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December 7, 2020

Mary Nichols, Chairwoman
Richard Corey, Executive Officer
California Air Resources Board
P.O. Box 2815
Sacramento, CA 95812

BY ELECTRONIC TRANSMISSION

RE: Comments to CARB Hydrofluorocarbon Rulemaking

Dear Chair Nichols and Executive Officer Corey:

Daikin U.S. Corporation is pleased to submit these comments in connection with the California Air Resources Board's proposed regulation of hydrofluorocarbons used in stationary air conditioning equipment (the "HFC Regulations"). Daikin U.S. Corporation ("Daikin") is a subsidiary of Daikin Industries, Ltd., the world's largest air conditioning equipment manufacturer.

In 2018, Daikin joined other air conditioning manufacturers and the Natural Resources Defense Council ("NRDC") in committing to the adoption of refrigerants with a global warming potential ("GWP") of less than 750 by 2023. Yet, as we outlined in our August 2020 letter, California lags behind international, and some U.S. state, activities to amend building codes to allow for the use of next generation refrigerants in homes and commercial buildings. Although we continue to advocate for changes to the California building code to allow for the use of A2L refrigerants by 2023, ***Daikin supports the development of an Alternative Compliance Path ("ACP") for stationary air conditioning equipment to 2025***. We believe it is essential to maintain a GWP 750 limit as a part of this pathway.

Implementation Date for VRV Heat Pump Systems

Variable Refrigerant Volume ("VRV") heat pump systems – also known as Variable Refrigerant Flow ("VRF") – are an innovative technology that provide increased comfort, installation flexibility, energy savings, and zonal temperature control. First pioneered by Daikin, and now widely used across Asia and Europe, this technology accounts for over 20% of the California commercial heating, ventilation, and air conditioning (HVAC) market. VRV products, a majority of which are heat pumps, can assist the state in pursuing its building electrification goals and the move away from fossil fuel use in buildings.

The U.S. Department of Energy defines VRV as "a multi-split system with at least three compressor capacity stages, distributing refrigerant through a piping network to multiple indoor blower coil units each capable of individual zone temperature control, through proprietary zone temperature control devices and a common communications network."

This technology provides superior energy efficiency that has been confirmed in many studies conducted in the U.S. and globally. Appendix A summarizes several of these studies that include field testing and simulations which address the needs of a variety of stakeholders, including government agencies, users, academia, and utilities. The general conclusion from these studies is that VRV can save energy in the range of 34% to 58% compared to traditional HVAC systems.

Despite these noted benefits, the safety standards that regulate VRV use – ASHRAE 15:2019 and UL 60335-2-40:2019 – effectively prevent VRV products from employing any of the currently available refrigerants that have a GWP below 750, due to Refrigerant Concentration Limit ("RCL") restrictions. Industry is seeking amendments to these safety standards, but more time is needed for adoption into the building next code cycle and for the development of mitigation methods.

As a result, VRV systems will be effectively banned in the state of California should CARB's regulation take effect prior to changes to the safety standards and building codes that will allow for the use of next generation refrigerants. ***Accordingly, Daikin requests that CARB establish an Alternative Compliance Path to allow for the use of virgin R-410A refrigerant in VRV technology until January 1st, 2026.***

Additionally, Daikin seeks several VRV-specific changes in the proposed regulation, as follows:

> Correction of VRV Leak Rates: In the Initial Statement of Reasons ("ISOR") (p. 94), Table 24 provides the baseline characteristics for stationary air conditioning products. The identified leak rates for non-residential air conditioners (i.e. 10% and 7%) are incorrect. The Western Cooling Efficiency Center ("WCEC") at the University of California, Davis recently conducted a study of 1,853 air conditioning/heat pump (AC/HP) systems installed in buildings across the East Side Union High School District in San Jose, California, and found that the annual emissions rate over the prior 4.22 years was significantly lower than the identified leak rates in the ISOR. WCEC found that the annual leakage rate of AC/HP equipment was 0.7% for R-410A equipment and 2.8% for R-22 equipment.
>
> International and domestic studies have found that VRV products have a far lower leak rate than the 10%, 7%, and 25% figures in the ISOR.[1] For example, the final report of the risk assessment of mildly flammable refrigerants published by the Japan Society of Refrigerating and Air Conditioning Engineers concludes that the probability of leakage from VRV systems is approximately 1%. In addition, according to a study conducted by VDKF in Germany, the average leak rate was similarly found to be approximately 1%. Accordingly, we believe that the more appropriate range of leak rates should be 1% to 2%. ***Daikin requests CARB use a more appropriate and accurate leak rate for VRV products***.

[1] *See* Appendix B.

