Energy and Efficiency in UC Davis Greenhouses

Lisa Slaughter, Sarah Dang, Alice Dien

ABSTRACT

This project explores how the UC Davis greenhouses currently use energy. The goal is to estimate energy usage by technology levels and to use literature to find useful interventions that can improve performance and save money. We hope to provide energy measurements and informed suggestions that act as baselines for future greenhouse research.

BACKGROUND

The UC Davis Greenhouses consume energy 24 hours a day, 7 days a week. The majority of this energy use is in the form of lighting, cooling, and heating control. With over 200 greenhouses on campus, the scale is vast. Unfortunately, very little of the greenhouse energy use is monitored and total use is unknown. Having recently received a large grant for upgrades, the greenhouse managers would like to investigate how the greenhouses use energy and whether there is any low-hanging fruit for energy savings.

OBJECTIVES

- Provide insights about greenhouse energy usage
- Propose interventions to improve energy efficiency
- Estimate feasibility of interventions

METHODS

Identify Greenhouse Sets

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Collect Data

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Estimate Annual Energy Usage

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Investigate Interventions

IDENTIFICATION OF GREENHOUSE SETS

The greenhouses were categorized by the following types according to their technologies:

1. **Low**: Passive
2. **Medium** : Basic thermostat, heating/cooling systems, full lighting systems, control system.
3. **High** : Medium technologies plus humidity control, position control, photovoltaic glazing, and other (currently) instrumentation.

METHODS (cont'd)

It was decided to focus on Level 2 greenhouses, as these are representative of the largest number of greenhouses available for investigation. Within this set, the Core and Orchard Park greenhouses have the most repeatability.

Core, small size: 5 greenhouses

Core, large size: 14 greenhouses

Orchard Park: 69 greenhouses

DATA ACQUISITION

Data acquisition techniques consisted of performing walkthroughs to take down nameplate information of various technologies and obtain current and power measurements where possible. Workers and managers were also interviewed about technology behaviors and usage scenarios. Square footage was gathered from the University building information site at http://facilitieslink.ucdavis.edu/

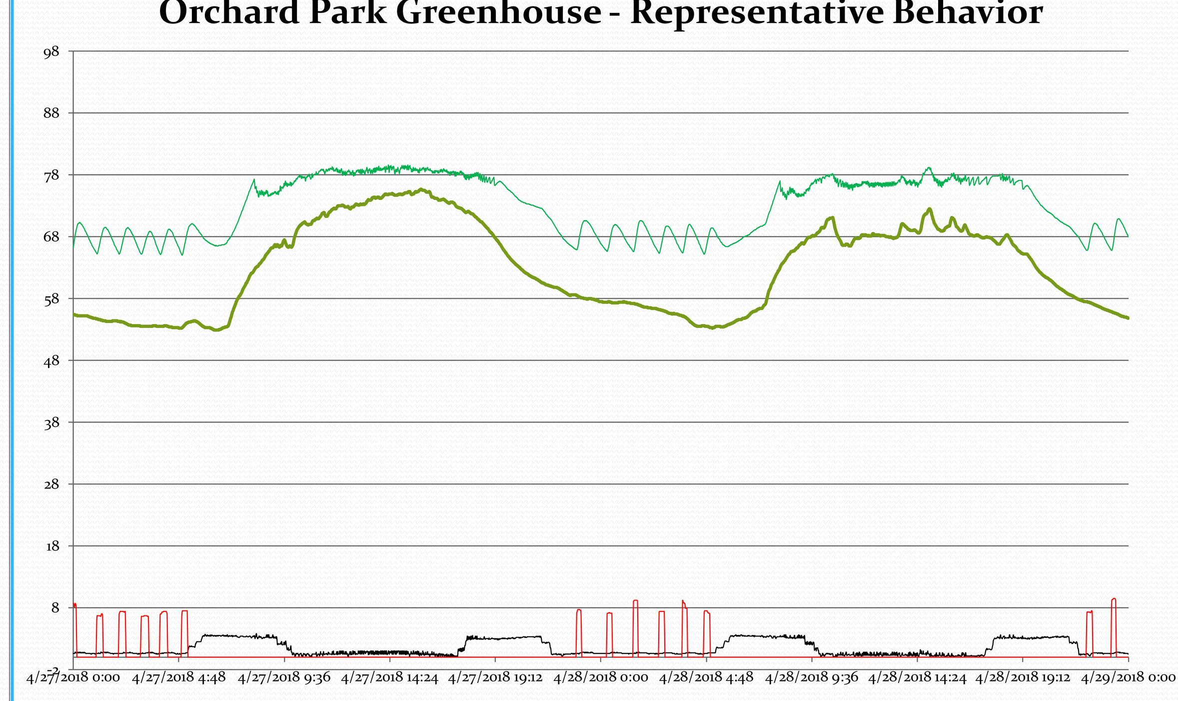
ENERGY CALCULATIONS

Since most of the greenhouses are not monitoring energy consumption, indirect methods were used. Annual usage for the largest contributors – lighting and heating- were estimated. Cooling is achieved by evaporative cooler, which uses a small pump to wet the pads and two fans to move the air across the pads. Because of this, the energy usage for cooling is negligible in comparison to heating and lighting and was omitted.

