UCDAVIS
Western Cooling Efficiency Center

Reducing Barriers to Indirect Evaporative Cooling

David Vernon

Co-Director of Engineering

UC Davis Western Cooling Efficiency Center

OUR MISSION

Accelerate the development and commercialization of efficient heating, cooling, and energy distribution solutions through stakeholder engagement, innovation, R&D, education, and outreach.

WCEC TEAM

KEY SPONSORS

California Energy Commission
California Utilities
Federal Agencies: DOE, DOD, NASA
Corporate Affiliates

Established April 2007
Part of the UC Davis Energy and Efficiency Institute

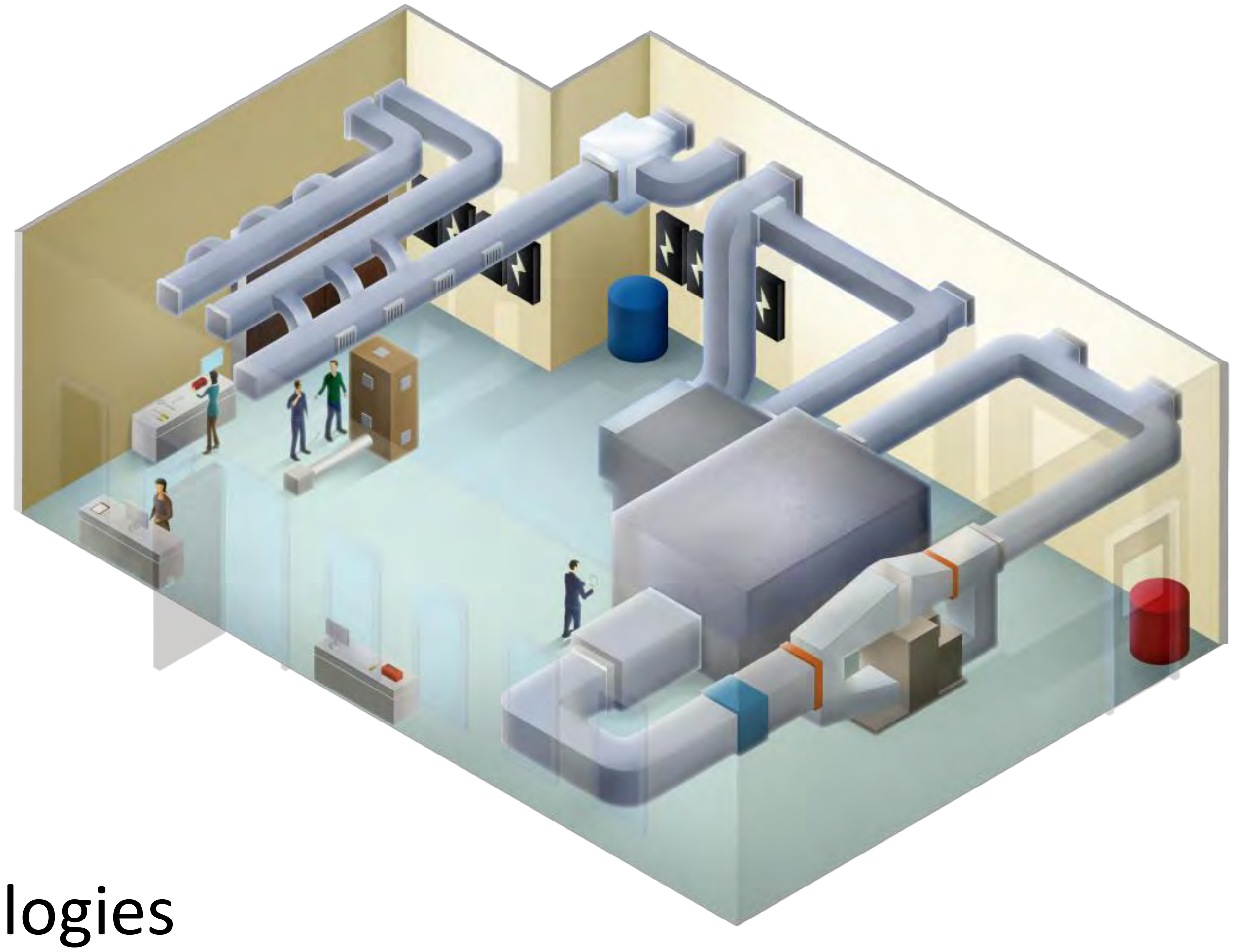
Vinod Narayanan Director
Mark Modera Associate Director