Definition of "New Air-Conditioning Equipment": CARB's proposed definition of "New Air-Conditioning Equipment" would have a significant negative impact on the use of air conditioning products in California. For example, under the current definition, it would be necessary to replace an entire VRV system (with low GWP refrigerant) even though only one of the outdoor units in a multi-module system might need to be replaced. This would put an unnecessary burden on users to replace entire systems when only one outdoor unit is out of order. Furthermore, replacement would be impossible because revisions to codes and standards for low GWP refrigerant VRV have not been completed. CARB has provided for refrigeration systems to align with the building permit date, but no such provision is available for air-conditioning.

Accordingly, Daikin proposes the following language:

Proposed Language Change. New Air-conditioning Equipment means any air-conditioning equipment that is one of the following:

a) First installed using new components, used components, or a combination of new and used components; or
b) An existing system with a single condenser and single evaporator that has a new exterior condenser, condensing unit or remote condensing unit.
c) An existing system having more than one condenser and/or more than one evaporator that is modified such that the system has experienced cumulative replacements, within any three-year time period, of components in full or exceeding 50 percent of the capital cost of replacing the entire air-conditioning system.

Clarification on Variance Provision

In the ISOR Appendix A (p. 39), the language for "variance" was changed from the July proposal to remove the condition "(d) The Applicant has a niche end-use or circumstance." ***Daikin seeks clarification as to whether manufacturers can apply for variances for non-niche end uses. Daikin also seeks clarification as to when CARB will begin accepting variance applications.***

Additionally, ISOR Appendix A (p. 40) provides the requirements for calculating emissions under a Force Majeure situation. ***Daikin seeks clarification on the CARB-determined factors to calculate these emissions.***

Reactions to the AHRI and EIA Proposals

Daikin supports the overall concept of the Air Conditioning, Heating, and Refrigeration Institute ("AHRI") proposal – outlined in the ISOR Appendix D. However, it must be noted that we do not support a specific element of the proposal that establishes differentiated discount rates for refrigerants.

Furthermore, while Daikin supports the overall reclamation concept in the Environmental Investigation Agency proposal, we cannot support the proposal as a whole due to concerns regarding the availability of R-410A that can be recovered for reclamation purposes.

Furthermore, Footnote 3 of Appendix D states that "In the absence of rigorous data demonstrating a lower leak rate, EIA recommends applying a 25% leak rate for [VRV] systems consistent with average leak rates for supermarket refrigeration systems with which [VRV] systems share the most common architectural properties." We would note, however, that a 25% leak rate does not reflect actual observed leak rates and therefore is inaccurate.

Additionally, we do not support the idea to include refrigerant service charges over the equipment lifetime. This should be limited to initial factory charge, as it is difficult for manufacturers to take full responsibility for installing and servicing procedures which are traditionally performed by contractors.

Should CARB adopt language from ISOR Appendix D, Daikin seeks clarification on the definitions of refrigerant "reclamation," "destruction," and "servicing" as well as the meaning of "destruction," "previously recovered," and "additional." For example, Appendix D (p. 3) addresses the "destruction of HFC-410A refrigerants recovered from air-conditioning equipment within California after January 1st, 2023" and states that "[destruction] of previously recovered and collected used refrigerant does not qualify as additional." Daikin seeks clarification as to whether this requirement is for equipment placed on the market after January 1st, 2023, or for any equipment regardless of when it was placed on the market and to be recovered after 2023.

Additional Points of Clarification

GWP Values: In the ISOR (p. 25), hydrocarbons are said to "have GWP values of 3." While R-290 and R-600a have this value, not all hydrocarbons have a GWP of 3. ***Daikin asks CARB to correct this statement to note that some but not all hydrocarbons have a GWP value of 3.***

Additionally, ***Daikin requests that CARB be consistent with the use of 100-year GWP values*** in the Executive Summary. This approach is consistent with other state, federal, and international regulations and is consistent other sections of the ISOR which utilizes the 100-year figures.

EPA SNAP Program: In the ISOR (p. 24), it is stated that A2L refrigerants must be approved under the U.S. EPA Significant New Alternatives Policy (SNAP) Program. However, the SNAP Program must approve new uses for all alternatives, no matter their ASHRAE 34 designation. ***Daikin requests CARB modify this language to note that all new alternatives must undergo the SNAP approval process.***

*****

Daikin looks forward to continuing to work with CARB, the California Energy Commission, and their sister agencies to ensure the accelerated adoption of low GWP refrigerants and other advancements that will help the state meet its climate change and HFC reduction goals. We are confident that our technologies and products can play a critical role to helping California meet its energy efficiency, GHG reduction, demand response, and building electrification targets.

Thank you for the opportunity to provide these comments.

