PROJECT RESULTS:
Improving Water and Energy Efficiency in California's Dairy Industry

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Introduction
California is the nation's top milk-producing state. It is critical to keep dairy cows cool during the hot summer months. Standard cooling methods, however, such as fans and spraying cows with water, require substantial amounts of electricity and water.

Goal
With the goal of reducing electricity and water consumption, the UC Davis Western Cooling Efficiency Center and the Department of Animal Science tested novel approaches for cooling dairy cows in a small-scale study. Researchers measured energy and water use and monitored the cows to determine the impact of four treatments:

- **Baseline**–a fan in the bed area with sprayers in the feed area.
- **"Optimized" Baseline**–a fan and sprayers in the feed area.
- **Conduction Cooling "Mats"**–the bed area is cooled using heat exchange mats. Water in the mats is cooled through a novel evaporative chiller.
- **Convection Cooling "Ducts"**–fabric ducting directs cool air onto the cows in the bed and feed areas. The air is cooled using a direct evaporative cooler.

Results
- Convection Cooling Ducts and Optimized Baseline were effective at reducing heat stress in cows.
- All cooling methods tested saved water in comparison to the baseline, however, the Convection Cooling Ducts used more electricity in the field test than anticipated. Researchers built and tested a higher efficiency evaporative cooler to reduce the Ducts energy use.

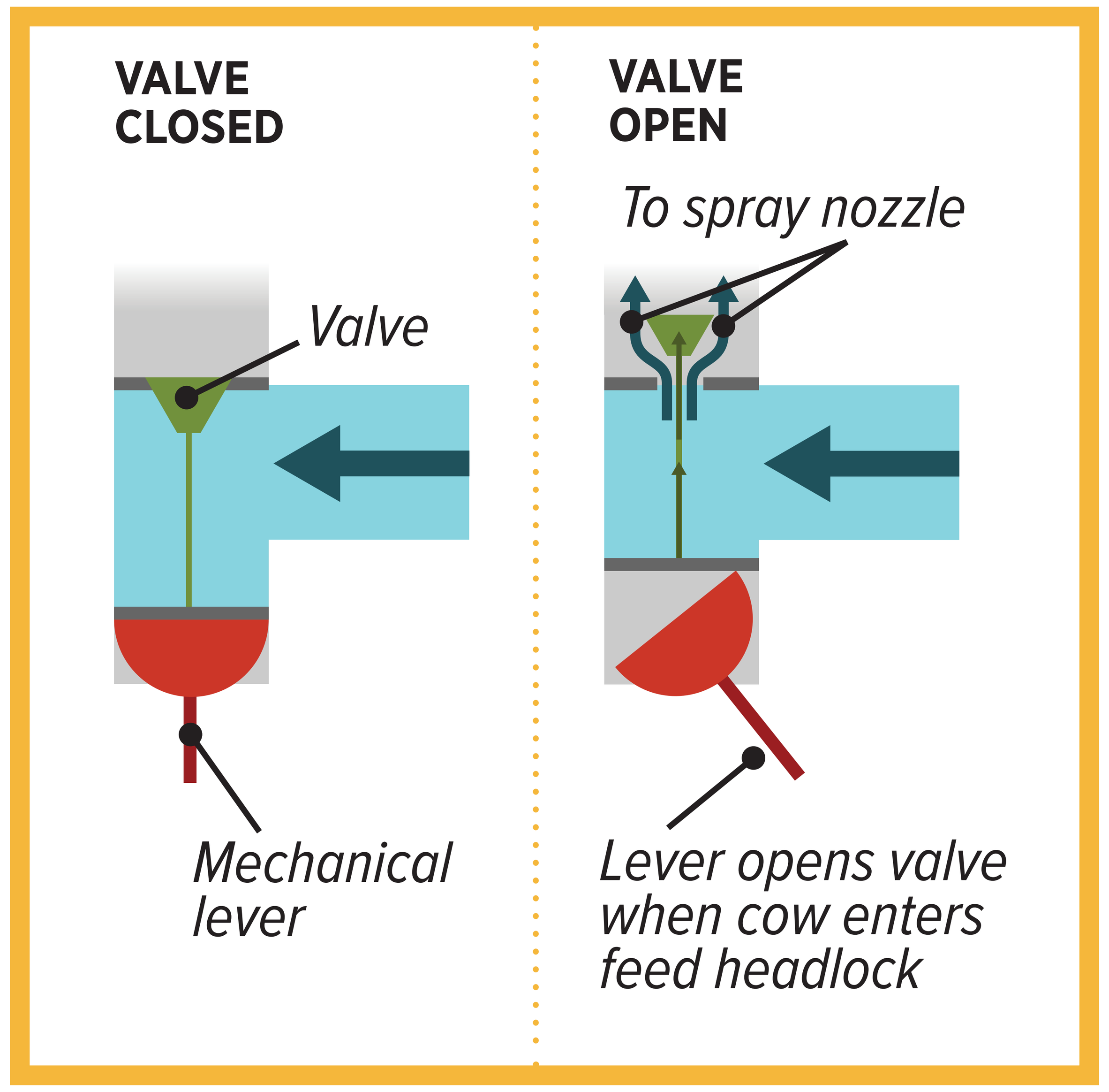
Benefits
New approaches to keeping cows cool will help dairies improve their productivity and cow health, while helping California meet its energy, water and climate goals.

Path forward
WCEC conducted a detailed analysis and determined that energy savings are possible with the Convection Cooling Ducts and new high efficiency evaporative cooler. However, barriers to adoption of the technology are concerning, as it presents a significant change to the types of cooling systems that dairy operators are used to.

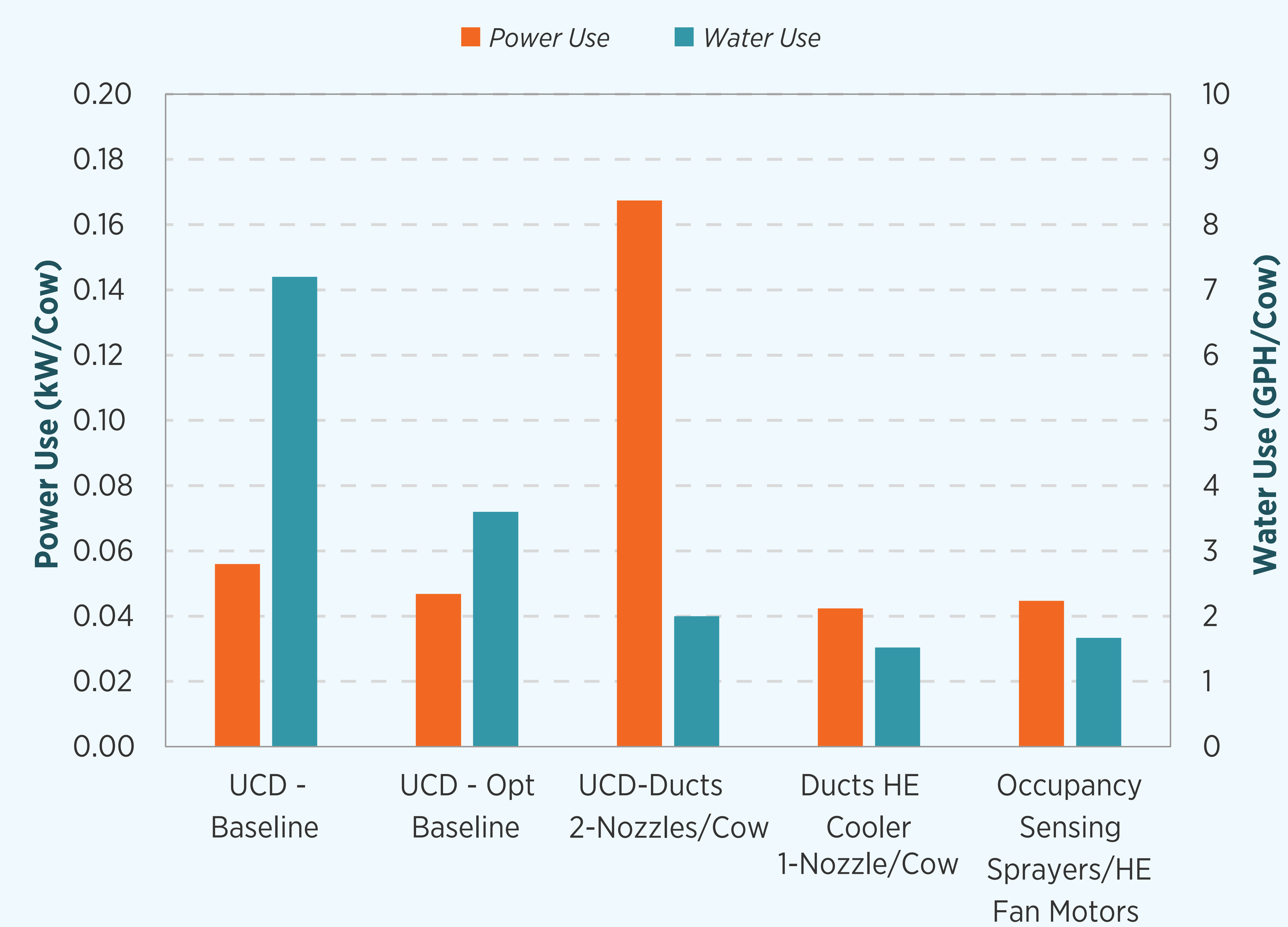
Researchers are also optimizing traditional fans and sprayers by using newly developed occupancy sensing sprayers (patent pending) and 72" fans with variable speed controls. The water spray frequency and fan speed will be controlled based on a recently developed heat transfer model that predicts cow cooling needs based on outdoor conditions.

