

# ET Summit 2019

Presented by



# Ventilation Solutions for Energy Efficient California Schools

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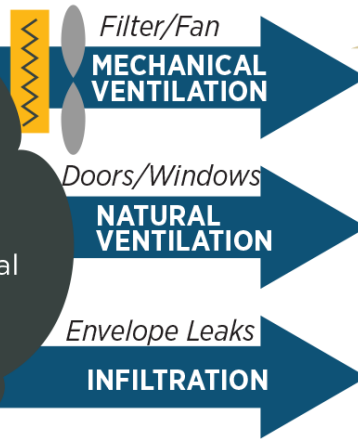
UC Davis Western Cooling Efficiency Center

## Ventilation Overview

### OUTDOOR POLLUTANT SOURCES

#### PARTICULATE MATTER

- Vehicle emissions
- Power generation
- Industrial and agricultural processes
- Wildfire smoke



### INDOOR POLLUTANT SOURCES

#### VOCS/FORMALDEHYDE

- Building materials
- Office equipment
- Cleaners/etc.

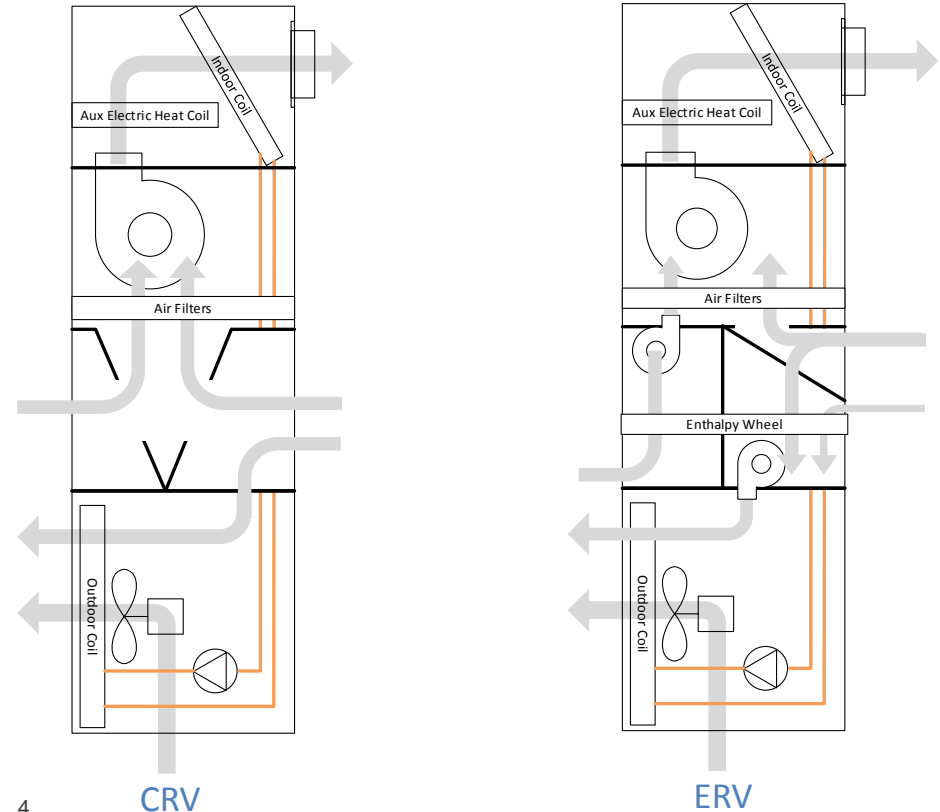
#### CARBON DIOXIDE (CO<sub>2</sub>)

- Building occupants



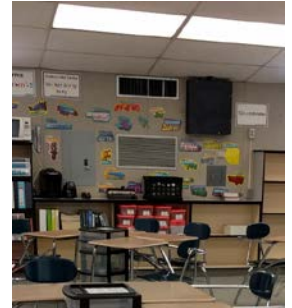
# Field Testing Packaged Wall-Mount HVAC Retrofits

- Heating/Cooling Equipment (3 Types)
  - Baseline Efficiency Gas/Electric
  - High Efficiency Gas Electric
  - High Efficiency Heat Pump
- Ventilation System Options (3 Types)
  - Constant Rate Ventilation (CRV)
  - Demand Control Ventilation with Economizer (ECON-DCV)
  - Energy Recovery Ventilation (ERV)
- Filters (2 Types)
  - MERV 8
  - MERV13



