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A Pathway to All-Electric Non-Res Baselines Now

If the CEC is to lead California towards truly carbon free non-residential buildings it needs to evaluate multiple low energy, cost effective solutions and how they might be applied at scale. The solutions to get there are widely available on the market and are being built across CA today.

We urge staff to establish an all-electric baseline for all non-residential buildings for Title 24 2022. Please see the attached letter for feedback on how this may be possible.

Additional submitted attachment is included below.

Red Car Analytics Comments - Proposed 2022 Energy Code on Electrification

Date: 10/20/2020

California Energy Commission
Docket Office, MS-4
Re: Docket No. 19-BSTD-03
1516 Ninth Street Sacramento, CA 95814
docket@energy.ca.gov

Subject: Staff Workshop: 2022 Energy Code Pre-Rulemaking–Proposed 2022 Energy Code on Electrification

Dear Commissioners:

We urge staff to establish an all-electric baseline for all non-residential buildings for Title 24 2022. Please see the attached letter for feedback on how this may be possible.

All Electric Non-Residential Baseline for Title 24, 2022

Red Car Analytics recommends the CEC adopt an all-electric baseline for the Title 24 2022 cycle for all non-residential building types. Based on standard all-electric systems used in buildings today and the proposed TDV 2022 draft metrics posted with CBECC-Com 2022.0.1, all-electric building systems can be found to be energy cost equivalent to their current natural gas counterparts. The information on non-residential buildings presented in the workshop on October 7th, 2020 showed mixed results with small buildings demonstrating all-electric solutions and larger buildings still lacking an all-electric path. While the work was presented as preliminary findings, we ask that more detail be provided to allow for input and collaboration with industry leaders who are familiar with how all-electric systems are configured and operate. Key information requested includes:

1. Posted files of the TDV metrics used.
2. Input assumptions for fan energy.
3. Input assumptions for primary cooling and heating equipment.
4. A short description of the alternate system configuration being utilized with any relevant information which would otherwise not be apparent from the name of a system only.

Philosophy of Representing Code Options with Energy Models

It is imperative when communicating energy efficiency opportunities to the public to provide enough context and definition for each energy end-use, if these changes or savings are substantial or subtle, and what is driving these changes or savings. The majority or public audiences are not familiar with building science and relationships between building architecture, construction, and use, and how those factors can impact the results of an energy efficiency enhancement. In the instance where common alternate building forms, construction or use patterns would significantly change the outcome of an energy efficiency measure, it is the responsibility of building energy modelers to represent these common scenarios or at the least indicate based on their professional experience if the change in efficiency would follow similar trends. We recognize time constraints and resources make this challenging and believe that through efforts to educate the audience the final energy model and analysis will ultimately be improved through robust feedback and opportunities for comments.

Recommended All-Electric Non-Residential Baseline

If the CEC is to lead California towards truly carbon free non-residential buildings it needs to evaluate multiple low energy, cost effective solutions and how they might be applied at scale. The solutions to get there are widely available on the market and are being built across CA today. They may, however, require an expanded understanding of what HVAC systems are being used and what key efficiency parameters result in an energy efficiency building.

Based on knowledge of building science, new construction trends, advanced HVAC systems, and common HVAC system configurations and controls, the CBECC-Com prototype models were enhanced by Red Car Analytics of several All-Electric HVAC systems for the same prototypes and found to show different results than those shared in the 10/7/20 workshop, indicating it is potentially achievable for most buildings in the 2022 cycle to have an All-Electric baseline. The following recommendations are meant to demonstrate what is possible within the confines of TDV cost effectiveness metrics proposed for 2022, the CASE reports presented for 2022, and EnergyPlus energy modeling software.

These are recommended for refinement and are presented as examples for input and discussion. Energy model files can be made available to the CEC for review.

In many buildings and climate zones the simulation examples found the same level of life cycle operational cost for the consumer as a natural gas baseline using the TDV 2022 metrics.

Recommended Non-Residential System Mapping

The following table provides a summary of the system recommendations by three categories of building size.

