

EnergyPro Building Energy Analysis

Single-story School Building



EnergyPro Building Energy Analysis

for a single-story school building

Project Scope

The purpose of the EnergyPro energy model was to evaluate the energy usage of a building installed with a CITY MULTI VRFZ solution compared to that of a variable-air-volume (VAV) system, a water-source heat pump (WSHP) system, and a hot-water/chilled-water four-pipe fan coil system. The selected systems were then compared with the CITY MULTI VRFZ solution across the country: Atlanta, GA, Miami, FL, Boston, MA, New York City, NY, Chicago, IL, Dallas, TX, Los Angeles, CA, and Seattle, WA. The goal of the energy model was to understand how CITY MULTI compared in terms of energy usage with standard HVAC systems in various climate zones.

Building Description

The simulated building chosen was an 82,000 square foot, single-story, rectangular-shaped school containing classrooms, labs, a theater, a gym, locker rooms, and administrative offices. The building was modeled in eight cities across the U.S.

Building specifications such as floor plans, R-Values, U-Values, etc., followed what was typical for construction values in each of the areas specified. The building was modeled in EnergyPro, and four simulations were created: a CITY MULTI heat-recovery system, a packaged rooftop variable-air-volume system, a boiler and a chiller serving four-pipe fan coil units and a water-source heat pump system. The non-HVAC energy usage such as lighting, plug loads, etc., were the same in all models (see the Engineering Assumptions Table for specifics).

All utility rates used in the savings analysis were obtained from www.eia.gov. The rates are provided in the Utility Rate Summary (Table 1).

Mitsubishi Electric Design Description

For the simulated school, CITY MULTI R2-Series heat recovery outdoor units in conjunction with PEFY high-static pressure ducted units were used to condition each zone. Each classroom was considered one zone and served by an individual indoor unit so that teachers could control the temperature as needed. A total of nine systems were modeled.

A dedicated outside air unit was included to supply the building with 22,000 cfm of outside air required for building occupants. The unit provided air at neutral conditions, which allowed the CITY MULTI R2-Series systems to satisfy cooling and heating loads. The dedicated outside air unit was the only piece of equipment in the model that used gas for heat.

VAV Design Description

The simulated school building was modeled with a gas-fired hot-water boiler and a packaged VAV system that included one rooftop packaged unit with an efficiency of 9.5 EER (Energy Efficiency Ratio). The VAV system handled both space conditioning and the outside air load. Each of the zones used one VAV box specified with a 30% minimum airflow and a hot water reheat coil.



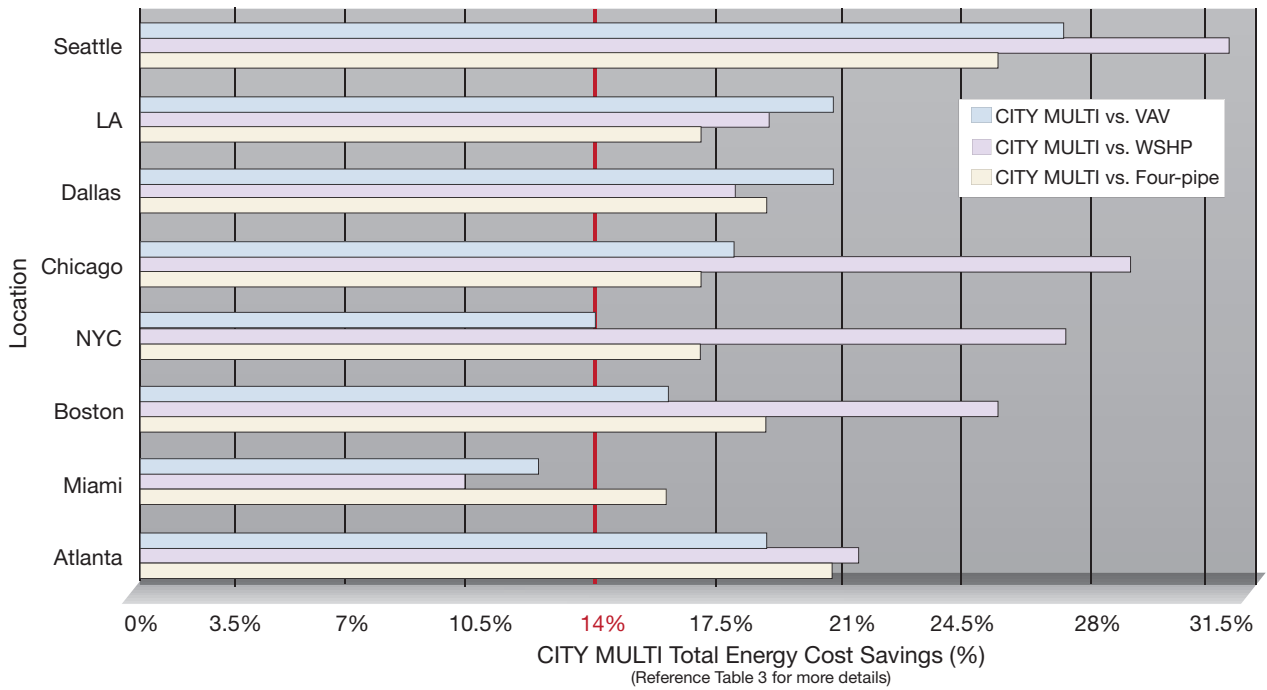
Water-source Heat Pump (WSHP) Design Description