# School Selection/Characterization

- Sacramento High School
  - 7 portable classrooms
  - Grades 10-12
  - 960 ft<sup>2</sup> of floor area
  - No HVAC ducting
  - LED lighting (Lighting power density 0.6 w/ft<sup>2</sup>)
  - Rooms was occupied 4-7 periods per day and the number of students per period varied from 20 to 36.
- Bakersfield Elementary School
  - 6 portable classrooms
  - Grades 1-3
  - 960 ft<sup>2</sup> of floor area
  - HVAC supply ducts with 2 registers (one classroom with 4 registers)
  - Fluorescent T8 lighting (Lighting power density 1.3 W/ft<sup>2</sup>)
  - 20-24 students



# Monitoring Approach

## Monitoring Periods

- Sacramento: February 8th, 2018 and March 22nd, 2019
- Bakersfield: May 1st, 2018 and April 12th, 2019

## Year-Long HVAC Operation and Environment Monitoring

- Total Power
- Supply, Return, Outdoor, and Room Air Temp/Humidity
- Supply Air Flow Rate (One time, track pressure)
- Outdoor Air Fraction (One time, track damper position)
- Outdoor and Room CO<sub>2</sub> and PM<sub>2.5</sub>

## Intensive Indoor Air Quality Monitoring (Three 1-week visits)

- CO<sub>2</sub> (Vaisala) (calibrate long-term measurement)
- PM<sub>2.5</sub> (DustTrak, gravimetric) (calibrate long-term measurement)
- Black carbon (ABCD)
- Ozone (2BTech)
- Formaldehyde (Time-resolved and passive)



## Field Results – Energy Impacts

- Fan power increase due to MERV 13 Filters averaged 20W (estimate 30kWh annually) in ventilation mode, consistent with manufacturer pressure drop data for filters.
- ECM motor reduced ventilation electricity consumption by 53%
- ERV system **increased** average electricity consumption by
  - 46% (Sacramento)
  - 10% (Bakersfield)
- ERV reduced winter peak demand by 38%
  - reduced electric resistance backup heat
- ECON-DCV most energy efficient strategy, saving:
  - 8% in Sacramento
  - 18% in Bakersfield
- Standby electricity consumption a significant concern
  - Estimate 3-5 watts for controls systems (small)
  - Up to 40 Watts for crankcase heaters, which may run 24/7

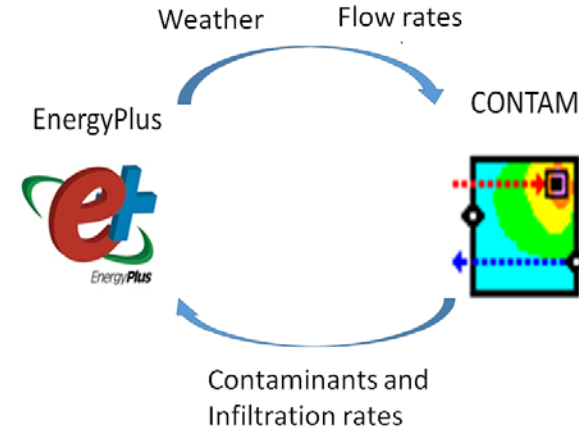
## Field Results – Indoor Air Quality

- CO<sub>2</sub> levels higher in high school (greater occupancy)
- Clear benefits of using MERV 13 air filters over MERV 8 in lowering PM<sub>2.5</sub> 41-45%.
- Air filter removal efficiency of black carbon appeared lower than for PM<sub>2.5</sub>
- Reducing ventilation rates when possible yielded lower concentrations of air pollutants from outdoor (e.g., ozone)
- Formaldehyde concentrations in classroom vary seasonally; the need for pre-occupancy flush ventilation is reduced in winter, especially in colder climate