Respectfully submitted,

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APPENDIX A: VRF Energy Savings and Environmentally Friendly Characteristics

Executive summary

Developed in Japan in 1982, Variable Refrigerant Flow (VRF) — also known as Variable Refrigerant Volume (VRV) — systems are known for their high energy performance. Thus, they can improve energy efficiency both in residential and commercial buildings, along with their other benefits including better comfort level, lower noise, and simultaneous heating and cooling potentials.

Among all the benefits VRF provides, energy savings is most sought after and studied. There are many research efforts and studies that have identified the energy savings potential that VRF can bring when compared to traditional heating, ventilation, and air conditioning (HVAC) systems. Some studies were done as field performance research, however, given the difficulty of conducting large scale field testing to cover a majority of models and climates, there are also studies using simulation tools to quantify and generalize trends.

This document provides a summary of several well regarded VRF energy saving performance studies, covering both field testing and simulation, from a variety of stakeholders including government agencies, users, academia, and utilities. Although from different perspectives and using different methods, the general conclusion from those studies is that VRF can save energy in the range of 34% to 58% compared to traditional HVAC systems. The table below shows the findings from the studies summarized in this letter:

Study Source	**VRV Energy Saving Benefit**	**Baseline Unit**
U.S. General Services Administration (GSA)	34-48%	Chiller, packaged units, etc.
Oak Ridge National Laboratory (ORNL)	17% for cooling 72% for heating	Conventional RTU
Italy field study	43% for cooling	Chiller
University of Maryland	41-58%	RTU
Electric Power Research Institute (EPRI) and PG&E	49%	RTU

Energy Saving Benefit Study

1.1. U.S. General Services Administration (GSA) study to compare energy and cost saving to conventional HVAC systems
(Reference paper No.1)

1.1.1. In this report, GSA conducted literature study to estimate the energy saving and cost saving benefit by utilizing VRF technology. The Moakley Federal Courthouse in Boston, Massachusetts has partially installed a VRF project, which is reviewed in this report.

Commercial buildings account for approximately 40% of the energy bills and 40% of the carbon dioxide emissions in the United States (USDOE 2012a). About a third of commercial building energy usage is for heating, cooling and ventilation (GSA 2012).

GSA is a leader among federal agencies in aggressively pursuing energy efficiency opportunities for its facilities and installing renewable energy systems to provide heating, cooling, and power to these facilities.

GSA has identified the best opportunities for VRF systems including buildings with these target characteristics:

- Inefficient HVAC systems and high energy costs
- Lack of cooling or inadequate cooling capacity, although adding cooling capability or capacity may increase total energy usage despite possible reductions in fan and heating energy usage
- Older and historical (listed or eligible for listing in the National Register of Historic Places), with limited room to install or change systems
- New building projects that can take advantage of opportunities to reduce floor-to-floor height, or increase usable floor space by removing mechanical equipment from inside the main building areas.
- VAV systems with electric reheat or heat pumps with electric back-up heat. Up to a 70% reduction in HVAC energy is possible from a VRF system with exhaust air heat recovery when compared to a VAV system with electric reheat, according to an energy modeling study (Hart and Campbell 2011).
- Significant heating requirements – the Midwest and Northeast are good places to look for opportunities in this regard.
- Inefficient fan systems
- Leaky or poorly designed or installed ductwork
- Already identified for HVAC upgrades, replacements, or energy improvements.

The energy saving potential by VRF is summarized in Table 6 as below (only partial table is shown). The average energy saving comparing to various traditional HVAC system is 34-48%.

GSA Study – Table 6: Potential HVAC Only Energy Savings from VRF Systems Compared to Other Systems

Chilled Water, VAV	Packaged VAV	Packaged CAV	Air-Source Heat Pump	Source
-	62%	39%	49%	Hart and Campbell 2012
36%	-	49%	-	LG 2011
34%	-	-	-	Goetzler 2007
33%	29%	-	33%	EES Consulting 2011- From Aynur 2010, Amarnath and Blatt 2008
-	43%	-	23%	EES 2011
-	-	55%	-	LG 2012
34%	45%	48%	35%	Average

GSA also looked into a few installed VRF systems. Four VRF projects in the Northwest are briefly described in Table 3 to illustrate the variety of projects being developed. These projects include retrofit and new construction. All of these projects are estimated to save energy and cost.

