Disposition for: Variable Refrigerant Flow (VRF) Systems

California Public Utilities Commission, Energy Division

March 1, 2017

[1. Review Scope 2](#_Toc476150241)

[2. Directed Revisions to Workpapers 2](#_Toc476150242)

[2.1. Revise Implementation, Measure and Cost Definitions 2](#_Toc476150243)

[2.2. Provide Additional Documentation to Support Technology Shift 2](#_Toc476150244)

[2.3. Provide Three-Pronged Test Documentation 2](#_Toc476150245)

[3. Detailed Review 2](#_Toc476150246)

[3.1. Workpapers Do Not Adequately Support the Case for a Technology Shift 3](#_Toc476150247)

[3.2. Analysis Methods and Tools May not be Consistent with DEER Methods and May Not Consider All Critical VRF System Characteristics 4](#_Toc476150248)

[3.3. Directed Revisions 4](#_Toc476150249)

[4. Additional Supporting Resources 6](#_Toc476150250)

# Review Scope

Table 1 - Workpapers

|  |  |  |  |
| --- | --- | --- | --- |
| **Workpaper ID** | **Rev** | **Workpaper Title** | **Official Submittal Date** |
| **SCE** |  |  |  |
| SCE13HC036 | 1 | Variable Refrigerant Flow Commercial Heat Pumps & Heat Recovery Systems >65kBtu/h | 4/4/2016 |
| PGECOHVC142 | 1 | Variable Refrigerant Flow Nonresidential Systems | 1/4/2016 |

# Directed Revisions to Workpapers

## Revise Implementation, Measure and Cost Definitions

The workpapers based on technology shift are not approved. CPUC staff directs PAs to update their programs, implementations and measure definitions to reflect the direction provided in this disposition. Revise all measure definitions, along with implementation and cost definitions, to reflect same technology code baseline measure definitions included in the Preliminary Ex Ante Review database (PEARdb) and covered in the document “Variable Refrigerant Flow Measure Impacts for Typical Commercial Buildings in California Climates.”

## Provide Additional Documentation to Support Technology Shift

The major contributor to the savings is due to a shift in technology between the baseline and the measure. CPCU staff require additional documentation demonstrating that the proposed upstream incentive approach has influence over the customer choice to choose one system design (in this case VRF) over another (such as a single zone heat pump or variable-air-volume system).

## Provide Three-Pronged Test Documentation

Technology shifts from non-electric heating sources require measures to satisfy the CPUC three-prong test.

# Detailed Review

The SCE13HC036 workpaper includes the following two measure definitions:

* >= 65 kBtu/hr Variable Refrigerant Flow Heat Pump DX Equipment replacing Package Variable Air Volume
* >= 65 kBtu/hr Variable Refrigerant Flow Heat Pump DX Equipment replacing Single Zone Package AC
* >= 65 kBtu/hr Variable Refrigerant Flow Heat Pump DX Equipment replacing Single Zone Package Heat Pump
* >= 65 kBtu/hr Variable Refrigerant Flow Heat Recovery DX Equipment replacing Package Variable Air Volume
* >= 65 kBtu/hr Variable Refrigerant Flow Heat Pump DX Equipment replacing Single Zone Package AC
* >= 65 kBtu/hr Variable Refrigerant Flow Heat Recovery DX Equipment replacing Single Zone Package Heat Pump

The PGECOHVC142 workpaper includes the following two measure definitions:

* Variable Refrigerant Flow Heat Pump < 80 tons
* Variable Refrigerant Flow Heat Pump > 80 tons
* Variable Refrigerant Flow Heat Recovery < 80 tons
* Variable Refrigerant Flow Heat Recovery > 80 tons

The workpaper savings are based on the comparison of a Variable Refrigerant Flow (VRF) system to a different technology, either a single zone air conditioner, single zone heat pump, or a variable-air-volume system. Savings estimates were developed using EnergyPro, which is a software primarily used for demonstrating compliance with Title 24 standards. The workpapers are not approved, and CPUC staff directs PAs to update their programs, implementations and measure definitions to reflect the direction provided in this disposition.