Additional field testing will take place in summer 2019 implementing either the Convection Cooling Ducts or optimized fans and sprayers.

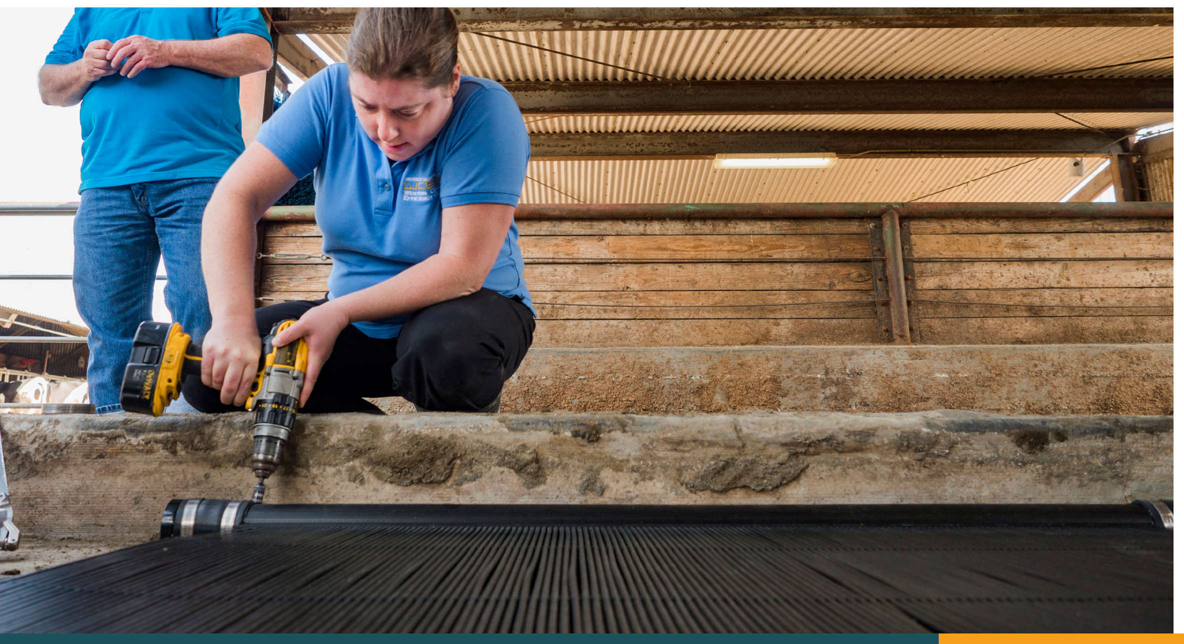
OCCUPANCY SENSING SPRAYER VALVE FUNCTION

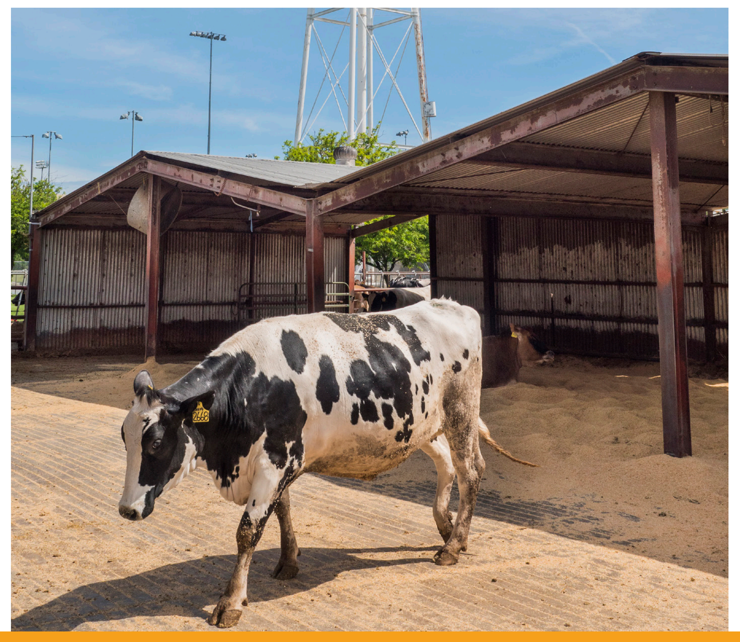


Installation of the convection cooling duct system and direct evaporative cooler



Power- and water-use per cow used for each technology approach





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PROJECT RESULTS:
Improving Market Conditions for Increased Adoption of Ground-Source Heat Pumps

Vinod Narayanan, Antash Najib, Curtis Harrington, Rachael Larson

Introduction

Ground-source heat pumps (GSHP) reduce energy required for cooling in summer and heating in winter by taking advantage of the more stable and moderate ambient temperatures of the ground. GSHPs come in a variety of geometries and configurations.

Goal

The goal of this project is to improve market conditions for increased adoption of ground-source heat pumps in California by identifying optimal designs for low-cost, shallow bore helical ground heat exchangers (GHEs) and providing the engineering information and installation guidance that is needed.

Results

This past year, WCEC researchers and collaborators developed and calibrated a computational model for the shallow bore helical GHE. The model uses electrical analogies of capacitance and resistance (CaRM) to describe the heat transfer in the ground source heat pump system. Researchers validated the model by comparing results with those reported in the literature and from field data. In addition, the researchers developed a computational fluid dynamics (CFD) model to simulate heat transfer phenomena that the simplified CaRM model neglects and to also obtain more detailed

