	**50,066**	**53,181**	**35,443**

Table 40: New York Estimated Annual Cost per Unit Floor Area ($/ft²)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	0.283	0.347	0.092
Cooling	0.180	0.207	0.119
Heating	0.664	0.692	0.359
HVAC Sub-Total	1.127	1.246	0.570
Lights	0.260	0.260	0.260
Electric Equipment	0.520	0.520	0.520
Non-HVAC Sub-Total	0.780	0.780	0.780
Grand Total	1.908	2.026	1.351
Conditioned Floor Area (ft^2)	26245.0	26245.0	26245.0

Table 41: New York Estimated Component Cost as a Percentage of Total Cost (%)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	14.8	17.1	6.8
Cooling	9.5	10.2	8.8
Heating	34.8	34.2	26.6
HVAC Sub-Total	59.1	61.5	42.2
Lights	13.6	12.8	19.3
Electric Equipment	27.3	25.7	38.5
Non-HVAC Sub-Total	40.9	38.5	57.8
Grand Total	**100.0**	**100.0**	**100.0**

Table 42: New York Estimated Annual Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
HVAC Components			
Electric	29,587	32,702	14,965
Non-HVAC Components			
Electric	20,478	20,478	20,478
Grand Total	**50,066**	**53,181**	**35,443**

Table 43: New York Estimated Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance

	Proposed Design (Multi V IV)		Baseline Design (Sys 4)	
Energy Type	Energy Use	Cost ($)	Energy Use	Cost ($)
Electric	398,240 kWh	35,443	562,536 kWh	50,066
Subtotal (Model Outputs)	1,358,795 kBTU	35,443	1,919,371 kBTU	50,066
	Percent Savings		Energy Use Intensity	
	Energy	Cost	Proposed Design (kBTU/ft^2)	Baseline Design (kBTU/ft^2)
Summary Data	**29.2 %**	**29.2 %**	**51.77**	**73.13**

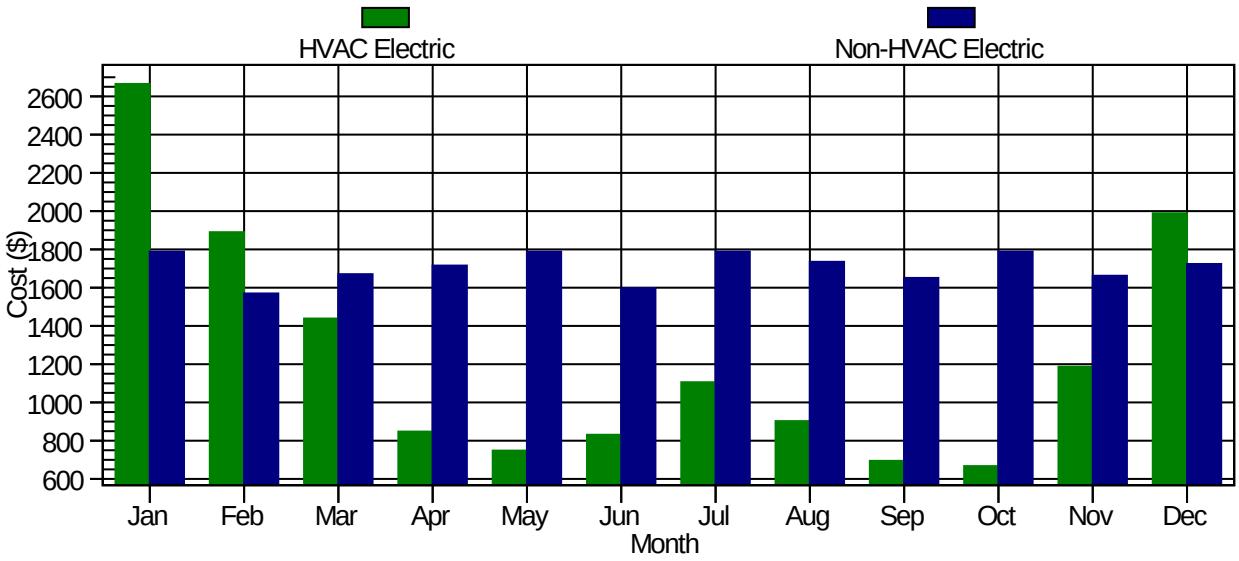

Table 44: New York Monthly HVAC and Non-HVAC Costs – Proposed Building (Multi V IV)