## Workpapers Do Not Adequately Support the Case for a Technology Shift

The primary contributor to the proposed savings is the shift from one type of HVAC system design and configuration (either a single zone air conditioner with gas furnace, a single zone heat pump, or a multi-zone variable-air-volume system with gas hydronic heating) to the VRF system. CPUC staff are not aware of any deemed HVAC measures that consider energy consumption differences due to fundamental differences between baseline and measure system definitions[[1]](#footnote-1). For example, DEER and PA workpapers include measures for high efficiency package HVAC equipment, but those savings assume the same system configuration and determine savings based on the features of the measure technology, such as higher cooling efficiency and improved part-load performance, compared to the baseline technology.

A change between baseline and measure technologies implies that the energy efficiency program influenced that change. However, workpapers do not include information to support that the program has any influence over the technology switch. In May of 2016, CPUC staff worked with the PAs (PG&E was the workpaper lead at that time) to develop customer survey questions intended to help identify typical system choices. The goal was to administer this survey as part of an effort to ascertain if PAs’ programs were influential (as well as the extent of that influence) of the choice to install a VRF system over some other system. CPUC staff is not aware of any progress on this effort.

## Analysis Methods and Tools May not be Consistent with DEER Methods and May Not Consider All Critical VRF System Characteristics

No information is provided that demonstrates the software and analysis approach are similar to DEER methods. It is not clear if the proposed modeling methodologies are consistent with DEER requirements. In order for the use of this software to be approved, documentation must be provided showing that it produces results similar to DEER. For example, workpaper authors should be able to demonstrate that using EnergyPro produces similar savings results as DEER for common deemed measures such as a 18 SEER packaged AC unit. At this time, PAs are directed to use the measure definitions and impacts described in Section 3.3, below. However, if the PAs still have a preference for using EnergyPro, CPUC staff will require this software comparison as part of any workpaper resubmission. PAs shall work with CPUC staff to develop the scope and content of this comparison.

Furthermore, it is not clear if the software adequately considers the many technical aspects of VRF systems that both increase and decrease the energy use of these systems compared to more conventional systems. Examples of this are piping distribution losses, performance of outdoor units during part-load and heat recovery options, or outdoor unit defrost operation. As a more specific example, VRF systems are typically installed with extensive networks of refrigerant piping. As the total length of refrigerant piping in the system increases, the capacity of the primary refrigeration unit as well as the remotely located space units must be increased. The additional capacity is needed to overcome the friction losses of the piping, yet the net deliverable cooling and heating capacities may not change. Thus, the overall efficiency of the system, both full load and part load performance, may decrease as the overall size of the refrigerant piping network increases.

## Directed Revisions

PAs are directed to use staff developed measure definitions and impacts for measures listed in Table 2. The approved measures are based on the same technologies for baseline and measure, with savings due to improvements of the overall system efficiency characteristics, but not shifts in technology between the baseline and measure. The baselines are Title 24 minimally compliant VRF or VRF heat recovery systems, while Tier 1 and Tier 2 systems are higher efficiency VRF systems.

Table 2 - Approved Variable Refrigerant Flow Measures

|  |  |
| --- | --- |
| Measure | Baseline |
| Heat Pump VRF System, Tier 1 | Heat Pump VRF System, Title-24 |
| Heat Pump VRF System, Tier 2 | Heat Pump VRF System, Title-24 |
| Heat Recovery VRF System, Tier 1 | Heat Recovery VRF System, Title-24 |
| Heat Recovery VRF System, Tier 2 | Heat Recovery VRF System, Title-24 |

Additional requirements are provided below:

### Approved Measure Definitions and Impacts Available in PEARdb

The approved measure definitions and energy impacts are available in the Preliminary Ex Ante Review database (PEARdb) accessible using the READI tool. At this time, impacts are available for the following building types:

* Primary School (EPr)
* Small Office (OfS)
* Large Office (OfL)
* Hotel (Htl)

### PAs are Required to Submit Revised Implementation and Cost Records

PAs are required to revise implementation records to refer to the approved measures listed in Section 3.3. Additionally, since measures now are based on increased efficiency of similar technologies, not a switch in technology, cost records need to be revised to include costs for the following technologies:

* Heat pump VRF system, Title 24
* Heat pump VRF system, Tier 1
* Heat pump VRF system, Tier 2
* Heat recovery VRF system, Title 24
* Heat recovery VRF system, Tier 1
* Heat recovery VRF system, Tier 2

### Additional Research Required to Support Technology Shift Measures

CPUC staff is not opposed to measure definitions that include a technology shift. However, PAs have not provided any research nor resulting evidence supporting that an upstream HVAC program would have influenced a customer’s decision to select the VRF technology over another system type or design. In order for these measures to be approved, PAs shall perform research that demonstrates typical system choices and that the choice to adopt VRF systems is primarily influenced by the PA programs. PAs shall work with CPUC staff to develop and carry out the research, and they may use EM&V funds.