To provide conditioning to the simulated school, water-source heat pumps with a 15.4 EER and a 4.7 COP (Coefficient of Performance) were modeled. The water-source heat pumps were served by a two-speed cooling tower and a pump to circulate the water. A supplemental condensing boiler was attached to the condenser water loop to provide heat when the cooling tower could not maintain the water-loop temperature. The outside air was conditioned by the water-source heat pumps. A single heat pump was provided to serve each of the zones.

Four-pipe Design Description

To provide conditioning to the simulated school, a chiller and boiler serving four-pipe fan coil units were modeled. A water-cooled screw chiller with an efficiency of 0.6kw/ton was used. The chiller was served by a two-speed cooling tower, and each was served by a set of pumps to circulate condenser water and chilled water. A condensing boiler with an efficiency of 91.5% provided hot water to the fan coil units. The outside air was conditioned by the fan coil units. A single fan coil unit served each of the zones.

CITY MULTI Total Energy Cost Savings



LEED NC 2.2 and CITY MULTI

CITY MULTI VRFZ Systems are helpful in obtaining points for LEED® (Leadership in Energy and Environmental Design) Energy and Atmosphere credit 1. The U.S. Green Building Council (USGBC) developed the LEED® Green Building Rating System™ as a voluntary, consensus-based national standard for developing high-performance, sustainable buildings.



Classrooms are significantly more problematic than other school areas such as cafeterias, libraries and auditoriums when it comes to achieving a comfortable indoor environment.

- Clear Seas Research report

Building energy savings can be demonstrated by performing a building energy model using the EnergyPro software available from EnergySoft, LLC. and comparing the building design with a baseline building as defined by ASHRAE 90.1-2004. EnergyPro is approved by the USGBC for EAc1 calculations. As shown below, the percentage of total energy savings relates directly to LEED credits.