Building Typology	Previous Gas Baseline System	Recommended All-Electric System
Small Non-Res	SZVAV or SZCAV	SZVAV Heat Pump or HRV-DOAS with Mini-Splits
Medium Non-Res	PVAV with Boiler	HRV-DOAS with VRF
Large Non-Res	VAVR with Boiler	VAVR with heat pump boiler (air source)

System	Description
SZVAV Heat Pump	Single zone variable air volume heat pumps with two-speed fans.
HRV-DOAS with Mini-Splits	A dedicated outdoor air unit with a heat recovery ventilation core and filter only providing neutral air. The outdoor air is capable of 1.5x ventilation rates at a minimum and provides demand control ventilation to zones where active controls are required based on Title 24. Zones are conditioned with dedicated mini-split heat pump units.
HRV-DOAS with VRF	A dedicated outdoor air unit with a heat recovery ventilation core and filter only providing neutral air. The outdoor air is capable of 1.5x ventilation rates at a minimum and provides demand control ventilation to zones where active controls are required based on Title 24. Zones are conditioned with variable refrigerant flow fan coils from an air sourced outdoor unit.
VAVR with heat pump boiler (air source)	Variable air volume with hydronic reheat and airside economizing. Hot water is provided by air sourced heat pumps. Cold water is provided by water cooled chillers and cooling towers.

Prototype Building	Simulation Software	Baseline System Configuration	Proposed System Configuration	Percent TDV Savings
Office Small	EnergyPlus 9.0	SZCAV and CASE 2022 Fan Power Method	SZVAVHP and HRV-DOAS and CASE 2022 Fan Power Method	+17%
Office Medium	EnergyPlus 9.0	PVAV, CASE 2022 Fan Power Credit and DCV modulating airflow	HRV-DOAS with VRF, CASE 2022 Fan Power Credit and DCV modulating airflow	+4%
Office Large	EnergyPlus 9.4	VAVR with boilers	VAVR with air source heat pump for heating	+1%
Primary School	EnergyPlus 9.0	SZVAV, CASE 2022 Fan Power Method and economizers	HRV-DOAS with VRF, CASE 2022 Fan Power Credit and DCV modulating airflow	+13%
Retail Stand-Alone	EnergyPlus 9.0	SZVAV, CASE 2022 Fan Power Method and economizers	HRV-DOAS with VRF, CASE 2022 Fan Power Credit and DCV modulating airflow	0%

Detailed Results

The following charts represent the percent energy difference using the TDV 2022 metric for all-electric system configurations verses a natural gas standard configurations. A positive number indicates the all-electric system is more energy efficient and a negative number means less energy efficient.

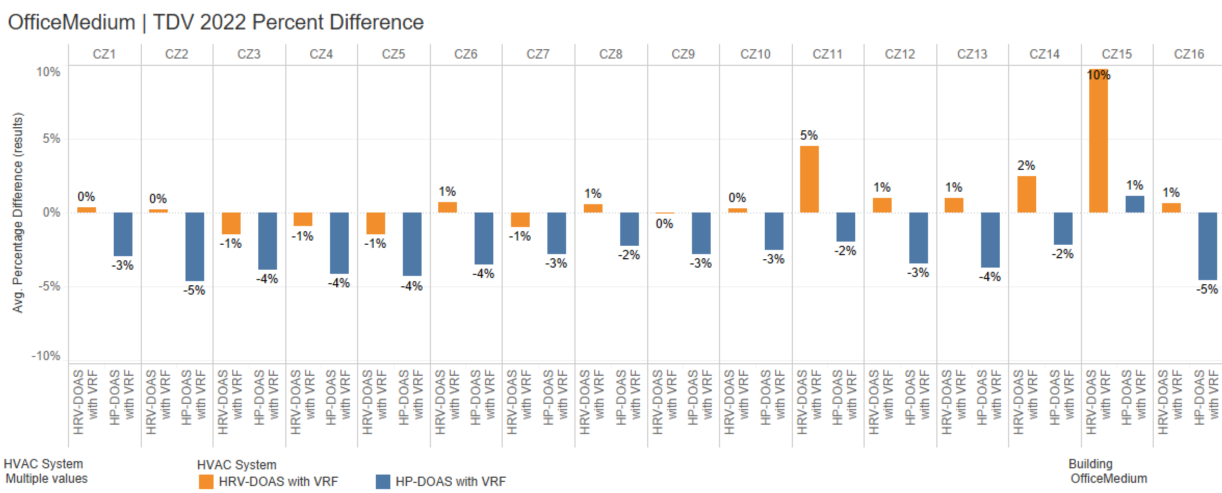


Figure 1: Medium Office percent change in TDV energy results for HRV-DOAS with VRF and HP-DOAS with VRF.

Figure 1 shows heat pump dedicated outdoor air system (HP-DOAS) results in higher TDV energy consumption while the heat recovery ventilator DOAS (HRV-DOAS) indicates an energy savings in some climates and -1% in mild climates, compared to a natural gas baseline system. The baseline is a packaged vav system with hot water reheat from a gas boiler with updated fan power allowances and including the same ventilation controls in spaces requiring demand control ventilation. This initial configuration suggests that a HRV-DOAS system is a viable option for developing an all-electric baseline for medium sized non-residential buildings.