13 Full-time Engineers
1 Behavioral Scientist
3 Graduate Students
6 Undergrad Students
4 Support Staff

WCEC EXPERTISE

Unique Leadership in

- Climate-appropriate cooling technologies
- Laboratory testing

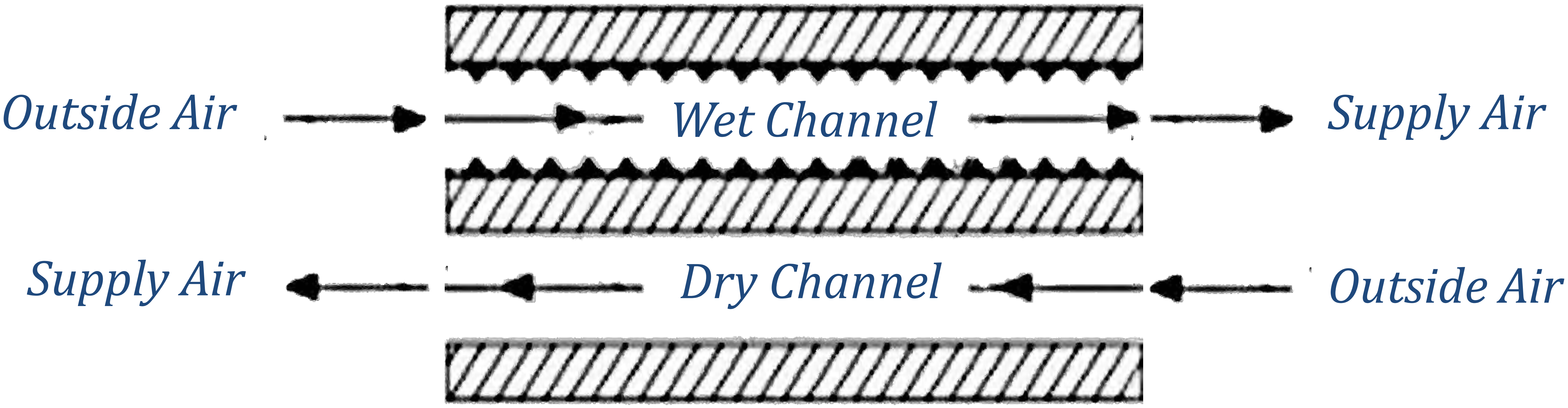


Significant Expertise in

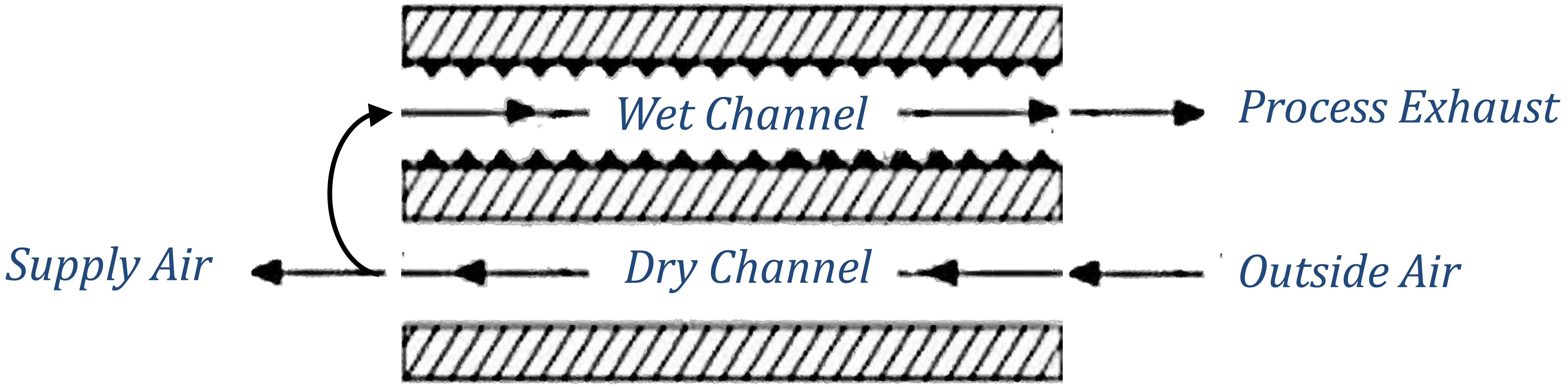
- 3rd party technology evaluation
- Modeling
- Field monitoring of HVAC technologies
- Distribution systems for ventilation and thermal energy
- Test standards development
- Human behavior
- Internet control of HVAC systems

Direct Evaporative Cooling