GSA Study – Table 3: Example VRF Projects

Project	**Building**	**VRF Implementation**	**Benefits**	**Source**
Mercy Corp Portland, Oregon	Renovation of the 42,000-ft2 historical 1892 Packer-Scott Building plus addition of 40,000 ft2. The building is primarily office space.	10 outdoor VRF compressors with energy recovery. DOAS system with variable supply flow, dedicated variable flow fans at the zones controlled by CO2 sensors in many zones.	HVAC energy performance was not modeled separately. Whole building energy usage is measured at 36 kBtu/ft2 versus modeled usage of 38 kBtu/ft2	New Buildings Institute 2011 Schnare 2011
Jamestown S'Klallam Tribe Medical Clinic Sequim, Washington	New 33,000-ft2 medical clinic	78-ton VRF system with heat pump and heat recovery operation. DOAS with energy recovery.	Estimated savings 41,400 kWh per year. Cost $2/ft2 more than VAV alternative.	BPA, 2012b

Lewis County PUD Chehalis, Washington	Renovation of 28,000-ft2 office building while building remained open.	56-ton VRF heat pump system with a DOAS using existing ductwork. Replaces old heat pumps. Selected over VAV alternative.	Estimated savings 25,000 kWh/year. Incremental cost, $75,000. Better heating comfort – formerly used a lot of electric space heat.	EES Consulting 2011, BPA 2012c
Lamb Building Eugene, Oregon	St. Vincent de Paul 37,500-ft2 4-story affordable housing building.	VRF with heating, cooling, and heat recovery.	Modeled savings of 80,000 kWh	BPA, 2012d

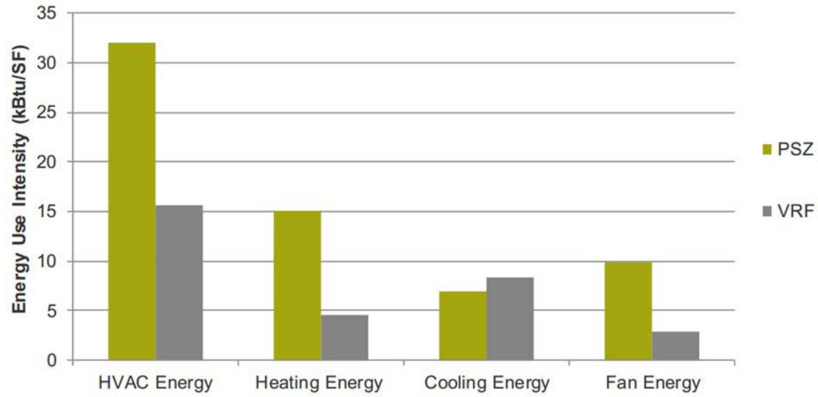
1.2. PG&E and Electric Power Research Institute (EPRI) joint field study
(Reference paper No.2)

1.2.1. This report documents the findings from a monitoring exercise on a 13 zone VRF-HR (heat recovery) system. The selected site for this VRF field monitoring project is a PG&E office building in Auburn, California which is in California Climate Zone 11. The building is a four story (a basement and three above ground floors) office building with approximately 8,466 square feet of conditioned space. The VRF system installed at this location is a 24-ton Mitsubishi City Multi 2-pipe VRF system with heat recovery capabilities (simultaneous heating and cooling operation is possible). The system has a total of 13 indoor units connected to it.

Data representing thermal and electrical characteristics of the VRF system was collected from the site for a period of 1 year – from June 2013 to May 2014. Both field-collected data analysis and modeling based on collected data were conducted. The energy model was developed using AecoSim Energy Simulator (AES), which is a front end for EnergyPlus.

Modeling showed that the EnergyPlus model can predict the energy usage of the modeled building within ±15% of actual energy use for the VRF system. Comparison between a modeled baseline and a VRF system showed significant energy savings in heating mode and fan energy savings.

1.2.2. Energy use for the packaged single zone (PSZ) model was compared to the energy use for the VRF model. The VRF model used significantly less energy. The resultant HVAC savings are 126 kWh/ton and 52 therms/ton, which is equal **to 51% of the PSZ HVAC energy use**. To help demonstrate the source of these savings, Figure 5-2 outlines the energy use intensity for the VRF and PSZ models.



PG&E and EPRI joint field study – Figure 5-2: Energy Use Intensity for the VRF and PSZ Models Highlighting the Source of Energy Savings.

1.2.3. Collected field performance data is shown in Figure 4-17 as below. The following analysis for this report is conducted by Daikin based on the information in this report and public available information. For further analysis out of this report, some notes are added to Figure 4-17 as shown in blue font.

