HVAC Retrofit at the Rifle Range

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ZNE: Path to Zero Net Energy

Introduction

The Energy Conservation Office (ECO) partnered with PG&E to pilot energy efficiency technology on the ECO building, known as the Rifle Range. The building was retrofitted with a new HVAC system in late December 2016, replacing the old furnace system with a variable refrigerant flow (VRF) heat pump and a new overhead LED lighting system powered through Ethernet connection.

Purpose

This project aims to quantify the amount of energy saved with the retrofit system for the Rifle Range building and to predict the future savings for the summer months. This project evaluates the implementation of emerging technologies, which can be used for other buildings on campus as well as adopted into the upcoming 2019 California Building Codes through PG&E. Furthermore, the energy savings of this project aligns with the ECO's mission statement to pursue campus energy efficiency.

Methodology

The building's energy use data was obtained through the campus PI data system which also serves the Campus Energy Education Dashboard (CEED). Simulation of the building energy consumption was completed through eQUEST. On eQUEST, three energy consumption models were created: baseline, switching to VRF, and switching to LED lights. The energy usage simulations were used to estimate the energy, money, and carbon saved from the new VRF system.

A Thermal Comfort Survey was conducted with the building occupants to find the indoor thermal satisfaction before and after the new retrofit. The same set of questions were asked for the comfort prior to December 2016 (before the retrofit) and in May 2017 (with the new systems in place). The survey asked occupants about the indoor temperature, air flow, lighting levels, air quality, and understanding of using the thermostat.

Survey Results

The Thermal Comfort Survey results showed that occupants were happier with the new retrofit system, although the majority of responses indicated that it was still slightly too cold. In response to the survey, the thermostat set point minimum for cooling was raised from 67 to 70 degrees Fahrenheit. Additionally, the Thermal Comfort Survey results showed that many users were not familiar with the new HVAC control system. In response, the user manual was simplified, customized, and distributed.

Commodity Data

We analyzed hourly natural gas and electricity meter readings via ECO's pi data system. We removed data with I/O errors and with inaccurate readings, such as in Figures 1. To then calculate the monthly energy consumption, we compared the maximum meter readings during a month to the maximum reading from the previous month.