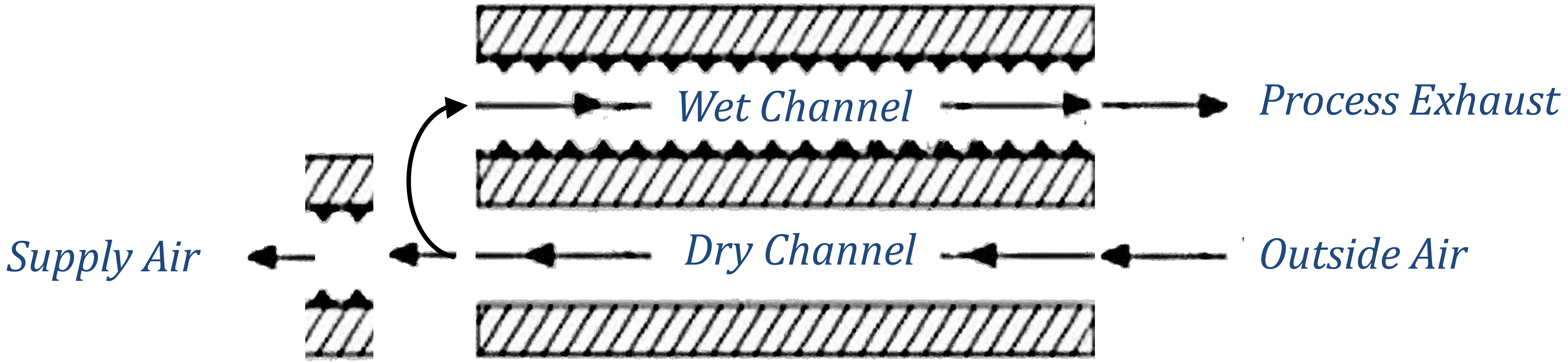
First Generation
Indirect Evaporative Cooling



Second Generation Indirect Evaporative Cooling



Third Generation
Indirect – Direct Evaporative Cooling



Indirect Evaporative Cooling Products: Large Buildings DOAS and ventialtion pre-cooling

Seeley CW-80

Air_2O CRS

Munters DOAS

Cambridge ESC

Indirect Evaporative Cooling Products: Light Commercial

Seeley CW-15

Air_2O

Indirect Evaporative Cooling Products: Residential

Seeley CW-3

Why Indirect Evaporative Cooling?

» Reduce energy consumption
» Reduce peak power

Why NOT Indirect Evaporative Cooling?