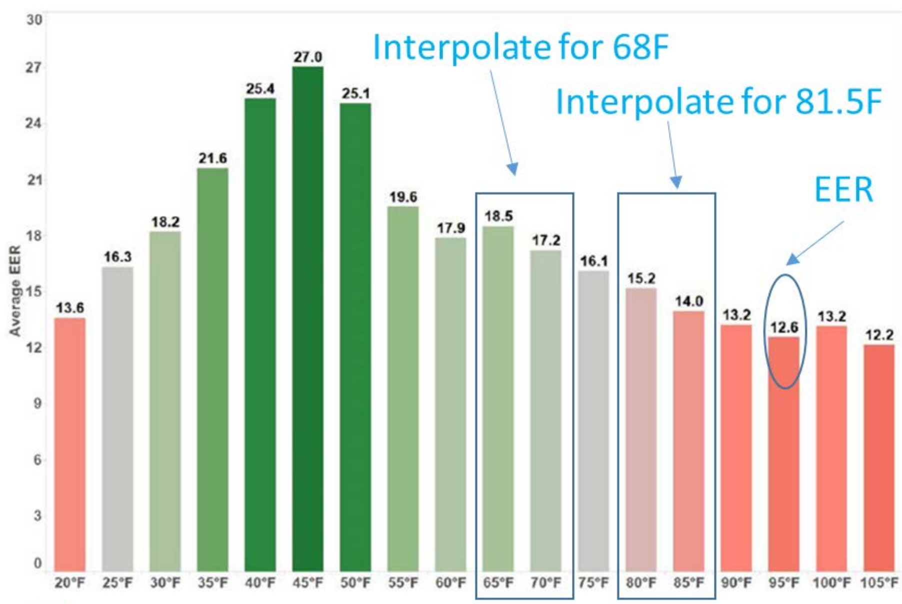


Figure 4-17
Average EER vs Temperature Bins

VRF system performance index such as EER and IEER can be estimated from Figure 4-17, as shown in table below.

$$IEER = (0.020 \cdot A) + (0.617 \cdot B) + (0.238 \cdot C) + (0.125 \cdot D)$$

Condition	A	B	C	D
OAT	95	81.5	68	65
IAT, DB	80	80	80	80
IAT, WB	67	67	67	67
Weight	0.02	0.617	0.238	0.125
EER	12.6	14.84	17.72	18.5
IEER	15.93814			

Value can be used to compare to manufacture data

Interpolated

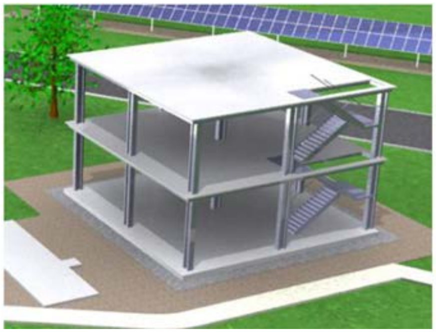
Since the actual unit PURY-P288T/YSJMU-A is no longer available in AHRI directory, and publicly available document only shows partial system rated performance, rated performance from active models is used to estimated missing non-ducted performance. The following table shows the comparison.

	EER	IEER
Actual unit performance in field	12.6	15.9
Estimated rating of tested unit	10.1	13.9
Testing result vs rating, improvement	25%	12%

The table above shows measured VRF performance (EER and IEER) in this study is better than its rating. The possible reason for this could be factors rating test procedure does not capture, such as longer partial load hours, oversizing, and heat recovery options.

1.3. Oak Ridge National Laboratory (ORNL) study to compare VRF field performance to a conventional rooftop unit.
(Reference paper No.3)

1.3.1. This paper discusses a research project that evaluates energy performance of a VRF system that has been installed and operated in Oak Ridge National Laboratory's new research facility, Flexible Research Platform (FRP). The performance of the VRF system has been monitored since the summer of 2014, and analyzed and compared with a baseline system, a conventional rooftop variable air volume (VAV) system with terminal electric reheat that is installed in the same facility.




1.3.2. The baseline rooftop and VRF system were alternately operated and monitored every week, and the system performances were compared. The hourly and daily energy consumption of both systems were characterized based on corresponding outdoor air temperatures. The analysis shows that the **VRF system uses 17% and 73% less energy** than the rooftop system in cooling and heating seasons, respectively. The chart below shows the daily energy consumption of both RTU and VRF systems.

