Bonneville Power Administration

Measure Summary Report: Variable Refrigerant Flow

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Executive Summary

Variable Refrigerant Flow systems typically comprise of one or more outdoor unit(s) connected through refrigerant lines to multiple indoor units. While similar to mini-split systems, the primary difference is that VRF systems can adjust cooling and heating outputs by adjusting the refrigerant flow and the variable speed compressor. This allows multiple indoor units to be connected using a common refrigerant line, rather than needing separate lines between each indoor unit and the indoor unit.

Systems allow a highly customizable configuration of 60 or more indoor units operating off one outdoor unit, connected by refrigerant lines. The amount of refrigerant flowing to each of the evaporators is controlled by the VRF system. The indoor units contain electronic expansion valves, direct expansion coils, and fans. The VRF system controls the variable speed drives, expansion valves and dynamic refrigerant circuitry. The outdoor and indoor units are connected by refrigerant lines.

There are two types of VRF systems: the standard, or heat pump type VRF, which provides either all heating or all cooling to multiple zones at a time. The other type is heat recovery VRF, which provides heating and cooling simultaneously to multiple zones with various cooling or heating demand. VRF systems with heat recovery capability cost more, but can minimize energy use by efficiently providing simultaneous heating and cooling. Instead of rejecting heat these systems can transfer heat from an area that needs cooling, such as a computer room, to another area, such as a perimeter office. The chart below summarizes various variable flow heat pump configurations, including the two VRF system types.

	Variable Capacity Split System Heat Pumps		**Variable Refrigerant Flow Heat Pumps**	
	Mini-Split Heat pump	**Multi-Split Heat pump**	**VRF Heat pump**	**VRF Heat Recovery Heat pump**
Cooling Capacity (tons)	0.75 - 4	0.75 - 4	6 - 30	6 - 24
Number of indoor units per outdoor condensing unit	1	2-8	Up to 50	Up to 50

Installation costs are highly dependent on the application, construction, system design and layout of the building, including whether the installation is new or retrofit. In addition, the emerging nature of the technology in the Northwest can inflate the cost of multi-split VRF systems. A separate ventilation system may be necessary, which could increase the VRF system cost.

There are several available price points from case studies and published reports. One survey of total costs showed that multi-split VRF systems were likely to be about 5% to 20% higher than the chilled water systems of similar capacity in the United States (Amarnath, 2008). Systems with heat recovery are assumed to be on the high end of that cost range.

There have been numerous articles written and modeling studies conducted to identify expected savings from VRF systems. However, there is high variability throughout the literature, ranging from 5 to over 50% savings compared with traditional HVAC equipment. This large range is due to variation in design, climate and baseline. For reference the average of all data points from the studies reviewed is 29%. The 5-20% range is expected to be more applicable to the northwest climates. Heat recovery systems will certainly yield more savings than non-heat recovery systems, but the literature is unclear regarding difference in savings between the two VRF system types. Therefore a 20% HVAC savings for all VRF systems is assumed for this report..

Table ES-1 summarizes a cost-effectiveness example for the VRF measure in a few selected retrofit applications. These applications were selected to represent a range of costs and savings values. The measure appears to be cost effective in all but one of the example cases.

Table ES-1 – VRF Retrofit Cost-Effectiveness Example

Building Type	Retro/New	Location	Life	Savings (kWh/sf/yr)	Cost ($/sf)	TRC B/C Ratio
LargeOffice	Retrofit	Seattle	20	0.30	0.23	1.7
LargeOffice	Retrofit	Boise	20	0.45	0.23	2.6
SmallOffice	Retrofit	Seattle	20	0.25	0.41	0.8
SmallOffice	Retrofit	Boise	20	0.52	0.41	1.7
Lodging	Retrofit	Seattle	20	0.38	0.33	1.6
Lodging	Retrofit	Boise	20	0.58	0.33	2.4

Estimates of regional savings potential are based on three factors: 1) baseline consumption data of commercial buildings in the region, 2) an assumed savings percentage of VRF systems from case studies and 3) applicable square footage data.

The twenty percent savings value was applied to baseline data and the results for savings range from 0.44 kWh/sf to 1.8 kWh/sf. Table ES-2 shows the 5-and 20-year technical potential by building type. The Commercial HVAC potential in the Sixth Plan is 304 aMW. Assuming BPA share of 42% (128 aMW), VRF savings represents 3.6% relative to the HVAC potential defined in the Sixth Plan.

Table ES-2 – BPA 20-Year VRF Technical Potential

Total 20-Year	5-YR aMW			20-YR aMW		
	Retrofit	**New**	**Total**	**Retrofit**	**New**	**Total**
Large Off	0.14	0.05	0.19	0.92	0.32	1.24
Medium Off	0.04	0.01	0.05	0.25	0.09	0.34
Small Off	0.04	0.02	0.06	0.28	0.10	0.38
K-12	0.11	0.02	0.13	0.68	0.15	0.83
University	0.01	0.00	0.02	0.08	0.02	0.10
Lodging	0.16	0.02	0.19	1.06	0.14	1.20
Hospital	0.01	0.00	0.01	0.06	0.01	0.07
OtherHealth	0.05	0.02	0.07	0.34	0.14	0.48
TOTAL	**0.57**	**0.15**	**0.72**	**3.67**	**0.98**	**4.64**

Variable Refrigerant Flow (VRF) systems are widely utilized around the world and are gaining in interest in the US and the Northwest. This report summarizes available information regarding VRF systems and provides some initial potential and cost-effectiveness estimates. The available data indicate acceptable ranges of savings and costs. However, much more research and analysis is needed to solidify these values and gain confidence in VRF as a cost-effective measure for the Northwest. This high level analysis shows that there is likely significant cost effective potential in the Northwest for VRF systems.

The energy efficiency savings for a VRF system can be highly dependent on the building type, occupancy patterns, operation and system design. Also, because VRF systems are heat pumps, the savings will vary over the northwest climate regions. The potential estimates in this report are based on generalized assumptions. The savings, costs, and their variations among building types and northwest climates need to be better understood through research and verification. The accompanying Excel model can easily be updated as more accurate data are identified.

1 Introduction

Objective

The objective of this report is to provide a summary of available energy efficiency data and information on variable refrigerant flow (VRF) technology in the Northwest. In addition, the BPA energy efficiency technical VRF system potential (BPA share of the total regional potential) is estimated based on available data. These estimates are provided as a proxy to indicate the relative magnitude of the measure's potential.

Background

Multi-split heat pump systems use multiple indoor units connected to a single outdoor unit. In a similar manner, variable refrigerant flow (VRF) systems that can provide efficient space conditioning for a wide range of larger commercial buildings. VRF systems are already prevalent in Asia and Europe, and there is increasing acceptance of the technology in the United States. VRF systems seem particularly appropriate for the Northwest due to their claimed performance improvements over traditional heat pump systems, but there is little available data to verify the savings, cost, and reliability in the region.

There are two types of VRF systems: the standard, or heat pump type VRF, which provides either all heating or all cooling to multiple zones at a time. The other type is heat recovery VRF, which provides heating and cooling simultaneously to multiple zones with various cooling or heating demand. VRF systems with heat recovery capability cost more, but can minimize energy use by efficiently providing simultaneous heating and cooling. Instead of rejecting heat these systems can transfer heat from an area that needs cooling, such as a computer room, to another area, such as a perimeter office. The energy efficiency savings for a VRF system can be highly dependent on the building type, occupancy patterns, operation and system design. Also, because VRF systems are heat pumps, the savings will vary over the Northwest climate regions. This report provides initial estimates of the market potential and will help guide the research and application of VRF systems in the region.

This study is being conducted concurrently with a VRF system market study being done by Electric Power Research Institute (EPRI) for BPA. The EPRI market study will identify, characterize and quantify VRF system installations in the United States over the last five years, defined by type (VRF or VRF heat recovery), whether new construction or remodel installation, manufacturer, and geographic region. Data for the Northwest will be a focus. A large component of the project will survey vendors and installers to reveal information about VRF products, product delivery and product position by the manufacturers. This information will be used to assess the state of the industry and to identify market barriers that may need to be overcome to facilitate energy efficiency applications of VRF systems.

2 VRF Technology

Technology Description

Variable Refrigerant Flow systems typically comprise of one or more outdoor unit(s), which contains one or more compressors, one of which is an inverter-driven variable speed compressor (Figure 1). Systems allow a highly customizable configuration of 60 or more indoor units operating off one outdoor unit, connected by refrigerant lines. The amount of refrigerant flowing to each of the evaporators is controlled by the VRF system. The indoor units contain electronic expansion valves, direct expansion coils, and fans. The VRF system controls the variable speed drives, expansion valves and dynamic refrigerant circuitry. The outdoor and indoor units are connected by refrigerant lines.