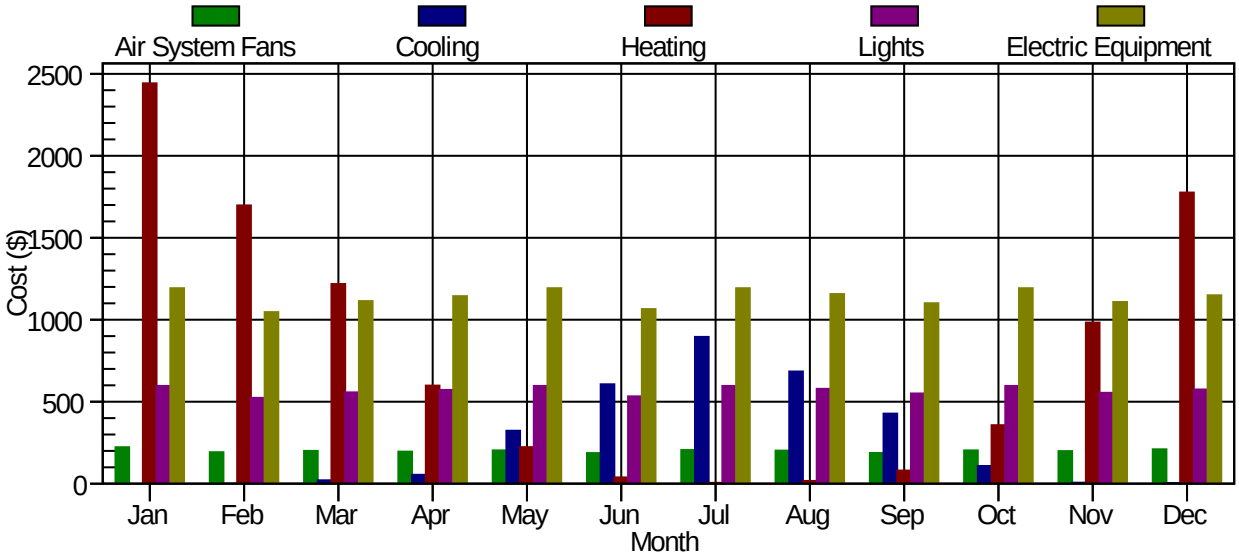

Table 45: Monthly Component Costs – Proposed Building (Multi V IV)

Table 46: New York Estimated Performance Rating Table - Performance Rating Method Compliance

		Baseline Building		Proposed Building		
End Use	Energy Type	Units	Results	Units	Results	Percent Savings
Interior Lighting	Electric	Energy kWh	76,698	Energy kWh	76,698	0 %
		Demand kW	23.6	Demand kW	23.6	0 %
Space Heating	Electric	Energy kWh	195,860	Energy kWh	105,988	46 %
		Demand kW	204.8	Demand kW	133.1	35 %
Space Cooling	Electric	Energy kWh	53,185	Energy kWh	35,143	34 %
		Demand kW	71.6	Demand kW	52.3	27 %
Fans - Interior	Electric	Energy kWh	83,396	Energy kWh	27,015	68 %
		Demand kW	15.5	Demand kW	5.5	65 %
Receptacle Equipment	Electric	Energy kWh	153,397	Energy kWh	153,397	0 %
		Demand kW	47.2	Demand kW	47.2	0 %
Energy Totals		Baseline Total Energy Use (kBTU)	1,919,371	Proposed Total Energy Use (kBTU)	1,358,795	29 %
		Baseline Annual Process Energy (kBTU)	523,390	Proposed Annual Process Energy (kBTU)	523,390	0 %