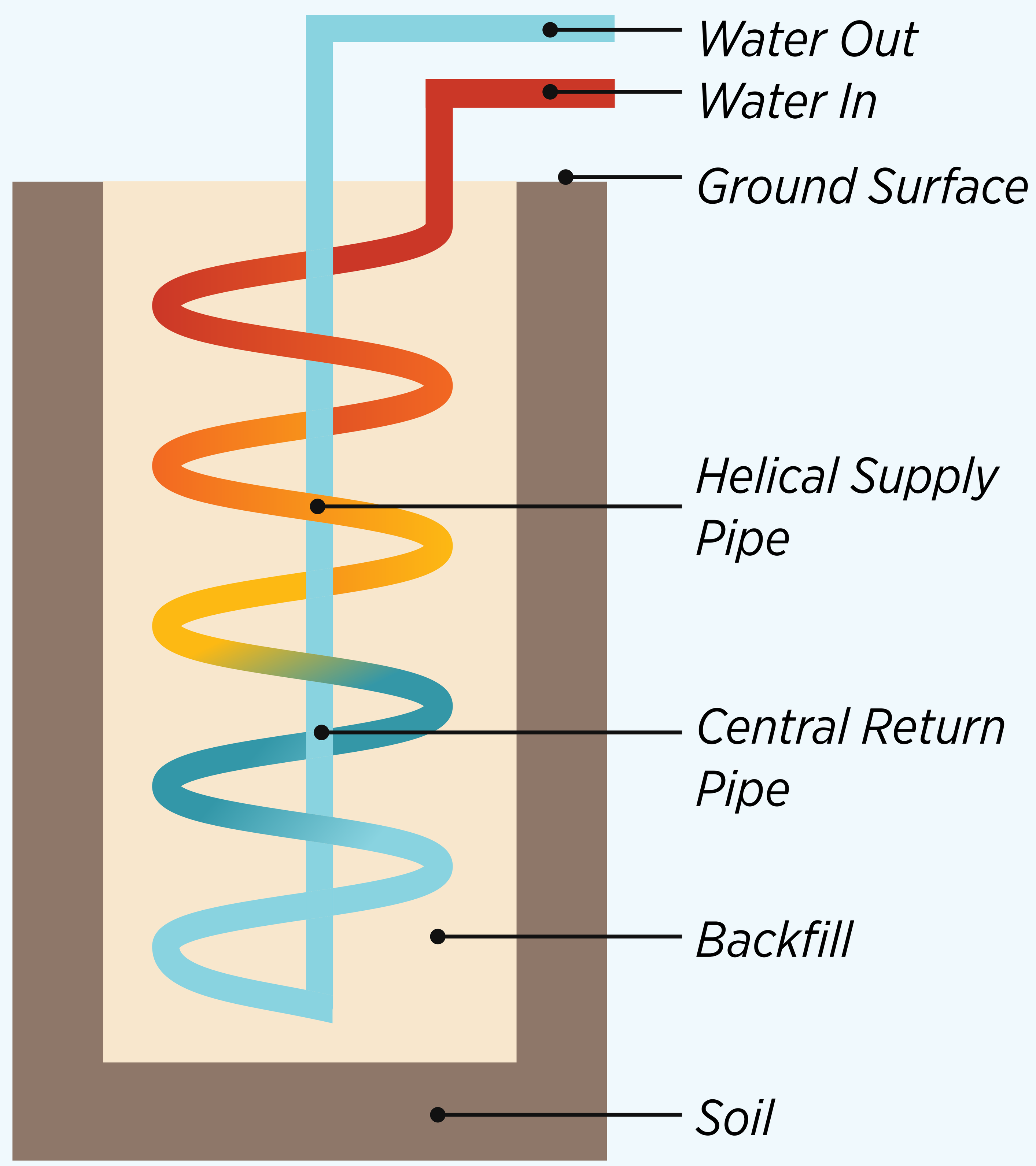
Benefits

Ground-coupled heat pumps transcend the performance limitations of air-source systems, saving energy and providing a carbon-free way to heat and cool homes.

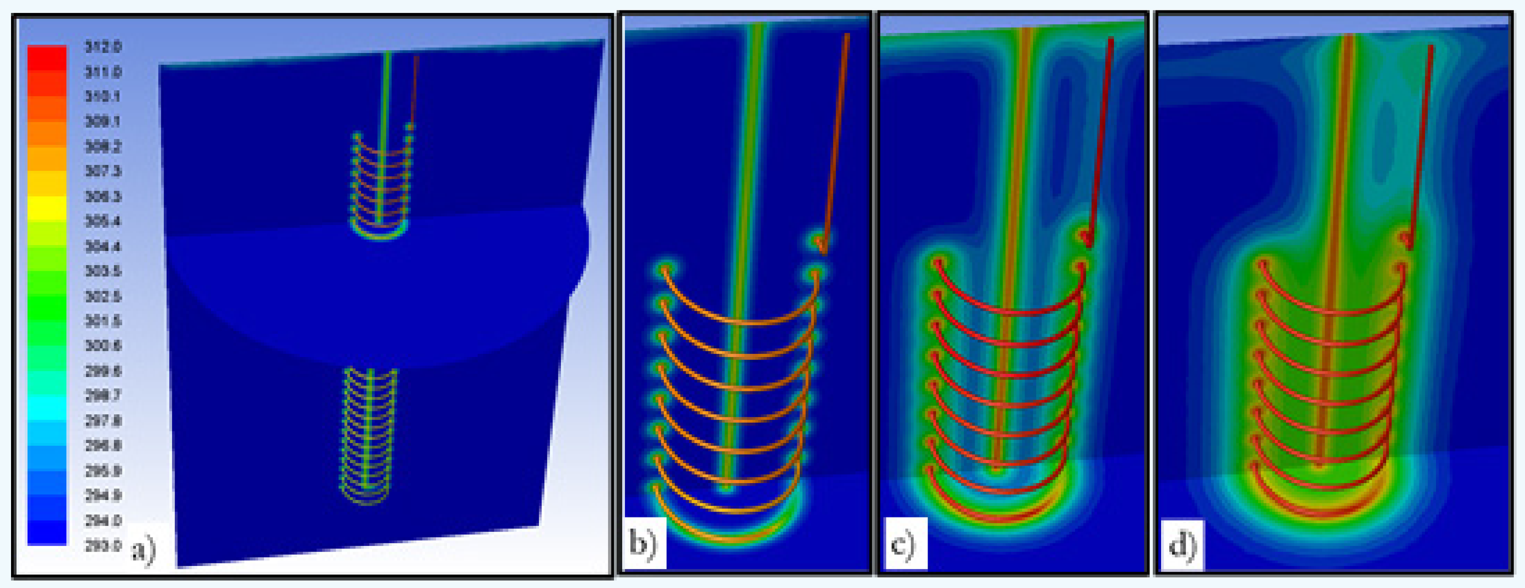
Path Forward

Installation of a controlled test facility with a GHE design based on the model is underway. The tests will also provide more information about multiple GHE interactions. The results from the tests and models will be used to generate design parameters (g-functions) that will be incorporated into Energy Plus.

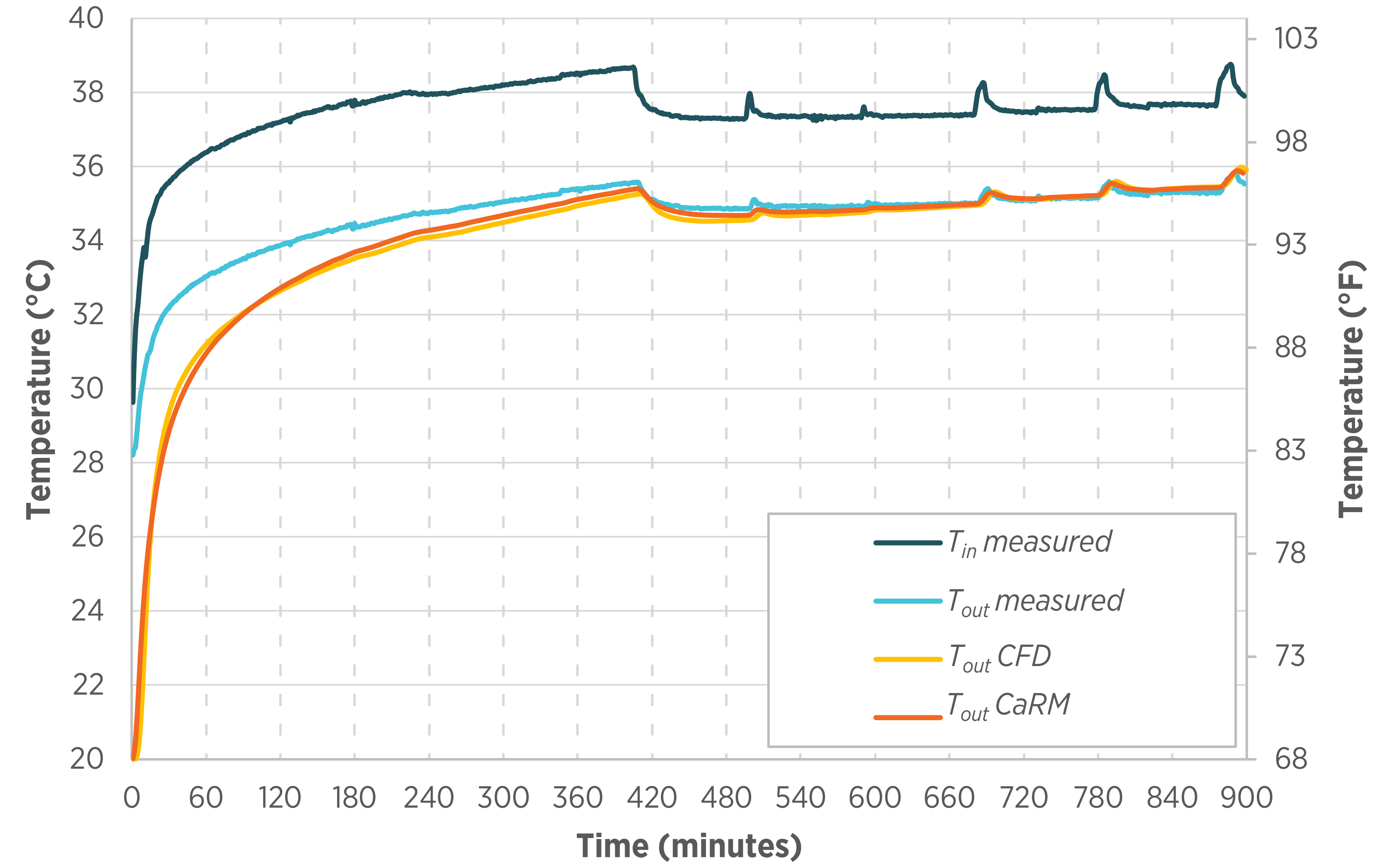
Diagram of the helical GHE modeled and installed at the field site.



Temperature contours of the GHE and surrounding soil after (a) one hour, complete model (b) one hour, top portion (c) six hours, top portion (d) 15 hours, top portion (e) 15 hours, bottom portion.