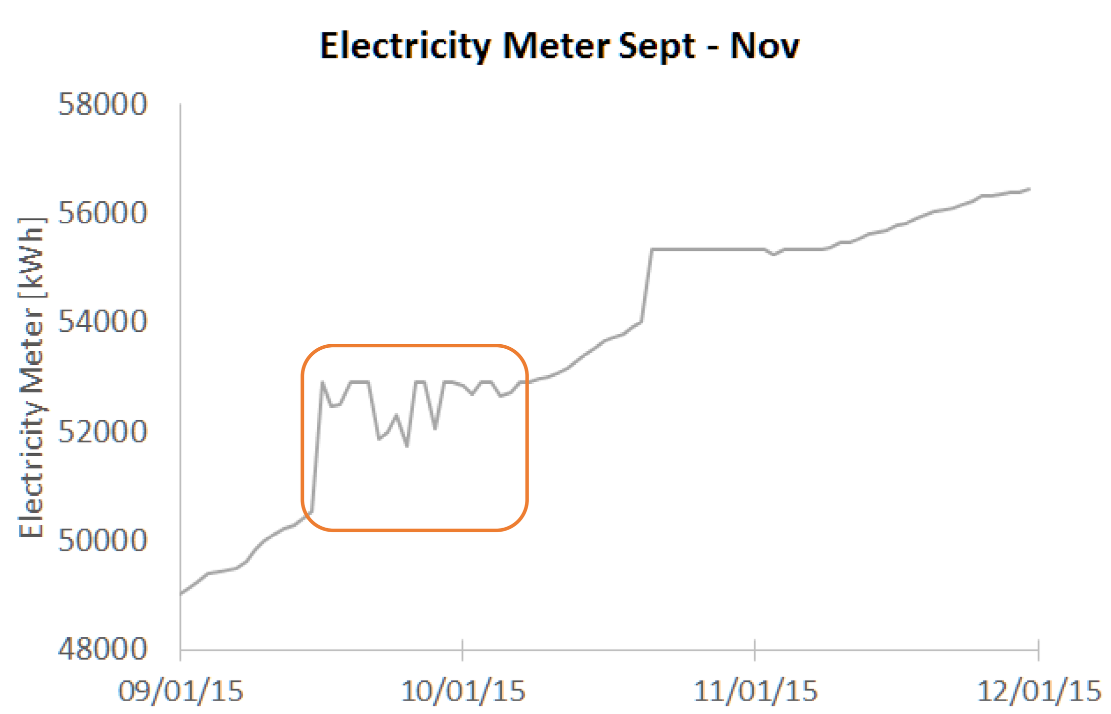

Figure 1. Rifle Range Electricity Meter over a three month time period. Because Rifle Range does not produce natural gas or electricity, meter readings should strictly increase. This figure show erroneous jumps due to meter glitches.

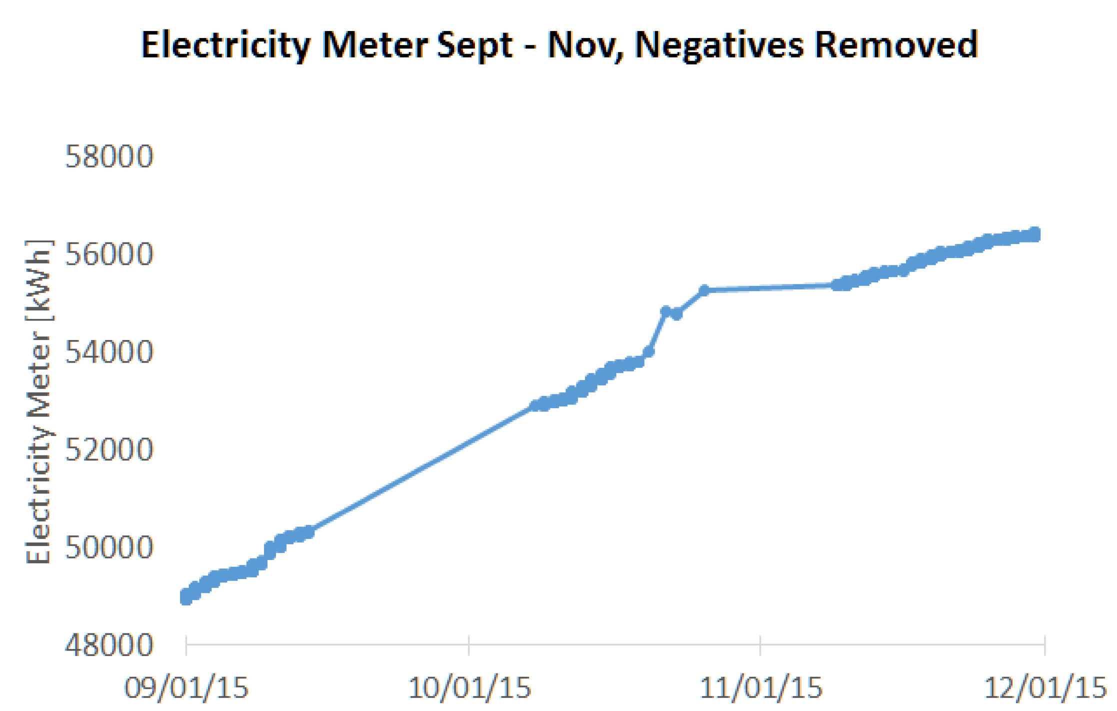

Figure 2. Electricity Meter over the same three month time period. We removed the data showing negative consumption as well as the time periods directly after a negative consumption, which reported inaccurately high consumption.