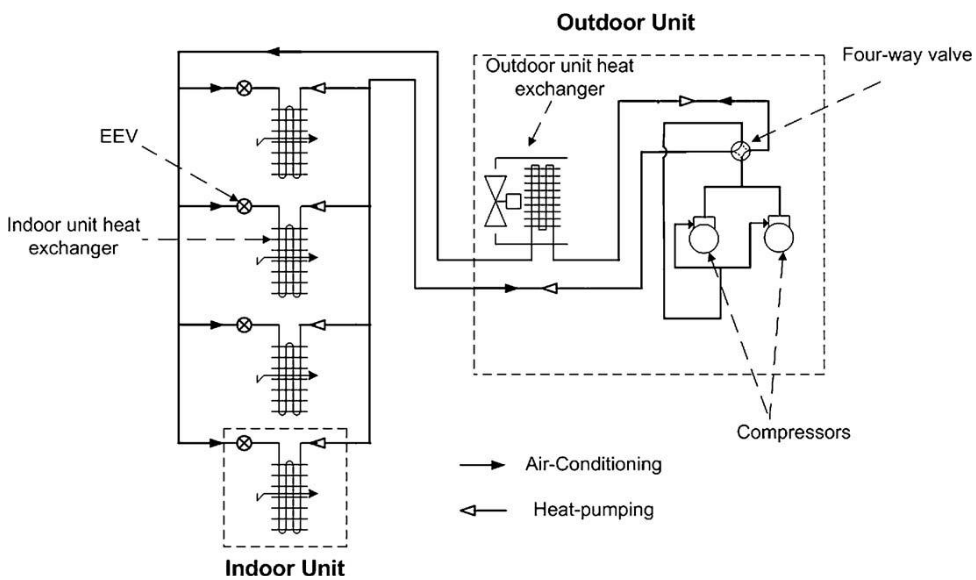

Figure 1 – VRF Overview
(Aynur, 2010)

Since VRF systems are a slightly different application of zonal heat pumps, which have been successfully implemented in Japan, China, and Europe, it has known technical viability. Sales in Japan (where the VRF concept was developed) and other parts of Asia have been strong. In Europe, where many existing buildings did not have existing air conditioning systems, retrofit opportunities have also created strong demand (Goetzler, 2007).

While similar to mini-split systems, the primary difference is that VRF systems can adjust cooling and heating outputs by adjusting the refrigerant flow and the variable speed compressor. This allows multiple indoor units to be connected using a common refrigerant line, rather than needing separate lines between each indoor unit and the indoor unit. (Figure 2) .

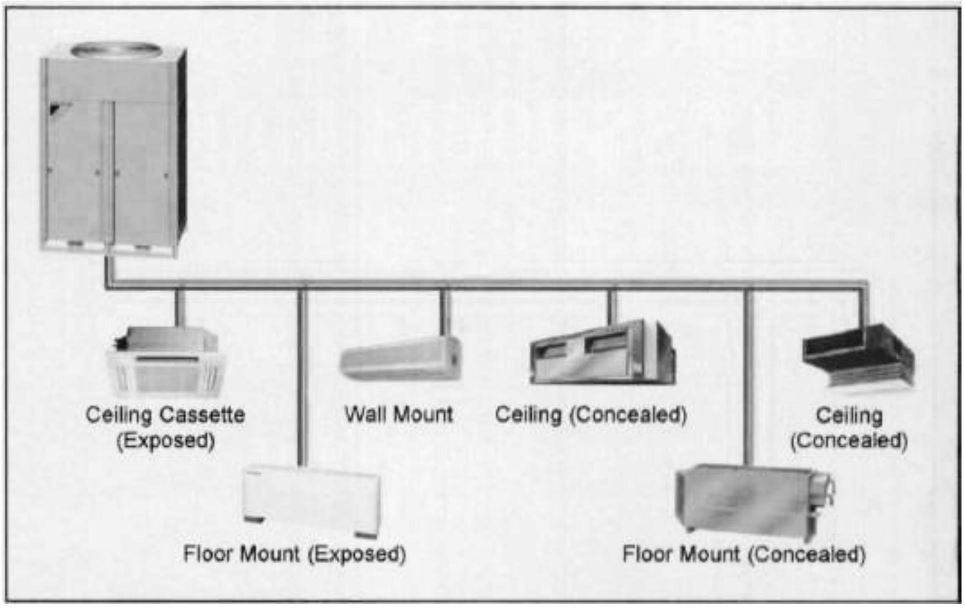

Figure 2 – Illustration of Variation in Indoor VRF Units
(Amarnath, 2008)

There are two types of VRF systems: standard VRF and heat recovery VRF. Standard VRF systems provide either all heating or all cooling to multiple zones at a time. However, if one area needs cooling and another area needs heating, particularly in shoulder season temperatures, electric resistance heat may be needed to maintain adequate thermal comfort. Heat recovery VRF, allows simultaneous heating and cooling to multiple zones using branch circuit selectors. Higher energy savings are possible using heat recovery and this will be discussed in subsequent sections. VRF can be further sub-divided into air-source and water-source, depending on if water or air is used as the heat sink/source for the outdoor unit. Water source VRF is a more recent system and less market ready than air cooled VRF (Yueming, 2009).

While VRF systems have appealing features, they also have some unique requirements that may result in additional energy consumption:

- At low ambient conditions, VRF systems may need to defrost the outdoor heat exchanger when operating in heating mode.
- Some VRF systems require special "oil return" operation to get the lubricant oil back to the compressor, which consumes extra energy compared with conventional packaged air source heat pumps.

How it Saves Energy

Several key VRF system features are associated with the energy saving claims. VRF systems minimizes (or eliminates) duct losses, which are can be 10-20% savings compared with a VAV system. Additionally, the variable nature of the compressors and distribution of refrigerant in VRF systems enable a wide range of capacity modulation which results in high part-load efficiency compared with traditional heat pumps or electric chillers. HVAC systems typically operate in the range of 40% to 80% of maximum capacity, so significant energy savings are possible by increasing both the range and the part-load efficiencies (Integrated Energy Efficiency Rating – IEER).

Additional savings can be realized through heat recovery. There are a variety of methods for heat recovery, including transferring heat using refrigerant. This is accomplished by extracting the superheat from the units in the cooling mode and transferring it to a zone needing heat. Most heat recovery techniques are proprietary.

Competing or Overlapping Technologies

VRF systems have several competing technologies, including energy efficiency measures for traditional heat pumps, chillers and variable air volume systems in larger buildings, and rooftop units and water source heat pumps in smaller buildings. Within chilled water and VAV systems, there are improvements that have the potential for energy savings, such as variable speed drives and economizer retrofits. These have the potential to overlap and compete with VRF systems. Table 1 shows some applicable baseline technologies by commercial building type. Note that ductless heat pump (DHP) systems are not included in the VRF category.

Table 1 - Applicable Baseline Technologies for VRF Systems
(Vowles, 2010)

Building Type	Office			School			Retail			Lodging		
Baseline HVAC System	DHP	VRF Multi-Split	VRF HR Multi-Split	DHP	VRF Multi-Split	VRF HR Multi-Split	DHP	VRF Multi-Split	VRF HR Multi-Split	DHP	VRF Multi -Split	VRF HR Multi -Split
Packaged single zone AC with gas furnace	X	X	X				X	X	X			
Packaged single zone heat pump	X	X	X				X	X	X			
VAV with electric re-heat		X	X									
VAV with hot water re-heat (gas boiler)		X	X									
Water-source heat pump												
Four-pipe unit ventilator (water cooled chiller & gas boiler)				X	X	X						
Packaged terminal AC unit				X	X	X				X	X	X
Ground-source heat pump				X	X	X						

Additionally, ground source heat pumps (GSHP) have the potential to compete directly for savings in small commercial buildings. GSHP systems are composed of multiple water-to-air heat pump units, which are connected with a ground loop heat exchanger through a common two-pipe water loop. Each heat pump can operate in either cooling or heating mode providing simultaneous cooling and heating.

Recent analysis for conditioning a small office building, showed GSHP to be more efficient than VRF in certain applications (Li, 2009). GSHP system saved 9.4% to 24.1% of HVAC energy compared with a heat recovery VRF system. The applicable range of savings for this study was applicable to Miami and Chicago, respectively. For mild climates like the Northwest, ground source heat pumps do not produce as significant savings as in Chicago due to the low cooling loads and modest heating loads. However, recent case studies agree that GSHP systems are generally more energy efficient than air-source systems including VRF.

3 Measure Data

Typical Unit of Measure

VRF system savings are based on efficient equipment operation especially at part load, better low and high ambient performance and from avoided duct losses. While VRF systems can replace chillers, rooftop systems, and heat pumps, the savings cannot be generalized, because savings vary depending on how the system is designed and operated. For example, additional energy savings can be acquired by separating the heating and cooling system from the code-required ventilation system; this separation allows smaller ductwork and potentially lower installation costs. In addition, a heat recovery VRF system code-exception for air-side economizers can minimize VRF system cooling savings.

For consistency with the Sixth Plan, VRF savings are represented as kWh per square foot of commercial space. This allows an estimate of regional potential by applying square footage data to savings values.

Costs

Installation costs are highly dependent on the application, construction, system design and layout of the building, including whether the installation is new or retrofit. In addition, the emerging nature of the technology in the Northwest can inflate the cost of multi-split VRF systems. A separate ventilation system may be necessary, which could increase the VRF system cost.

However, there are several available price points from case studies and published reports. One survey of total costs showed that multi-split VRF systems were likely to be about 5% to 20% higher than the chilled water systems of similar capacity in the United States (Amarnath, 2008). Systems with heat recovery are assumed to be on the high end of that cost range.

Cost data for a Mitsubishi R2 model VRF system installed in an office building in Lewis County are shown in Table 2. This project is a retrofit. The system includes 72 individual climate zones and will replace 7 rooftop heat pump units.