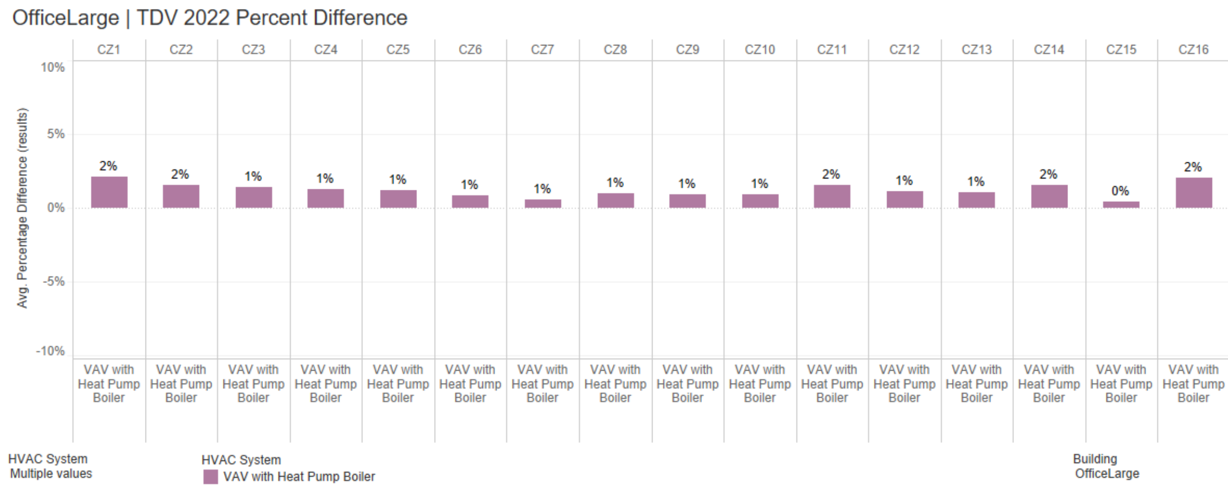


Figure 2: Large Office percent change in TDV energy results for VAV with heat pump boilers.

In Figure 2 the large office building was converted to an EnergyPlus 9.4 file to allow for the inclusion of a heat pump object to replace the natural gas boilers. Based on an assumed efficiency of 3.5 COP for the heat pump the results show a 0% to 2% overall TDV energy reduction from a VAV system with natural gas boilers (0.80 COP). Note the VAV system was also updated to EnergyPlus 9.4 to make all other parameters the same.

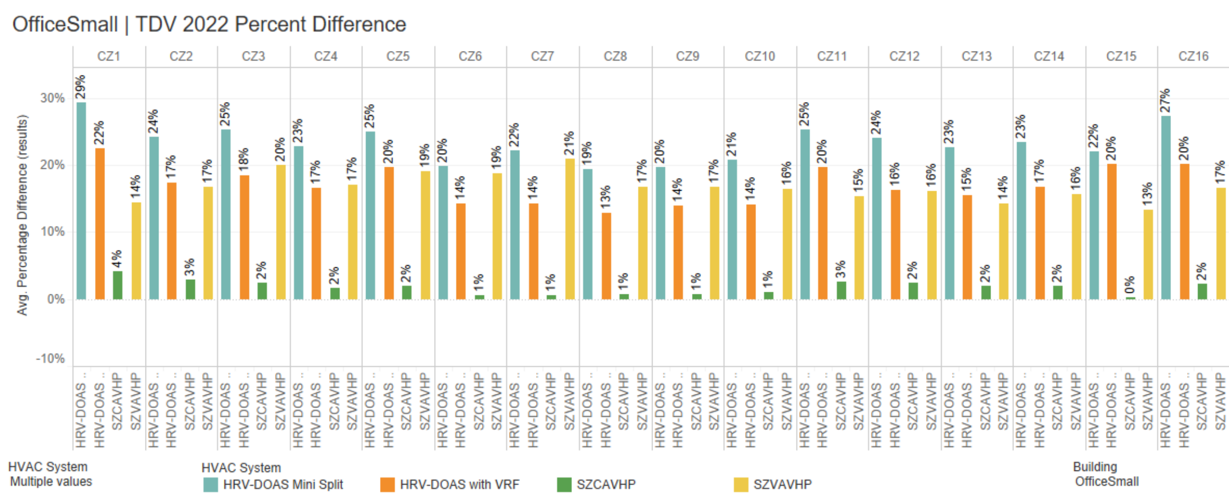


Figure 3: Small Office percent change in TDV energy results for two DOAS configurations and two packaged heat pump configurations.

