Application of Variable Refrigerant Flow (VRF) Systems in Non-Residential Buildings

CALIFORNIA
TECHNICAL FORUM

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Presentation Overview

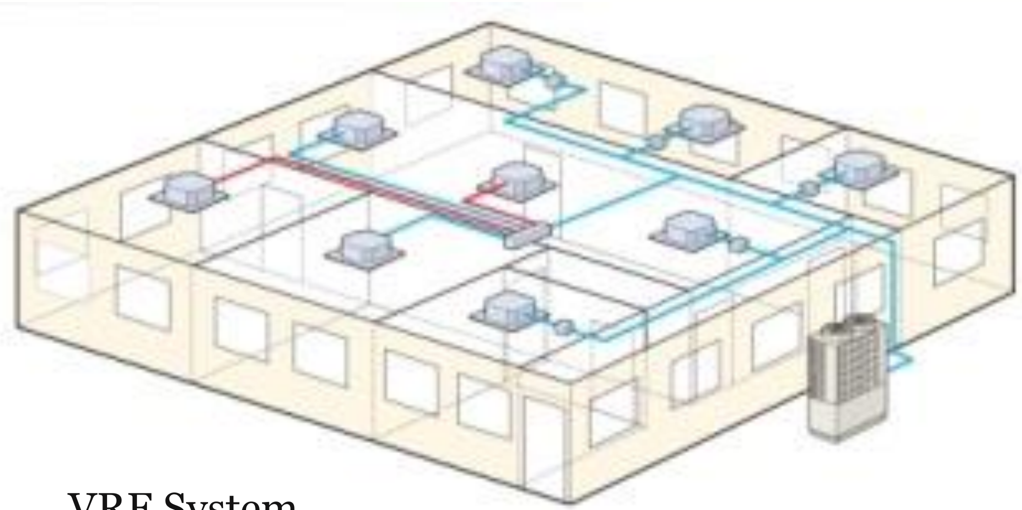
Objective: Seeking TF approval of the Modeling Tool

- Measure Description
- Program Implementation
- Abstract Data and Methods
- Summary of Proposed Parameters
- Appendix
    1. ED Comments
    2. Modeling Tool Evaluation
    3. Baseline Models
    4. Three Prong Test

Measure Description

- ## Overview

Variable Refrigerant Flow systems can replace conventional air conditioning or heat pump systems with more efficient units that provide refrigerant to conditioned zones depending on their need for cooling (or heating) without ductwork. Outside air is provided via a separate system, and so is not dependent on the flowrate of conditioned air. Duct losses are eliminated, though existing ductwork may be reusable to supply outside air.



VRF System
Courtesy of Mitsubishi Online Products Image

Measure Description

Base Cases

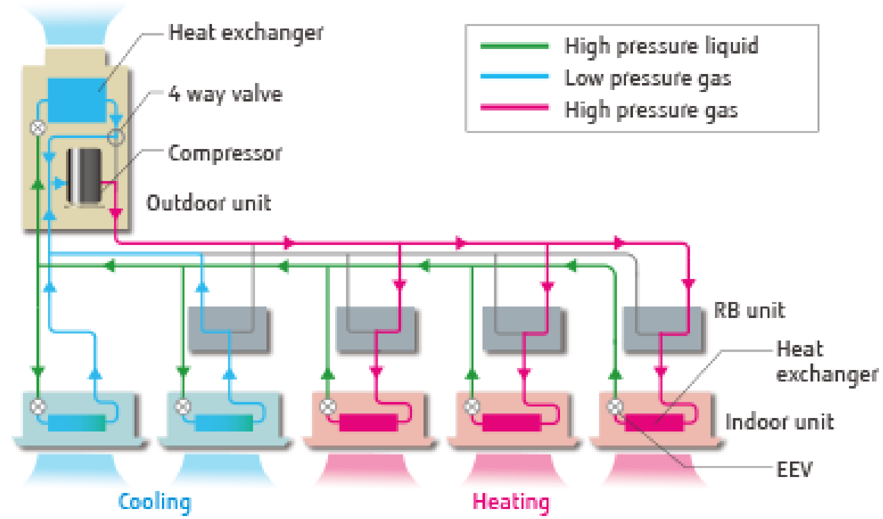
1. Packaged single zone DX w/ gas furnace
2. Packaged single zone heat pump
3. Multi-zone VAV w/ DX cooling and HW reheat
4. Multi-zone VAV w/ DX cooling and electric resistance reheat

Minimum Efficiency Requirements of Title 24 2013, Cooling

	Cooling Capacity	Cooling Efficiency
Packaged Single Zone DX with Gas Furnace	≥ 65,000 Btu/h and < 135,000 Btu/h	11.2 EER, 11.4 IEER
	≥ 135,000 Btu/h and < 240,000 Btu/h	11.0 EER, 11.2 IEER
	≥ 240,000 Btu/h and < 760,000 Btu/h	10.0 EER, 10.1 IEER
Packaged Single Zone Heat Pump	≥ 65,000 Btu/h and < 135,000 Btu/h	11.0 EER, 11.2 IEER
	≥ 135,000 Btu/h and < 240,000 Btu/h	10.6 EER, 10.7 IEER
	≥ 240,000 Btu/h and < 760,000 Btu/h	9.5 EER, 9.6 IEER

Measure Case

1. VRF heat pump
2. VRF heat pump w/ heat recovery



VRF Heat Recovery Diagram
Courtesy of Fujitsu Online Product Image

Program Implementation

- **Units:** per ton AC

- **Measure Application and Delivery Type**
  - Upstream/Midstream (targeted distributor), Deemed (NEW, ROB)

- **Eligibility**
  - Climate Zones: All
  - Building Types: Small Office, Medium Office, Education – Primary, and other building types if the measure is cost effective

- **Target Market**
  - Rebates are offered to distributors for installation in the following scenarios:
    - New construction of non-residential buildings
    - Replacement of existing unitary or split-system AC or HP equipment or VAV systems in non-residential buildings.