Table 2 - Lewis County Case Study Cost	
Description	**Cost**
Basic Mechanical	$165,000
Mechanical insulation	$8,000
Refrigerant pipe/equipment	$400,000
Heat trans/air distribution	$40,000
Air Hand system clean	$17,000
Adjustment/Balance	$20,000
TOTAL VRF COST	**$650,000**
BASE COST	$574,960
INCREMENTAL COST	**$75,040**

Based on this price point, the total cost for the VRF system is $650,000 and the incremental cost is $75,040. This is a cost premium of 13.1% and tracks well with general costs from published case studies outside the region.

EPRI's VRF market study may improve this estimate and give a more accurate range for the Northwest. However, a 5-20% premium is assumed for this study. Since the 13% value is near the midpoint of this range, we will use it as a proxy for the cost effectiveness value.

However, in order to utilize the percent incremental value, the baseline costs must be established. The Sixth Plan (PC-HVACEQUIP-6P.xls) contains a data set of numerous cooling system types for commercial buildings and their associated costs ($/ton). These costs range from approximately $700/ton to $1200/ton for the system sizes of interest in this study. Then, using a value of 400 square feet per ton and the 13%, we can define a range of incremental costs from $0.23/sf in larger buildings to $0.41/sf in smaller buildings.

While these costs can be used as an initial proxy, there are many variables and assumptions built into these values. The installed and incremental cost of VRF systems is expected to be further and more accurately defined through additional research and pilot demonstrations.

Savings

It is clear from case studies and experiments that climate and design decisions play a major role in realized savings from VRF systems. Real performance of VRF systems in buildings may not be as good as what is described by manufacture's data, mainly because of design constraints for both outdoor and indoor units, length of refrigerant pipe length and gravitational barriers if there is a large vertical distance between indoor and outdoor units (Amarnath, 2008). Therefore, a careful design and site-specific savings are required for each building project. Additionally, most reported savings studies are for warm and humid climates, so the relevance of these values to the Northwest needs to be verified. Table 3 summarizes reported savings estimates from a variety of sources. Most of the sources are based on simulation results and many were developed and provided by manufacturers.

Table 3 - Literature Review of VRF Savings Estimates

Location	Building Type	Baseline Technology	Savings	Source	Notes	Heat Recovery
United States	Generic	Generic	5-20%	Amarnath, 2008	based on modeling studies	Site Dependent
Shanghai	10-Story Office	Fancoil Plus fresh air	10%	Zhou, 2006	Simulation Results	
Humid Subtropical	Variable	Fancoil Plus fresh air	10%	Aynur, 2010	Literature Review	YES
Shanghai	Office	Fancoil Plus fresh air	19%	Li, 2009	Simulation Results	
Shanghai	10-Story Office	VAV Rooftop	20%	Zhou, 2006	Simulation Results	
United States	Variable	VAV Rooftop	27%	Aynur, 2009	Simulation Results	YES
United States	Generic	200-Ton Chiller	30%	Amarnath, 2008	Manufacturer Data	
Brazil	Generic	VAV Rooftop	30%	Roth, 2002	Simulation Results	
Humid Subtropical	Variable	Chiller/Boiler	30%	Aynur, 2010	Literature Review	YES
Italy	Office	Chiller/Boiler	35%	Amarnath, 2008	Manufacturer Data	
Humid Subtropical	Variable	Chiller/Boiler	35%	Aynur, 2010	Literature Review	YES
Humid Subtropical	Variable	VAV Rooftop	20-57.9%	Aynur, 2010	Literature Review	YES
Eugene, OR	Multi-Family Housing	Packaged Heat Pumps	33%	EWEB, 2010	Simulation Results	YES
Seattle	Assisted Living	4-pipe	53%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	Assisted Living	Heat Pump	42%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	School	VAV Rooftop	43%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	School	Water Source Heat Pump	39%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	School	Air to Air Heat Pump	23%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	Hotel	4-pipe	40%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	Hotel	Heat Pump	37%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	Office	Air to Air Heat Pump	11%	Mitsubishi, 2010	Manufacturer Simulation	YES
Seattle	Medical Clinic	Air to Air Heat Pump	14%	Mitsubishi, 2010	Manufacturer Simulation	YES

Based on these case studies and, specifically the recommendations in Amarnath and Blatt, *Variable Refrigerant Flow: Where, Why and How*, a conservative 5-20% savings range is assumed to be applicable to the Northwest for purposes of estimating potential. Heat recovery systems will certainly yield more savings than non-heat recovery systems, but the literature did not clearly identify a distinct difference in savings values between standard VRF systems and VRF with heat recovery. Therefore a 20% HVAC savings is assumed for VRF systems in the northwest for all applications. For reference the average of all data points in Table 3 is 29% and the median is 30%. .

The twenty percent savings value was applied to baseline data and the results range from 0.44 kWh/sf to 1.8 kWh/sf and are described in more detail in the Energy Efficiency Potential section.

Measure life

It is assumed for this study that VRF has a similar lifetime (20 years) to conventional air conditioning refrigerant systems (Aynur, 2010).

Other Cost-Effectiveness Parameters

Measure cost-effectiveness depends primarily on incremental capital cost, savings, and life. Below are brief descriptions of the other cost-effectiveness parameters used in the Council's PROCOST model to determine regional (Total Resource Cost) cost effectiveness.

Load Shapes

The following load shapes were used in PROCOST for retrofit and new measures:

- EXCOMM - Existing Shell and HVAC Measures
- NEWCOMM – New Shell and HVAC Measures

Operation and Maintenance Cost or Savings

There were no O&M costs or benefits quantified for this analysis.

Non-Energy Benefits

There were no non-energy benefits quantified for this analysis. However, VRF system non-energy benefits may include:

- Better temperature control in smaller zones
- Lower building costs or more rentable space, due to smaller mechanical space requirements – smaller interior mechanical rooms and less space required for ductwork between floors, as well as smaller exterior equipment space requirements

- Easier retrofits where clearance for installing ductwork is an issue or where existing ductwork can be used for code-required ventilation system
- Lighter equipment weight, potentially reducing structural requirements

Periodic Replacement Costs

There were no periodic replacement costs or benefits quantified for this analysis.

Gas Savings

There were no gas savings quantified for this analysis.

Avoided Cost

The avoided cost used is the “Sixth Plan Mid-C Final” price forecast used in the Sixth Plan and approved by the RTF. In addition, the Risk Mitigation Credit of $43/MWh was used for retrofit measures and $58/MWh for lost opportunity (new construction) measures. This credit is added to the avoided cost and is representative of retrofit measures.

Cost Effectiveness

The Council's ProCost model was used gain some initial insight into possible cost effectiveness ranges for VRF. Table 4 summarizes cost-effectiveness for the VRF measure in a few selected retrofit applications. These applications were selected to represent a range of costs and savings values. The measure appears to be cost effective in all but one of the example cases.

Table 4 – VRF Retrofit Cost-Effectiveness Example

Building Type	Retro/New	Location	Life	Savings (kWh/sf/yr)	Cost ($/sf)	TRC B/C Ratio
LargeOffice	Retrofit	Seattle	20	0.30	0.23	1.7
LargeOffice	Retrofit	Boise	20	0.45	0.23	2.6
SmallOffice	Retrofit	Seattle	20	0.25	0.41	0.8
SmallOffice	Retrofit	Boise	20	0.52	0.41	1.7
Lodging	Retrofit	Seattle	20	0.38	0.33	1.6
Lodging	Retrofit	Boise	20	0.58	0.33	2.4

Table 5 shows the cost-effectiveness results for the new construction case. These measures are defined as "lost opportunity" measures. By definition, lost opportunity measures are assigned the higher risk mitigation credit of $58/MWh. The overall result is the new construction applications for VRF tend to be more cost-effective than the retrofit measures.

Table 5 – VRF New Construction Cost-Effectiveness Example

Building Type	Retro/New	Measure	Life	Savings (kWh/sf/yr)	Cost ($/sf)	TRC B/C Ratio
LargeOffice	New	Seattle	20	0.29	0.23	1.9
LargeOffice	New	Boise	20	0.43	0.23	2.8
SmallOffice	New	Seattle	20	0.29	0.41	1.0
SmallOffice	New	Boise	20	0.43	0.41	1.5
Lodging	New	Seattle	20	0.46	0.33	2.0
Lodging	New	Boise	20	0.69	0.33	3.1

4 Market

Applications

Heat recovery VRF systems are generally applicable to buildings where heating and cooling requirements vary by zone. For example, if the interior of a building requires cooling, while the perimeter requires heating. Other good examples are buildings where different thermal comfort is required for different uses, such as health facilities and hotels. Specific building types are discussed in further detail in the Energy Efficiency Potential Section.

Market Opportunities and Barriers

As with any emerging technology there are both opportunities and barriers that affect market penetration. The advantage VRF systems have compared with other emerging technologies, is the technology is robust and well developed (outside the US). The primary research needs are to gain experience with these systems in the US (especially the Northwest) and obtain data for comparison with traditional systems such as chillers. A summary of opportunities and barriers is included below:

Opportunities

- Energy Efficiency – Eliminates duct losses and high part load efficiency
- Modular installation – relatively light weight compared with chillers
- Design flexibility – Single outdoor unit can be connected to many indoor units of varying capacity and configuration (e.g., wall-mount, ceiling mount, etc.)
- Improved comfort control – Numerous zones are possible within one building and controlling these zones is easy and precise.
- Lower maintenance costs (possible) – No water treatment costs

Barriers

- Lack of understanding and awareness of energy efficiency benefits
- First cost is higher – VRF systems generally have higher first costs than Chiller, heat pumps, and rooftop units.
- Refrigerant piping – while this can also be an advantage compared with ductwork, it also has the possibility of refrigerant leaks that are hard to find.
- Replacement parts – since these technologies are manufactured in Japan, concerns over availability and cost of replacement parts have been raised.