Figure 3 shows the small office building saves energy compared to a baseline constant volume packaged unit with a furnace for all configurations of all-electric system examined.

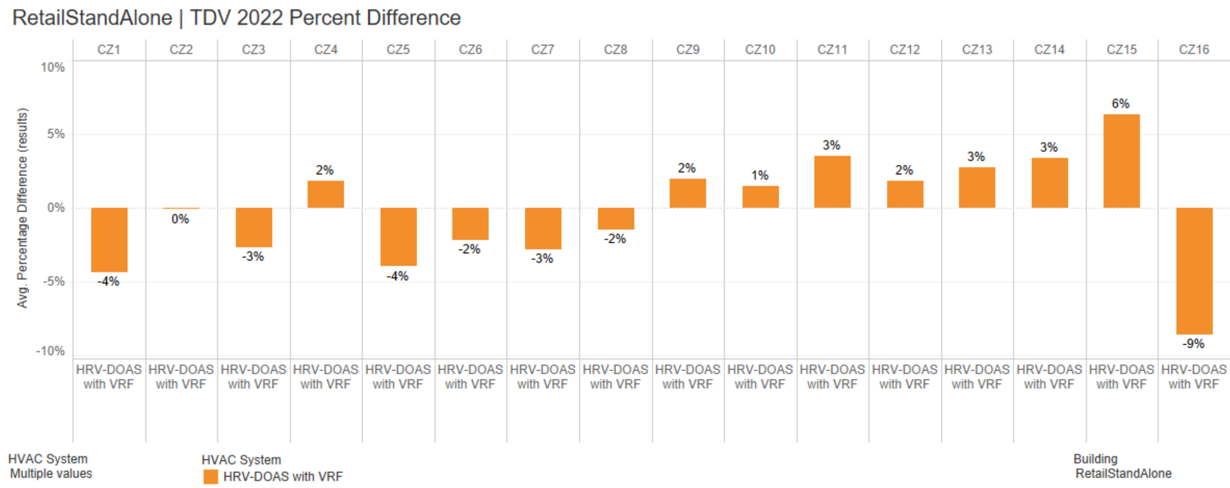


Figure 4: Retail percent change in TDV energy for an HRV-DOAS with VRF system.

Figure 4 shows the retail stand-alone prototype nearly breaks even in all climate zones with an all-electric system configuration (HRV-DOAS with VRF) compared with a baseline of SZCAV and SZVAV baseline units with furnaces. This building type should be evaluated with other all-electric systems such as mini-splits or with SZVAV heat pump units to identify more energy-savings all-electric system options.

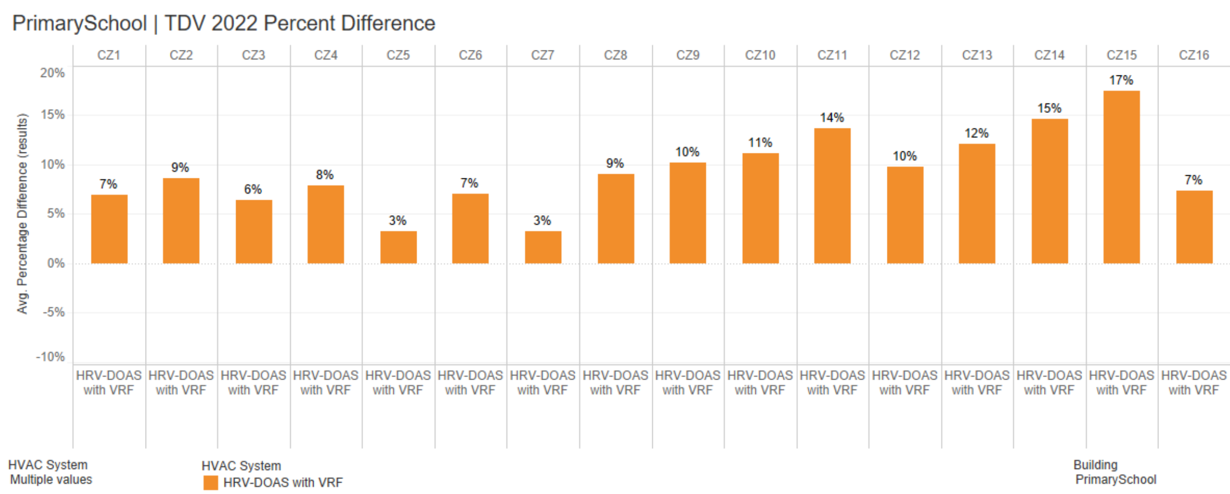


Figure 5: Primary school percent change in TDV energy for an HRV-DOAS with VRF system.