» Limited to dry climates
» Design complexity (sizing and need separate heat source)
» Installed cost
» Water consumption

Past system layout:
Separate unit adds:

- Design steps
- Controls step
- Weight
- Cost

Hybrid packaged product:

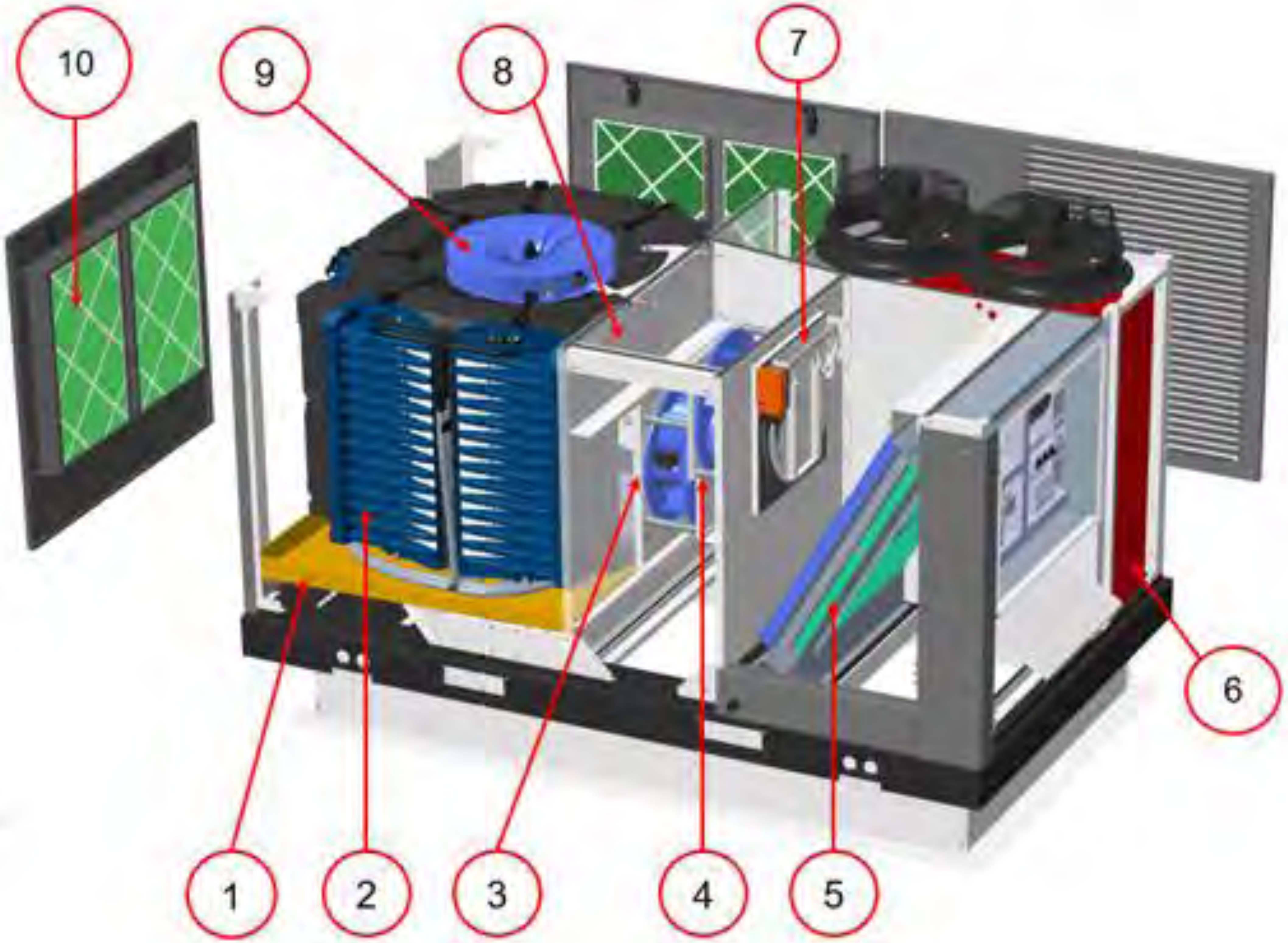
- Adds a little weight
- Close to "like for like"