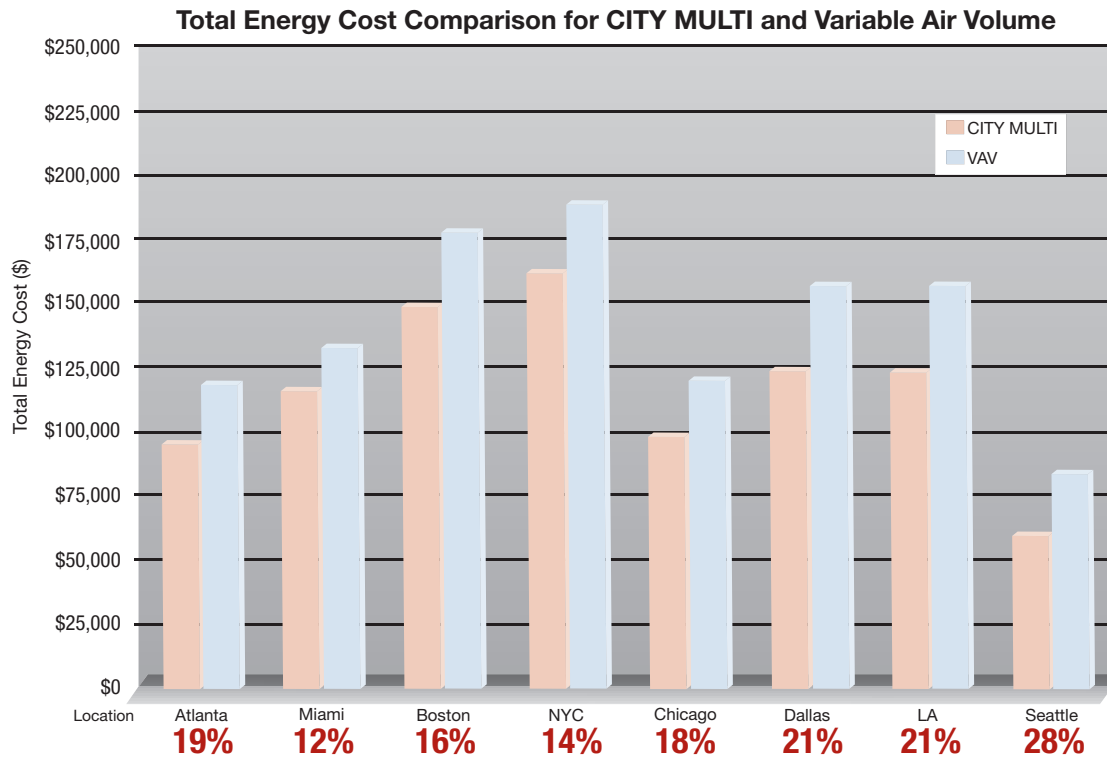
LEED Points based on Total Energy Savings (EA Credit 1)		
New Buildings	Existing Building Renovations	Points
10.5%	3.5%	1
14%	7%	2
17.5%	10.5%	3
21%	14%	4
24.5%	17.5%	5
28%	21%	6
31.5%	24.5%	7
35%	28%	8
38.5%	31.5%	9
42%	35%	10

The graphs on the following page show the percentage savings of CITY MULTI VRFZ over the ASHRAE 90.1-2004 baseline which is the VAV system as well as other system types.



“Buildings are responsible for 30% of the energy utilized in the United States and over 60% of the electricity consumed throughout the country.”