Commercial Availability

VRF systems are readily available in the Northwest. The primary VRF manufacturers include Daikin, Mitsubishi, Toshiba, and Fujitsu. These manufacturers have been developing and producing VRF systems in Japan for nearly 20 years, in Europe for over 10 years, and this technology has been slowly migrating to the U.S. A few notes about the product lines from each of these manufactures are included below:

Daikin

Daikin offers primarily two models of VRF systems; the VRV III for large commercial applications (alternative to chilled water systems), and the VRV-S for small commercial applications.

The VRVIII offers heat pump or heat recovery configurations in sizes for individual outdoor units ranging from 6 to 20 tons.

The VRV-S is targeted for light commercial or residential applications, including retail, small office, restaurant, hotel, healthcare, and schools, as well as single and multifamily residential applications. Depending on the model, one outdoor unit can be connected to up to eight indoor units, providing either heating or cooling from one system. The outdoor unit sizes range from 3 to 4 tons, and the most efficient unit is rated at 14.3 SEER and 8.15 HSPF.

Mitsubishi

Mitsubishi offers four lines of VRF systems: the R2-Series, the Y-Series, the H2iY-Series, and the S-series. They use the term "city-multi" to describe their VRF technology. The overall product line (outdoor units) rages from 5 to 30 tons of cooling and from 80 kBut/hr to 405 kBtu/hr for heating.

R2-SERIES (Heat Recovery)

The R2 system is available in sizes ranging from 5 to 24 tons of cooling and a heating capacity up to 320 kBtu/hr. It is a heat recovery system that simultaneously cools and heats different zones within a building. The R2-Series can support up to 50 indoor units and are available in both 208/230V and 460V applications.

Y-SERIES (Heat Pump)

The Y-Series is available in sizes ranging from 6-30 tons of cooling. The 6-20 ton sizes meet or exceed Energy Star Light Commercial requirements. It is a two-pipe system which enables simultaneous heating and cooling, for up to 50 individual zones.

H2iY-Series (Heat Pump- Cold Climate)

H2i stands for “Hyper-Heating Inverter” technology, which provides improved heating capacity and lower outdoor temperatures (i.e., full heating capacity at 0° F outdoor ambient temperature). The 6-16-ton units of this model meet the Energy Star Light Commercial requirements, and exceed the ASHRAE 90.1 (2010) ratings.

W-Series WR2, WY (Heat Recovery and Heat Pump Systems)

W-Series units combine the convenience of water-source systems with VRF technology. They include heat recovery units for simultaneous cooling and heating, and heat pump units. These models are available in up to 30 tons maximum capacity.

S-SERIES (Single Phase Heat Pump)

The S-Series is a single phase system suited for light commercial or residential applications. Available in 3 or 4-ton sizes, it can provide cooling or heating for up to eight individual zones.

Toshiba

Toshiba offers three VRF system ranges, the Mini SMMS (up to 4 tons), the SMMS (up to 38 tons), and the SHRM which is a 3-pipe system that includes heat recovery.

MiNi-SMMS

The Mini-SMMS is a small VRF system that can include up to 9 indoor units and provide up to 4 tons of cooling. It is applicable to for light commercial and residential applications. The MiNi-SMMS outdoor units are available in 3 sizes (0.8, 1.0, and 1.3 tons) and can supply 6, 7 or 9 indoor units. The EER is up to 4.29.

Super MMS

The SMMS performs with a COP of 4.25 in its 6.4-ton size. Units are available with capacities from 4 to 38 tons of cooling. Each outdoor unit incorporates two new DC twin-rotary compressors and dual-inverter drives. The Inverter control operates with more and smaller steps (increase in control steps) and ensures a more precise and stable temperature control.

SHRM

The SHRM is a heat recovery VRF system (3-pipe VRF) which provides simultaneous heating and cooling to different zones or rooms. The cooling capacity range is from 6.4 to 24 tons. Up to 48 indoor units can be connected to a single system. The energy efficiency ratio is up to 3.97.

Fujitsu

Fujitsu also offers a wide range of products from residential to large commercial applications. The outdoor unit sizes range from 4 tons (J-Series) to the larger and more efficient V-II series at 38 tons (135 kW).

Pacific Northwest Sales Information

Sales information will be provided in the forthcoming *Analysis of Variable Refrigerant Flow (VRF) Heat Pump Technology Position in the United States* to be released by EPRI in 2011. However, lists of Daikin and Mitsubishi projects in the region are included in the appendix. Institutional buildings, schools and universities are the most common installations.

5 Energy Efficiency Potential

Codes and Standards

There are various organizations nationwide that establish or recommend minimum efficiency levels for unitary air conditioning equipment, including ASHRAE. Beginning in 2010, new minimum efficiency levels were put in place including federal minimums, ASHRAE standards, Energy Star, and CEE. These codes and standards result in relatively similar minimum efficiency levels for AC equipment and form the basis for state codes. In addition, a new (effective January 1, 2010) part load cooling efficiency metric, the Integrated Energy Efficiency Ratio (IEER) has replaced the former Integrated Part Load Value (IPLV). Table 6 summarizes these minimum efficiency levels and the new IEER values for systems above 65 kBtu/h.

Table 6 – Performance Levels for Unitary AC Equipment

Size Category (Btu/hr)	Heating Section Type	Federal Minimums (1/1/2010)	ASHRAE 90.1-2007 (1/1/2010)	EER IEER Δ	ENERGY STAR (5/1/2010)	EER IEER Δ	CEE Tier 1 (Current)	CEE Tier 2 (Current)
≥65k -<135k	Electrical Resistance	11.2 EER	11.2 EER 11.4 IEER	0.2	11.7 EER 11.8 IEER	0.1	11.7 EER	12.2 EER
	All Others	11.0 EER	11.0 EER 11.2 IEER	0.2	11.5 EER 11.6 IEER	0.1	11.5 EER 11.9 IPLV	12 EER 12.4 IPLV
≥135k -<240k	Electrical Resistance		11.0 EER 11.2 IEER	0.2	11.7 EER 11.8 IEER	0.1	11.7 EER	12.2 EER
	All Others		10.8 EER 11.0 IEER	0.2	11.5 EER 11.6 IEER	0.1	11.5 EER 11.9 IPLV	12.0 EER 12.4 IPLV
≥240k -<760k	Electrical Resistance	Not defined	10.0 EER 10.1 IEER	0.1	Not defined	--	10.7 EER	11.0 EER
	All Others	Not defined	9.8 EER 9.9 IEER	0.1	Not defined	--	10.5 EER 10.9 IPLV	10.8 EER 12.0 IPLV
≥760k	Electrical Resistance	Not defined	9.7 EER 9.8 IEER	0.1	Not defined	--	9.9 EER	10.4 EER
	All Others	Not defined	9.5 EER 9.6 IEER	0.1	Not defined	--	9.7 EER 11.0 IPLV	10.2 EER 11.0 IPLV

In the Northwest, both Washington and Oregon energy codes include minimum efficiency levels consistent with the ASHRAE Standard 90.1-2007 (see Table 6). Both Idaho and Montana adopted the IECC for their commercial building energy codes.

The VRF performance requirements for SEER, HSPF, EER, and COP must meet the same efficiency levels as the conventional or unitary air conditioners and heat pumps listed in

ASHRAE 90.1. Two levels of IEER performance were established for the VRF systems. The first level is 10 percent higher than the unitary performance levels. The second level will be 15 percent higher than the unitary IEER levels and will become effective on July 1, 2012. (Doppel, 2010).

Washington also has the requirement for an economizer on computer/server room AHU's. Without one, the unit's SEER must be 15% higher than Code. A VRF system that includes heat recovery can be exempt from the economizer requirement, because the cooling energy savings were assumed to be equal (Lewellen, 2010). Below is an excerpt from Washington State 2010 building code for non-residential buildings.

> *51-11-1433*
>
> ***Economizers.***
>
> *Air economizers meeting the requirements of Section 1413 shall be provided on all new systems including those serving computer server rooms, electronic equipment, radio equipment, telephone switchgear.*
>
> > ***EXCEPTIONS:***
> >
> > *Variable refrigerant flow (VRF) systems, multiple-zone split-system heat pumps, consisting of multiple, individually metered indoor units with multi-speed fan motors, served on a single common refrigeration circuit with an exterior reverse-cycle heat pump with variable speed compressor(s) and variable speed condenser fan(s). These systems shall also be capable of providing simultaneous heating and cooling operation, where recovered energy from the indoor units operating in one mode can be transferred to one or more indoor units operating in the other mode, and shall serve at least 20 percent internal (no perimeter wall within 12') and 20 percent perimeter zones (as determined by conditioned floor area) and the outdoor unit shall be at least 65,000 Btu/h in total capacity. Systems utilizing this exception shall have 50 percent heat recovery effectiveness on the outside air. For the purposes of this exception, dedicated server rooms, electronic equipment rooms or telecom switch rooms are not considered perimeter zones. This exception shall be limited to buildings of 60,000 square feet and less.*

In Washington, to meet the code exception for an economizer, the VRF system must include 50% heat recovery from exhaust air, which is typically used to pre-heat or pre-cool code-required ventilation air.