Orchard Park

One of the Orchard Park greenhouses is equipped to monitor energy consumption and is representative of the other 68 houses in the Orchard Park complex. It can easily be seen that lighting accounts for the majority of electricity use. Setpoints as well as lighting and heating behaviors were obtained through visual analysis of this data.

Orchard Park Greenhouse - Representative Behavior



METHODS (cont'd)

Lighting usage was calculated for 4 lights per greenhouse according to a schedule of 8 hours per day. Heating usage was calculated using

$$Q = Fc_p\rho(T_R - T_S)t$$

The resulting heat (Q) was combined with boiler efficiency and converted to kWh equivalent.

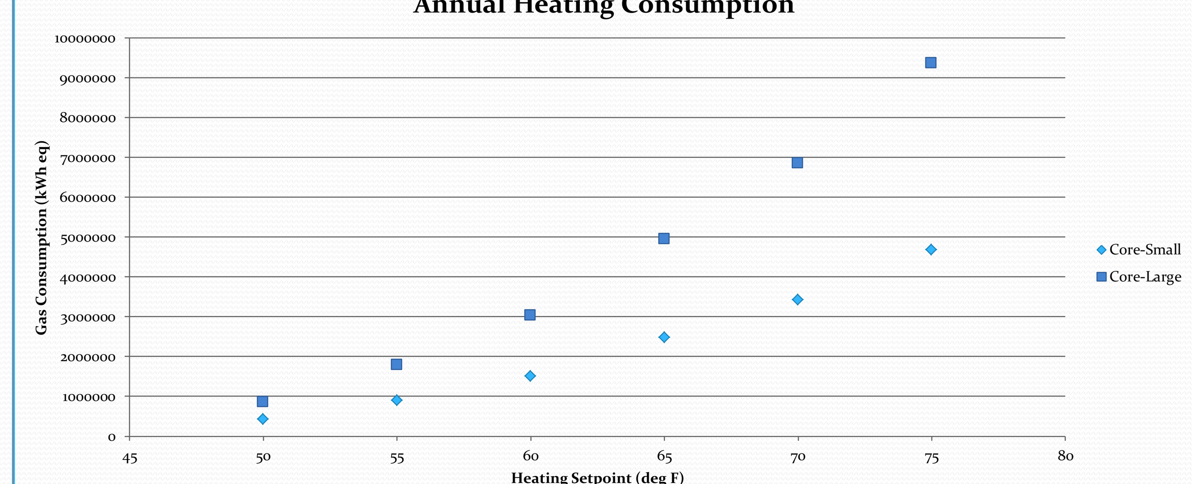
Core – Large and Small

There are two sizes of greenhouse in the Core complex. The small size is exactly half the length of the large size and has one furnace for heating as opposed to two. The calculation for gas usage is the same for both:

$$Q = U \cdot A \cdot DD \cdot \frac{1}{EER} \cdot \frac{24\,hour}{1\,day}$$

This was converted to kWh equivalent. Since a variety of setpoints are used for various crops, a sensitivity analysis was performed by varying the base temperature used for heating degree days.

Annual Heating Consumption



RESULTS

Energy use of the three greenhouses investigated are shown below.

	Energy Use (kWh/year)		Cost ($/year)	
	One House	All Houses	One House	All Houses
Core, small	25,281	126,406	$983.75	$4,918.75
Core, large	48,258	675,617	$2,025.78	$28,360.94
Orchard Park	26,651	1,838,948	$1,378.70	$95,130.33
Total	-	2,640,971	-	$128,410.02

POSSIBLE INTERVENTIONS

1) Change Orchard Park Lighting Schedule

By going to a 4-hour a day schedule for half the year (instead of 8 hours year-round) , savings of $13,816 are available. This would involve a human being manually adjusting the timer attached to 280 individual lights once during fall and once during spring.

RESULTS (cont'd)

2) Install Photo-Switches in Orchard Park

Because the current lighting system in Orchard Park is operated by manual timer from 5am-9am and 5pm-9pm, there are many periods of time where the lights are on while the sun is shining. Replacing these timers with a switch that senses light levels would decrease usage by 99% for annual savings of $53,000 when considering device cost of $15.00 each.

3) Replace HPS Lighting with LEDs

LED lighting uses significantly less energy than high-pressure sodium. Research from MIT shows that plants are unaffected by differences as long as appropriate specifications are used. Separating lighting and heating allows lighting to be used on warm but overcast days.

4) Install Water-Filled Polyethylene Bags

Installing heat sinks such as polyethylene bags filled with water would smooth out the internal temperature curve of the greenhouses, resulting in less heating and cooling costs. These would absorb heat during the warm parts of the day, re-radiating it as the temperature drops.

FUTURE WORK

- Fiscal and energy savings calculations for polyethylene bags and LED lights
- Design and investigate pyranometer system
- Install appropriate sensors to measure energy usage

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CONTACT

Lisa Slaughter: lmslaughter@ucdavis.edu, lisa.m.slaughter@gmail.com
Sarah Dang: shdang@ucdavis.edu
Alice Dien: adien@ucdavis.edu

ACKNOWLEDGEMENTS

We would like to thank Chris Durand for his assistance with data acquisition.