VRF Life Cycle Cost Analysis

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Introduction

- Purpose: Discuss life cycle cost trade-offs for VRF with other HVAC systems
- Outline
  - Life cycle cost parameters
  - Hypothetical retrofit example: VRF compared to VAV with electric reheat
    - Energy cost
    - Maintenance
    - Repair and replacement
    - Life cycle cost and payback results

Life Cycle Cost Analysis

- Present value $P = F\,[1/(1+i)^n]$
  - P = present value
  - F = future value
  - i = discount rate
  - n = number of years in the future
- Total present value – sum of the present value of all future costs
- Life cycle cost comparison
  - An alternative choice is economical if its present value is less than the present value of an alternative
  - VRF alternative compared to a conventional HVAC alternative

Life Cycle Cost Parameters

Parameter	Value	Source
Period of analysis, years	15	Life of equipment
Discount rate, real	3%	FEMP LCC parameters, (Rushing et al. 2011)
Inflation	0.9%	
Energy cost escalation (source value 1.0%, used general inflation of 0.9% to simplify analysis)	0.9%	
Maintenance, Repair and Replacement Costs		
Overhead and profit (OH&P)	30%	RS Means 2012
Labor Rate	$55.30	RS Means 2012

HVAC Equipment First Costs

- Estimated average for major retrofit and new construction from literature review and interviews
- VAV with electric reheat $20/ft^2
- CAV with gas heat* $18/ft^2
- VRF $24/ft^2
- References
  - Amarnath and Blatt 2008
  - BPA 2012b
  - BPA 2012c
  - EES Consulting 2011
  - Goetzler 2007
  - Hart and Campbell 2012
  - Phone call with Hunter-Davisson, 4-27-12
  - Phone call with Daikin, 4-17-12

*CAV information provided but not used in life cycle cost example below

Energy Cost Percentage Reduction

- Estimated average percentage reduction in energy cost for VRF compared to conventional HVAC systems based on literature review.
  - Primarily based on reported energy modeling; no monitored savings. Does not include current research on part load
- Compared to VAV with electric reheat 45%
- Compared to CAV with gas heat* 36%
- Sources
  - EES Consulting 2011 (references Aynur 2010, Amarnath and Blatt 2008
  - Goetzler 2007
  - Hart and Campbell 2012
  - LG 2011, 2012

*CAV information provided but not used in life cycle cost example below

Example: VRF Compared to VAV Electric Reheat

- Hypothetical existing office building, 48,000 ft^2
- Existing system is old VAV electric reheat system with inadequate cooling capacity and duct work. Building internal floor plan being changed.
- Retrofit project includes total replacement of existing units and air distribution system
- Cooling load is 120 tons
- Two replacement alternatives are being considered
  - VAV with electric reheat
  - VRF with DOAS

Description of Example Retrofit Alternatives

- Retrofit alternative 1: VAV with electric reheat
  - Four 30 ton packaged rooftop units
  - 10 terminal units per system, 40 terminal units
  - First cost, $21/ft^2, total $1,008,800
    - $21/ft^2 is higher than $20/ft^2 average assuming some additional retrofit duct costs
  - Assuming 10% energy cost savings relative to existing system
- Retrofit alternative 2: VRF
  - Three 30 ton VRF compressor units
  - 20 fan coil units per system, 60 terminal units
  - One 20 ton DOAS unit
  - First cost, $24/ft^2, total $1,152,000
  - Assuming 45% energy cost savings relative to existing system

Energy Cost Savings

Existing Annual Energy Usage	kBtu/ft^2	Source
Total Energy Usage	67.7	kBtu/ft^2
Heating	20.5	kBtu/ft^2
Cooling	6.1	kBtu/ft^2
Fans	4.1	kBtu/ft^2
HVAC electricity total	8.4	kWh/ft^2
HVAC gas total	0.02	therms/ft^2
Annual Energy Cost	$/ft^2	Total
Existing HVAC Energy Cost	$0.89	$42,561
VAV energy cost with 10% savings	$0.80	$38,305
VRF energy cost with 45% savings	$0.49	$23,408
Annual energy cost savings	$0.31	$14,896

- Energy usage for medium offices built 1990 to 2003, adjusted to electric reheat from primarily gas heat (CBECS 2003)
- Energy usage is national average, not at a particular climate location
- Energy cost, $0.1032/kWh, $0.99/therm, Standing Standard Project Committee 90.1
- VAV retrofit 10% energy savings estimated for example