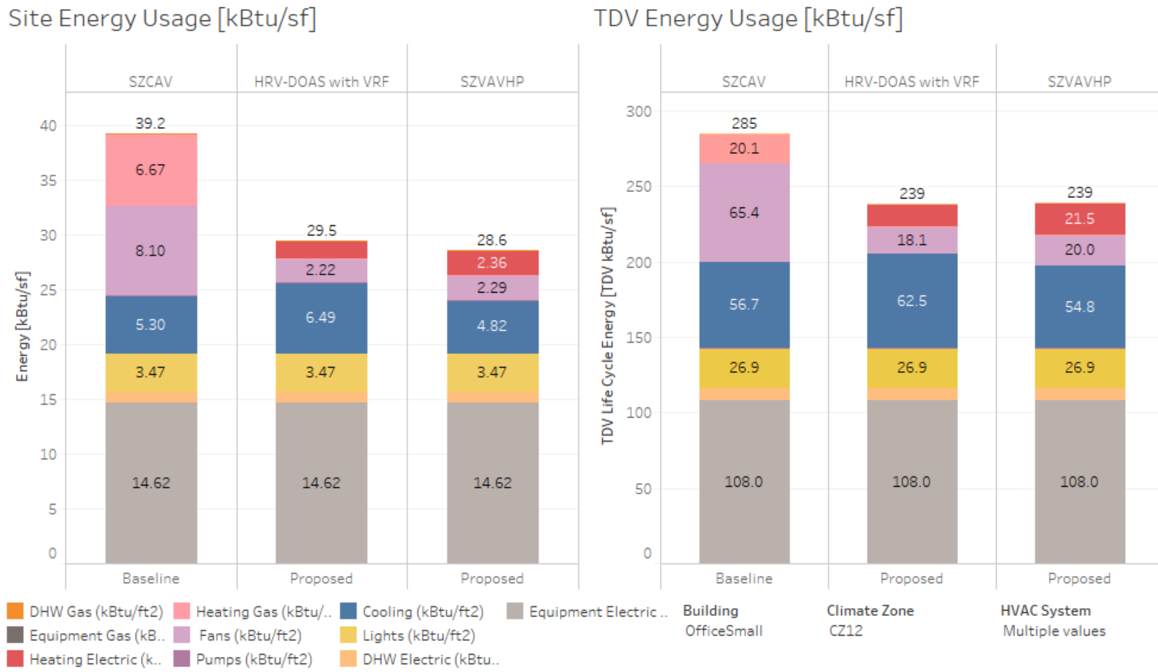
Figure 5 shows the primary school prototype achieves energy savings in each climate zone for the all-electric system configuration (HRV-DOAS with VRF) to a baseline of SZVAV units with furnaces.

Energy Results by End Use, Sampling of Climates

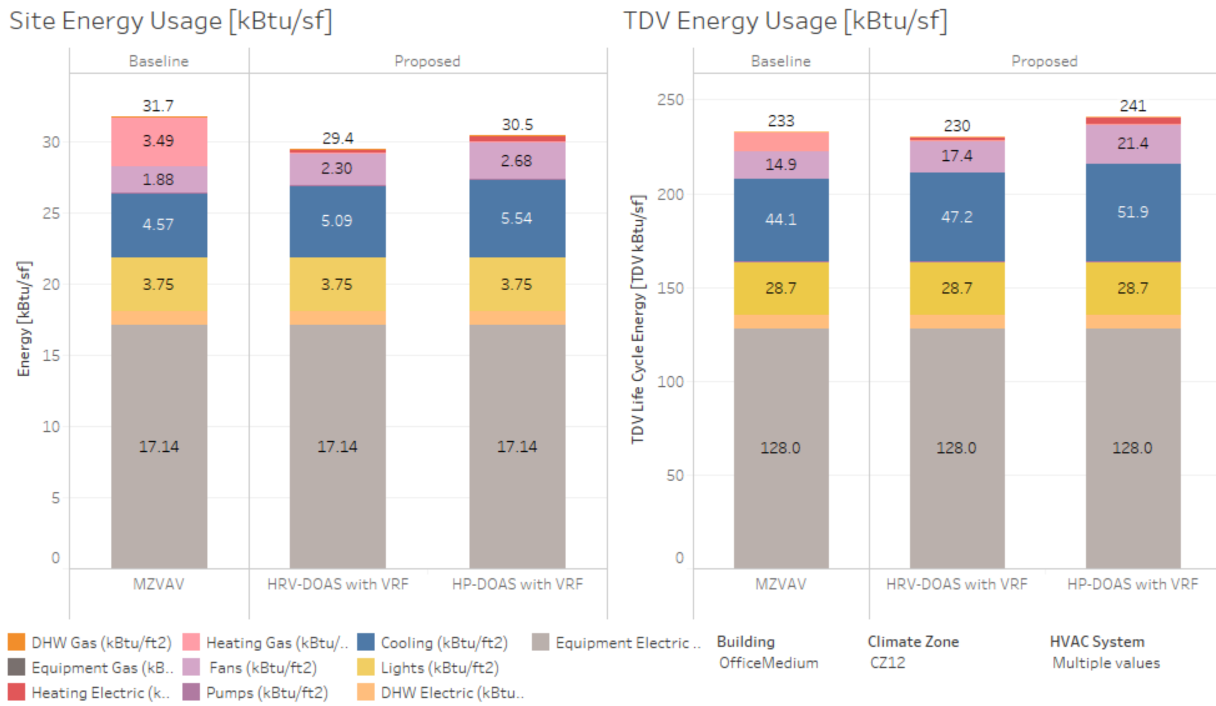
The following charts are included to provide information on what energy end uses for each system configuration in both site energy use and in TDV energy use with the TDV 2022 factors applied for both natural gas and electricity. These values were updated for the 2022 code cycle to best reflect the forecasted cost of energy and are represented as hourly multipliers when applied to energy use today.