- **Market Potential**
  - VRF has a large market potential.
  - According to LG (2011), VRF has only a 3% share of the North American AC market
  - PG&E & SCE's upstream VRF program savings claims were 4.2 MW, 11 GWh during 2013-14 program cycle. It has potential to become High Impact Measure (HIM), with over 1% portfolio savings.

Abstract Data and Methods: Baseline

- Baseline modeling
  - Simulation prototypes from California Building Energy Code Compliance (CBECC)
  - Baseline HVAC system and operations details from DEER
- Baseline methodology
  - Modify CBECC EnergyPlus prototypes to align with DEER
    - NEW: Modify HVAC system and operational parameters in CBECC prototypes to match DEER new building prototypes
    - ROB: From the NEW prototype, further modify LPD and envelope performance characteristics to match DEER 2003 vintage
  - Simulate base case using EnergyPlus, weather from CZ2010
  - Compare resultant base case EUIs to DEER EUIs

Abstract Data and Methods: Baseline

Scenario	System Description	Gross Rated COP, cooling	COP, heating	Fan static press. (in H2O)	M-F Operation	Sat Operation
Small Office 3-Prong Test	Packaged SZ DX w/ gas furnace	4.334	0.8	2.5	8am - 6pm	8am - 6pm
Small Office Gas Heat	Packaged single zone DX w/ gas furnace	3.891	0.8	2.5	8am - 6pm	8am - 6pm
Small Office Electric Heat	Packaged single zone heat pump	3.795	3.666	2.5	8am - 6pm	8am - 6pm
Medium Office Gas Heat	VAV w/ DX cooling and HW reheat	3.876	0.8	2	8am - 6pm	8am - 6pm
Medium Office Electric Heat	VAV w/ DX cooling and electric resistance reheat	3.356	1	2	8am - 6pm	8am - 6pm
Education – Primary Gas Heat	VAV w/ DX cooling and HW reheat	3.891	0.8	2	8am - 7pm	None
Education – Primary Electric Heat	Packaged single zone heat pump	3.795	3.666	1.25	8am - 7pm	None

Abstract Data and Methods: Measure

- Measure modeling
  - Evidence of EnergyPlus VRF module performance
    - Tianzhen Hong, et. al. “A New Model to Simulate Energy Performance of VRF Systems”
    - EPRI-PG&E emerging technology study
  - VRF system performance

Scenario	System Description	Cooling	COP, heating	Fan static press. (in H2O)
All	VRF Heat Pump	11.9 EER / 19.4 IEER	3.95	0.8
All	VRF Heat Pump w/ heat recovery	12.2 EER / 19.7 IEER	3.64	0.8

    - performance curves from Daikin and Mitsubishi

Abstract Data and Methods: Measure

- Measure methodology
  - Simulate using EnergyPlus

    (for details, see Raustad, et al (2013), Final Report: Technical Subtopic 2.1: Modeling Variable Refrigerant Flow Heat Pump and Heat Recovery Equipment in EnergyPlus)

    - VRF heat pump
    - VRF heat pump with heat recovery

Questions for the TF on Measure

- Is the VRF module of EnergyPlus sufficiently accurate?
- If unknown, then what criteria should be used to judge?

Additional Proposed Parameters

- **Measure Costs**
  - VRF incremental cost relative to base case

		SZ RTU	PVAV reheat
	Installed costs ($/ton)	$4,254	$5,714
VRF HP	$4,849	$594	-$865
VRF HP w/ HR	$6,214	$1,959	$500

  - Cost survey of 4 distributors, 2 manufacturers, and one contractor engineer
- **EUL**
  - 15 years
  - Source: DEER 2008, "Air Conditioners / Heat Pumps (split and unitary)," from updated EUL_Summary_10-1-08
- **NTG**
  - 0.89; Source: DEER 2011, "All package and split system AC & HP replacements."

Questions for the TF on these Parameters

- Shall we include other VRF benefits, such as cost savings for reduced duct area?

Summary of Parameters

Parameter	Value (or Range)	Confidence Level (High, Medium, Low)
kWh/year	275 – 588	Low
kW/year	0.07 – 0.24	Low
Therms/year	8.58 – 9.21	Low
EUL	15	Medium
IMC	$547	Medium
NTG	0.85	Medium

Estimated TRC: 1.1 – 2.1

Additional Information Needed

- Describe additional research plans or needs
- Areas of uncertainty that need shoring up
  - **Measure**. Concern that design and installation characteristics necessary to achieve the estimated performance are not likely to be achieved in actual practice
  - **Baseline**. Different system configuration and operation from measure
  - **Fuel Substitution**. Ex-ante consultants do not accept the proposed baseline system for the three-prong test as representing the required most efficient, same fuel, technology.
  - **EnergyPlus**. Concern that additional testing and verification is needed to ensure results for EnergyPlus as used to represent typical expected comparative energy use results for VRF and non-VRF systems are reasonable.