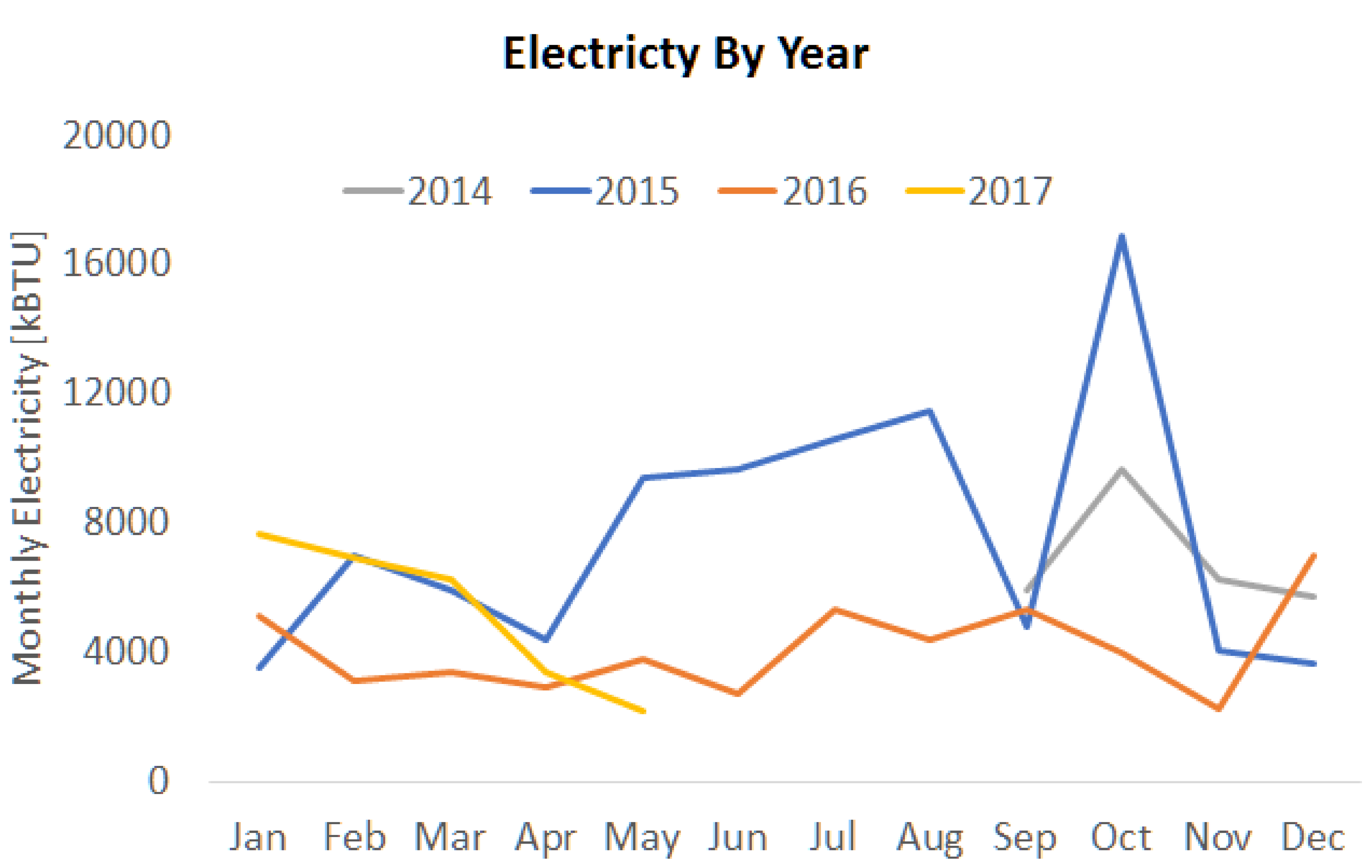

Figure 3. Monthly electrical energy consumption divided by years. Note that although 2017 initial shows higher electricity use, the retrofit means 2017 has no natural gas use.