All charts present energy in a common unit of 1000 British thermal units, or kBtu, per the conditioned floor area of the prototype model (sf). This metric is often referred to in the building design community as the Energy Use Intensity (EUI) for a building. Note these EUI values are for prototypical buildings and will vary with actual site use depending on the age and function of a building.

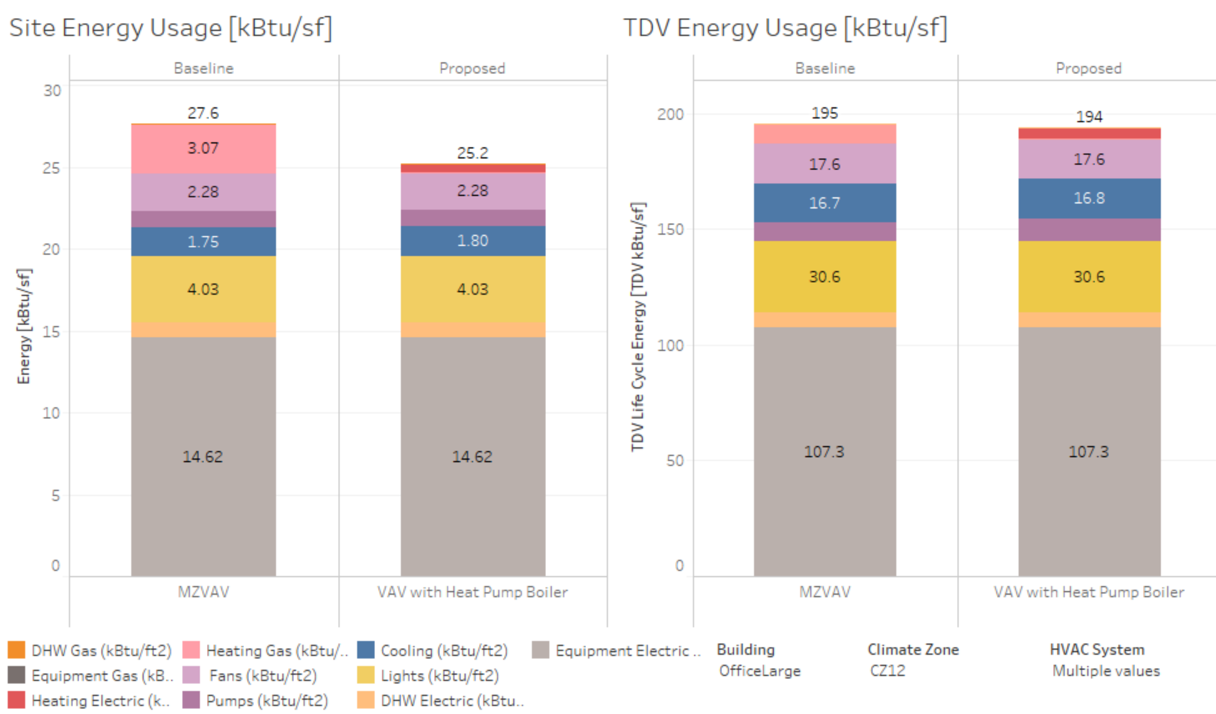
Annual Energy Results of Small Office, Climate Zone 12



