General Services Administration
Public Buildings Service

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VARIABLE REFRIGERANT FLOW

VRF Systems Promise Savings in Targeted Building Types and Climates

Variable Refrigerant Flow (VRF) heating, ventilation, and air conditioning (HVAC) systems use refrigerant as their cooling/heating medium. A compressor unit, typically located on a roof, is connected through refrigerant lines to multiple indoor fan coil units, each individually controllable by its user. The system is capable of simultaneously cooling one area while heating another, and can transfer heat from spaces being cooled to spaces being heated and vice versa. Also, they are small, modular, and can be installed without the use of a crane. This high-performance HVAC technology was invented in Japan more than 20 years ago and has large installed bases in several countries but it's a relative newcomer to the U.S., which, according to a major VRF manufacturer, can claim only 3.4% of the market[1]. However, because VRF has proven to be effective under certain circumstances, particularly in retrofits of older buildings where room for additional ductwork is limited, and because it promises energy and cost savings when compared with many other HVAC systems, GSA's GPG program recently assessed the technology. Preliminary findings suggest that VRF systems can achieve 34% and higher HVAC energy cost savings.

INTRODUCTION

"Information and research available on VRF suggest that it can reduce energy usage and provide suitable space conditioning. It makes sense for GSA to begin thorough assessment and targeted deployment in cost-effective applications."

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PERFORMANCE SPECIFICATIONS
Energy-Efficiency

COOLING (IEER)[2]	
High-Efficiency Conventional	**14-17**
Majority of VRF	**16-20+**
HEATING (COP)[3]	
Conventional	**3.2-3.3**
Majority of VRF	**3.2-3.5+**

What We Did

RESEARCHERS CONSULT AVAILABLE LITERATURE & INDUSTRY EXPERTS

Because VRF promises energy and cost savings, and because it seems to be particularly well suited to a certain subset of GSA buildings, GPG commissioned researchers at the Pacific Northwest National Laboratory (PNNL) to evaluate the technology. GSA does not yet have a VRF implementation that is suitable for field study, so PNNL's evaluation was based largely on a critical survey of the available VRF literature and discussions with industry experts. Researchers also took into consideration a partial VRF installation at GSA's Moakley Federal Court House in Boston, Massachusetts, four additional installations in the Pacific Northwest, a review of VRF simulation work, a hypothetical application of the technology to selected parts of the GSA portfolio, and a life cycle cost analysis (LCCA) that compares VRF technology with a VAV system with electric reheat. PNNL's evaluation indicates that Variable Refrigerant Flow technology merits GSA's serious consideration.

FINDINGS

34% PROJECTED HVAC ENERGY REDUCTION ACROSS RANGE OF CLIMATES Preliminary findings suggest that VRF systems can achieve 34% and higher HVAC energy savings relative to new systems that are code-compliant and older inefficient systems, in a range of building types and climates.

Also, when compared with energy-efficient HVAC systems, including high-performance conventional systems and newer systems such as radiant panels, VRF systems may offer similar or lower energy usage.

CONDITIONS FOR COST-EFFECTIVE RETROFITS PNNL analysis further indicates that for retrofits GSA should focus on buildings where the installation of VRF technology would involve a premium of less than $4.00 per ft^2, when compared to other code-compliant HVAC systems, and/or energy usage that is higher than the GSA average of 60.7 $kBtu/ft^2$ and energy costs that are higher than the GSA average of $0.89/therm and the EIA[4] average of $0.10/kWh.

TARGETED DEPLOYMENT & ASSESSMENT RECOMMENDED While there are many indications that VRF technology would serve GSA well in its efforts to reduce energy use and greenhouse gas emissions, much of the available literature lacks critical evaluation of actual field energy performance. For this reason, the research team recommends that GSA should establish and evaluate two or more pilot projects before recommending deployment.