Tailored Thermostat Guide Sample

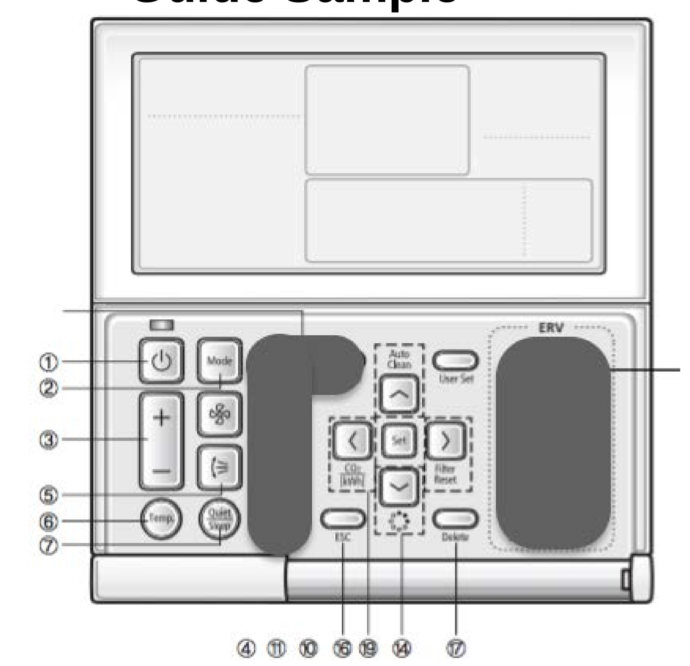

Image 1. A tailored thermostat guide was created as a response to the results from the thermal comfort survey that occupants had varied understanding of how to use the thermostat. A guide was made to help the occupants increase understanding how to alter thermostat settings to improve thermal comfort.

eQUEST Simulation

Our first goal was to simulate the pre-retrofit system (Figure 4,5), and then switch the model to reflect the retrofit changes. Within eQUEST there is no option to implement a VRF system, so for the post retro-fit building simulation we chose the Variable Volume and Temperature(VVT) system. These two system are the most similar option we had, but to account for this discrepancy we found another simulation source that compared VRF and VVT [1]. It was found that the VRF used 11% less energy than a VVT while in cooling operation. The way this source modified the VVT system to make it comparable was to increase the coefficient of performance (COP) to 4.5. When this was done to our eQUEST model we again saw about 11% savings during the cooling cycle, so the COP 4.5 results displayed below are our best best VRF equivalent (Figure 6).