CaRM and CFD model predict return temperatures from the GHE within 0.20% of each other



PROJECT RESULTS:
Improving Indoor Air Quality in California Schools

WCEC: Theresa Pistochini, Robert McMurry, Sarah Outcault
LBNL: Wanyu R. Chan, Xiwang Li, Brett C. Singer

Introduction

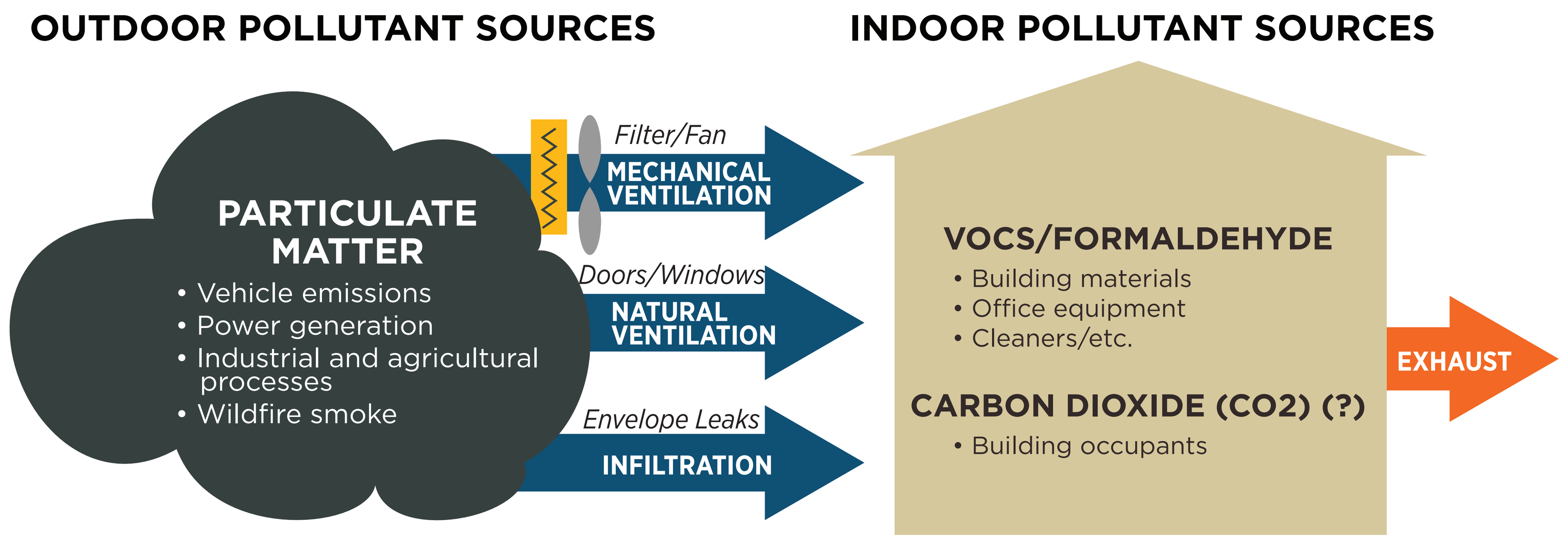
HVAC systems provide necessary mechanical ventilation to classrooms. Ventilation is needed to remove indoor pollutants such as volatile organic compounds and formaldehyde, and carbon dioxide (CO_2). There is increasing evidence that CO_2 exhaled by occupants is an indoor pollutant that can affect decision making performance [1]. This is particularly important in spaces that are densely occupied, such as classrooms. Importantly, studies have found that ventilation impacts student performance and attendance [2].

Goal

During the 2016-2017 school year, UC Davis characterized HVAC systems, CO_2 concentrations, and indoor thermal conditions in 104 classrooms that had replaced their single zone HVAC systems within the past three years.

Results

- Overall, classrooms with recent HVAC retrofits had higher ventilation rates than reported generally in the literature, including in a recent California study [3].
- **The ventilation rates of many classrooms were below the requirements of the ASHRAE 62.1 standard or California's Title 24.**
- **65% of the classrooms were under-ventilated.**
- Classrooms with wall-mount systems, commonly used in portable classrooms, had higher CO_2 concentrations and lower estimated ventilation rates than classrooms with rooftop units.
- Classrooms with economizers, with and without demand control ventilation, tended to have lower mean CO_2 concentrations. But, many were still under-ventilated compared to the minimum requirement.
- Inadequate ventilation was found in classrooms at all grade levels.
- Under-ventilation was caused by improperly selected equipment, lack of commissioning, incorrect fan control settings and maintenance issues (e.g., dirty filters).
- Surprisingly, many teachers reported that they were satisfied with their indoor air quality even when indoor CO_2 levels routinely exceeded 1700 ppm. This shows the importance of CO_2 sensing for monitoring ventilation systems.



Mechanical ventilation systems deliver filtered outdoor air to a space to reduce indoor pollutants

References
1) *U. Satish, M. Mendell, K. Shekhar, T. Hotchi, D. Sullivan, S. Streufert and W. Fisk, "Is CO2 an Indoor Pollutant?" Environmental Health Perspectives, vol. 120, no. 12, pp. 1671-1677, 2012.*
2) *W. J. Fisk, "The ventilation problem in schools: literature review," Indoor Air, International Journal of Indoor Environment and Health, vol. 27, no. 6, pp. 1039-1051, 2017.*
3) *Mendell, M.J, et al., "Association of classroom ventilation with reduced illness absence: a prospective study in California elementary schools," Indoor Air, vol. 23, no. 6, pp. 515-528, 2013.*

Benefits

Ensuring adequate classroom ventilation will save California school districts money and protect and support the health and well-being of students and teachers. If ventilation in all classrooms met Title 24 requirements, California school districts could see an estimated $33 million in revenue due to fewer student absences [3].

Recommendations

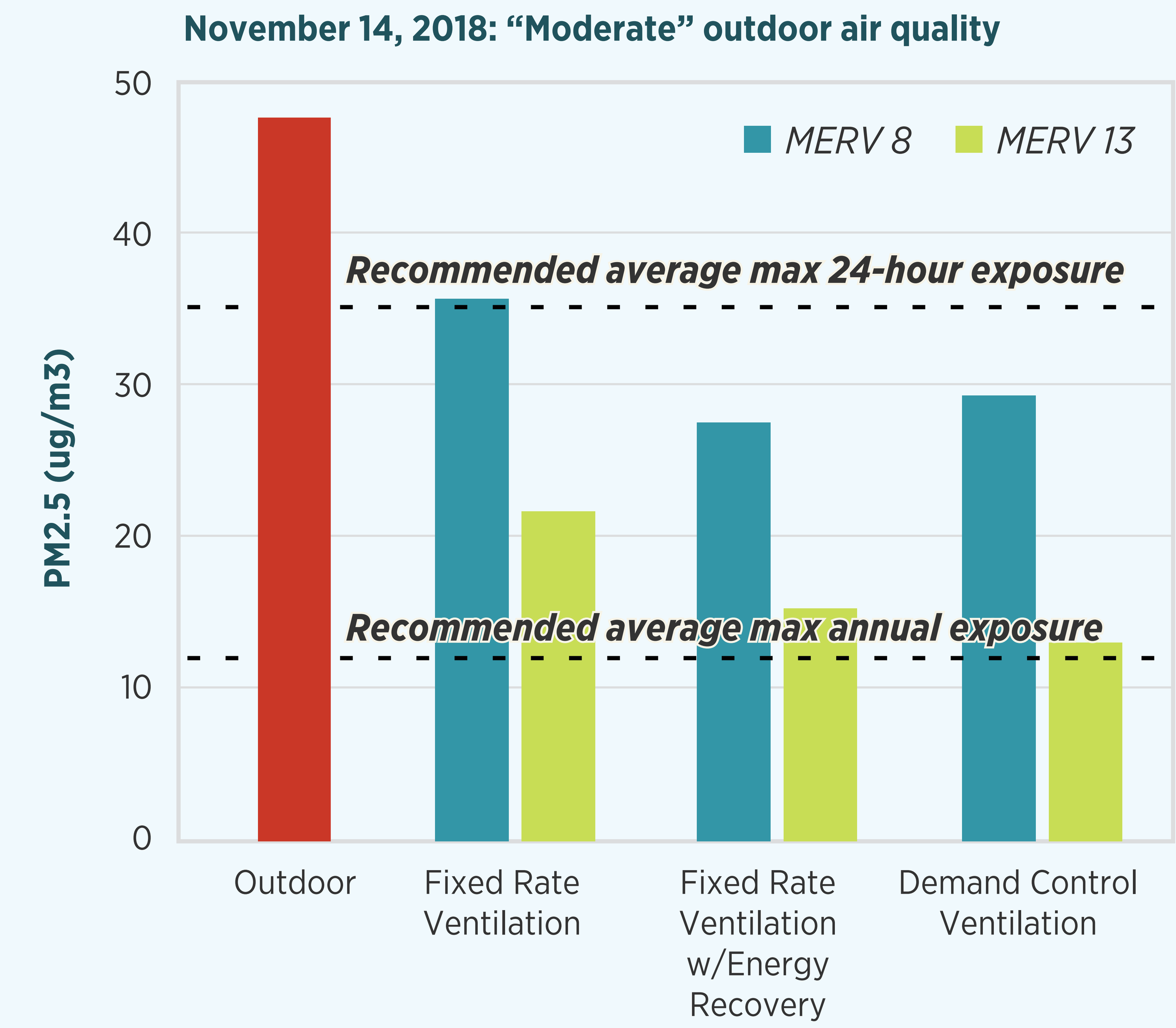
- **Better oversight** to ensure that the right HVAC equipment is purchased, installed, and commissioned properly in classrooms.
- **Performing routine filter maintenance.**
- **Running HVAC fans** as required during occupancy to bring in fresh air.
- **Monitoring classroom CO_2** concentrations with a CO_2 sensor in the thermostat or as a stand-alone sensor.