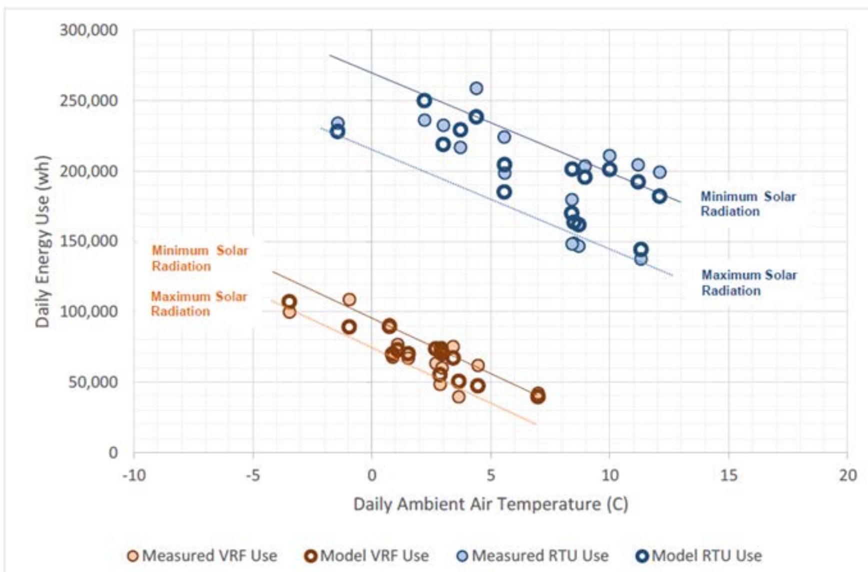


Figure 5. Daily RTU and VRF energy use as a function of outdoor air temperature

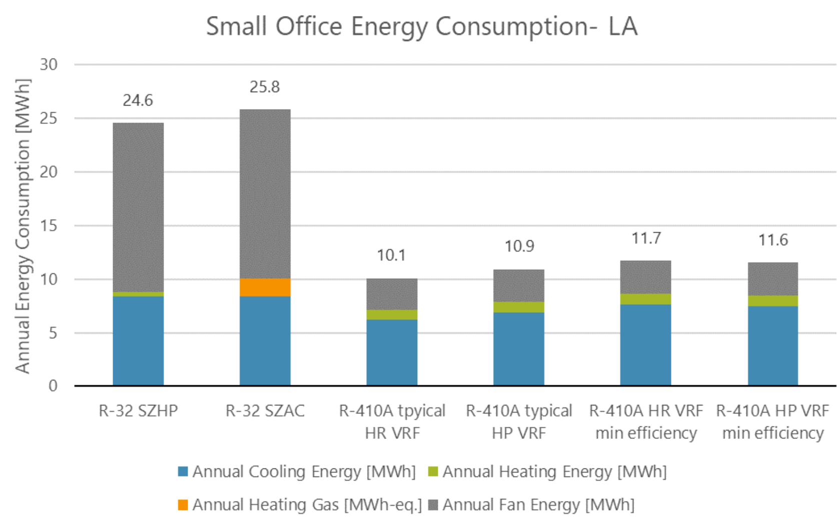
1.4. <u>Energy and total CO_2 emission comparing R-410A VRF and A2L RTU by OTS</u> (Reference paper No.4)

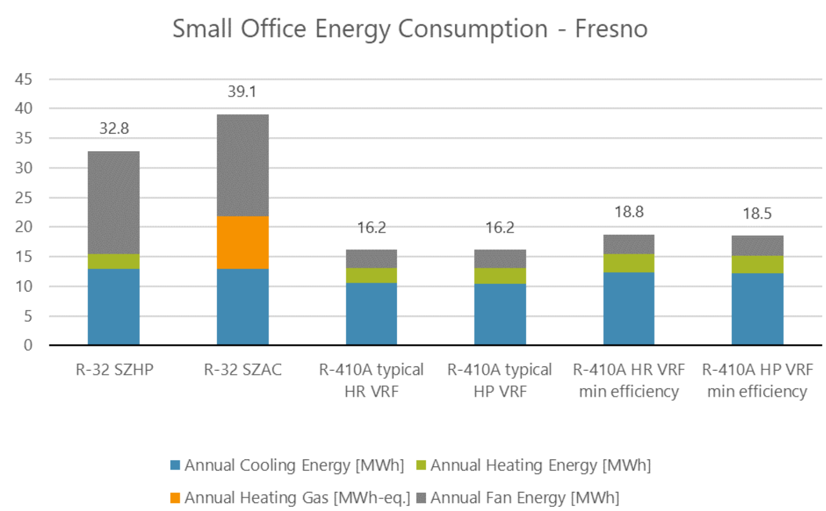
This paper compares the environmental impacts of RTUs using R-32 against VRF systems continuing to use R-410A in equivalent circumstances, by estimating CO_2 emission that considers both the direct emissions of greenhouse gas (GHG) refrigerants and the indirect emissions resulting from the energy consumption of such systems. Analyses are performed on a small office building in two California locations simulated using CBECC-Com and EnergyPlusTM. Simulations showed dramatic energy savings for the VRF systems relative to RTUs. While the direct refrigerant emissions of the R-410A systems were considerable, most simulations showed comparable and even lower lifetime emissions for the VRF systems due to their simulated energy savings relative to the RTUs.