Examples of savings estimations for the technology shift cases can be found in the “*Variable Refrigerant Flow Measure Impacts for Typical Commercial Buildings in California Climates”* document described in Section 4.

### Fuel-Switching Measures Must Satisfy the CPUC “Three-Pronged” Test Requirements

Technology shifts from non-electric heating sources require measures to satisfy the CPUC three-prong test. The CPUC three-prong test for fuel-substitution programs requires that the proposed technology not increase source BTU consumption. When calculating the source energy impact, the technology offered by a program must be compared with the most efficient cost-effective technology available that uses the fuel that is to be substituted with electricity. Cost-effectiveness is defined as having a TRC and PAC benefit-cost ratio of 1.0 or greater.

# Additional Supporting Resources

To support the development of VRF measures and this disposition, CPUC staff and the ex ante team undertook a research and development effort involving:

1. Investigation of VRF technologies including performance and energy use characteristics
2. Improvements to the DEER energy modeling software and analysis tools so that all features of VRF systems could be explicitly modeled in the software using all of the DEER modeling assumptions
3. Development of revised measure definitions for VRF measures applicable to a subset of DEER building types

Refer to the following resources for additional information on the development of VRF modeling capabilities, measure definitions and impacts:

*Variable Refrigerant Flow Measure Impacts for Typical Commercial Buildings in California Climates:* This document provides a summary of simulations that were performed to support the development of VRF measures. Representative DEER building prototype models were utilized for four building types with a range of baselines that include both conventional systems and VRF systems. Simulations were performed using the latest version of DOE-2.3, which has expanded capabilities to enable accurate modeling of VRF systems.

*Variable Refrigerant Flow Performance Assessment for Typical Commercial Building in California Climates:* This report presents the results of the CPUC staff and ex ante team VRF investigation. The object of this investigation was to perform simulation-based comparisons between VRF systems and conventional heating and air conditioning systems. Representative DEER building prototype models were developed for four building types with a range of configurations of both conventional systems and VRF systems. Expanded capabilities to allow more accurate modeling of the range of commonly installed VRF systems were developed and implemented into the building energy use simulation software tool used for previous DEER analysis. The models used for the conventional packaged heat pump systems were also improved to ensure comparison with the VRF systems are reasonable and represent current expected comparative performance. An energy use and demand performance comparison analysis was then performed for climates across California.

*Modeling Tool Updates:* The ex ante team completed a revision to the modeling software used for the most recent DEER update (DOE-2.3), based on the results of the investigation performed in the Variable Refrigerant Flow Performance Assessment described above, that includes the following modeling features updates[[2]](#footnote-2):

* Multi-zone VRF systems: This includes multiple indoor fan coils connected via a common refrigerant circulation loop to outdoor refrigeration compressor units. The systems may be specified with or without heat recovery. The refrigerant circulation loop model is a physics based, mass flow model that includes considerations for conductive and friction losses as well as the impact of piping size/length on delivered heating and cooling capacities.
* Dedicated Outdoor Air System: A dedicated outside air system (DOAS) has been added since these systems are often incorporated with VRF and other zonal systems. The DOAS also includes several exhaust, supply and heat recovery options.

1. PAs submit hundreds of workpapers to support their deemed programs. CPUC staff does not review all workpapers, and any workpaper not reviewed by CPUC staff is automatically approved, subject to staff review on a prospective basis. At this time, staff is not aware of any HVAC measures whose savings are due to a change between baseline and measure technology. DEER includes one example of this technology shift, heat pump water heaters, where heat pump water heaters are compared against a baseline of conventional electric resistance storage water heaters. [↑](#footnote-ref-1)
2. For complete information on the updated VRF modeling features, refer to the updated DOE 2.3 documentation within the VRF simulation tool archive posted with the VRF assessment and measure impacts reports. [↑](#footnote-ref-2)