- LEED Reference Guide for Green Building Design and Construction, 2009

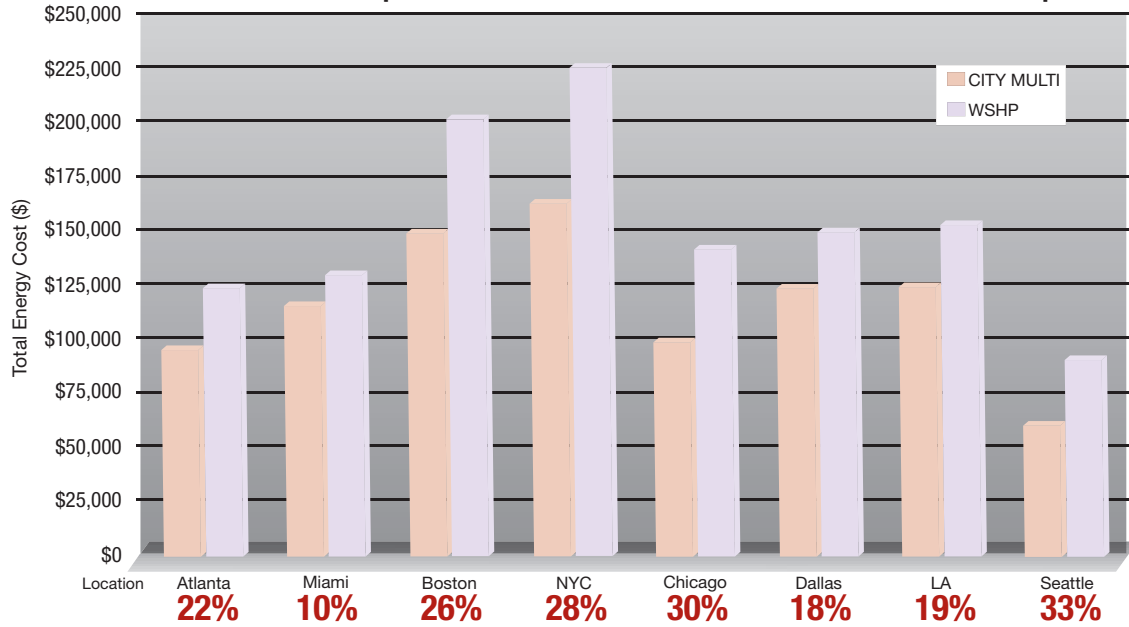


CITY MULTI as compared to VAV

A VAV system is the baseline defined by ASHRAE 90.1 2004 for this building size and type. Energy usage was calculated for the buildings using both systems. On average, the CITY MULTI system saw a total energy cost savings of 19% when compared with the VAV systems, and a 31% average savings when comparing HVAC energy cost.

The savings varied greatly based upon the modeled location and the applied local utility rates. Based on the average energy cost savings from the models, future projects would meet the LEED EA credit 1 prerequisite and qualify for three LEED points. Specific results for each city are in the Energy Usage Summaries (Tables 3, 4).

Total Cost Comparison for CITY MULTI and Water-source Heat Pump

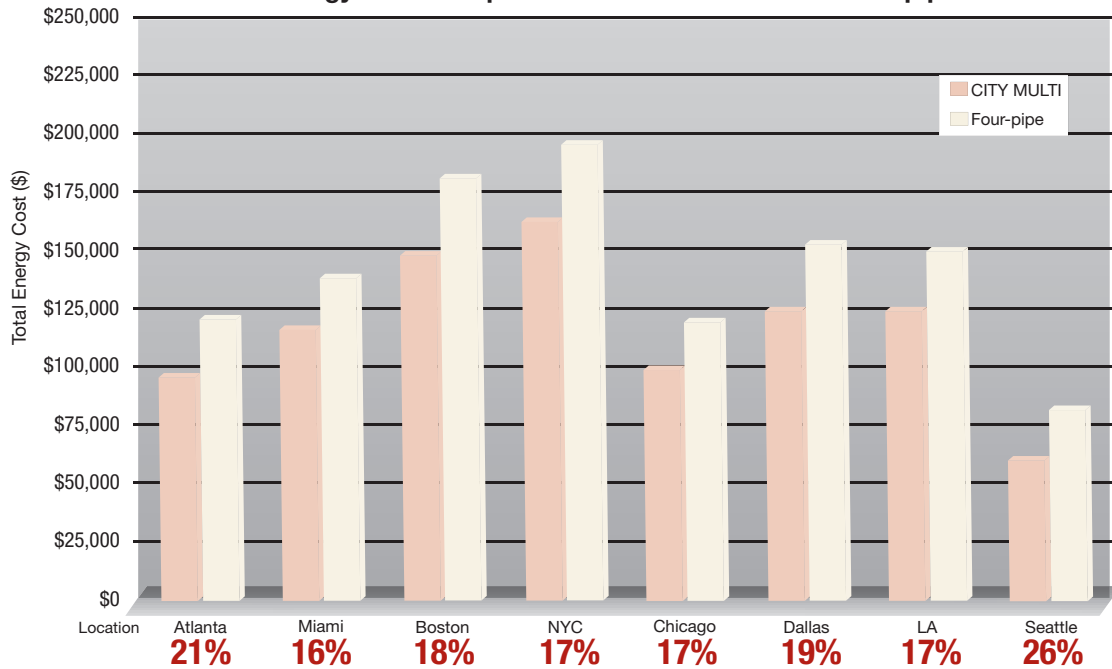


CITY MULTI as compared to WSHP

WSHP systems have recently become a popular choice for schools needing to replace outdated HVAC systems. Energy usage was calculated for the buildings using both systems. The total energy cost savings realized with the CITY MULTI system was dramatic: 23% on average compared to a WSHP system.