Hybrid packaged product:

Seeley Climate Wizard Hybrid

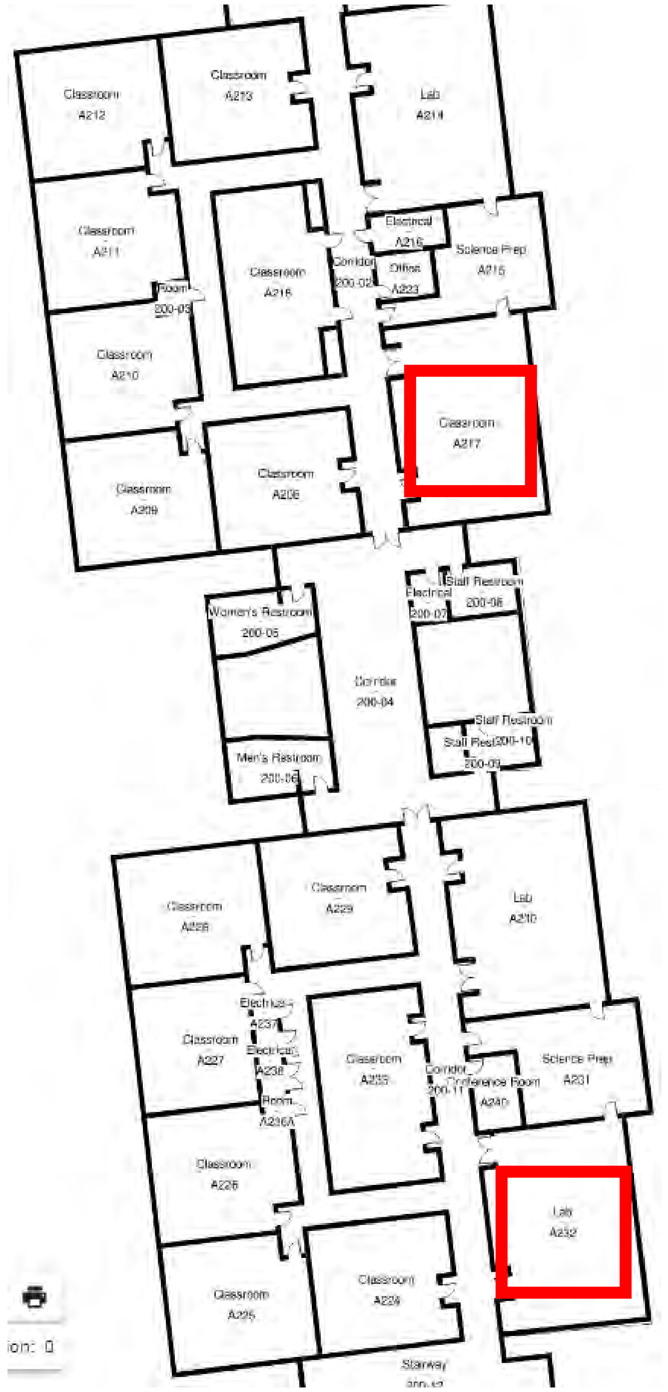
Air2O Hybrid CRS

Climate Wizard Hybrid

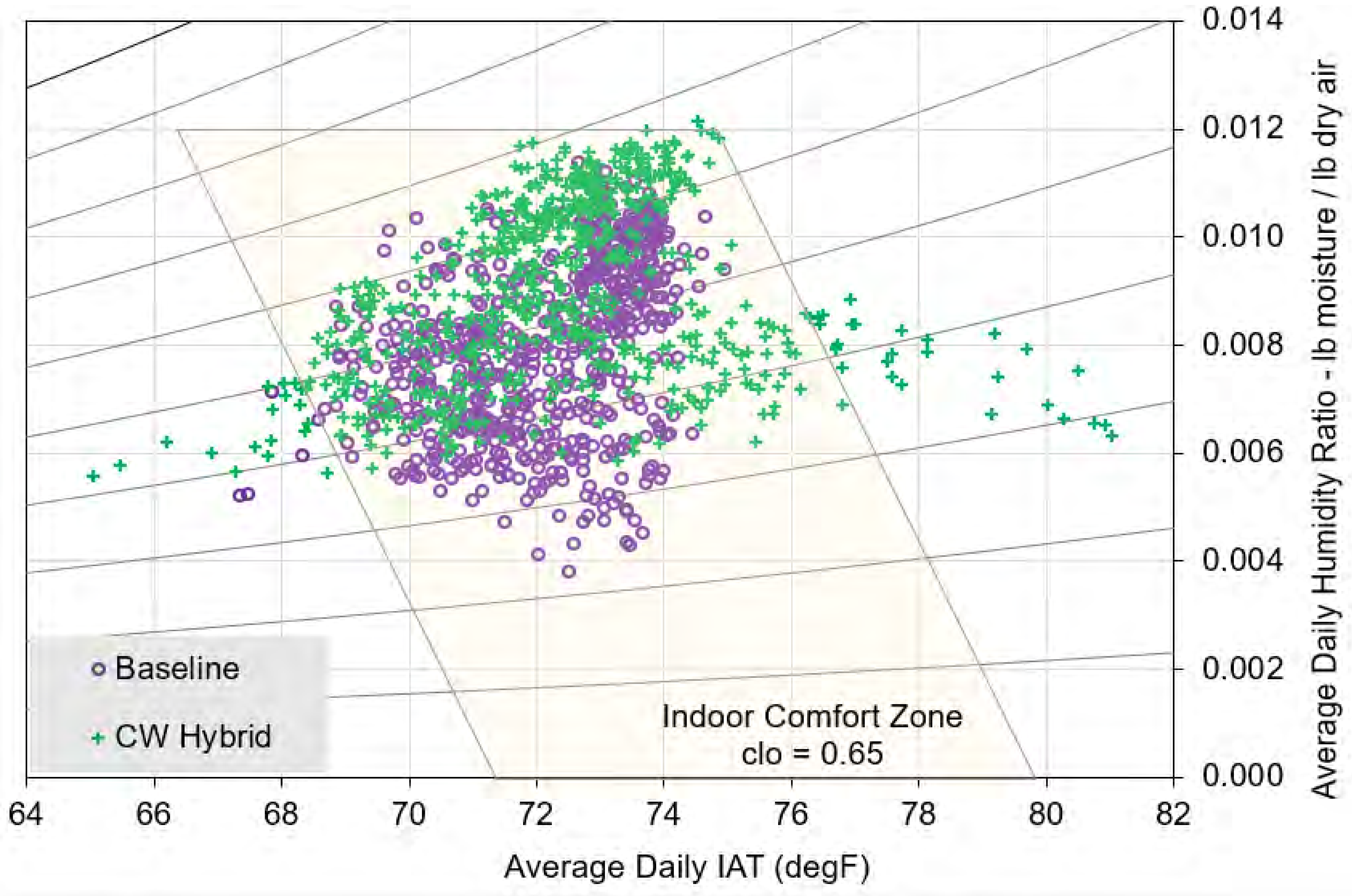


Callout No#	Description
1	CW water tank
2	Heat exchangers
3	CW supply fan
4	DX supply fan
5	Evaporator coil assembly
6	Condenser coil
7	DX Damper
8	CW Damper (not visible)
9	CW exhaust fan
10	Outdoor air filters