Table 47: New York Estimated LEED 2009 EA Credit 1 Points Reference Table

New Construction % Cost Savings	Existing Building Renovations % Cost Savings	LEED 2009 Points Awarded
12%	8%	1 pt
14%	10%	2 pt
16%	12%	3 pts
18%	14%	4 pts
20%	16%	5 pts
22%	18%	6 pts
24%	20%	7 pts
26%	22%	8 pts
28%	24%	9 pts
30%	26%	10 pts
32%	28%	11 pts
34%	30%	12 pts
36%	32%	13 pts
38%	34%	14 pts
40%	36%	15 pts
42%	38%	16 pts
44%	40%	17 pts
46%	42%	18 pts
48%	44%	19 pts

Chicago Results

Table 48 through Table 56 summarize the energy usage and cost savings for the Chicago location (climate zone 5A). The whole building energy cost savings over the baseline (Sys 4, Packaged rooftop heat pump system) for the Multi V IV Heat Recovery VRF systems was 32.2%.

Table 48: Chicago Estimated Annual Energy Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	7,646	8,706	2,264
Cooling	3,596	4,569	2,602
Heating	25,642	25,505	11,639
HVAC Sub-Total	**36,883**	**38,780**	**16,504**
Lights	6,596	6,596	6,596
Electric Equipment	13,192	13,192	13,192
Non-HVAC Sub-Total	**19,788**	**19,788**	**19,788**
Grand Total	**56,671**	**58,568**	**36,292**

Table 49: Chicago Estimated Annual Cost per Unit Floor Area ($/ft²)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	0.291	0.332	0.086
Cooling	0.137	0.174	0.099
Heating	0.977	0.972	0.444
HVAC Sub-Total	1.405	1.478	0.629
Lights	0.251	0.251	0.251
Electric Equipment	0.503	0.503	0.503
Non-HVAC Sub-Total	0.754	0.754	0.754
Grand Total	2.159	2.232	1.383
Conditioned Floor Area (ft^2)	26245.0	26245.0	26245.0

Table 50: Chicago Estimated Component Cost as a Percentage of Total Cost (%)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
Air System Fans	13.5	14.9	6.2
Cooling	6.3	7.8	7.2
Heating	45.2	43.5	32.1
HVAC Sub-Total	**65.1**	**66.2**	**45.5**
Lights	11.8	11.2	17.4
Electric Equipment	23.6	22.5	34.8
Non-HVAC Sub-Total	**34.9**	**33.8**	**54.5**
Grand Total	**100.0**	**100.0**	**100.0**

Table 51: Chicago Estimated Annual Costs ($)

Component	ASHRAE Standard 90.1-2007		Proposed
	Sys 4	Sys 6	Multi V IV - VRF
HVAC Components			
Electric	36,883	38,780	16,504
Non-HVAC Components			
Electric	19,788	19,788	19,788
Grand Total	**56,671**	**58,568**	**36,292**

Table 52: Chicago Estimated Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance

	Proposed Design (Multi V IV)		Baseline Design (Sys 4)	
Energy Type	**Energy Use**	**Cost ($)**	**Energy Use**	**Cost ($)**
Electric	422,002 kWh	36,292	658,966 kWh	56,671
Subtotal (Model Outputs)	1,439,872 kBTU	36,292	2,248,392 kBTU	56,671
	Percent Savings		Energy Use Intensity	
	Energy	Cost	Proposed Design (kBTU/ft²)	Baseline Design (kBTU/ft²)
Summary Data	**36.0 %**	**36.0 %**	**54.86**	**85.67**