Additionally, ASHRAE Standard 90.1 -- Energy Standard for Buildings Except Low-Rise Residential includes the following addendum (Addendum cp) for VRF equipment*:*

> *Cooling EER and heating COP efficiency levels are proposed for a full range of product cooling capacities at standard rating conditions listed in AHRI Standard 1230. The proposed SEER, HSPF, EER, and COP levels are identical to the minimum efficiencies for conventional ducted air cooled air conditioners and applied heat pumps listed in ASHRAE 90.1. Higher IEER levels are being proposed because these products are primarily designed to operate in zoning applications and at part-load conditions. The first tier of IEER values is effective immediately, while the second phase will become effective on July 1, 2012.*
>
> *The minimum IEER requirements for VRF systems have been set at 10% higher than minimum unitary equipment requirements with approval from the VRF industry. On July 1, 2012 that minimum will be increased to 15% above the unitary requirement, further emphasizing the superior partload performance of VRF equipment.*

This addendum will affect the code-required minimum IEERs for VRF systems in Idaho, Montana, and LEED buildings.

Applicability

In order to estimate energy efficiency potential for VRF systems, the appropriate applications need to be specified. In general, heat recovery VRF systems will be cost effective where simultaneous heating and cooling is frequently needed. Other good applications are where individual zone control is important, such as office buildings, hotels, hospitals nursing homes, and schools.

Therefore, the following Sixth Plan commercial building categories are assumed to be applicable: Large Office, Medium Office, Small Office, K-12, University, Lodging, Hospitals and Other Health.

Recent Experience

Installation by Building Type

Installations in the Northwest by commercial building type are shown in Figure 3. This data is compiled from Mitsubishi and Daikin vendor data (Vowles, 2010). Office buildings comprise the largest percentage of systems in the region. However, hotels and motels also comprise a large percentage. Figure 3 does not represent all Northwest applications and may not be a statistically significant sample, but it does reinforce the applicable market segments.

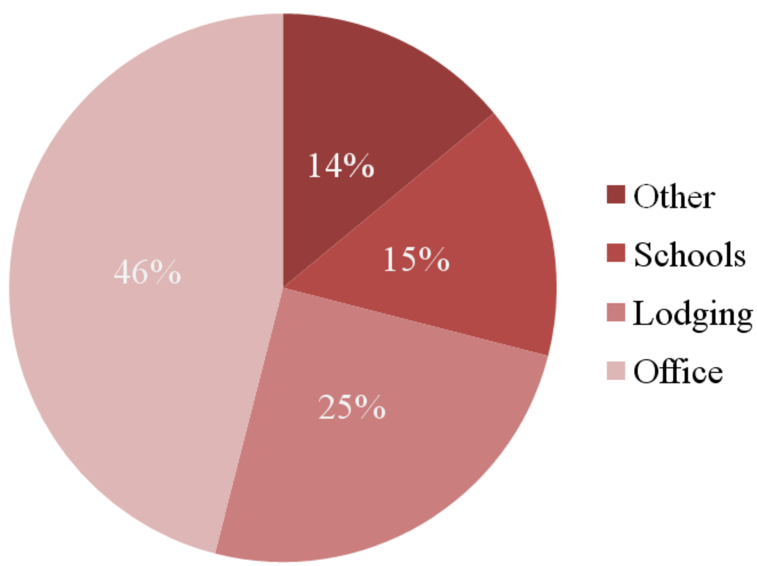

Figure 3 – Sample of VRF Systems in the Northwest, by Building Type

Pacific University Case Study

One example of a VRF system installation in the Northwest is in the Gilbert Hall at Pacific University. Pacific's campus is located 24 miles west of Portland, Oregon. Gilbert Hall is a dormitory facility in which a Mitsubishi Electric VRF system with heat recovery system was installed.

Five different HVAC systems were analyzed for the dormitory: finned-tube radiators, radiant floor heating and cooling, water source heat pumps, Mitsubishi Electric VRF zoning and ground source heat pumps. Pacific selected the VRF zoning system with heat recovery due to the cooling needed for university summer programs and cost within the project budget. The range of use between zones allowed the outdoor units to be sized for block loads, electrical cost savings due to fewer condensing units on the roof than individual split systems, and the potential for higher efficiency equipment without the need for supplemental electric heat (Heizer, 2010).

The project claimed a 44% energy savings over than the average student housing building in the Northwest. It is unclear how the baseline was calculated or how much of the savings can be attributed to the VRF system, but savings were significant and Pacific is very pleased with the results (Heizer, 2010).

Market Saturation

Market saturation is low in the Northwest, primarily due to low consumer acceptance and cost barrier for VRF retrofits in larger commercial buildings. While there are systems installed in the region, for estimates of potential, saturations in applicable buildings are assumed to be zero, even though it is clear that VRF is beginning to gain traction. Applicability percentages will need to change as saturation data is gather through EPRI's efforts.

Achievable Potential Estimates

Estimates of regional savings potential are based on three factors: 1) baseline consumption data of commercial buildings in the region, 2) an assumed savings percentage of VRF systems from case studies and 3) applicable square footage data.

Table 7 shows the assumed baseline space conditioning consumption data for the region based on building type and heating fuel type. These values are from the Sixth Plan[1] models and are not intended to be rigorous energy use intensities (EUI) for all applications and building designs. However, they are useful for a regional estimate of potential. Total space conditioning load used for VRF savings is baseline space conditioning plus ventilation consumption. Note that this is HVAC EUI data only and only includes electric heat savings.

[1] Values come from the "2008 Savings" tab of the PC-HVACEQUIP-6P-D7.xls supply curve file

Table 7 – Baseline Space Conditioning Energy Consumption

		Large Off	Medium Off	Small Off	Big Box	Small Box	High End	Anchor	K-12	University	Warehouse	Supermarket	Mini Mart	Restaurant	Lodging	Hospital	Other Health	Assembly	Other
Heating	kWh/ sq.ft.	1.0	1.3	1.3	1.0	0.8	0.8	1.0	1.2	1.7	0.5	2.3	2.3	2.5	1.1	4.0	2.0	2.5	2.3
Cooling		3.0	2.0	1.5	1.5	1.5	3.0	3.0	1.0	2.0	0.3	3.0	3.0	6.0	1.3	5.0	3.0	2.5	1.6
Total		4.0	3.3	2.8	2.5	2.3	3.8	4.0	2.2	3.7	0.8	5.3	5.3	8.5	2.4	9.0	5.0	5.0	3.9

Savings values for each commercial building were calculated by multiplying the baseline consumption by percentage savings. Based on the literature discussed in Section 3, savings of 20% of HVAC consumption is assumed to represent VRF savings in Northwest buildings. The VRF Potential spreadsheet model allows these percentage savings to be easily modified if new data become available. Savings by building type are show in the matrix in Table 8.

Applicability factors are used to apply square footage savings to commercial buildings in the region. Table 8 shows an estimate of percentage of square footage that can be conditioned effectively with VRF systems. They are the same percentages assumed to applicable to heat pump heat from the Council's PC-HVACEQUIP-6P-D7.xls supply curve file.

Note that these are raw technical savings values for applicable buildings in the Northwest. There are no embedded percentages in the applicability factors that account for overlap with compete technologies or installation of other efficient space conditioning measures. These estimates are only intended to guide planning.

Table 8 shows the detailed measure matrix for VRF in the Northwest. The matrix includes the 18 commercial building segments used by Sixth Plan. For each of these segments, savings for both new and retrofit conditions are defined. The applicability factors are the percentage of square footage in that segment that is eligible for VRF upgrades. The "Qualitative Applicability" column is not related to any of the numerical values; it represents a summary of the published articles and reports.