When comparing the energy cost used by the HVAC systems alone, CITY MULTI was 37% less cost on average. The savings seen by CITY MULTI is detailed in the Energy Usage Summaries (Tables 3, 4).

Total Energy Cost Comparison for CITY MULTI and Four-pipe



CITY MULTI as compared to Four-pipe

A four-pipe fan coil unit system is a standard HVAC package used in many building types. Energy usage was calculated for the buildings using both systems. On average, the total energy cost savings realized with the CITY MULTI system was 19% when

compared to a four-pipe fan coil unit system and a 32% average savings when comparing HVAC energy cost. The chiller efficiency exceeded the ASHRAE 90.1 standard by 0.1kw/ton. Savings were fairly constant across all locations and are detailed in the Energy Usage Summaries (Tables 3, 4).

Engineering Assumptions

Weather Profile based on locations shown in the ASHRAE Design Temperature table.

Item	Design Assumption
Building Area	As defined by the plans (~82,000 sq. ft.)
Glass selection	Double Thermal Break Clear U-Value: 0.660 SHGC: 0.630
Walls	Construction: Wood frame Insulation: R-13 Total Assembly U-Value: 0.102
Roof	Construction: R-19 Roof over Metal Deck Insulation: R-19 Total Assembly U-Value: 0.045 Reflectivity: 0.7
CITY MULTI VRFZ system	CITY MULTI R2-Series heat recovery system. Ducted units were used to serve the individual zones, and a dedicated outdoor air unit was provided to precondition outdoor air before delivering it to the indoor units.
Packaged VAV HVAC systems	Rooftop packaged VAV, 9.5 EER, with hot water reheat provided by a hot water boiler at 91.5% efficiency. All pumps were sized per ASHRAE std. 90.1-2004 recommendations.
Water-source Heat Pump HVAC system	Water source heat pumps served by a two-speed cooling tower and a 91.5 % efficient supplemental boiler. The heat pumps have an efficiency of 15.4 EER and a COP of 4.7. All pumps were sized per ASHRAE std. 90.1-2004 recommendations.
4-Pipe Fan Coil Unit HVAC system	Fan Coil Units served by a 91.5% efficient boiler, a water cooled screw chiller with an efficiency of 0.6kw/ton and a two-speed cooling tower. All pumps were sized per ASHRAE std. 90.1-2004 recommendations.
Miscellaneous Loads	School: 1.0 Watts/ft ²
Schedules	Standard ASHRAE 90.1 Profile and Operation Schedules
Utility Rates	See Utility Rate Summary Table

Energy savings, operating efficiency, quality and reliability, and sound levels are the top factors considered important when implementing comfort solutions for K-12 schools
- according to a recent study by Clear Seas Research.



Table 1. Utility Rate Summary

	Atlanta	Miami	Boston	NYC	Chicago	Dallas	LA	Seattle
Electric (\$/KWH)	0.1117	0.1174	0.177	0.1975	0.1094	0.1394	0.1498	0.0775
Gas (\$/Therm)	1.356	1.492	1.507	1.298	1.112	1.063	1.153	1.109

Table 2. ASHRAE Design Temperature

	Atlanta	Miami	Boston	NYC	Chicago	Dallas	LA	Seattle
Summer DB 0.40%	93	91	91	91	91	100	85	85
Summer MWB 0.40%	75	71	73	74	74	74	64	65
Winter DB 99.6%	18	46	7	11	-6	17	43	23