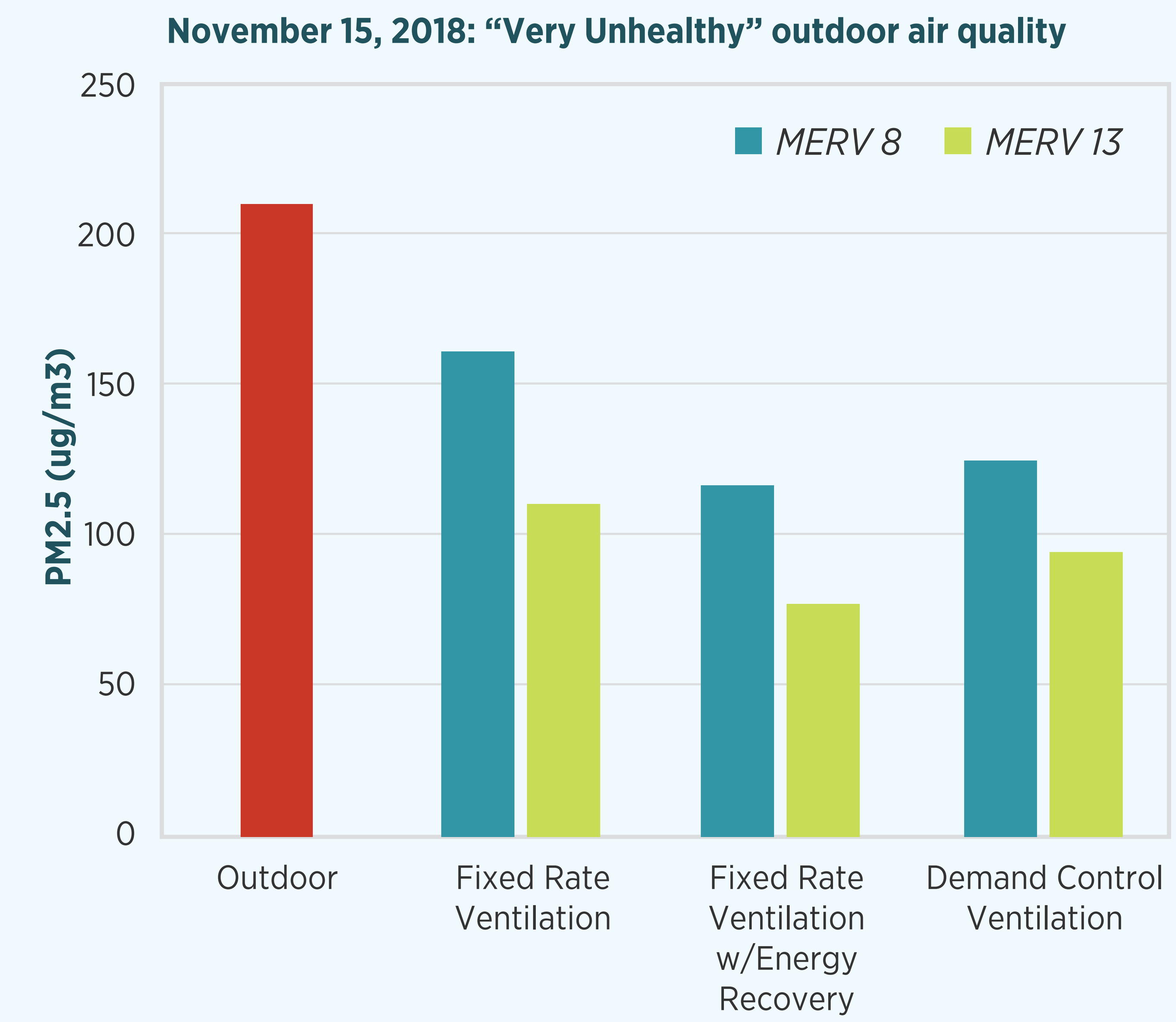
Path Forward

UC Davis is currently conducting two field demonstrations comparing three ventilation system options in two schools:

- Standard vs energy recovery vs demand control
- Standard vs high efficiency equipment
- Two filter options (MERV 8 vs MERV 13)

The analysis of results is ongoing and is being used to calibrate EnergyPlus models that will generate equipment recommendations for different regions of California.





Recent smoke days resulting from the Camp Fire showed the benefits of MERV13 filters. Poor air quality from the Camp Fire resulted in school closures in the Sacramento and Bay Area regions. In Sacramento area classrooms, MERV13 filters reduced indoor PM2.5 concentrations by 30-50% compared to MERV8.

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Advancing Demand Response in the Water Sector

UC DAVIS Center for Water-Energy Efficiency

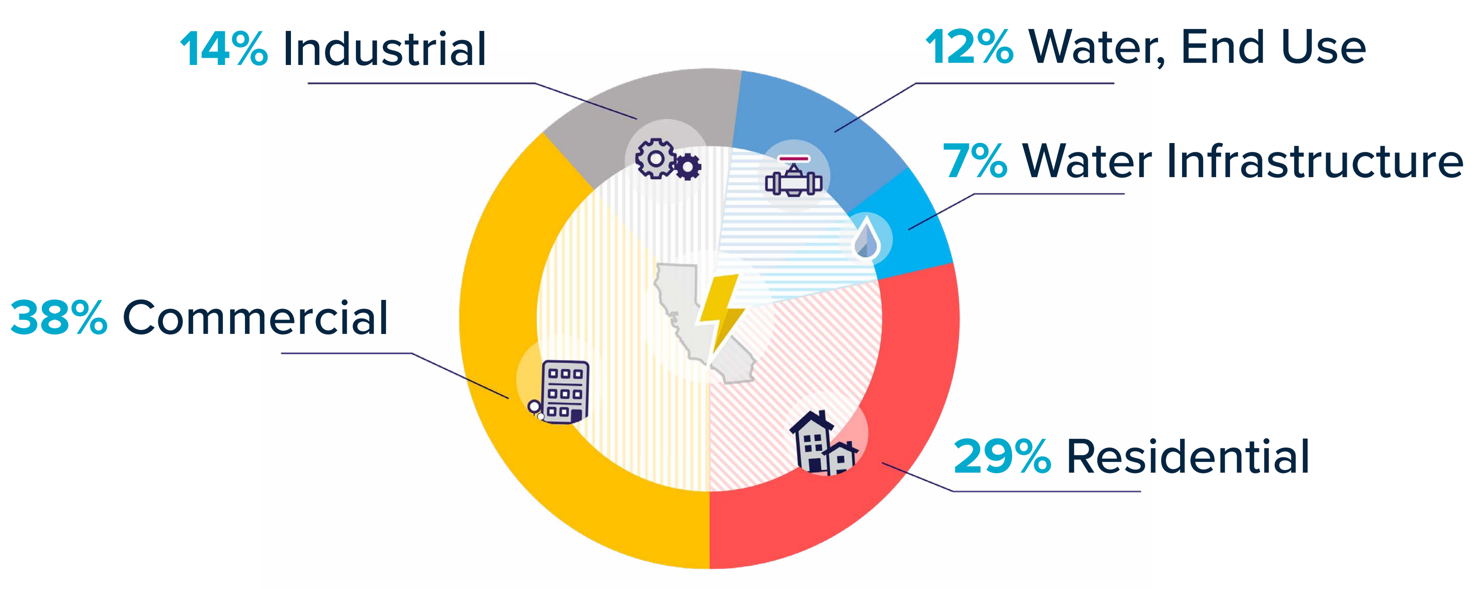
Frank Loge, Principal Investigator • Erin Musabandesu and Gregory Miller, Graduate Student Researchers

Project Purpose

To enable energy demand response in the water sector through **technological advancement**.

Why the Water Sector?

- **Water infrastructure** accounts for **7% of energy use** in California. In 2017, it was estimated that water distribution systems used roughly 1,150 GWh of energy.
- Water systems typically operate with coinciding water and energy demands. However, water systems have potential for energy demand flexibility.