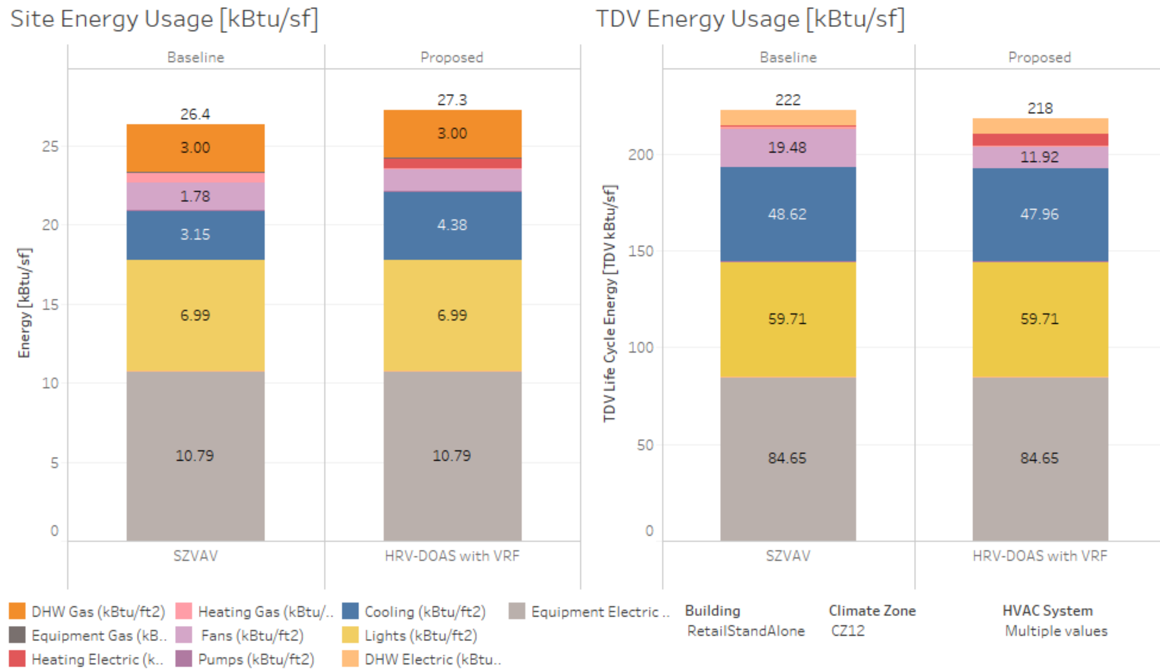
Annual Energy Results of Medium Office, Climate Zone 12



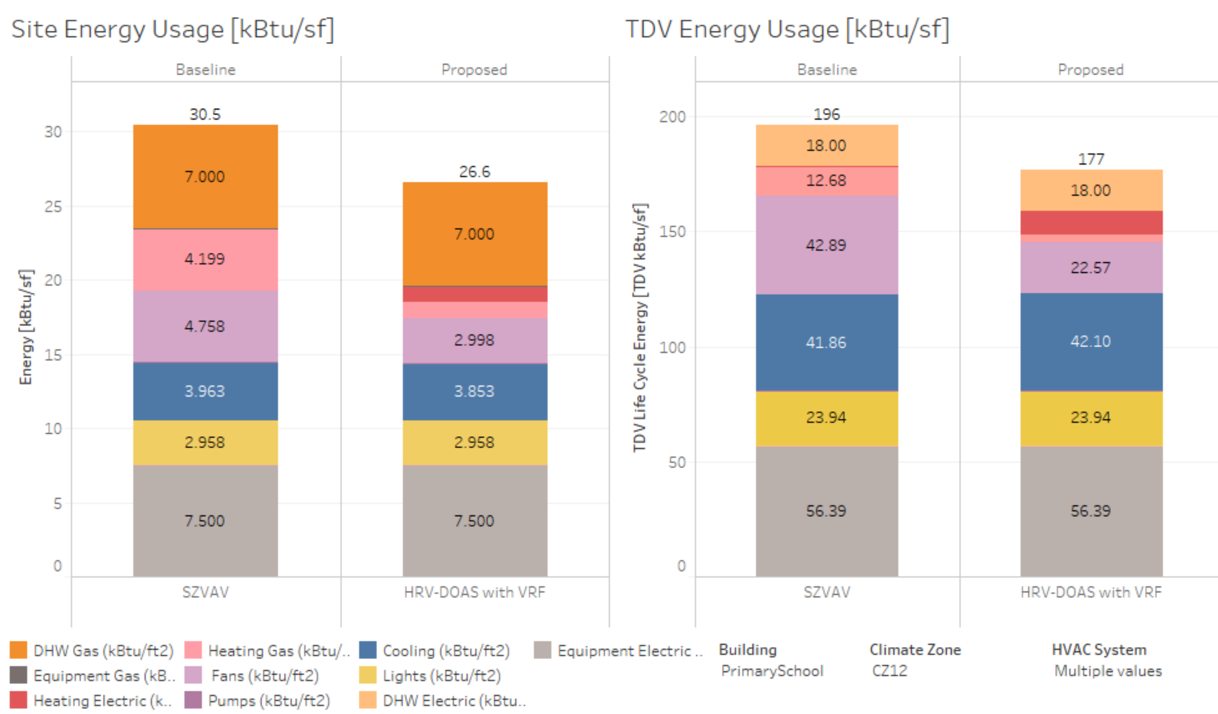
Annual Energy Results of Large Office, Climate Zone 12