Summary of Questions for the TF

- What are appropriate base case systems?
- How should we deal with the difference between ventilation systems?
- Is the EnergyPlus VRF module sufficiently accurate? If unknown, then what criteria should we use to test?
- Should other VRF benefits, such as reduced duct area, be included in the cost analysis?

Appendix

1. ED Comments
2. Modeling Tool Evaluation
3. Baseline Models
4. Three Prong Test

ED Comments

Comments dated 5/13/2015 from CPUC ED consultant on VRF workpaper development:

1. Fuel substitution

- "most efficient same-fuel substitute technologies available" in their baseline case.

2. Modeling tool

"Any software used for the energy modeling should be investigated for":

- "theoretical foundation and reasonableness to adequately represent both the agreed upon baseline and measure technologies;"
- "ability to incorporate all applicable DEER assumptions currently used in the DEER analysis tools

ED Comments

Comments dated 5/13/2015 from CPUC ED consultant on VRF workpaper development:

3. Baseline

- “the baseline needed to be an industry standard practice baseline providing a similar level of service as the measure technology.”
- “thus different approaches to conditioned space ventilation and airflow or temperature controls were not acceptable.”
- “the majority of savings are derived from the reconfiguration and change in control sequence of the air distribution system that can be included into the “most efficient same-fuel substitute technologies available” required in the baseline system for the test.”
- “Ex-ante consultants do not accept the proposed baseline system for the three-prong test as representing the required most efficient, same fuel, technology. As noted above, the majority of savings for the proposed VRF measure definition comes from system features more appropriately included in both the baseline and measure system definitions.”

Modeling Tool Evaluation

Comments dated 5/13/2015 from CPUC ED consultant on VRF workpaper development:

Modeling tool

Validate EnergyPlus Using DOE 2.2: However, it is more important that the savings values be reasonably close to DEER values. For example, workpaper authors should be able to demonstrate that using EnergyPlus produces similar savings results as DEER for common deemed measures such as an 18 SEER packaged AC unit.

PG&E Response:

EnergyPlus should not have to be validated against DOE 2.2. DOE 2.2 is not the standard by which the industry, including ASHRAE, has agreed to validate modeling tools. Plus, staff requests a research study prior to WP approval, which violates "best available data" standard.

Modeling Tool Evaluation

PG&E provided a research document on the evaluation of EnergyPlus modeling VRF systems to ED on Sep, 2014

Calculating Part Load Performance

Raustad said in his paper (2013) that the VRF module is able to use curve coefficients and rated system performance to determine the part load performance of the VRF system accurately with respect to the manufacturers data.

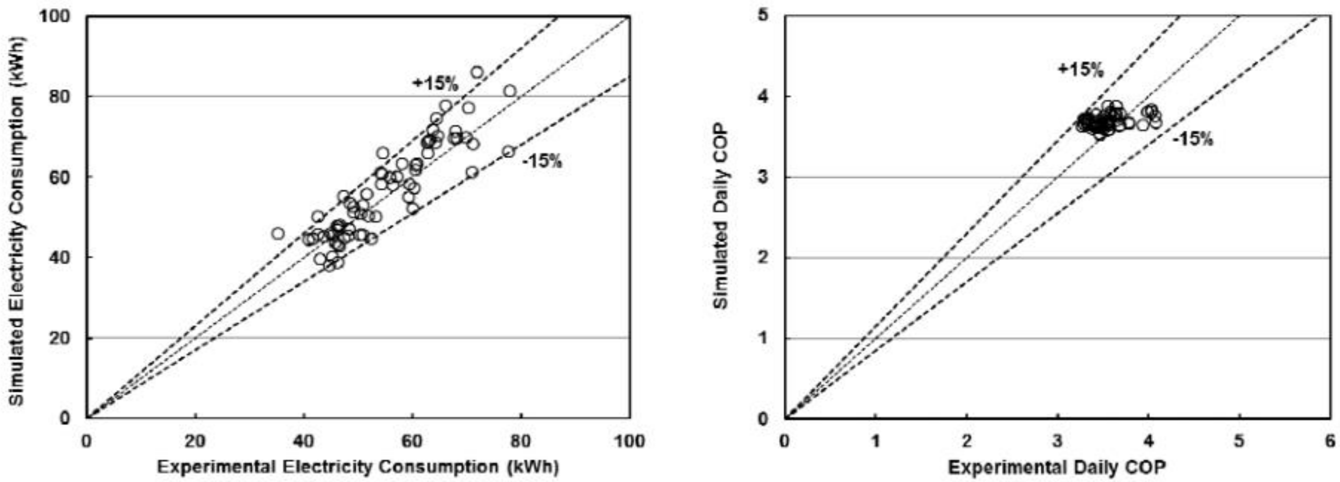
“The heating capacity is predicted within error margins -0.94% and 0.98%. The heating electric power is predicted within error margins of -3.31% and 3.97%... The cooling capacity is predicted within error of margins of -1.34% and 1.10%. The cooling electric power is predicted within error margins of -0.85% and 0.87%.”

Modeling Tool Evaluation

VRF Field Tests - University of Maryland Field Tests

Yunho Hwang at the University of Maryland conducted a series of field tests comparing the actual performance of a VRF Heat Pump system in their lab/office space to simulations carried out in EnergyPlus.