Table 3. Total Energy Usage Summary

		Atlanta	Miami	Boston	NYC	Chicago	Dallas	LA	Seattle
CITY MULTI	Total KWH	837,838	994,513	795,274	799,794	845,757	881,942	831,110	735,900
	Total Therm	1,858	23	5,524	4,187	6,037	1,351	121	3,175
	Total MMBTU	3,047	3,398	3,268	3,150	3,492	3,147	2,850	2,830
	Total Cost	\$96,106	\$116,790	\$149,088	\$163,394	\$99,238	\$124,378	\$124,639	\$60,553
VAV	Total KWH	884,221	1,081,132	761,315	796,238	800,043	1,034,776	985,254	731,866
	Total Therm	14,743	3,971	28,919	25,054	29,626	12,452	8,732	24,362
	Total MMBTU	4,494	4,089	5,492	5,224	5,694	4,778	4,237	4,935
	Total Cost	\$118,759	\$132,849	\$178,333	\$189,777	\$120,468	\$157,484	\$157,659	\$83,737
WSHP	Total KWH	1,027,918	1,108,919	998,372	1,047,407	1,086,978	1,048,255	1,019,075	976,591
	Total Therm	6,536	50	17,289	15,215	20,356	4,445	310	13,295
	Total MMBTU	4,163	3,791	5,138	5,098	5,747	4,024	3,511	4,664
	Total Cost	\$123,681	\$130,261	\$202,766	\$226,612	\$141,551	\$150,851	\$153,014	\$90,429
Four-pipe	Total KWH	987,745	1,184,952	849,388	884,982	879,902	1,057,185	998,122	836,524
	Total Therm	7,857	115	20,902	16,643	21,323	5,577	1,081	15,816
	Total MMBTU	4,158	4,057	4,991	4,686	5,137	4,167	3,516	44,38
	Total Cost	\$120,983	\$139,284	\$181,841	\$196,386	\$119,972	\$153,299	\$150,765	\$82,370
MMBTU Savings	CM vs. VAV	32%	17%	40%	40%	39%	34%	33%	43%
	CM vs. WSHP	27%	10%	36%	38%	39%	22%	19%	39%
	CM vs. Four-pipe	27%	16%	35%	33%	32%	24%	19%	36%
Cost Savings	CM vs. VAV	19%	12%	16%	14%	18%	21%	21%	28%
	CM vs. WSHP	22%	10%	26%	28%	30%	18%	19%	33%
	CM vs. Four-pipe	21%	16%	18%	17%	17%	19%	17%	26%

Table 4. HVAC Only Energy Usage Summary

		Atlanta	Miami	Boston	NYC	Chicago	Dallas	LA	Seattle
CITY MULTI	Total KWH	409,856	566,531	367,292	371,812	417,775	453,960	403,128	307,918
	Total Therm	1,858	23	5,524	4,187	6,037	1,351	121	3,175
	Total MMBTU	1,586	1,937	1,807	1,689	2,030	1,685	1,389	1,369
	Total Cost	\$48,300	\$66,545	\$73,335	\$78,868	\$52,418	\$64,718	\$60,528	\$27,385
VAV	Total KWH	456,239	653,150	333,333	368,256	372,061	606,794	557,272	303,884
	Total Therm	14,743	3,971	28,919	25,054	29,626	12,452	8,732	24,362
	Total MMBTU	3,032	2,627	4,030	3,763	4,233	3,317	2,776	3,474
	Total Cost	\$70,953	\$82,605	\$102,581	\$105,251	\$73,648	\$97,824	\$93,547	\$50,568
WSHP	Total KWH	599,936	680,937	570,390	619,425	658,996	620,273	591,093	548,609
	Total Therm	6,536	50	17,289	15,215	20,356	4,445	310	13,295
	Total MMBTU	2,702	2,330	3,677	3,637	4,286	2,563	2,049	3,203
	Total Cost	\$75,876	\$80,017	\$127,014	\$142,086	\$94,730	\$91,191	\$88,903	\$57,261
Four-pipe	Total KWH	559,763	756,970	421,406	457,000	451,920	629,203	570,140	408,542
	Total Therm	7,857	115	20,902	16,643	21,323	5,577	1,081	15,816
	Total MMBTU	2,697	2,596	3,529	3,225	3,676	2,706	2,055	2,977
	Total Cost	\$73,180	\$89,040	\$106,088	\$111,860	\$73,151	\$93,639	\$86,653	\$49,202
MMBTU Savings	CM vs. VAV	48%	26%	55%	55%	52%	49%	50%	61%
	CM vs. WSHP	41%	17%	51%	54%	53%	34%	32%	57%
	CM vs. Four-pipe	41%	25%	49%	48%	45%	38%	32%	54%
Cost Savings	CM vs. VAV	32%	19%	29%	25%	29%	34%	35%	46%
	CM vs. WSHP	36%	17%	42%	44%	45%	29%	32%	52%
	CM vs. Four-pipe	34%	25%	31%	29%	28%	31%	30%	44%

*CITY MULTI is abbreviated as 'CM' in the above tables.