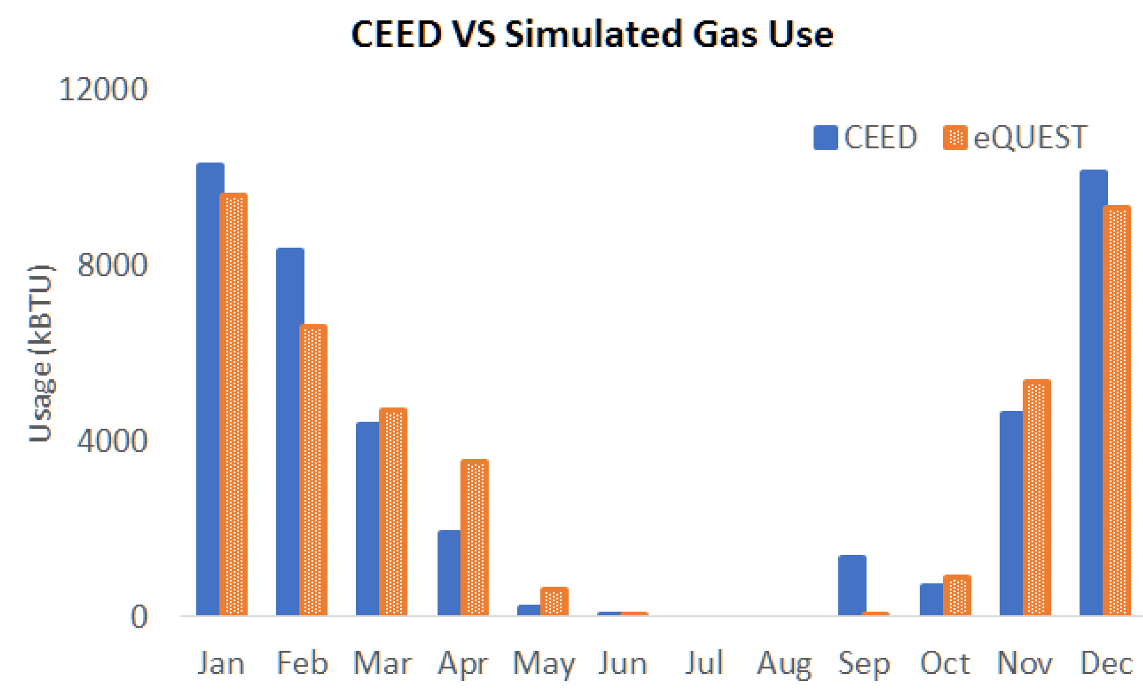

Figure 4. Comparison of the gas use between the eQUEST simulation and measured data from 2014-2016. This comparison shows that the building envelope created in eQUEST is in good agreement with the previous HVAC system. The eQUEST model underestimates the gas use by 3%. These simulation results are our 'baseline' case.

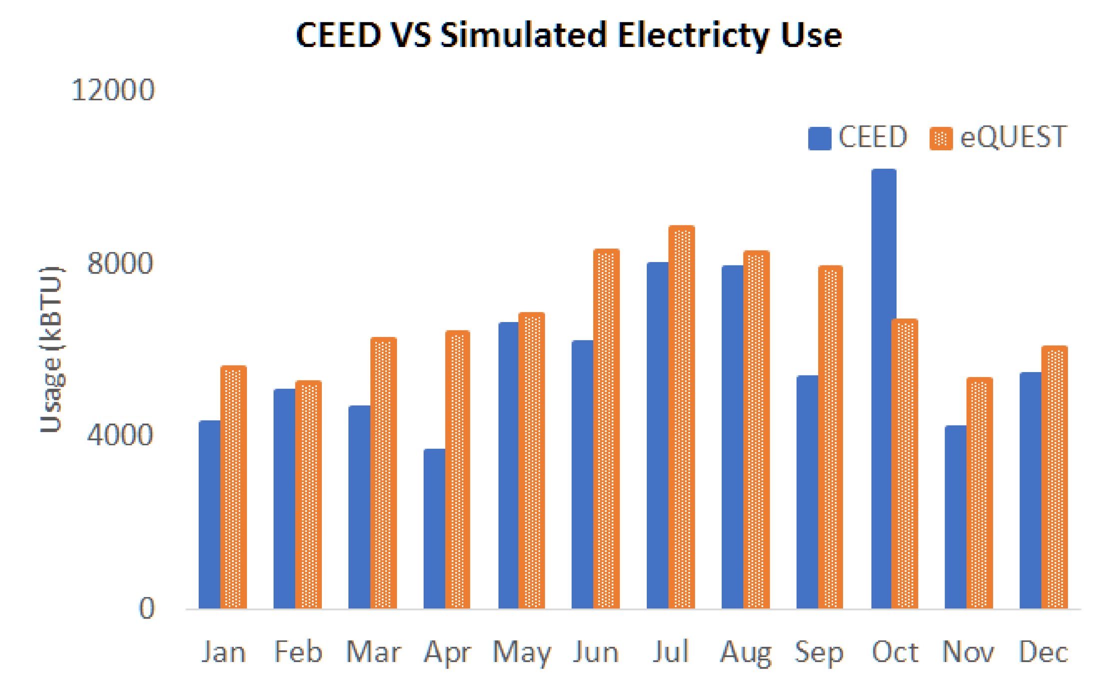

Figure 5. Comparison of the electricity use between the eQUEST simulation and measured data from 2014-2016. This comparison shows that the building envelope created in eQUEST is in good agreement with the previous HVAC system. The eQUEST model over estimates the electricity use by 14%.