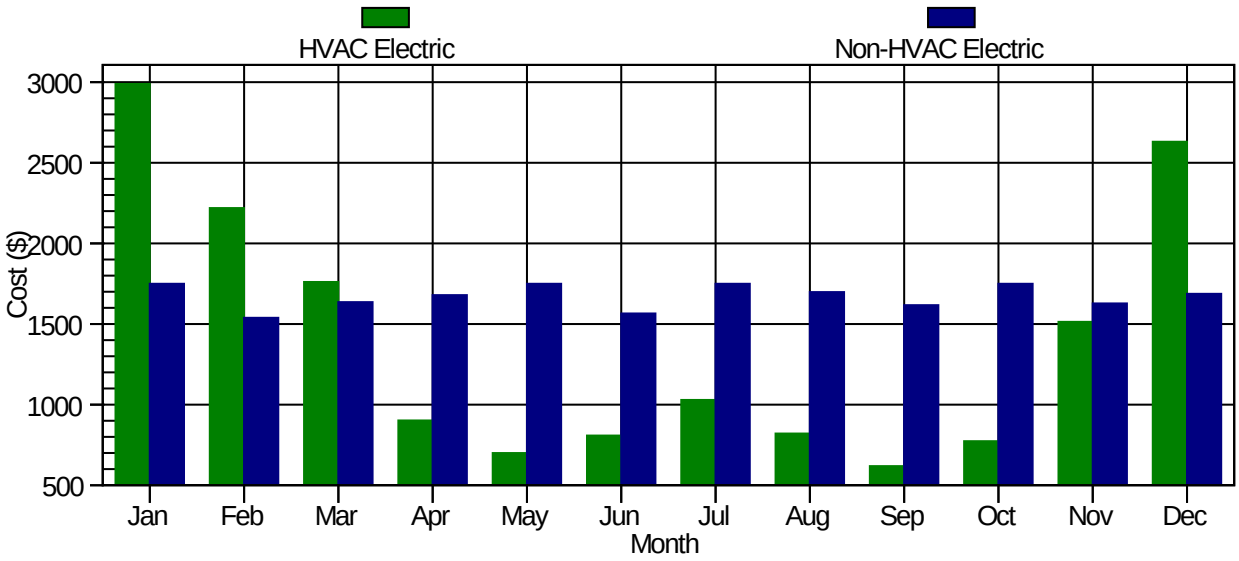

Table 53: Monthly HVAC and Non-HVAC Costs – Proposed Building (Multi V IV)