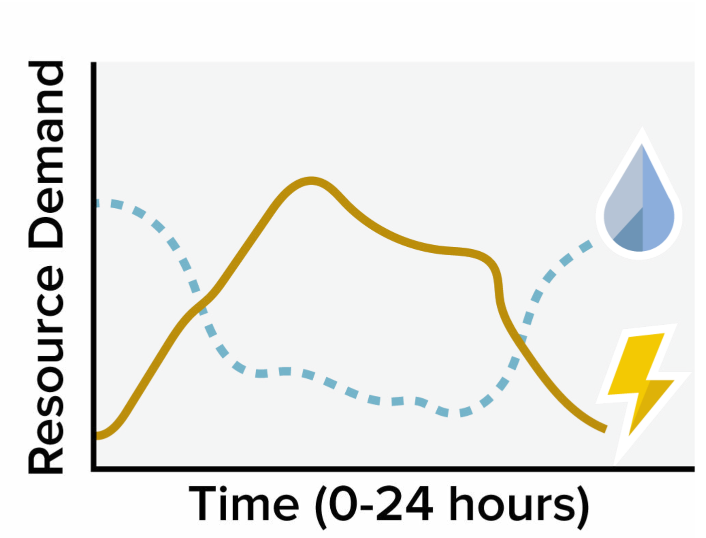


Breakdown of statewide electricity use in California.

Innovative Solution

This project will:

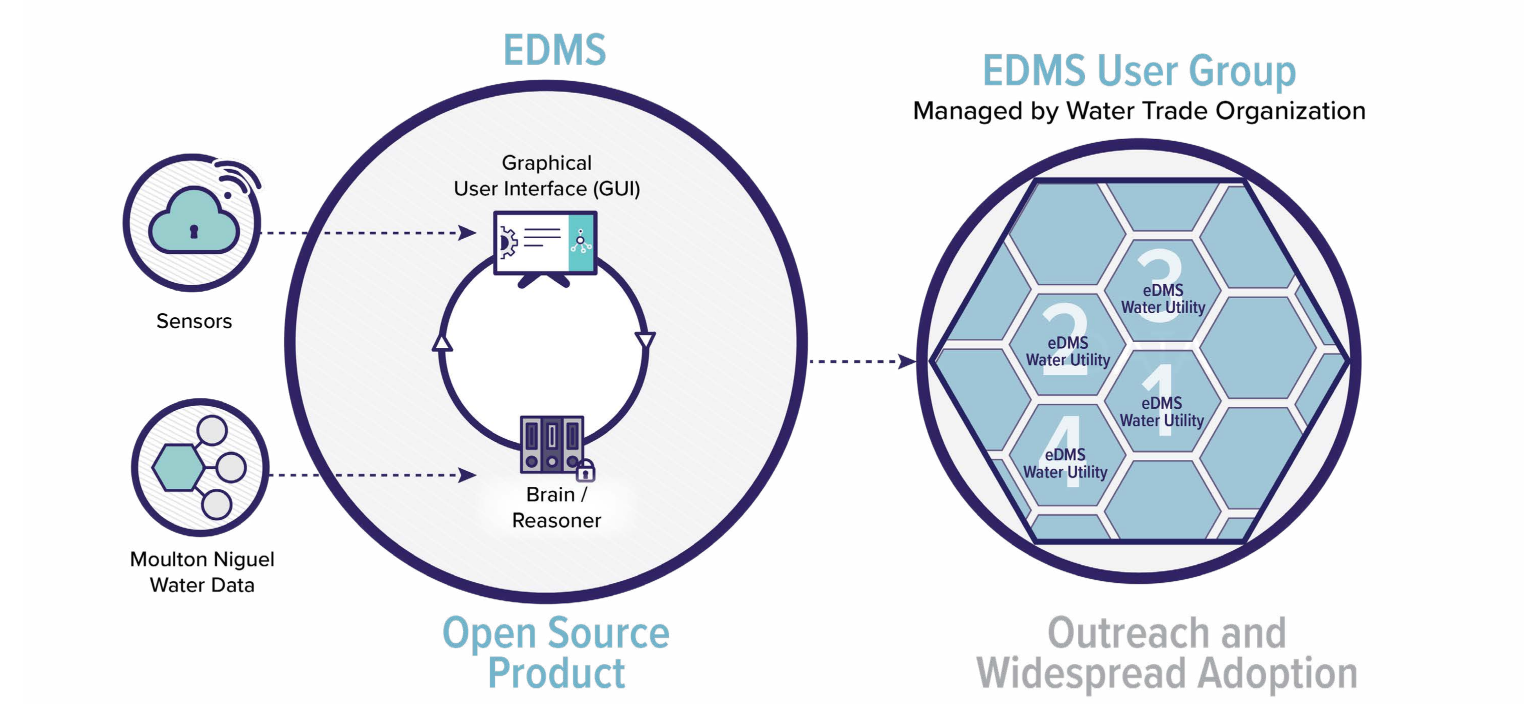
- Develop an **Energy Demand Management System (EDMS)** that enables water utilities to participate in energy load shifting to respond to various energy rate programs
- Pilot the EDMS to optimize energy while continuing to meet customer demands for the Moulton Niguel Water District **(MNWD)** drinking and recycled water systems which serves over **170,000 customers** in Southern California



Water system energy loads can be shifted with modified water storage and pumping operations.

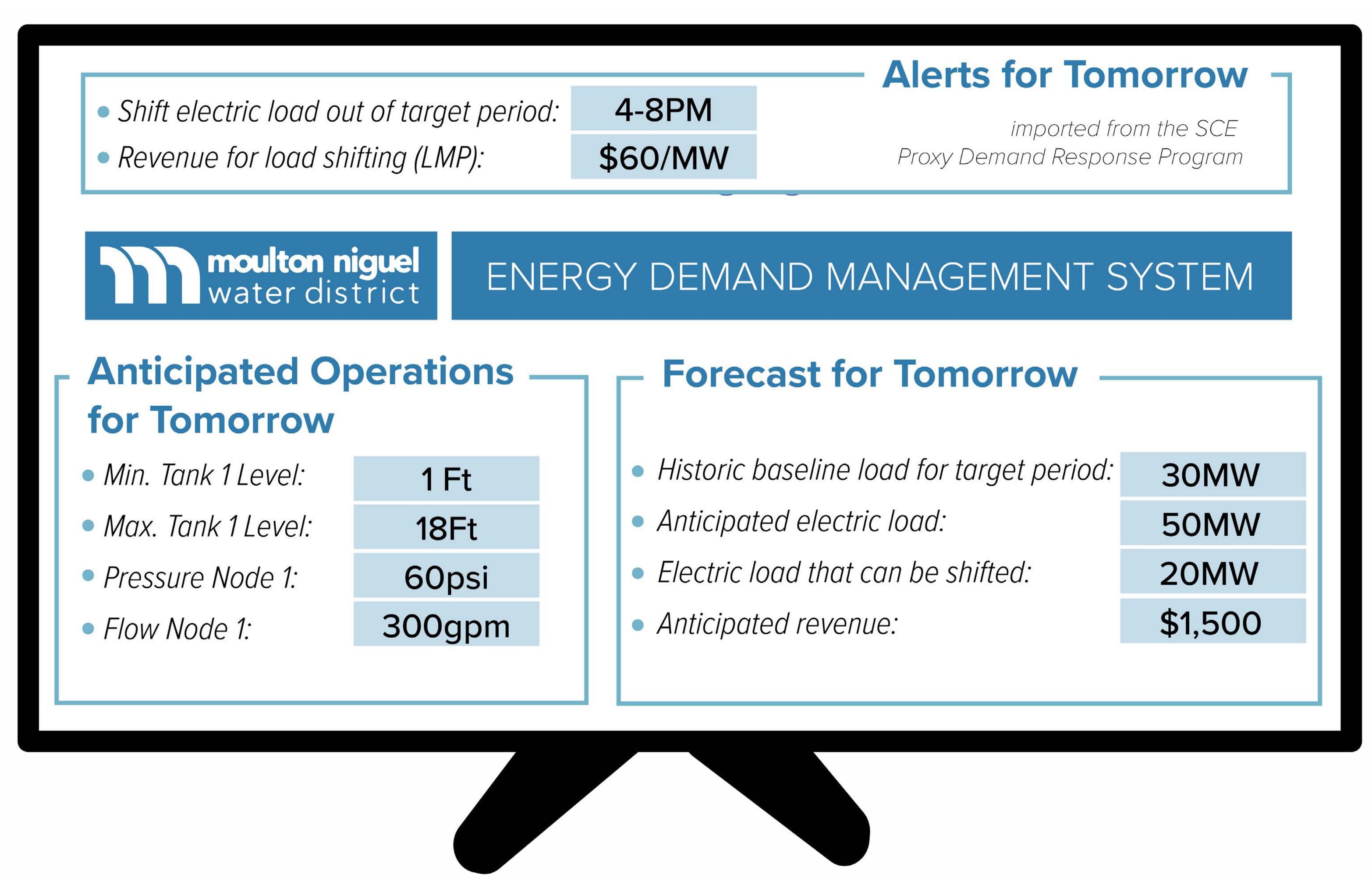
Energy Demand Management System

The proposed EDMS **provides forecasted operating recommendations** based on a selected energy rate programs by utilizing: real time and historical water system operation data, a hydraulic simulation model, optimization algorithms, operation analytics, and energy rate program data. The EDMS will be produced as an **open source software** and released to the public with widespread outreach activities.