"The root-mean-square deviations of weekly and monthly electricity power consumptions for the total simulation period between the simulated and measured values are 11.12 kWh and 37.58 kWh, respectively. The averages of the absolute values of the weekly and monthly relative errors for the total simulation period are 2.40% and 2.22%, respectively." (Hwang)



(a) Daily electricity power consumption

(b) Daily COP

Modeling Tool Evaluation

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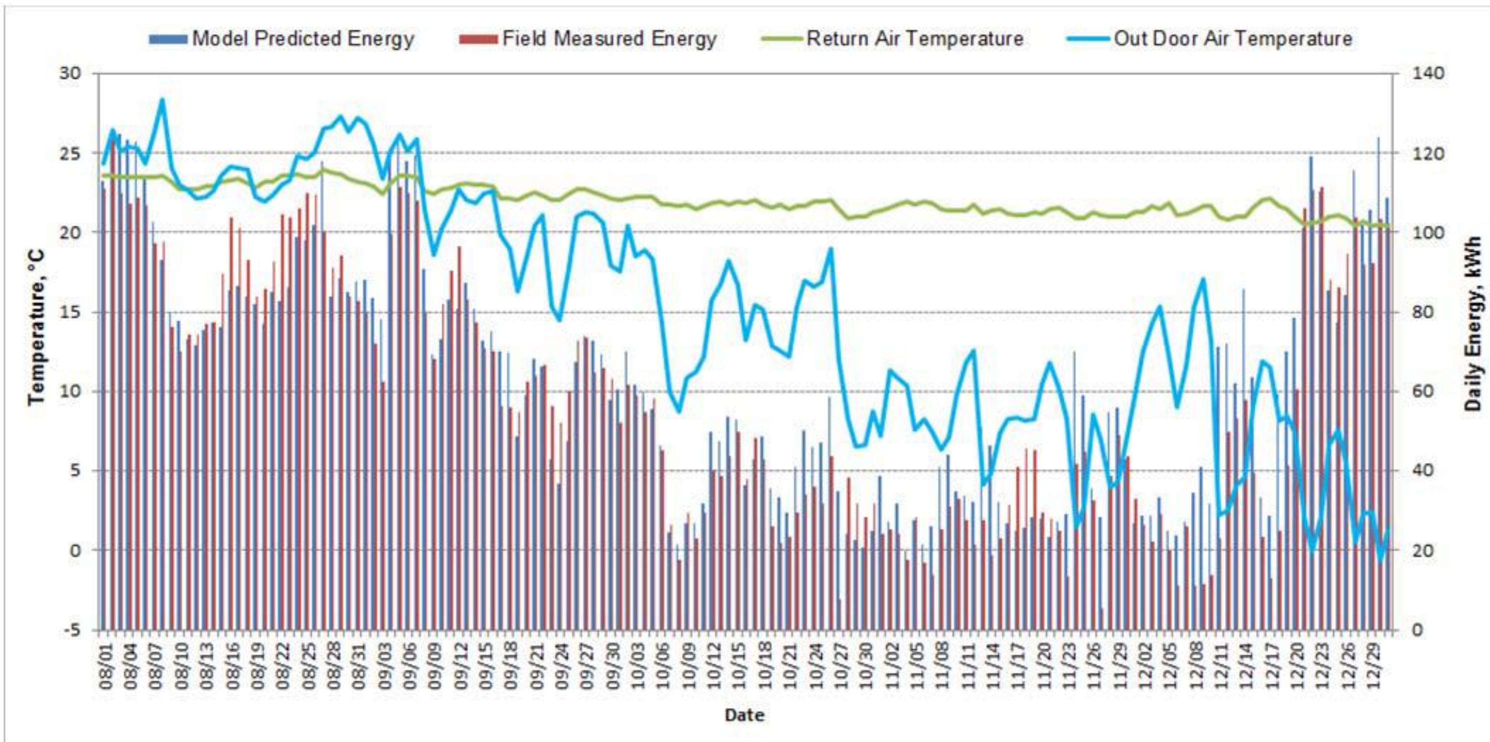
VRF Field Tests - EPRI Field Site – Knoxville TN

A 72 kBtu/h Mitsubishi VRF Heat Recovery system was installed in a lab and warehouse space in an EPRI building in Knoxville, TN. The data shows that the system performance is closely replicated by the EnergyPlus VRF module