VAV Maintenance, Repair and Replacement

Cost Items	Period, years	Qty.	Hours, each	Labor Cost	Cost, each	Material Cost	Cost with	Present Value
Maintenance							Annual	
Economizer maintenance	1	4	0.83	$184	$0	$0	$240	$2,861
Terminal unit maintenance[1]	1	40	0.93	$2,066	$40	$1,600	$2,686	$32,063
Replace RTU air filters	1	Annualized estimate					$813	$9,710
Subtotal maintenance							$3,739	$44,634
Repair/Replace							Year 10	
Replace fan bearings and motors	10	4	9.87	$2,183	$416	$1,663	$2,837	$2,111
Repair terminal units[1]	10	40	1.2	$2,654	$0	$0	$3,451	$2,568
Replace refrigerant	10	4	3.3	$730	$81	$268	$1,297	$965
Subtotal repair/replace							$7,585	$5,644
Total								$50,278

[1] Terminal unit repair from RS Means 2004 did not include material cost. Material cost assumed to be part of unit replacement at end of 15 year life.

Compressor (not fan or economizer) maintenance and repair assumed to be the same between the 4 VAV systems, and the 3 VRF and 1 DOAS system

VRF Maintenance, Repair and Replacement

Cost Items	years	Qty.	Hours,	Cost	Cost,	Cost	Cost	Value
Maintenance							Annual	
Fan coil filter change	0.5	60	0.25	$830	$5	$300	$2,937	$35,058
Check/clean fan coil condensate systems	1	60	0.25	$830	$0	$0	$1,078	$12,873
Replace DOAS air filters	1	Annualized estimate					$69	$825
Subtotal maintenance							$4,084	$48,757
Repair/Replace							Year 10	
Fan coil motor replacement[1]	10	60	3.1	$10,286	$140	$8,400	$24,292	$18,075
Replace DOAS fan bearings and motors	10	1	9.87	$546	$416	$416	$709	$528
Replace refrigerant	10	4	3.3	$730	$162	$536	$1,646	$1,225
Subtotal repair/replace								$19,828
Total								$68,584

[1] Fan coil motors are shown as being replaced in year 10. This value may be too short on average for direct driven digital electrically commutated motors used for many/most of these units. Data on actual life of this equipment was not available

Sources of Maintenance, Repair and Replacement Costs

- Most labor hours and material costs are from RS Means Facilities Maintenance and Repair (RS Means 2004).
  - Labor cost/hour shown under life cost analysis parameters.
  - Material costs adjusted to 2012, 1% average inflation.
- Economizer maintenance from PNNL staff
- Fan coil filter cost, RS Means 2012
- RTU and DOAS filter cost, annualized estimate based on Arnold et al. 2005
- Check/clean fan coil condensate system, REHVA 2004
- ECM motor cost, Heschong Mahone Group et al. 2010
- Combined VRF and DOAS refrigerant volume estimated as twice VAV systems refrigerant volume based on phone call with Daikin 4-17-12

Life Cycle Cost Results

Cost Categories	Present Value				
	First Cost	HVAC Energy Cost	Maintenance	Repair/ Replace	Total
VAV	$1,008,000	$457,278	$44,634	$5,644	$1,515,556
VRF	$1,152,000	$279,447	$48,757	$19,828	$1,500,032
Net Present Value, VRF-VAV	$144,000	-$177,830	$4,123	$14,183	-$15,524

- VRF alternative has a lower life cycle cost and is the economical choice in this case when considered over a 15 year period and with the other economic parameters identified
- VRF alternative has higher maintenance, repair and replacement costs, and the present value of those costs offsets almost 10% of the present value of the energy cost savings

Payback with Energy Maintenance, Repair and Replacement

	First Cost	Annual Energy Cost	Annual Maintenance	Annualized Repair and Replacement	Total with Energy and Non-energy Costs
VAV	$1,008,000	$38,305	$3,739	$473	$42,516
VRF	$1,152,000	$23,408	$4,084	$1,661	$29,153
VRF minus VAV	$144,000	-$14,896	$345	$1,188	-$13,363
Payback, years		9.7			10.8

Observations

- Analysis of the economics of VRF systems should include looking at maintenance, repair and replacement costs
- The non-energy costs can have a material impact on the economic return including net present value, and effective payback
- The example presented in this report is just one case. Results for VRF compared to other system types such as constant volume systems, or other energy efficient systems such as radiant cooling or chilled beams will differ substantially.
- Life cycle costs are sensitive to the economic parameters. A robust analysis will consider the reasonable range of these parameters. Additional costs such as loans and tax impacts may also be considered.
- This type of analysis would be improved by better information on the maintenance, repair and replacement costs for VRF system components.

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