EDMS Software Architecture Overview

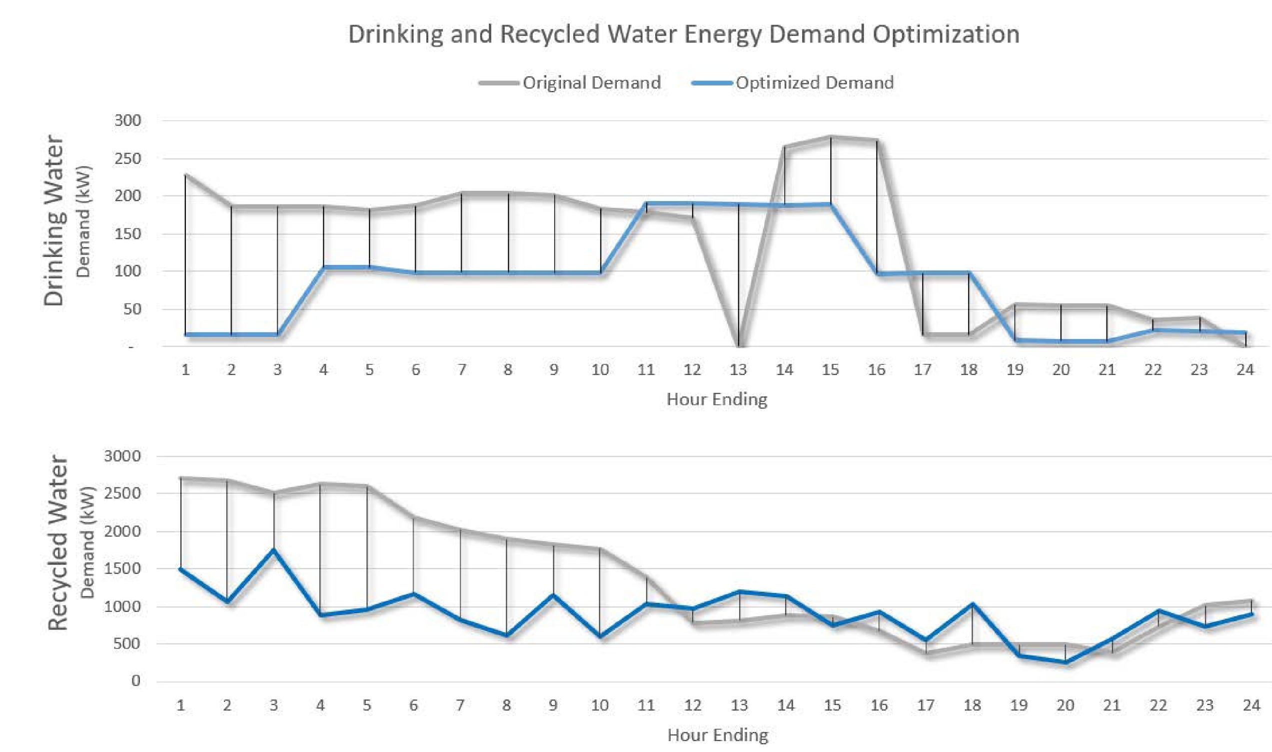
An EDMS user interface will allow water utilities to **visualize how forecasted operations compare to real operations** – with recommended adjustments to optimize energy demand and costs.



Example prototype of the EDMS graphical user interface.

Preliminary Results

A preliminary analysis of the MNWD water systems' energy demand flexibility was conducted by optimizing operations to the average hourly 2017 California Independent System Operator wholesale electric pricing.



Energy-Cost Optimization Simulations for the Drinking Water and Recycled Water Systems produced reductions to peak energy demand and total energy usage. The Drinking Water System shifted the majority of energy usage to periods of reduced greenhouse gas emission factors.

The drinking water system shows greater energy load shifting flexibility and energy efficiency potential, but is much less energy intensive than the recycled water system.

Optimized Scenario	Drinking	Recycled
Energy reduction	39%	34%
Emissions reduction	42%	36%
Emissions reduction from efficiency	92%	96%
Emissions reduction from load shifting	8%	4%

Energy-Cost Optimizations Results Summary

Statewide Impacts/Path Forward

Analysis will identify grid benefits that would be realized if the EDMS is scaled statewide. It has the potential to:

- **Balance** current **oversupply** of renewable energy
- **Reduce statewide electricity use** over 400 GWh/yr
- Help integrate new electric vehicle charging loads without adding distribution capacity

UC Davis will partner with a water trade organization who will help develop and support an EDMS Water Utility user group to encourage statewide adoption.

Energy and Water Savings from Onsite Water Reuse in the Wine Industry

UCDAVIS Center for Water-Energy Efficiency

Frank Loge, Principal Investigator • Amanda Rupiper, Graduate Student Researcher

Project Objective

Quantify the potential **water and energy savings** by utilizing an onsite reverse osmosis **(RO)** treatment system to recycle and reuse water at Jackson Family Wines **(JFW)**.

Technology Demonstration

The Vibratory Shear Enhanced Process **(VSEP)** technology will be used to **treat barrel wash wastewater** for **onsite reuse.** This project is unique in the following ways:

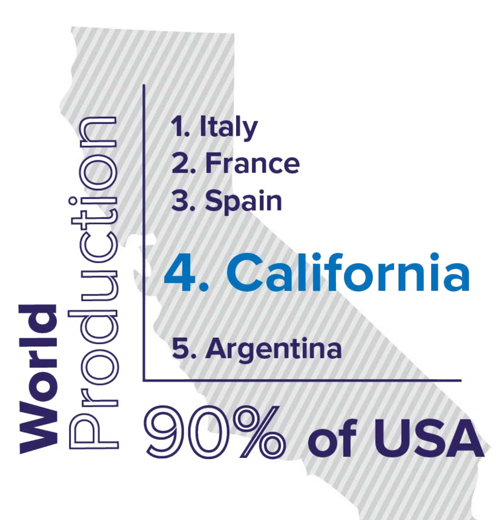
- **VSEP treats its own reject stream**, resulting in higher water recoveries (up to 90%) than conventional systems
- This will be the **first application of a vibratory RO membrane** and the first demonstrated reuse of non-potable water **for indoor processing at a winery**

VSEP water recycling technology demonstration at the winery

Barrel washing line at the winery

Why a Winery?

- California is a global leader in wine production
- **The JFW facility** in Sonoma County **accounts for 2%** of the wine production in California