Annual Energy Results Retail Stand-Alone, Climate Zone 12



Annual Energy Results Primary School, Climate Zone 12



Documentation of Modeling Inputs

Fan System Efficiency

Fan pressure for each system was based on the Fan Power Budget CASE 2022 report for fans of specific size and set pressure limits for components in the unit. Unit size was based on the prototype model and an assumption that one central system, as described in Title 24, serves each floor of a building.

		Fan Total Static Pressure	Fan Efficiency	Fan Motor Efficiency
		inches	%	%
Large Office	VAV Boiler	5.36	60%	94%
	VAV Heat Pump Boiler	5.36	60%	94%
Medium Office	PVAV	4.40	60%	94%
	HRV-DOAS VRF	3.85	60%	94%
	HP-DOAS VRF	4.65	60%	94%
Small Office	HRV-DOAS Mini Split	2.60	60%	94%
	SZVAV HP	2.50	60%	94%
	SZVAV	2.50	60%	94%
	SZCAV HP	2.50	60%	94%
	SZCAV	2.50	60%	94%
	HRV-DOAS VRF	2.60	60%	94%
Primary School	SZVAV	3.15	60%	94%
	HRV-DOAS VRF	4.10	60%	94%
Retail Stand Alone	SZVAV	2.50	60%	94%
	HRV-DOAS VRF	2.60	60%	94%

HVAC System Sizing in Energy Model

The a key component in many of the systems is ensuring the software sizes and represents the components at their appropriate capacity for the prototype building. The following inputs were utilized when building the EnergyPlus models.

		Central System Sizing	Zone System Sizing
Large Office	VAV Boiler	Peak Sensible Load	design day load
	VAV Heat Pump Boiler	Peak Sensible Load	design day load
Medium Office	PVAV	Peak Sensible Load	design day load
	HRV-DOAS VRF	Ventilation x1.5	design day load
	HP-DOAS VRF	Ventilation x1.5	design day load
Small Office	HRV-DOAS Mini Split	Ventilation x1.5	design day load
	SZVAV HP	Peak Sensible Load	design day load
	SZVAV	Peak Sensible Load	design day load
	SZCAV HP	Peak Sensible Load	design day load
	SZCAV	Peak Sensible Load	design day load
	HRV-DOAS VRF	Ventilation x1.5	design day load
Primary School	SZVAV	Peak Sensible Load	design day load
	HRV-DOAS VRF	Ventilation x1.5	design day load
Retail Stand Alone	SZVAV	Peak Sensible Load	design day load
	HRV-DOAS VRF	Ventilation x1.5	design day load

Heating and Cooling Efficiencies

This includes electric equipment efficiency rated COP and natural gas boiler or furnace specified efficiency. This represents the compressor or combustion device only and is calculated by modifying the rated equipment minimum efficiencies necessary for the energy model.

Cooling Element	Heating Element	Cooling Efficiency	Heating Efficiency
		%	%
CHW Plant	Natural Gas Boiler	5.17	0.80
CHW Plant	Heat Pump Air Source	5.17	3.50
DX	Natural Gas Boiler	3.40	0.80
VRF Air Source	VRF Air Source	3.85	3.77
VRF Air Source	VRF Air Source	3.85	3.77
DX	DX HP	3.85	3.77
DX	DX HP	3.85	3.77
DX	Natural Gas Furnace	4.63	0.80
DX	DX HP	3.85	3.77
DX	Natural Gas Furnace	3.85	0.80
VRF Air Source	VRF Air Source	3.85	3.77
DX	Natural Gas Furnace	3.80	0.80
VRF Air Source	VRF Air Source	3.80	3.74
DX	Natural Gas Furnace	3.80	0.80
VRF Air Source	VRF Air Source	3.80	3.74

Respectfully submitted,

Neil Bulger & Hillary Weitze

Red Car Analytics
Purpose | Passion | Performance
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