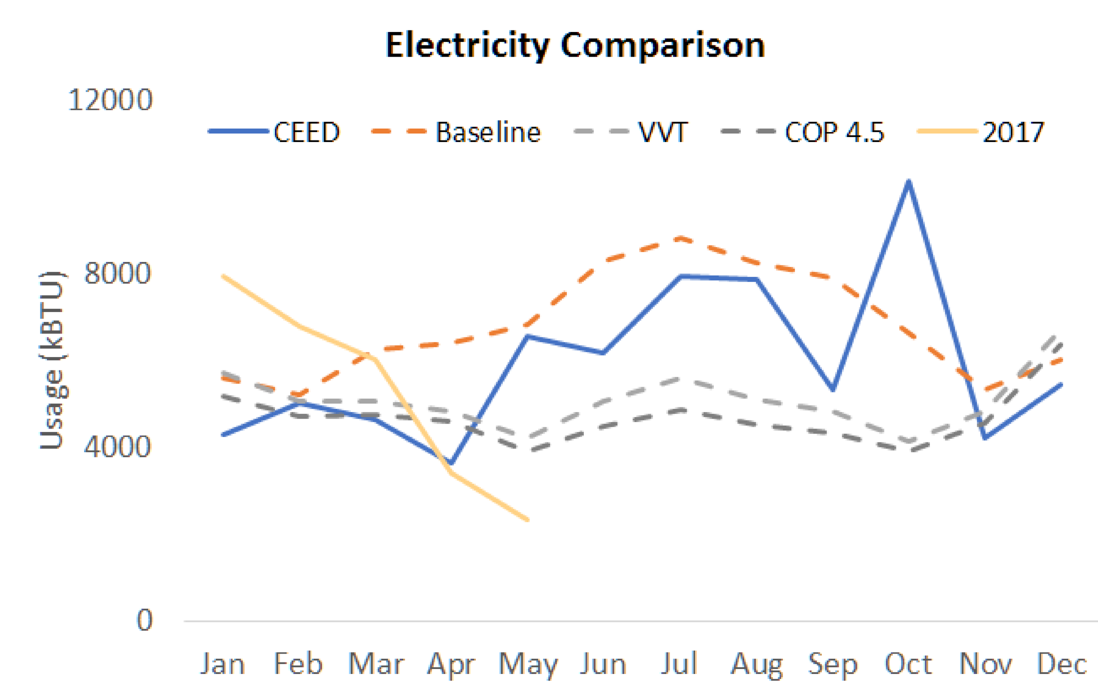

Figure 6. This comparison between simulations shows that the VVT and COP 4.5 simulation use less electricity overall when compared to the previous buildings baseline simulation 'baseline' or the 2014-2016 average 'CEED'. The 2017 data shows that during the cooling season the simulation underestimates the expected energy use, but over estimates the energy use as the heating season begins in May. It is expected the Summer months will see an increase in electricity use, but it is expected to stay lower than the electricity use pre-retrofit.

Savings Summary of eQUEST Results

Summary	Baseline	CEED	COP 4.5	Savings
Annual Cost[1]	$1,803	$1,628	$1,014	$614
Carbon[2] [ton/year]	6.07	5.98	1.20	4.78
EUI [kBTU/ft^2]	36.4	33.7	16.7	17.0

Table 1. From our predictive model we were able to estimate the annual cost savings of the all electrified 'VRF' system. We used the Davis Utilities source for pricing on natural gas and electricity [2] to calculate the anual cost. The carbon estimate was made by accounting the natural gas burned on site and its carbon output, and using information provided by UC Davis sustainability to determine which fraction of electrical energy used on campus is carbon free [3,4].

Conclusions

- The retrofit slightly increased occupant thermal comfort and thermostat adjustments were made to reflect responses from the survey.
- Although the natural gas and electricty data are highly variant, the new HVAC system already saves energy, carbon, and money.
- The eQUEST model predicts that the savings will persist forthe rest of 2017 and thus also in future years.

Recommendations

- Conduct Thermal Comfort Surveys as the season progresses to track if thermostat settings are in line with occupant comfort.
- Improvements to the consistency of electricity consumption database records.

References

[1] Zhou, Y. Energy simulation in the variable refrigerant flow air-Conditioning system under cooling conditions. Energy and Buildings 2007, 39, 212–220.
[2] http://utilities.ucdavis.edu/rates/index.html
[3] https://www.eia.gov/tools/faqs/faq.php?id=73&t=11
[4] http://sustainability.ucdavis.edu/progress/climate/renewable_energy.html

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