This study looked at both energy consumption and life cycle climate potential (LCCP) of a R-410A VRF system installed in a small office, and a R-32 RTU system at the same building. **The conclusion is VRF has significant less energy consumption (roughly 50% of RTU), while its LCCP is similar to low GWP refrigerant RTU.**

1.4.1. Energy Consumption Comparison

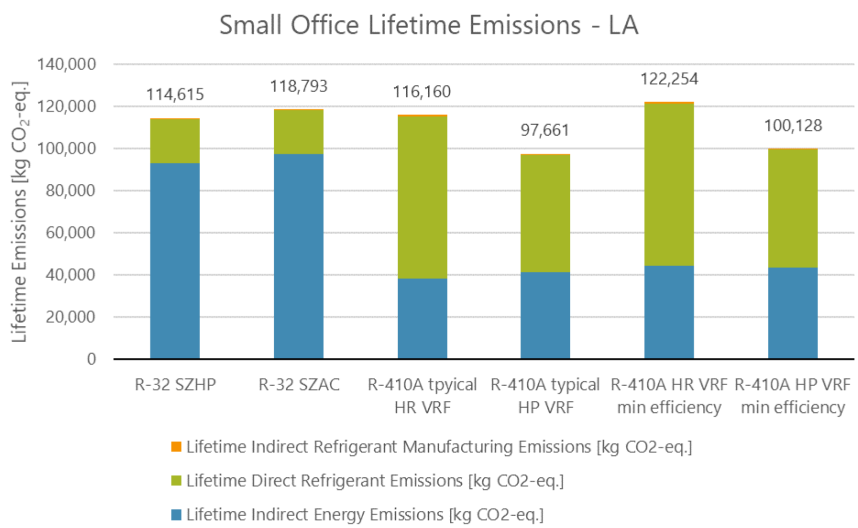
This study is conducted by using a default small office building model embedded in CBECC-Com along with inbuilt VRF and RTU models. Both typical VRF model and min efficiency model are calculated, even though min efficiency VRF mode is very rare in the market. As shown below, **even minimum efficiency VRF energy consumption savings in both LA and Fresno is around 50%**.

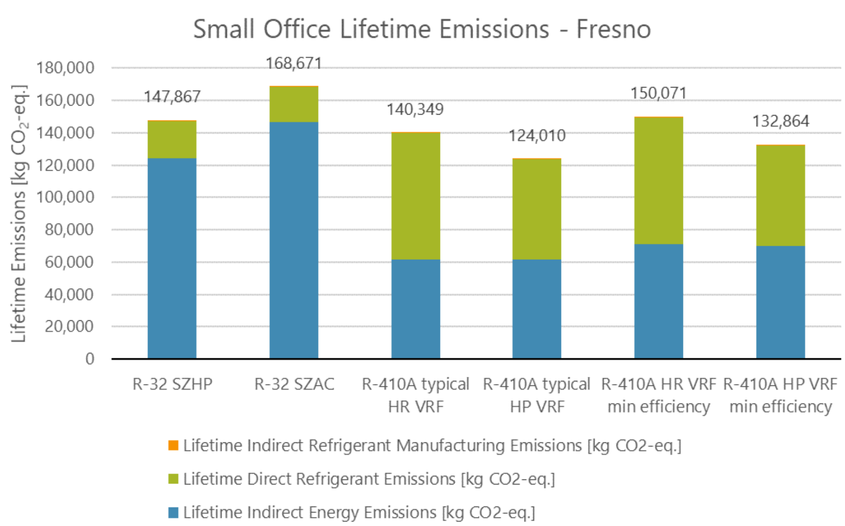




1.4.2. CO_2 Emission Comparison

This study identified that assumed 7% annual refrigerant leak rate has big impact at LCCP result. And there are other studies concluded with less annual leak rate, including EPA vintage model's 4.3%. However, even with 7% annual leak rate, the two charts below show that **VRF with R-410A has similar total CO_2 emission to R-32 RTUs units.** For both LA and Fresno, VRF and RTU in this study show similar LCCTP at the same level. Even with higher GWP of R-410A, VRF can compensate with its high energy efficiency when comparing with low GWP refrigerant in traditional RTU units.





1.5. <u>VRV and conventional VAV system energy consumption and comfort level comparison by simulation, University of Maryland.</u>
(Reference paper No.5)

1.5.1. Performance of two widely used air conditioning (AC) systems, variable air volume (VAV) and variable refrigerant flow (VRF), in an existing office building environment under the same indoor and outdoor conditions for an entire cooling season is simulated by using two validated respective models and compared.