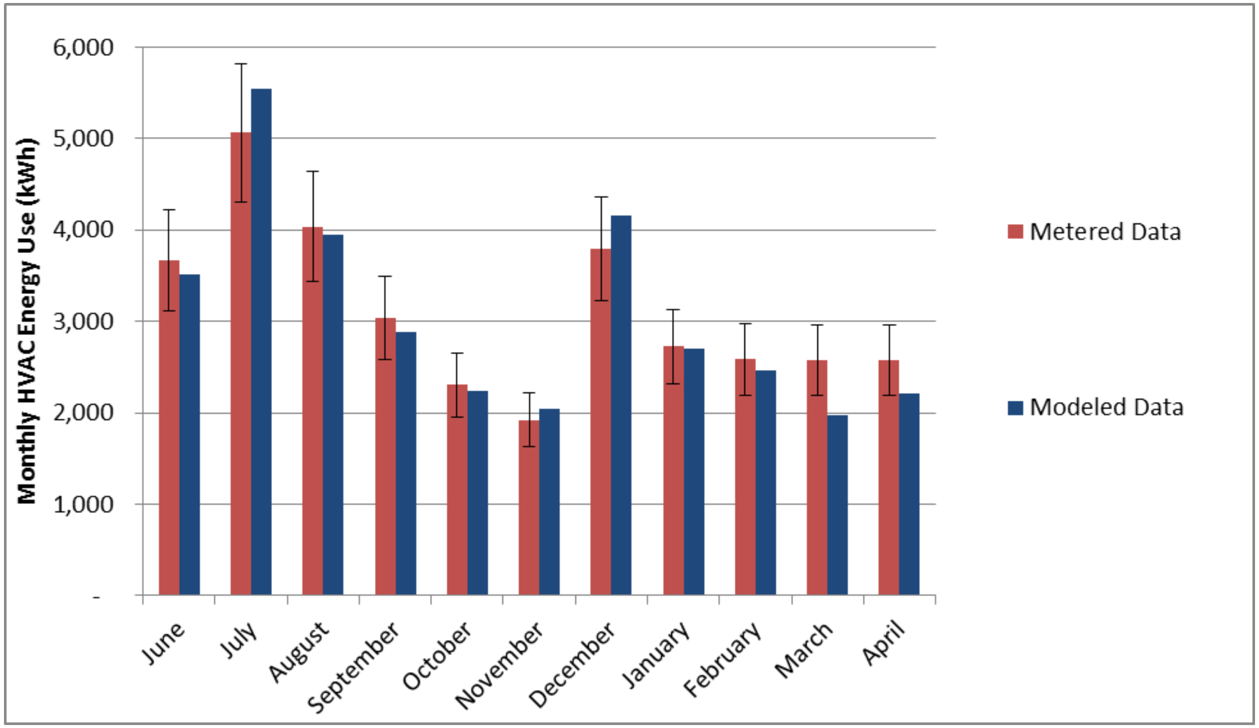


Modeling Tool Evaluation

VRF Field Tests - PG&E Field Site Auburn, CA

The field test was performed at an 8,000 square foot PG&E office building in Auburn, California.

Overall, the EnergyPlus model accurately predicts system performance, albeit with some deviation in March and April.



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Simulation Tool Comparisons

Table 1: Ability of common energy modelling tools to simulate VRF performance.

Simulation Tool	VRF Modelling Capabilities
EnergyPlus	Built-in VRF Heat Pump and Heat Recovery system options Individually defined indoor and outdoor units Lab and field data corroborate simulated performance VRF and heat balance algorithms are published Suction and condensing temperature not currently included as input variables
EnergyPro	Built-in VRF Heat Pump and Heat Recovery system options Lump indoor units and input blended unit performance No published lab or field data
eQUEST 3.64/3.65	No VRF module. Several workarounds proposed by VRF manufacturers and members of the building simulation community.
eQUEST 3.7 (forthcoming release)	VRF Heat Pump module, with no Heat Recovery options Individually defined indoor and outdoor units Will be able to accommodate varying suction and condensing temperatures
Trace700	Built-in VRF Heat Pump and Heat Recovery system options Individually defined indoor and outdoor units No published lab or field data Proprietary algorithms
IESVE	No VRF module. Two workarounds proposed by IES development team

Modeling Tool Evaluation

Simulation Tool Comparisons

There are strengths and limitations with each of the tools.

EnergyPlus and eQUEST 3.7 are the top of the list for use in the VRF work paper update.

Using eQUEST 3.7

- greatly simplify the baseline model generation because DEER models could be used.
- it does not have a Heat Recovery option and the majority of commercial VRF installations are Heat Recovery systems.
- eQUEST is only able to model one HVAC system per zone. This would pose a limitation in the VRF work paper modelling effort because larger VRF installations are commonly installed with a dedicated outdoor air system (DOAS) operating in parallel to the VRF system.
- One final limitation of using eQUEST 3.7 is that there do not appear to be any case studies yet comparing field performance of VRF systems to eQUEST 3.7 model results.

Baseline Models

Reasons for using CBECC EnergyPlus building prototypes:

- Prototypical models available that are minimally T24 compliant; will modify as needed
- Unlike eQuest, EnergyPlus can model Heat Recovery VRF systems and multiple HVAC systems per thermal zone. Therefore, EnergyPlus is able to model all of the common VRF installations in commercial buildings.
- To create DEER prototype in EnergyPlus is technically challenging and costly.*
    - *Joe Huang led **a team of 7 and spent over 1 year** to translate Title 24 ACM files from DOE2.1E to EnergyPlus in 2007.*
    - *Joe said, "it would require obtaining a **license** to work on the DOE-2.2 source code, as well as the **technical support or collaboration of its developer** (Jeff Hirsch)."*
    - *Joe has developed DEER translations from DOE2.2 to energy plus on 3 building types (including large office), two vintages, and three climate zones. It took him **more than a half year** to do it.*
    - *In the email to Sherry Hu's inquiry on the translation of DEER prototype to EnergyPlus on 7/20/2715, Joe said,*

*"The conversion is not a straightforward process. There were **some measures that could not be translated** either due to different capabilities of the two programs, or the models being too different to get correspondence.*

*Furthermore, I found the **results sometimes to be quite different**, in particular I found heating energies to be 10 to 20 times smaller with EnergyPlus than with DOE-2.2. What I'm trying to say is that there will be a substantial learning curve before we can say with confidence that the translated EnergyPlus models are equivalent in intent and performance to the DOE-2.2 DEER models."*

**Reference: Joe Huang, Comparison of simulation results for three DEER building types in three southern California climates using DOE-2.2 and EnergyPlus,*

Baseline Models

Reasons for using CBECC EnergyPlus building prototypes:

- **We believe using CBECC EnergyPlus prototypes are reasonable since they are consistent with T24 Codes & Standards and ASHRAE Standards. They are supported by the DOE and national building industry experts.**

"As part of DOE's support of **ANSI/ASHRAE/IES Standard 90.1**, researchers at **Pacific Northwest National Laboratory** (PNNL) apply a suite of prototype buildings covering 80% of the commercial building floor area in the United States for new construction, including both commercial buildings and mid- to high-rise residential buildings, and across all U.S. climate zones. These prototype buildings–derived from **DOE's Commercial Reference Building Models**–**cover** all Reference Building types (with the exception of supermarkets), and also an additional prototype representing high-rise apartment buildings. As Standard 90.1 evolves, PNNL makes modifications to the commercial prototype building models, with **extensive input from ASHRAE 90.1** Standing Standards Project Committee members and other **building industry experts**."

https://www.energycodes.gov/commercial-prototype-building-models

The U.S. Department of Energy (DOE), in conjunction with **three of its national laboratories**, developed commercial reference buildings, formerly known as commercial building benchmark models. These reference buildings play a critical role in the program's energy modeling software research by providing complete descriptions for whole building energy analysis using EnergyPlus simulation software.

There are 16 building types that **represent approximately 70% of the commercial buildings in the U.S.,** according to the report published by the National Renewable Energy Laboratory titled *U.S. Department of Energy Commercial Reference Building Models of the National Building Stock*. These modules provide a consistent baseline of comparison and improve the value of computer energy simulations using software such as EnergyPlus.

Experts consulted during the development process:

- *Tianzheng Hong, LBNL; Ryohei Hinokuma, Daikin; Richard Raustad, Florida Solar Energy Center; Joe Huang, Whit Box Technologies; Bing Liu, PNNL; Paul Reeve, JJL Consulting*

Baseline Models

- DEER Prototypes
  - Documented in 2004-2005 DEER Update Study
  - Based on the references published during 1994-2002
  - All the reference links in the DEER study currently do not work
  - Prototypes were updated several times by Ex Ante consultants. But detailed reasons for updates, relevant reference and documents are hard to find.

Reference:

- *DEEResource.com website*
- *Final Report on Technology Energy Savings, Volume II: Building Prototypes*, Prepared for The California Conservation Inventory Group by Neos Corporation, 1994 (DEER 1994);
- *CaNCCalc Building Energy Efficiency Measure Analysis Software*, (NCC) developed by James J. Hirsch & Associates for the Savings by Design new construction energy efficiency program, offered by California's Investor Owned Utilities (IOU) as authorized by the California Public Utilities Commission (CPUC);
- *High Performance Commercial Building Systems, Element 6, Project 2.1, Relocatable Classroom DOE-2 Analysis Report*, Prepared by Davis Energy Group, Inc. for the California Energy Commission, Public Interest Energy Research Program, 2002 (HPCBS.)

Baseline Models

DEER and CBECC Models

- Small offices

- Similar HVAC - package single zone DX with gas furnace and Heat Pump
- Similar geometries
- Different floor numbers and area. DEER model is a two story building with roughly double the building area.

- Primary Schools

- Similar HVAC
- Different geometries. CBECC uses a “U” shape. DEER uses a rectangular, 2 building geometry.

Medium Offices

- DEER only has small and large office type.
- Similar HVAC, packaged VAV system.
- Similar floor plan but CBECC has 3 floors, where DEER large office has 10 floors.
- CBECC medium office type has 53,628 ft^2, which we is representative of a common building type served by the program.

Baseline Models

Modifications to CBECC Models

- The intention is to make the CBECC models perform similar to a DEER models
- For new constructions, CBECC models are updated DEER HVAC input parameters and schedules.
- HVAC EUI will be used as a comparative metric. If the HVAC **EUI** is with 10% of the DEER model, the modified CBECC model will be considered suitable for use in the VRF work paper.