Table 8 – VRF Applicability Matrix by Climate Area

		Seattle				Portland				Boise				Missoula			
		Life	Savings (kWh/sq. ft.)	Qualitative Applicability	% Applicability	Life	Savings (kWh/sq. ft.)	Qualitative Applicability	% Applicability	Life	Savings (kWh/sq. ft.)	Qualitative Applicability	% Applicability	Life	Savings (kWh/sq. ft.)	Qualitative Applicability	% Applicability
Large Office	Retrofit	20	0.800	Moderate	9.5%	20	0.800	Moderate	9.5%	20	0.800	Moderate	9.5%	20	0.8000	Moderate	9.5%
	New	20	0.800	Moderate	20.0%	20	0.800	Moderate	20.0%	20	0.800	Moderate	20.0%	20	0.8000	Moderate	20.0%
Medium Office	Retrofit	20	0.650	Good	23.0%	20	0.650	Good	23.0%	20	0.650	Good	23.0%	20	0.6500	Good	23.0%
	New	20	0.650	Moderate	7.0%	20	0.650	Moderate	7.0%	20	0.650	Moderate	7.0%	20	0.6500	Moderate	7.0%
Small Office	Retrofit	20	0.550	Good	21.6%	20	0.550	Good	21.6%	20	0.550	Good	21.6%	20	0.5500	Good	21.6%
	New	20	0.550	Moderate	8.0%	20	0.550	Moderate	8.0%	20	0.550	Moderate	8.0%	20	0.5500	Moderate	8.0%
Big Box	Retrofit																
	New																
Small Box	Retrofit																
	New																
High End	Retrofit																
	New																
Anchor	Retrofit																
	New																
K-12	Retrofit	20	0.440	Moderate	10.8%	20	0.440	Moderate	10.8%	20	0.440	Moderate	10.8%	20	0.4400	Moderate	10.8%
	New	20	0.440	Moderate	14.0%	20	0.440	Moderate	14.0%	20	0.440	Moderate	14.0%	20	0.4400	Moderate	14.0%
University	Retrofit	20	0.740	Moderate	9.3%	20	0.740	Moderate	9.3%	20	0.740	Moderate	9.3%	20	0.7400	Moderate	9.3%
	New	20	0.740	Moderate	2.0%	20	0.740	Moderate	2.0%	20	0.740	Moderate	2.0%	20	0.7400	Moderate	2.0%
Warehouse	Retrofit																
	New																
Supermarket	Retrofit																
	New																
Mini Mart	Retrofit																
	New																
Restaurant	Retrofit																
	New																
Lodging	Retrofit	20	0.480	Good	24.3%	20	0.480	Good	24.3%	20	0.480	Good	24.3%	20	0.4800	Good	24.3%
	New	20	0.480	Good	30.0%	20	0.480	Good	30.0%	20	0.480	Good	30.0%	20	0.4800	Good	30.0%
Hospital	Retrofit	20	1.800	Moderate	1.0%	20	1.800	Moderate	1.0%	20	1.800	Moderate	1.0%	20	1.8000	Moderate	1.0%
	New	20	1.800	Moderate	1.0%	20	1.800	Moderate	1.0%	20	1.800	Moderate	1.0%	20	1.8000	Moderate	1.0%
Other Health	Retrofit	20	1.000	Moderate	7.6%	20	1.000	Moderate	7.6%	20	1.000	Moderate	7.6%	20	1.0000	Moderate	7.6%
	New	20	1.000	Moderate	5.0%	20	1.000	Moderate	5.0%	20	1.000	Moderate	5.0%	20	1.0000	Moderate	5.0%
Assembly	Retrofit																
	New																
Other	Retrofit																
	New																

The Sixth Plan estimates of total square footage were applied to the measure matrix in Table 8. Table 9 shows the 20 year savings potential by building type. Note that these are estimates of Technical Potential. The potential is also the BPA share of regional potential, which is assumed to be 42% for commercial measures. Figures 4 and 5 show annual technical potential using a ramp rate similar to the Sixth Plan Emerging Technologies ramp rate. In this case the ramp rate is applied as a percent of the total potential acquired each year.

Table 9 – BPA 20-Year VRF Technical Potential

Total 20-Year	**5-YR aMW**			**20-YR aMW**		
	Retrofit	**New**	**Total**	**Retrofit**	**New**	**Total**
Large Off	0.14	0.05	0.19	0.92	0.32	1.24
Medium Off	0.04	0.01	0.05	0.25	0.09	0.34
Small Off	0.04	0.02	0.06	0.28	0.10	0.38
Big Box	-	-	-	-	-	-
Small Box	-	-	-	-	-	-
High End	-	-	-	-	-	-
Anchor	-	-	-	-	-	-
K-12	0.11	0.02	0.13	0.68	0.15	0.83
University	0.01	0.00	0.02	0.08	0.02	0.10
Warehouse	-	-	-	-	-	-
Supermarket	-	-	-	-	-	-
MIniMart	-	-	-	-	-	-
Restaurant	-	-	-	-	-	-
Lodging	0.16	0.02	0.19	1.06	0.14	1.20
Hospital	0.01	0.00	0.01	0.06	0.01	0.07
OtherHealth	0.05	0.02	0.07	0.34	0.14	0.48
Assembly	-	-	-	-	-	-
Other	-	-	-	-	-	-
TOTAL	**0.57**	**0.15**	**0.72**	**3.67**	**0.98**	**4.64**

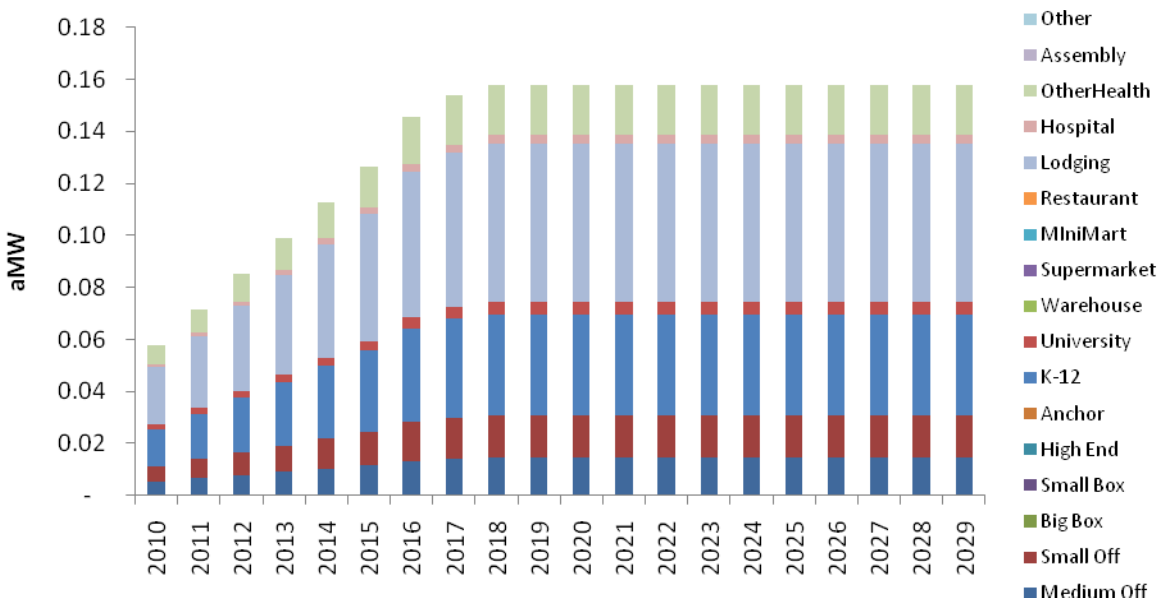

Figure 4 – Annual BPA Retrofit Potential for VRF

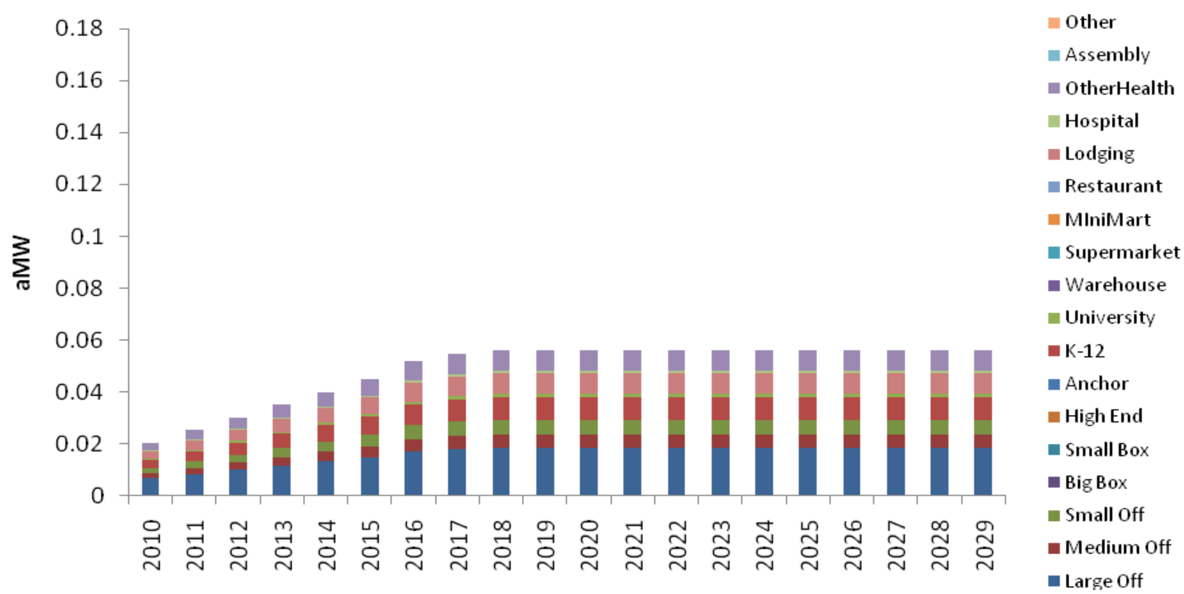

Figure 5 – Annual BPA New Construction Potential for VRF

The overall regional commercial potential in the Sixth Plan is 1410 aMW and the BPA share is approximately 592 (42%). The Commercial HVAC potential in the Sixth Plan is 304 aMW. Assuming BPA share of 42% (128 aMW), VRF savings represents 3.6% relative to the HVAC potential defined in the Sixth Plan.

6 Summary

Variable Refrigerant Flow (VRF) systems are widely utilized around the world and are gaining in interest in the US and the Northwest. This high level analysis shows that there is likely significant cost effective potential in the Northwest for VRF systems.

Total BPA share of regional potential for DCV is estimated to be 4.64 aMW based on these conservative estimates. Higher savings and applicability values are possible, but more research is needed to gain confidence in these estimates.