1.5.2. VRF system has a ventilation system with HRV that provides free cooling. The simulation tool is EnergyPlus. The conventional VAV system has a combination of reheated and non-reheat indoor units. The performance comparison is done for summary, as shown in the chart above. **VRF saves energy consumption in the range of 41-46%.** At the same time, VRV system cannot keep comfort level for rooms equipped with non-reheat indoor units because even the minimum air flow from VAV box is over-cooling the room. VRF system maintains comfort level with no issue.

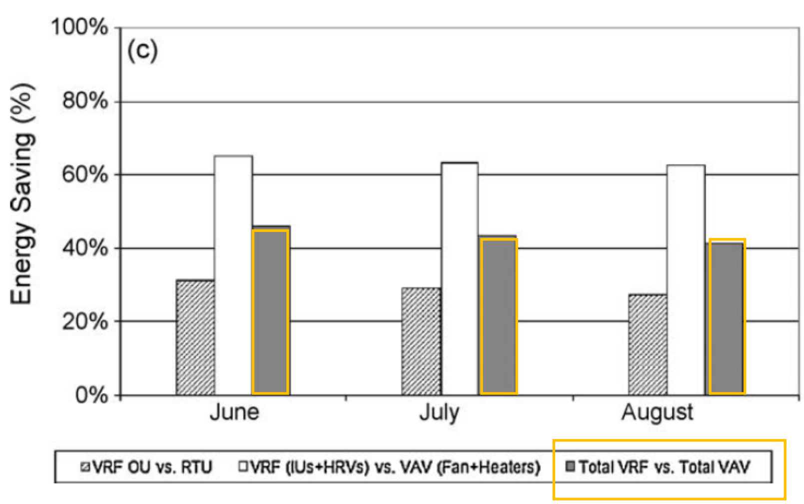


Fig. 2. Monthly energy consumption of the VAV and VRF systems and the energy-saving potential of the VRF system, (a) VAV system, (b) VRF system, (c) energy-saving potential of the VRF system.

1.5.3. Other combination of VAV systems were also studied and found there is a trade-off between energy consumption and comfort level for VAV system. If VAV system is all reheated indoor units, then **comfort level will be better but more**

energy will be used such that VRF will save energy around 52-58%. On the other hand, VAV system with all no-reheat indoor units will suffer indoor comfort level when some energy can be saved.

2. Reference papers

1. Variable Refrigerant Flow Systems, 2012, Brian Thornton, Anne Wagner, GSA.
2. Field Analysis of Commercial Variable Refrigerant Flow Heat Pumps. EPRI, Palo Alto, CA: 2014. 3002004364.
3. Evaluation of Variable Refrigerant Flow (VRF) Systems Performance in ORNL's Flexible Research Platform (FRP), Piljae IM, Jeff MUNK, Kwanwoo Song, ORNL and Samsung Electronics.
4. Estimation of Lifetime CO2 Emissions of Commercial HVAC Equipment through Building Energy Modeling, 2020, Optimized Thermal Systems.
5. Field Performance Measurements of VRF System with Subcooling Heat Exchanger, 2012, Yunho Hwang, Laeun Kwon, Reinhard Radermacher, Byungsoon Kim, University of Maryland.

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APPENDIX B: Summary of VRV Leak Rate Studies

Organization	Country	Year	VRV Leak Rate	Method
Ministry of Economy, Trade and Industry	Japan	2008	**3.5%**	• Calculated from the total consumption and data (40,000 samples) gathered from contractors. • The leak rate includes the amount of recovered refrigerant during servicing, so **the actual leak rate is expected to be lower.**
The Japan Society of Refrigerating and Air-Conditioning Engineers (JSRAE)	Japan	2017	**Approx. 1%**	• Data of incidents was collected from Japan Refrigeration and Air Conditioning Industry Association (JRAIA) members. • JRAIA determined the probability and average amount of leakage for indoor and outdoor units on a yearly basis.
VDKF	Germany	2010-2012	**Approx. 1%**	• Data was collected from contractors using VDKF's leakage and energy control system (electronic log book system).
Öko-Recherche	Germany	2014	**3.8%**	• Data was collected from 352 contractors.
Manufacturers	United Kingdom	2019	**2%**	• Two manufacturers provided the leak rate data for the CIBSE study.
Department of Energy	United Kingdom	2014	**3.5%**	• It was determined from analysis of F-gas log books that annual leakage rates from operation of heat pumps were of the order of 3.8% of installation charge for nondomestic applications and 3.5% for domestic applications
Department of the Environment and Energy	Australia	2018	**2%** **(Service rate)** **2.7%** **(Theoretical leak rate)**	• The service rate is the annual rate of replacement of losses of refrigerant from operating equipment, expressed a percentage of the total possible bank in that stock of equipment.