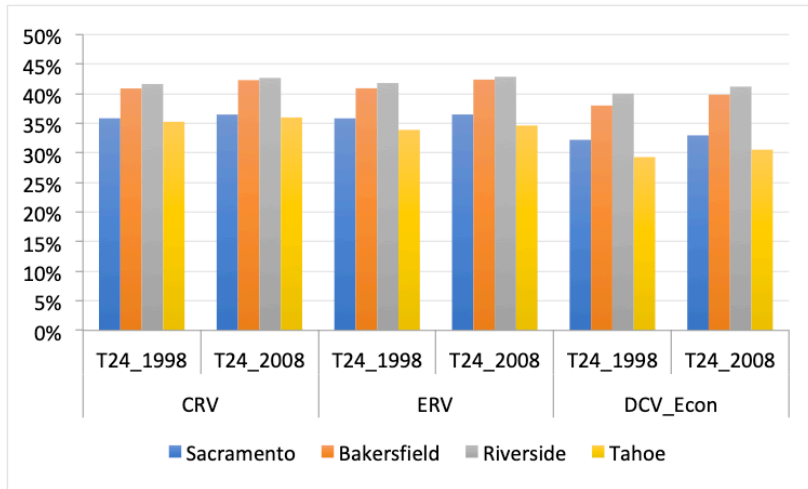
## IAQ and Energy Modeling Methods

- Co-simulation using EnergyPlus (DOE) and Contam (NIST)
  - Energy modeling in EnergyPlus
  - Contaminant modeling in Contam
  - Enables multiple contaminants
  - Enables loss of contaminants in HVAC
- Simulation of retrofit options:
  - 4 Climate zones (CZ10, CZ12, CZ13, CZ16)
  - 3 systems CRV, ERV, DCV + Economizer
  - 2 classroom vintages: 1998, 2008
  - 2 classroom types: elementary, secondary
  - 2 HVAC filter MERV ratings: 8, 13



## Modeling Results – PM2.5

% Reduction in PM2.5 comparing MERV8 and MERV13 air filters



Number of school days with indoor PM<sub>2.5</sub> >12 ug/m<sup>3</sup> (annual ambient standard)

		CRV 1998	CRV 2008	ERV 1998	ERV 2008	DCV 1998	DCV 2008
Sacramento*	MERV 8	25	26	24	27	31	31
Sacramento*	MERV 13	2	1	1	1	4	3
Bakersfield	MERV 8	66	66	66	66	72	74
Bakersfield	MERV 13	22	19	22	19	25	23
Riverside	MERV 8	89	90	89	89	93	93
Riverside	MERV 13	12	8	11	8	12	10
Tahoe	MERV 8	67	68	71	72	88	87
Tahoe	MERV 13	2	2	3	3	5	4

\* 2018 November excluded from Sacramento results due to the unusual impact from wildfire.

## Modeling Results: Energy

- MERV13 filters increased HVAC energy consumption by 29-38 kWh annually (2-4% of energy used by HVAC system)
- Average Savings of ERV or ECON-DCV systems compared to CRV
  - ECON-DCV Upgrade Cost - \$770
  - ERV Upgrade Cost - \$1780

kWh (%)	ERV - Elementary	ERV - Secondary	ECON-DCV - Elementary	ECON-DCV - Secondary
Sacramento	95 (8%)	34 (3%)	305 (26%)	268 (20%)
Bakersfield	-40 (-3%)	-92 (-7%)	228 (20%)	199 (15%)
Riverside	-143 (-13%)	-183 (-14%)	172 (16%)	163 (13%)
Tahoe	910 (43%)	870 (39%)	916 (43%)	705 (32%)

This project was funded by California Energy Commission's Electric Program Investment Charge (EPIC) program.

For more information, contact Yu Hou at [yu.hou@energy.ca.gov](mailto:yu.hou@energy.ca.gov)

The project report is currently in the CEC publication process

Publication on previous project results:

<https://authors.elsevier.com/a/1Zssc1HudMzk9z>

Available free until November 27.

Thank you

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Check for updates

Ventilation rates in California classrooms: Why many recent HVAC retrofits are not delivering sufficient ventilation

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ABSTRACT

Previous research has shown that under-ventilation of classrooms is common and negatively impacts student health and learning. To advance understanding of contributing factors, this study visited 104 classrooms from 11 schools that had recently been retrofitted with new heating, ventilation, and air-conditioning (HVAC) units. CO<sub>2</sub> concentrations were measured multiple times during each visit to determine the relationship between CO<sub>2</sub> concentration and ventilation rates.

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