Baseline Models

		Small Office				Medium/Large Office					
		Gas Heat		Electric Heat		Gas Heat		Electric Heat		Gas Heat	
Parameters shown for comparison purposes only	**Basics**	CBECC	DEER	CBECC	DEER	CBECC	DEER	CBECC	DEER	CBECC	DEER
	Floor Area (SF)	5,500	10,002	5,500	10,002	53,628	174,960	53,628	174,960	24,413	
	Number of Floors (#)	1	2	1	2	3	10	3	10	1	1
	Geometry Description	Rectangle	Rectangle	Rectangle	Rectangle	Rectangle	Rectangles	Rectangle	Rectangles	U	Two Rectangula
	Roof Type	Attic	Flat	Attic	Flat	Flat	Flat	Flat	Flat	Flat	Flat
	HVAC System										
	Heating Type	Gas Furnace	Gas Furnace	Heat Pump	Heat Pump	Boiler	Boiler	Elec in TUs	Elec in TUs	Boiler	Furnace
	Cooling Type	DX Cooling	DX Cooling	Heat Pump	Heat Pump	Dx Cooling	Dx Cooling	Dx Cooling	Dx Cooling	Dx Cooling	Dx Cooling
	Distribution and Terminal Units	Single zone, constant air volume air distribution, one unit per occupied thermal zone	Single zone, two speed fan air distribution, one unit per occupied thermal zone	Single zone, constant air volume air distribution, one unit per occupied thermal zone	Single zone, two speed fan air distribution, one unit per occupied thermal zone	Dx coil in AHU and VAV terminal box with damper and hot water reheat coil	PVAV with Dx coil in AHU. No AHU heating coil, but with hot water re-heat TUs.	Dx coil in AHU and VAV terminal box with damper and electric reheat coil. Maybe Heat pump also in AHU	PVAV with Dx coil in AHU. No AHU heating coil, but electric resistence TUs	Dx coil in AHU and VAV terminal box with damper and hot water reheat coil	Single zone, twc fan air distribut unit per occupie thermal zone
	Zoning Patern	Core and Shell	Core and Shell	Core and Shell	Core and Shell	Core and Shell	Core and Shell	Core and Shell	Core and Shell	Per Space Type	Per Space Type
	Number of Zones (#)	5	10	5	10	15	50	15	50	12	14
	Number HVAC Systems (#)	5	10	5	10	3	10	3	10	1	14
	Heating Sizing	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcc
	Cooling Sizing	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcode	Autosize/Hardcc
Parameters to be taken from directly from DEER	Heating Efficiency (COP)	0.8	0.8	NA	3.666	0.8	0.8	NA	1	0.8	0.8
	Cooling Efficiency (Gross Rated COP)	3.844	3.891	NA	3.795	3.421	3.876	NA	3.356	3.302	3.891
	Supply Air Temperature (F)	95/55	100/55	NA	90/55	95/55	95/55	NA	95/55	95/55	100/55
	Supply Fan Efficiency (%)	0.4275 or 0.4325	NA	NA	0.55	0.5766	0.54	NA	0.54	0.5834	NA
	Supply Fan Motor Efficiency (%)	0.865 or 0.855	NA	NA	NA	0.93	NA	NA	NA	0.94	NA
	Supply Fan Pressure Drop ("H2O)	2.5	NA	NA	1.25	4	2	NA	2	4	NA
	Supply Fan (kW/flow)	NA	0.000298	NA	1	NA	NA	NA	NA		0.000298
	Fan Control	Single Speed	Two Speed	NA	Two Speed	VFD	VFD	NA	VFD	Single Speed	Two Speed
	Drybulb High Limit (F)	No Econo	70	NA	70	Differential DB	70	NA	70	Differential DB	70
	Economizer Lockout	No Econo	No	NA	No	No	No	NA	No	No	No
	Fan Schedule	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs
	Cooling Schedule	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs
	Heating Schedule	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs	See Sched Tabs

3 Prong Test

1. The program/measure/project must not increase source-BTU consumption. Proponents of fuel substitution programs should calculate the source-BTU impacts using the current CEC-established heat rate.

2. The program/measure/project must have TRC and PAC benefit-cost ratio of 1.0 or greater.

3. The program/measure/project must not adversely impact the environment.

3 Prong Test - Model Runs for Small Office Buildings

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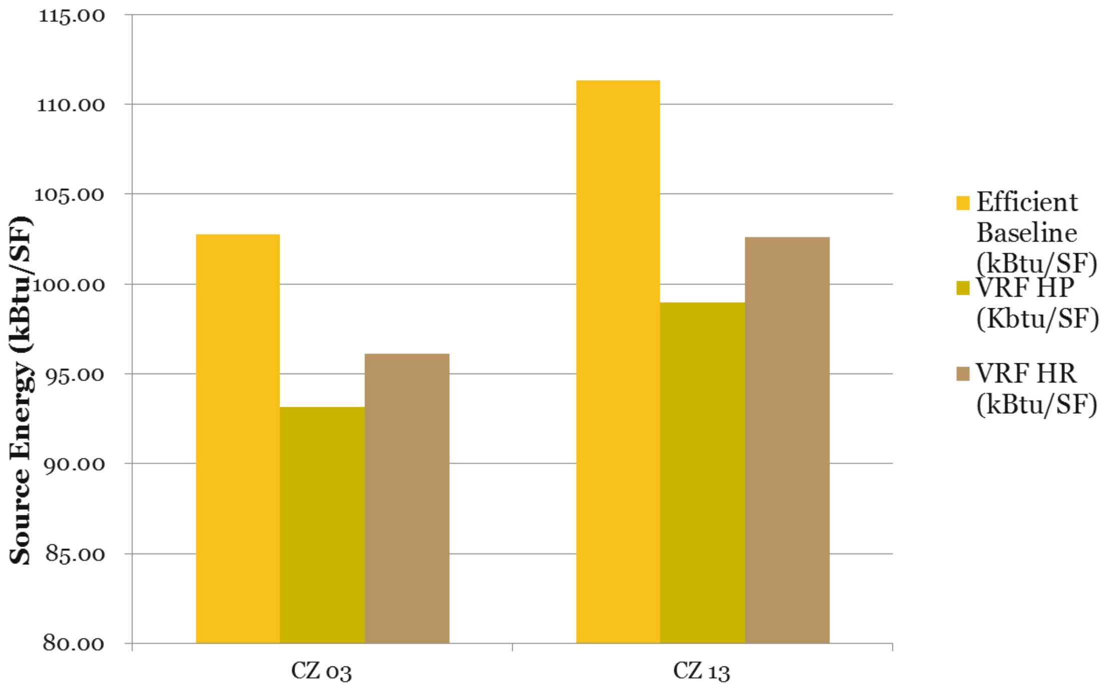
Efficient Baseline is used