Winery Water-Energy Life Cycle

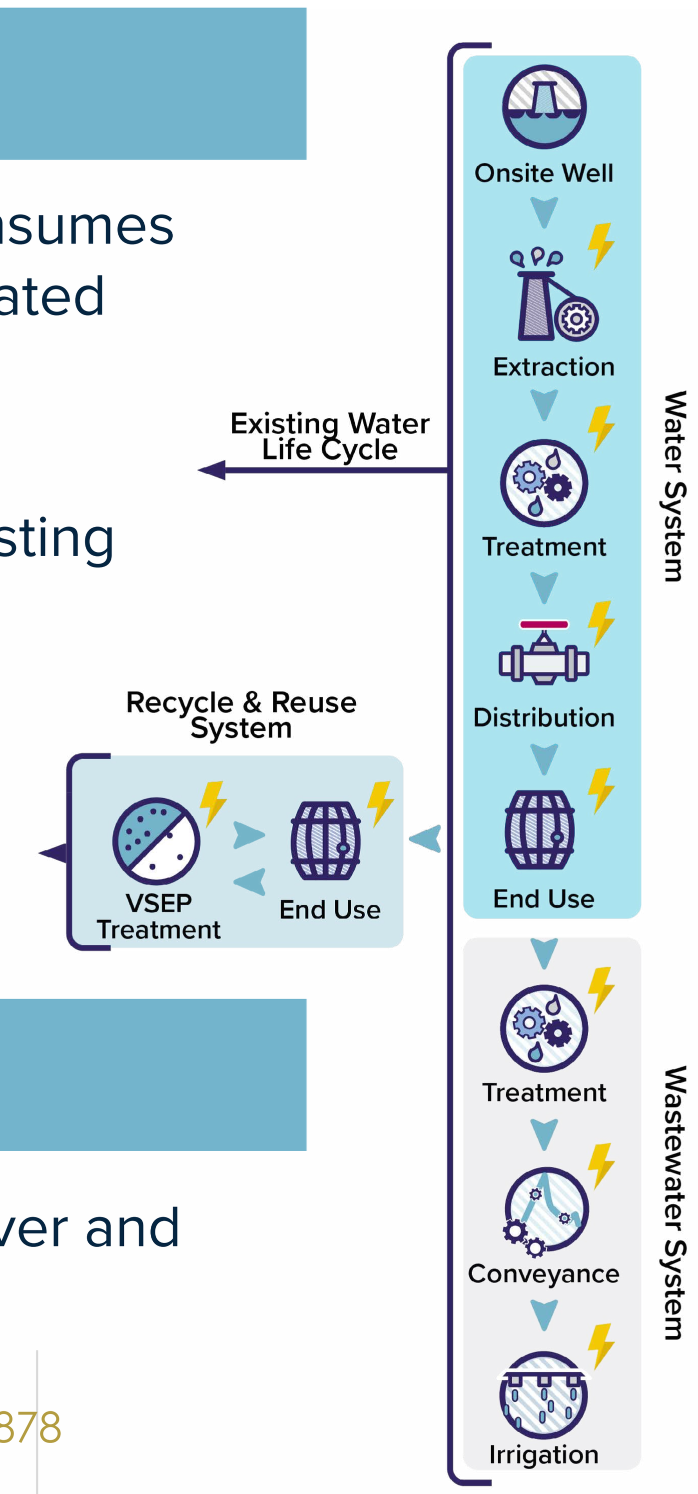
Every step of the water life cycle at the winery consumes energy. When water is reused, many of the associated energy requirements are in turn eliminated.

Existing Life Cycle:

Energy is consumed through every step of the existing **water** and **wastewater systems**.

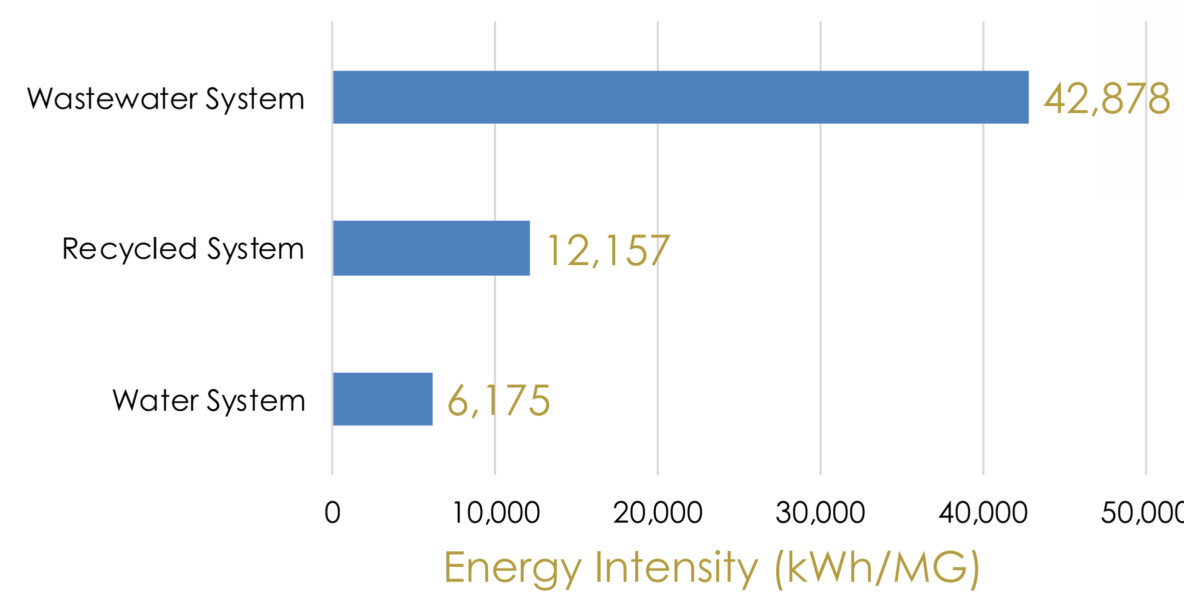
Proposed Reuse Life Cycle:

Recycling and reuse **eliminates the energy** requirements of the existing water and wastewater systems.



Energy Intensity

Energy Intensity **(EI)** is the energy required to deliver and treat a unit of water onsite.



Energy intensity of the individual water and wastewater systems at the winery

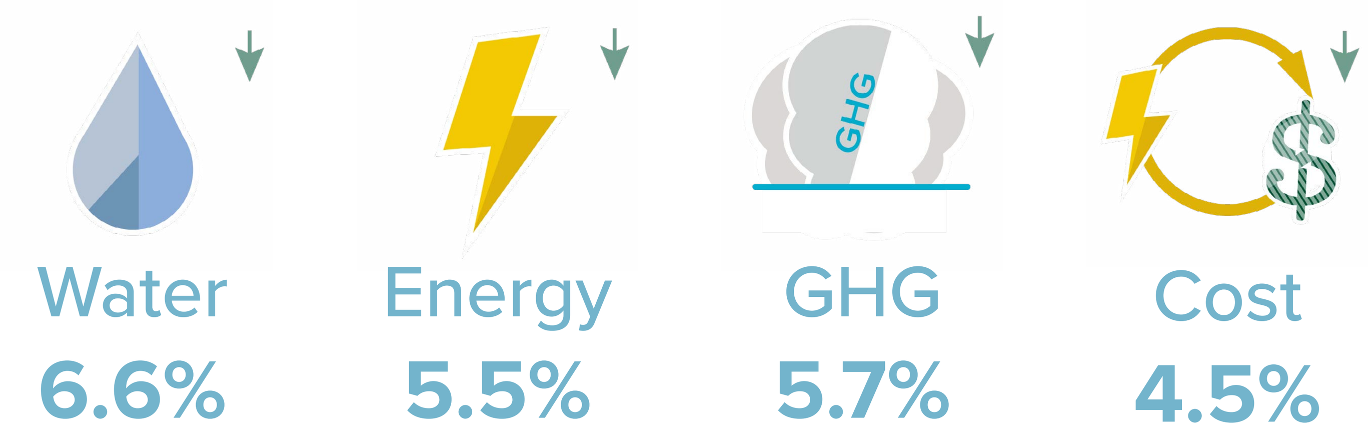
The wastewater system has a high EI. The recycled water configuration can treat up to 90% of the wastewater and only utilizes 25% of the energy needed for the wastewater system.

	Existing Conditions	Post Water Recycling	% Difference
Freshwater Use (GPY)	1.6M	160K	90%
Energy Use (kWh/y)	67K	25K	63%

Water and energy reductions as a result of onsite water recycling

Projected Resource Savings

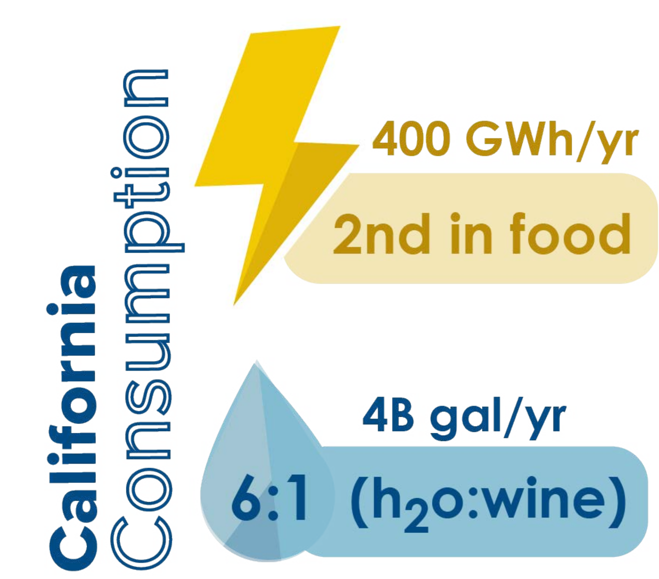
1.5MG of water per year are utilized for barrel washing alone. **Using VSEP to recycle 90% of that water** would result in a **facility-wide reduction** of potable water demands by **6.6%**.



Facility-wide projected savings

The Path Forward for California

The success of this project will **open a path** to onsite reuse for other progressive industries **by demonstrating** the potential **benefits and safety** of these systems to regulators, businesses, and consumers. **Water intensive industries** in California can reduce **fresh water consumption** while also **reducing energy use** and in turn, reducing GHG generation. For the wine industry alone, uptake of onsite technologies could result in annual water savings of up to **3.6 billion gallons**.



Resource consumption of the California wine industry