Note also that the preliminary cost-effectiveness analysis indicates that VRF benefit cost ratios are in the 1 – 2 range. If the upcoming research shows that either costs are higher, or savings are lower relative to the assumptions in this report, then the cost effectiveness will decrease and could fall below 1.0 in more cases.

Research Needs

This report summarizes available information regarding VRF and provides some initial potential and cost-effectiveness estimates. The available data indicate acceptable ranges of savings and costs. However, much more research and analysis is needed to solidify these values and gain confidence in VRF as a cost-effective measure for the Northwest. These research areas may include:

- Measure Definition - better savings and cost differences between standard and heat recovery VRF are needed.
- Costs – continue to build a database of installed costs for VRF systems both from commercial installation and case studies. In addition, some addition baseline cost data are needed in order to more carefully define the measure or incremental cost.
- Savings – both baseline consumption and VRF savings need to be better understood and documented.

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Appendix

MITSUBISHI ELECTRIC

HVAC Advanced Products Division

Pacific Northwest Projects

Air National Guard
Great Falls, MT
Contractor: Central Plumbing and Heating Phone: 406.761.2557
Equipment: (1) PURY-P96 (11) Ducted Indoor units
Project Size: 8 Ton

ADA County
Assessors Office
Boise, ID
Constractor: YMC Brad White PM
Engineer: CSHQA Boise Dan Gostch
Equipment: PURY and Ducted fan Coils
Project size: 100 Ton

ADA County
Indigent Services
Boise, ID
Constractor: YMC Brad White PM
Engineer: CSHQA Boise Dan Gostch
Equipment: PURY and Ducted fan Coils
Project size: 100 Ton

Alex Building (Under construction)
Seattle, WA
Contractor: GB Systems

Aljoya House Assisted Living
Tacoma, WA
Contractor: Emerald Air Contact: Doug Happe PE @ 253-872-5665
Equipment: PURY Outdoor Units, 200 Indoor fan coils
Project Size: 260 Ton

Bellingham Bank
Bellingham, WA
Contractor: Bel-Aire
Equipment: PURY-126 w/ PMFY Slot Diffusers

Bella Mira Condominium Project
Issaquah, WA
Contractor: Emerald Air Contact: Doug Happe PE @ 253-872-5665
Equipment: (5) PURY 100 / (22) PDFY Ducted Indoor Units
Project Size: 50 Ton

Bremerton HS
Bremerton, WA
Contractor:
Equipment: PURY and Ducted fan coils
Size: 40 Tons

Bethel School District
Tacoma, WA
Contractor: Modern Building Systems
Equipment:
Project Size: 10 Ton

Brookings School District
Brookings, Or
Contractor: Harborview Pat Neid (Owner): 541-469-4415
Equipment: (2) PURY-P108 Outdoor (20) PDFY Ducted Indoor units
Owner: Neil Walker Cell: 541-661-2807
Coos Curry Electric: Power Company: Steve Deraita 541-469-4030
Project Size: 18 Ton

Chinese Cultural Center
Seattle, WA
Contractor: United Systems
Equipment: (1) PURY-P96 (5) PMFY slot Diffusers

Covenant Shores Assisted Living
Mercer Island, Washington (Design Build)
Contractor: Air Motion contact: Sergio 253-202-9715
Owner Contact: Dan Hodges 206-268-3028
Equipment: (5) PURY 100 / (50) PDFY - Ducted Indoor units
Project Size: 50 Ton

Central Plumbing and Heating Office (Design Build)
Great Falls. MT
Contractor: Central Plumbing and Heating Phone: 406.761.2557
Equipment: (1) PURY-P96 (1) PURY-P108 (26) PDFY, PMFY and PLFY
Project Size: 20 Ton

Coral Sales
Portland Oregon (Design Build)
Contractor: American Heating / Contact: Smitty @ Cell 503-793-2566
Equipment: (1) PURY-P126 (12) PDFY, PMFY
Project Size: 10 Ton

Clyde Hotel (Completed 2006)
Portland OR
Contractor: Portland Mechanical: Eric Van Orden Ph: 503-656-7400
Equipment:
Project Size: 50 Ton

Clearwater Hotel and Casino (Completed March 2006)
Port Angeles, Washington
Contractor: McDonald Miller (Design Build) mark.reynolds@macmiller.com)
Owner contact: Sam Askew (Primary) or Mark Crowell 360-598-8700
Project Size: 180 Ton

Columbia Shores (Under construction)
Portland OR
Contractor: HVAC Incorporated
Equipment: R2 System - 50 Tons

Champion Church
Bellevue, WA
Contractor: Air Systems
Equipment: PURY P96 & 108 Wall units and ceiling mount
Project Size: 20 Ton

DOT TI
Tacoma, WA
Contractor: Sunset Air
Equipment / Project: 40 Ton

Department of Public Safety Building (January 2006)
Salem, OR
Contractor: TCMS & Complete Comfort Contact: Clint – 503-789-2415
Equipment: (2) PURY-100 w/ (18) PLFY & PKFK
Project Size: 20 Tons

Eureka City Hall Office Building Phase I (Completed 2004)

Eureka Montana (Design Build)
Contractor: Brown Electric Contact: Kevin Brown Phone: 406-889-3642
Equipment: (2) PURY 100 / (12) PDFY Ducted Indoor Units
Project Size: 20 Ton

Eureka City Hall Building Phase II (Completed 2005)
Eureka Montana
Contractor: Brown Electric Contact Kevin Brown Phone: 406-889-3642
Equipment: (2) PURY 100 / (12) PDFY Ducted Indoor Units
Project Size: 20 Ton application

Enpower Commercial Office Space (Completed 2004)
23rd and Jackson, Seattle Washington (Design Build)
Contractor: GB Systems Contact: Chris Fratini 206-229-4867 WA
Equipment: (3) PURY Outdoor Units / (12) PDFY – Ducted Indoor units
Project Size: 30 ton

Fire Station 6.8
Tacoma, WA
Contractor: Capital Heating & Cooling Bill 360-491-7450
Project Size: 10 Ton

Fire Station 6.5
Puyallup, WA
Contractor: Capital Heating & Cooling, Bill 360-491-7450
Equipment:
Project Size: 10 Ton

Franciscan Health Hospital (April 2006)
Bremerton, WA
Contractor: Emerald Air Contact: Doug Happe-253-872-5665
Equipment: (2) PURY-P108 W/ (8) PDFY Fan Coils
Project Size: 20 Tons

Gates Foundation
Seattle, WA
Contractor: Mckinstry
Equipment: PUHY-P108 / Wall mount units
Project Size: 8 Ton

Gaston Bay
Bellingham, WA
Contracotr: Andgar Inc. Kevin Pike 360-366-9900
Equipment: PURY-P144 Units PDFY- Ducted
Project Size: 30 Ton

Glacier Electric Office Building (January 2006)
Cutbank, Montana
Contractor: Rude Sheet Metal Contact: David Irvan Ph: 406-873-2261
Equipment: (2) PURY-P96 (19) PLFY PDFY Indoors
Project Size: 20 Ton

Green Valley Retirement Home (Under Construction)
Springfield, OR
Contractor: Comfort Flow
Equipment: Pury-P168, 192, 144 and Ducted Units
Project Size: 50 Ton

Highlands Condominiums (Under construction)
Seattle WA
Contractor: GB Systems
Equipment: PURY and ducted fan coils
Project Size: 60 Tons

Horizon House
Seattle, WA
Contractor: MacDonald Miller
Equipment: (1) PURY-P192 (17) Ducted and Wall mounts
Project Size: 16 Ton

Honda Marine (Under Construction)
Everett, WA
Contractor: Duo-Tek Duong Cun 206-916-6848
Project: 80 Ton (4 PURY 234) Ducted fan Coils

Idaho National Guard Office Building – Phase One
Boise, Id
Contractor: RM Mechanical Contact: Don Atkison 208-362-0131
End User Contact: Captain Clayton Anderson 208-422-6752
Equipment: (4) PURY Outdoors, 25 PLFY, PDFY Indoor
Project Size: 60 Ton

Idaho National Guard Office Building –Phase Two
Boise, Id (Gowen Field)
Contractor: Ridgeway
Equipment: (4) PURY Outdoors, 25 PLFY, PDFY Indoor
Project Size: 60 Ton

Key Bank Training Facility (December 2005)
Redmond, WA
Contractor: Air Systems
Contact: Tara Streck – 253-572-9484
Equipment (2) PURY-100 W/ (8) PDFY Indoor units
Project Size: 20 Tons

Keyport Energy
Bremerton, WA
Contractor: Miller Sheet Metal Contact: Pete 360-479-1737
Equipment
Project Size: 10 Ton

Lang Office Building
Portland OR
Contractor: WA Botting
Equipment: (1) PURY-P96 (5) Indoor Fan Coils
Project Size: 10 Ton

La Salle Hotel Expansion
Seattle, WA
Contractor: Emerald Air Doug Happe PE @ 253-872-5665
Equipment:
Project Size: 20 Ton

Lancaster Office Building
Portland, OR
Contractor:
Equipment:
Project Size: 10 Ton

La Salle Hotel (May 2006)
Seattle, WA
Contractor: Emerald Aire Contact: Doug Happe – 253-872-5665
Equipment: (2) PURY-100 W/ (10) PDFY Indoor units
Project Size: 20 Tons

Lake Washington Residence (April 2006)
Seattle, WA
Contractor: Emerald Aire
Contact: Hat – 253-872-5665
Equipment: (1) PURY-P108

Hotel Delux / Mallory Hotel (Completed July 2006)
Portland Oregon
Contractor: HVAC Inc Contact: Diane Gardner @ 503-462-4822
Developer: David Kennedy Phone: 503-784-6295
Owner (Maintenance) Contact: Oliver 503-219-2094
Equipment: (18) PURY –P108 Outdoor / (185) Ducted indoor units

Project Size: 190 Ton application

Mark Spencer Hotel (Under Construction)
Portland, OR
Contractor: Portland Mechanical
Equipment: (9) PURY 168-234 Outdoor 125 Indoor Fan coil
Size: 100 Tons

Marriott
Tacoma, WA
Contractor: TRS Contact Clay Hand 253-312-0488
Application: Hotel Rooms
Owner Contact: Mike Irish 253-591-9100
Equipment: PURY-100 and Ducted Fan Coils 10 Ton

Mechanical Agents
Seattle, WA
Contractor: McKinstry Co.