Item	Baseline	Efficient Baseline	VRF Heat Pump	VRF Heat Recovery
HVAC System	5 x packaged single zone units with air cooled DX cooling and gas furnace	5 x packaged single zone units with air cooled DX cooling and gas furnace	1 x VRF outdoor unit connected to 5 x ducted VRF indoor units that cannot perform simultaneous heating and cooling	1 x VRF outdoor unit connected to 5 x ducted VRF indoor units that can perform simultaneous heating and cooling
Outdoor Air Delivery	Fixed OA damper at unit	OA damper with economizer at unit	Ducted directly to indoor units	Ducted directly to indoor units
Economizer	Not present	Integrated differential drybulb economizer on all units	Not present	Not present
Heating Efficiency (COP)	0.8	0.8	3.95	3.64
Cooling Efficiency (COP)	SEER 13	SEER 15	11.9 EER / 19.4 IEER	12.2 EER / 19.7 IEER
Fan Motor Efficiency	0.86	0.86	0.95	0.95
Fan Static Pressure ("H2O)	2.5	2.5	0.8	0.8
Performance Curves	Curves from DOE air cooled DX equipment	Curves from DOE air cooled DX equipment	Daikin RXYQ120TPTJU custom Heat Pump curves	Mitsubishi PURY-P96YKMU-A custom Heat Recovery curves

1st Prong – Source Energy



The VRF measures decrease source-BTU consumption.

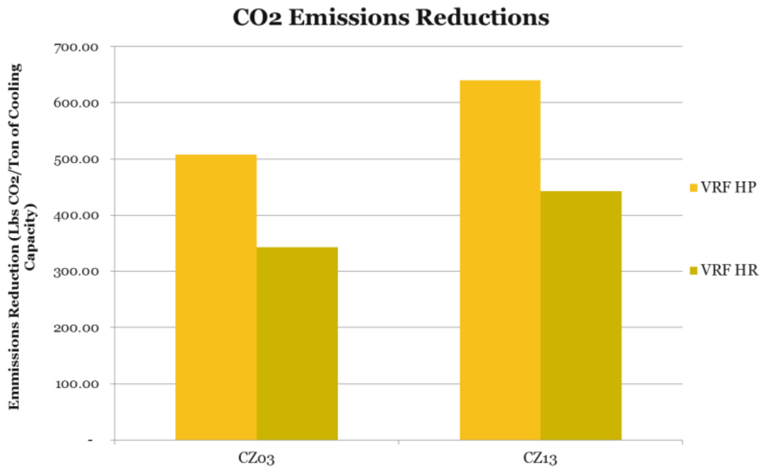
2nd Prong – TRC and PAC

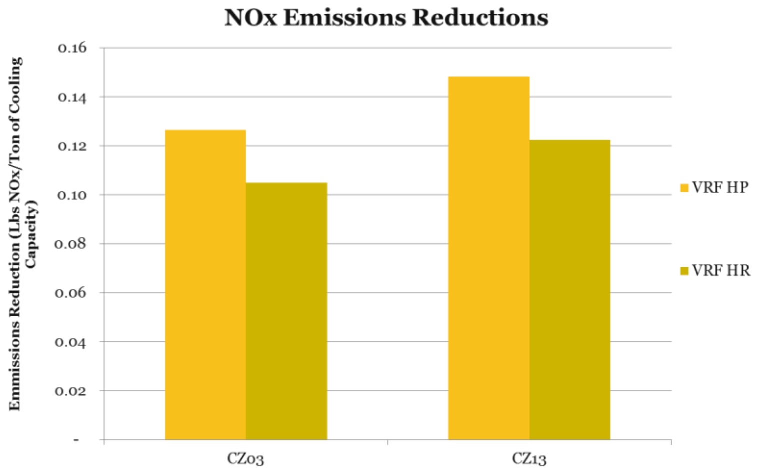
	TRC	PAC
CZ03 – HP	2.64	4.90
CZ03 – HR	0.72	2.64
CZ13 – HP	3.39	6.29
CZ13 – HR	0.95	3.49
Average	**1.93**	**4.33**

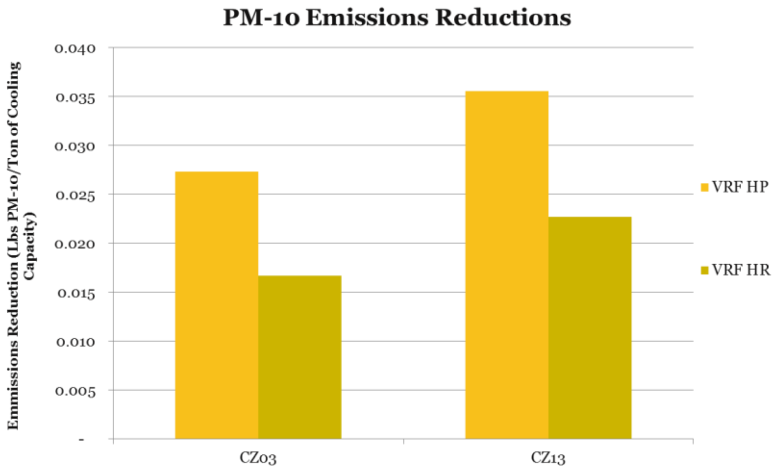
The average TRC is 1.93, which passes TRC test. Some Heat Recovery systems are currently not passing TRC test.

PG&E's VRF program will be designed so that overall program passes TRC and PAC testing.

3rd Prong – Environmental Impact







The VRF measures positively impact the environment.

Thank you!

Contact Sherry Hu, s1hu@pge.com