CITY MULTI®

VRFZ TECHNOLOGY



Advantages of CITY MULTI over Comparable Systems

The EnergyPro model demonstrated that CITY MULTI systems offer reduced energy costs because of part-load efficiency and the ability to simultaneously cool and heat. CITY MULTI R2-Series heat recovery systems can simultaneously cool and heat different zones, which allows energy to be recovered from one zone and used in another, resulting in a huge increase in efficiency and energy savings over all of the compared systems.

There are some major areas in which the CITY MULTI system offers an advantage over other systems:

- 1. Initial Cost:** CITY MULTI systems consist of an outdoor unit, an indoor unit in each zone, a BC controller (R2-Series only), refrigerant piping, and a very simple controls system. A four-pipe fan coil unit system includes a boiler, chiller, fan coil units, pumps, hot water piping, chilled water piping, a controls system, etc. A water-source heat pump system includes a cooling tower, supplemental boiler, condenser water piping, condenser water pumps, heat pumps, a controls system, etc. The reduced equipment required and ease of installation makes the CITY MULTI a superior first cost solution.
- 2. Comfort:** One of the biggest advantages that CITY MULTI VRFZ solutions have over other systems is the increased comfort level for the occupants. VRFZ technology allows indoor units to operate at the precise level necessary to maintain room temperature which, when combined with the powerful controls system, allows the occupants to experience consistent comfort throughout the day.
- 3. Quiet Operation:** CITY MULTI indoor and outdoor units operate at low sound levels; for example, a 20-ton outdoor unit operating at high speed has a sound level of 63 dB(A). Some indoor models have an operating sound level in the low 20 dB(A)s range, depending on fan speed and duct design. For contrast, the sound level for normal conversation is approximately 60 dB(A).
- 4. Installation Space:** CITY MULTI systems do not require a mechanical room. Outdoor units can be installed outside either on grade or the roof and piped directly to indoor units, eliminating the need for pumps. Depending on the type of indoor unit, they can be installed in plenum spaces, on walls, or in the ceiling. Refrigerant piping is routed to the BC controller, also located in the plenum space, and then to the outdoor unit.
- 5. Installation Time:** Because there are fewer components in a CITY MULTI system, the time it takes for installation is much shorter than for other systems. An indoor unit can be mounted and piped from the BC controller in hours.
- 6. Flexibility:** The zoning capabilities of CITY MULTI systems allow for one indoor unit to be taken offline without affecting other indoor units. An outdoor unit can also be shut down and affect only a few zones. However with other systems if an air-handling unit should fail, or a component of the central mechanical system should fail (chiller, cooling tower or pumps) a large portion, if not all, building conditioning would be lost.
- 7. Versatility:** CITY MULTI systems offer a choice of inside air handlers: ducted, wall-mounted, ceiling-mounted, and floor-mounted. Many other systems only offer limited indoor unit selections.
- 8. Efficiency:** CITY MULTI R2-Series systems have the ability to recover energy when simultaneously cooling and heating, thereby reducing energy and increasing operating efficiency. Variable refrigerant flow zoning technology also allows CITY MULTI to automatically adjust to changing loads in each zone, maintaining the required temperature levels and operating at a lower cost.
- 9. Maintenance:** CITY MULTI systems require significantly less maintenance; typically only requiring filter changes. CITY MULTI systems have a life expectancy of 15 to 20 years. Water-source heat pump systems require regular maintenance to maintain the compressor and keep the system functioning properly.



Mitsubishi Electric Advanced Products Division
3400 Lawrenceville Suwanee Road
Suwanee, GA 30024

Phone: 888-467-7546 Fax: 800-658-1458

Form No. EPBROSVM(GA)-7-09 V2

For more information visit www.mehvac.com



Please recycle.

©2009 Mitsubishi Electric & Electronics USA, Inc. CITY MULTI is a registered trademark of Mitsubishi Electric. The three-diamond logo is a registered logo of Mitsubishi Electric Corporation.