Projected Payback for VRF vs VAV

REASONABLE PAYBACKS ARE THOUGHT TO BE ACHIEVABLE (shown in white)

VRF vs VAV with Gas Reheat or CAV

34% Projected Energy Cost Savings

Added Cost $/ft² \ Energy Cost Savings, $/ft²	$.10	$.14	*$.18	$.22	$.26	$.30	$.34	$.38
$1	10	7	6	5	4	3	3	3
$2	20	14	11	9	8	7	6	5
$3	30	21	17	14	12	10	9	8
**$4	40	29	22	18	15	13	12	11
$5	50	36	28	23	19	17	15	13
$6	60	43	33	27	23	20	18	16

VRF vs VAV with Electric Reheat

45% Projected Energy Cost Savings

Added Cost $/ft² \ Energy Cost Savings, $/ft²	$.13	$.19	*$.24	$.29	$.34	$.40	$.45	$.50
$1	8	5	4	3	3	3	2	2
$2	15	11	8	7	6	5	4	4
$3	23	16	13	10	9	8	7	6
**$4	30	22	17	14	12	10	9	8
$5	38	27	21	17	15	13	11	10
$6	45	32	25	21	17	15	13	12

* Average GSA Portfolio Energy Cost Savings (based on GSA average usage of 60.7 $kBtu/ft^2$, GSA average cost of $0.89/therm, and EIA[3] average cost of $0.10/kWh)

** Average Added Cost

CONCLUSIONS

These Findings are based on the report, "Variable Refrigerant Flow Systems" which is available from the GPG program website, www.gsa.gov/gpg.

For more information, contact GSA's GPG program gpg@gsa.gov

What We Concluded

BUILDINGS TARGETED FOR VRF SHOULD MEET SPECIFIC CRITERIA

As mentioned, targeted retrofits should have an estimated cost premium for VRF that is less than $4.00 per ft^2 and/or energy usage that is higher than the GSA average of 60.7 $kBtu/ft^2$ and energy costs that are higher than the GSA average of $0.89/therm and the EIA[5] average of $0.10/kWh. In addition, existing buildings being considered for VRF should include one or more of the following characteristics:

- need for HVAC upgrades with limited room for ductwork changes
- climates with significant heating loads
- buildings with electric reheat, supplemental heat, or primary heating
- 5,000 to 100,000 ft^2 (larger buildings can be evaluated on a case-by-case basis)
- buildings with enclosed spaces that would benefit from independent temperature control.

For new construction, targeting larger-scale high-performance buildings is recommended. The size and climate characteristics identified for existing buildings also apply to new buildings.

Barriers to Adoption

VRF IMPLEMENTATION IN GSA PORTFOLIO MUST OVERCOME OBSTACLES

At least three obstacles stand in the way of GSA's moving aggressively on VRF implementation: lack of independent suppliers; high first costs; and uncertainty about energy savings benefits.

SUPPLIERS Manufacturers provide VRF technology through an integrated supply system, which includes installation, design training, quality control, and sometimes part or all of the design itself. GSA will have difficulty reconciling this with the design/bid/build approach it uses for procurement.

FIRST COSTS First costs can be relatively high compared to conventional alternatives. However, targeting projects that are appropriate for VRF can reduce this discrepancy. In fact, for some renovations, like those needing increased heating or cooling capacity in buildings that are constrained for space, VRF systems may be less expensive than conventional ones. Also, as familiarity with VRF systems spreads and competition increases, costs may come down.

UNCERTAINTY ABOUT THE ENERGY SAVINGS Because there is a scarcity of thorough case studies and a heavy reliance on model estimates, questions remain about the magnitude of energy savings that can be realized with VRF.

Reference above to any specific commercial product, process or service does not constitute or imply its endorsement, recommendation or favoring by the United States Government or any agency thereof.

Footnotes

[1]LG (2012), "Variable Refrigerant Flow, Innovative Technology Can Cut Small-format Retailer's HVAC Energy Cost by 45%." Seoul, Korea: LG.

[2]Integrated Energy Efficiency Ratio (IEER) measures cooling part-load EER efficiency (cooling output divided by total energy consumption) on the basis of weighted operation at various load capacities.

[2]Coefficient of Performance (COP) is the ratio of heating or cooling provided to electrical energy consumed. Higher COPs equate to lower operating costs.

[4]EIA (2012). "Average Retail Price of Electricity to Ultimate Customers: By State by Sector, Latest Year" Washington D.C.: Energy Information Administration, U.S. Department of Energy. Accessed June 25, 2012 at http://205.254.135.7/electricity/data.cfm.

[5]ibid

Technology for test-bed measurement and verification provided by Mitsubishi.