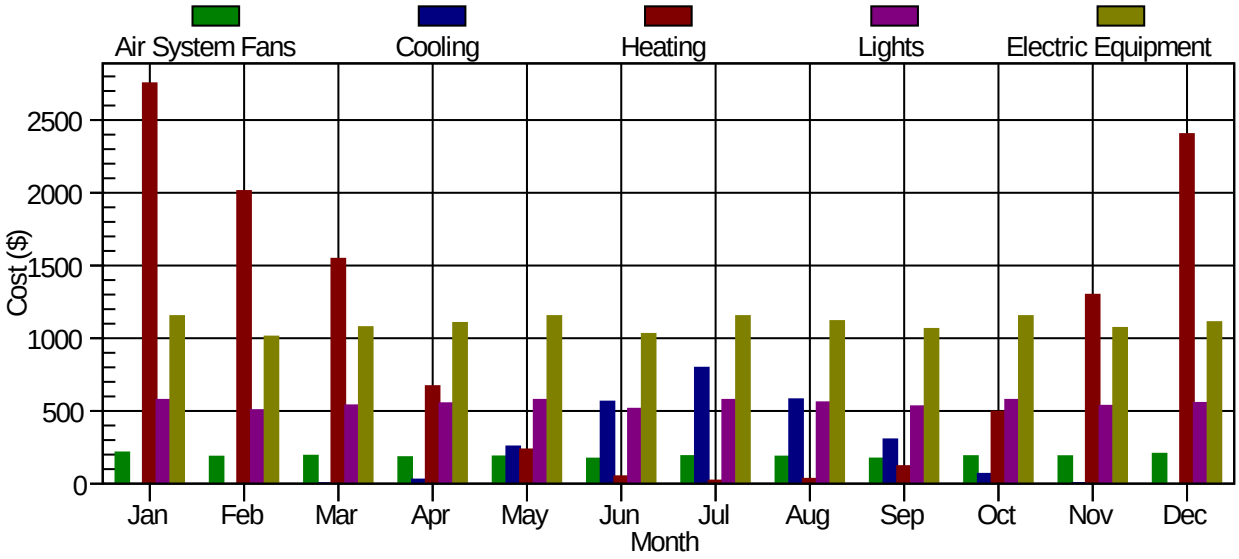

Table 54: Monthly Component Costs – Proposed Building (Multi V IV)

Table 55: Chicago Estimated Performance Rating Table - Performance Rating Method Compliance

		Baseline Building		Proposed Building		
End Use	**Energy Type**	**Units**	**Results**	**Units**	**Results**	**Percent Savings**
Interior Lighting	Electric	Energy kWh	76,698	Energy kWh	76,698	0 %
		Demand kW	23.6	Demand kW	23.6	0 %
Space Heating	Electric	Energy kWh	298,159	Energy kWh	135,332	55 %
		Demand kW	268.0	Demand kW	222.8	17 %
Space Cooling	Electric	Energy kWh	41,810	Energy kWh	30,255	28 %
		Demand kW	64.0	Demand kW	50.6	21 %
Fans - Interior	Electric	Energy kWh	88,902	Energy kWh	26,320	70 %
		Demand kW	16.6	Demand kW	5.2	69 %
Receptacle Equipment	Electric	Energy kWh	153,397	Energy kWh	153,397	0 %
		Demand kW	47.2	Demand kW	47.2	0 %
Energy Totals		Baseline Total Energy Use (kBTU)	2,248,392	Proposed Total Energy Use (kBTU)	1,439,872	36 %
		Baseline Annual Process Energy (kBTU)	523,390	Proposed Annual Process Energy (kBTU)	523,390	0 %

Table 56: Chicago Estimated LEED 2009 EA Credit 1 Points Reference Table

New Construction % Cost Savings	Existing Building Renovations % Cost Savings	LEED 2009 Points Awarded
12%	8%	1 pt
14%	10%	2 pt
16%	12%	3 pts
18%	14%	4 pts
20%	16%	5 pts
22%	18%	6 pts
24%	20%	7 pts
26%	22%	8 pts
28%	24%	9 pts
30%	26%	10 pts
32%	28%	11 pts
34%	30%	12 pts
36%	32%	13 pts
38%	34%	14 pts
40%	36%	15 pts
42%	38%	16 pts
44%	40%	17 pts
46%	42%	18 pts
48%	44%	19 pts

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

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, and referring to ASHRAE standards, LEED projects earn points during the certification process, and then are awarded certification levels.

The Multi V IV VRF air conditioning system is engineered for sustainable green building and provides opportunities for designers to claim many LEED prerequisites and credit points. Table 57 contains LG Electronics' recommendations and strategies to earn LEED points for new construction certification using Multi V IV VRF systems.

Table 57 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 environmentally friendly refrigerant R410A. • LG Multi V IV offers exceptional energy performance with state of the art controls, high efficiency variable speed fan assemblies, and a combination of variable speed compressors. • Select heat recovery equipment options. • Use LG Multi V IV heat recovery systems and ERV (Heat Recovery Ventilator). (http://lg-vrf.com/air-technologies.aspx)
	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 IV uses multiple indoor units, allowing the designer to provide individual control for each space. • LG's building management controllers and communication gateways make it easy to monitor energy usage and control Multi V IVsystem 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) and Air Cleaner. (http://lg-vrf.com/air-technologies.aspx)
	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 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

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™
- Carrier Corporation, HAP Quick Reference Guide 1998-2012