Madison Office Building
Portland, OR
Contractor: American Heating
Equipment: (2) PURY –P126 Outdoor (6) PDFY Indoor
Project Size: 20 Ton

MCTV
Portland, OR
Contractor: Reitmeire Mechanical Contact:
Equipment: W/ (8) PDFY Fan Coils
Project Size: 10 Tons

Missoula Office Building
Missoula, MT
Contractor: Anderson Heating / Contact: John Anderson 406-728-8048
Equipment: (4) PURY 100 w/ (24) PDFY Ducted Fan Units
Project Size: 40 Ton

Mississippi Lofts (Under construction)
Portland OR
Contractor: Portland Mechanical
Equipment: PURY 192,168,126, Ducted fan coils
Project Size: 50 Tons

Missoula Office Building
Missoula, MT
Contractor: Anderson Heating / Contact: John Anderson 406-728-8048
Equipment: (2) PURY-P96 w/ (12) PDFY Ducted Fan Units
Project Size: 25 Ton

North Valley Medical Center
Great Falls, MT
Contractor: Central Plumbing and Heating
Equipment: PURY-P96 PEFY and PDFY Ducted Fan coils
Project Size: 10 Tons

Our House Medical Offices
Portland, OR
Contractor: Entek Corp. 360-883-5462
Equipment:
Project Size: 10 Tons

PLU Ramstad Hall
Tacoma, WA
Contractor: Hermanson Contact: Trevor Moser – 253-575-9700
Equipment: (2) PURY-P108 W/ (5) PDFY Fan Coils
Project Size: 20 Tons
Pacific University Dormitory (Summer 2006)
Portland, OR

Contractor: American Heating
Equipment: (8) PURY-P96 W/ (55) PDFY, PMFY & PKFY Indoor units
Project Size: 80 Tons

Pacific Plaza (Under Construction)
Tacoma, WA
Contractor: Air Systems Contact: Doug Crawford
Equipment: PURY and Ducted fan Coils
Project Size: 150 Ton

Reed College Dorms
Portland OR
Contractor: Hunter Davisson
Equipment: PURY and Ducted fan Coils
Project Size: 150 Ton

Residence Inn
Jansen Beach, OR
Owner Contact: Erin Hight @ 503-285-9888
Contractor: Reitmeire Mechanical
Project Size: 20 Ton

Ram Building (TI Build-out)
Bellingham, WA
Contractor: Bel-Air
Equipment: (1) PURY-P168 (1) CMB 1010 (Indoor Units added w/ Tenants)

Roberson Condominiums (Under Construction)
Tacoma, WA
Contractor: Narrows Heating Contact: Jim Still 627-7543
Equipment: PURY-P96, P108, PDFY Fan coils
Project Size: 70 Ton

Raliegh Hill High School
Portland, OR
Contracto: American Heating
Equipment: PURY and Ducted fan coils
Size: 100 Ton

Russell House
Bellevue, WA
Contractor: Sunset Air
Equipment: PURY-P192 Ducted Units
Project Size: 16 TR

Seattle Aquatics Center (Completed 2005)
Federal Way, Washington
Contractor: WA Botting
Engineer: Tres West Tacoma WA - Bruce Gustefson 253-472-3300
Owner Contact Joe Hicker @ 206-296-1706
Equipment : (1) PURY 100 (4) PKFY Wall Mounted Units
Project Size: 10 Ton

Sheraton Hotel Office Floor
Seattle, WA
Contractor: Vital Mech Kevin Almond
Equipment:
Project Size: 20 Ton

Stillwater Elementary
Carnation WA
Contractor: TRS Mechanical
Equipment: PURY and Dusted fan coils

The Springs at Tanasbourn
Portland, OR
Contractor: American Heating

Equipment: PURY / Ducted Fan Coils
Project Size: 200 Tons

Seattle University (September 2005)
Seattle, WA
Contractor: Auburn Mechanical
Contact: Matt Wells – 253-838-1617
Equipment: (1) PUHY-100 W/ (3) Fan Coils
Project Size: 10 Tons

Seattle Pacific University
Classrooms and Office space
Seattle, WA
Contractor: MCS
Equipment: PURY and ducted fan coils
Size: 80 Ton

Sunset Club
Seattle, WA
Design: Don Iverson PE Coffman Engineers Seattle WA 206-623-0717
Contactor: GB Systems Chris Fratini 206-229-4867 WA
Equipment: PURY Systems 40 Ton

T-Mobile
Factoria, WA
Contractor: McKinstry Contact: Daryl Kapp
Equipment: PUHY-96 PEFY High Static units

Team Estrogen
Portland, OR
Contractor: Pro-Temp Contact: Daryl 503-233-6911
Equipment: (1) PURY-P96 Outdoor (1) Indoor Units
Project Size: 20 Ton

USGS – United States Geological Service
Tacoma, WA
Contractor: Air Systems Contact Dan Hamilton: 253-572-9484
Equipment: (5) PURY-P108 Outdoor (35) Indoor Units
Project Size: 45 Ton project

United States Border Crossing
Malta, Montana
Contractor:
Equipment:
Project Size: 10 Ton

Union Beach House (Microsoft Retreat / Recreation House)
Washington Peninsula
Contractor: Sunset Air Lacy, WA
Equipment: (2) PURY-126 Various Indoor units

Valley Professional - Office Space (Completed 2004)
Vail, CO
Owner Contact: Tye Stockton: 970-477-5336

Washington Mutual Bank (Completed 2004)
Commercial Office Space / Bank
23rd and Jackson, Seattle WA
Contractor: GB Systems Contact: Chris Fratini 206-229-4867
Equipment (1) PURY 100 / (12) PDFY Indoor units
Project Size**:** 10 Ton application

Wilcox School (Completed 2005)
833 NE 74 Ave, Portland, OR 97213
Contractor American Heating / Contact Smitty Cell 503-793-2566
Owner Contact: Dorothy Gillies Ph: (503) 916-5570 EXT 8332
Equipment: (4) PURY / (12) PDFY Ducted Indoor units

Project Size: 40 Ton

Rainier Boys and Girls Club
Bellevue, WA
Contractor:
Equipment: PURY and Ducted fan coils
Project Size: 40 Tons

Riverside Office Building (February 2006)
Puyallup, WA
Contactor: Emerald Aire
Contact: Doug Happe -253-872-5665
Equipment: (2) PURY-100 W/ (12) PDFY & PKFY Inddor units
Project Size: 20 Tons

Seattle Lighting Corporate Office (May 2006)
Seattle, WA
Contractor: Tri Mechanical / Contact: Jerry Brockmann
Owner Contact: Buff Little 800-689-1000
Equipment: (2) PURY-P108 W/ (18) PDFY, PMFY, PLFY Indoor Units
Project Size: 20 Tons

Sheraton Hotels Corporate Offices (January 2006)
Seattle, WA
Contractor: Vital Mechanical
Contact: Kevin Almon – 253-630-6933
Equipment: (2) PURY-100 W/ (15) PKFY Fan Coils
Project Size: 20 Tons

Title and Trust – 8 Story Office Building
Portland, OR
Contractor: American Heating Brian Shea
Equipment: (3) PURY-P144 Outdoor / Ducted Fan Coils
TI Build-out (Indoor units added w/ tenants)

University of Oregon
Portland
Contractor: Hydro Temp
Equipment: PURY / Ducted fan Coils
Project Size: 20 Tons

University of Washington (Savory Hall)
Seattle, WA
Contractor: Auburn Mechanical
Engineer: Wood Harbinger Contact: Tera Fretrop
Equipment: R2 300 Tons Ducted fan coils

Willamette University
Canengie Hall
Contractor: Hunter Davisson
Equipment: PURY and Ducted Fan coils
Size: 50 Ton

Xaiver Hall / Seattle University
Seattle, WA
Contractor: McKinstry Contact: Mark Frisk
Equipment: PURY-192 PDFY Ducted fan coil
Project Size: 16 Ton

Yakima Assisted Living Community (December 2005)
Yakima, WA
End User: Mark Overbey Phone: 509-949-3941
Contractor: All Seasons HVAC Contact: Terry Poe (509) 248-6380
Equipment: (4) PURY-100 W/ (38) PKFY Fan Coils
Project Size: 40 Tons