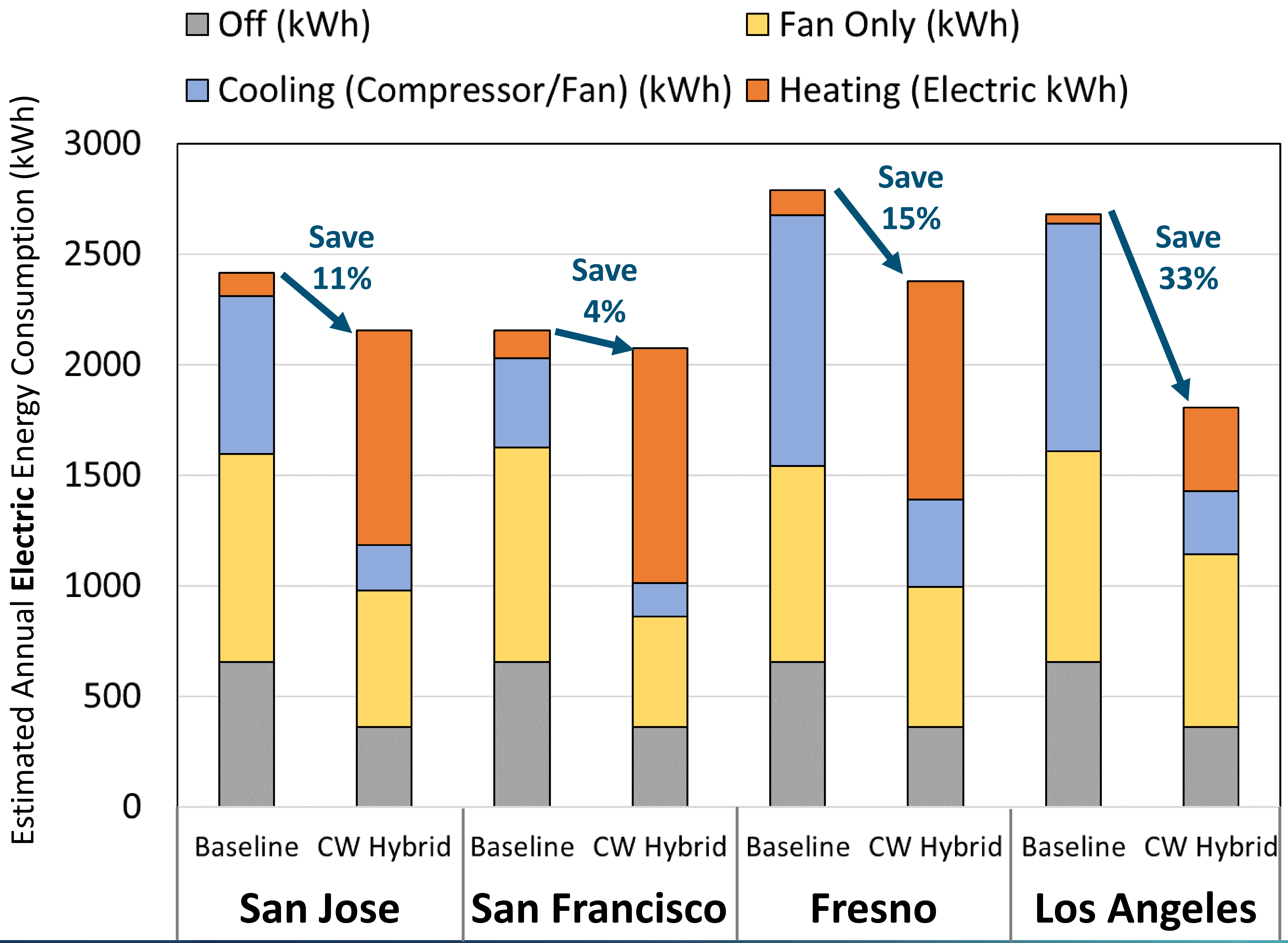
San Jose High School Classroom Field Test April 2021 -Continuing



Indoor Comfort



San Jose Field Test: Hybrid Unit Vs Existing Roof Top Unit



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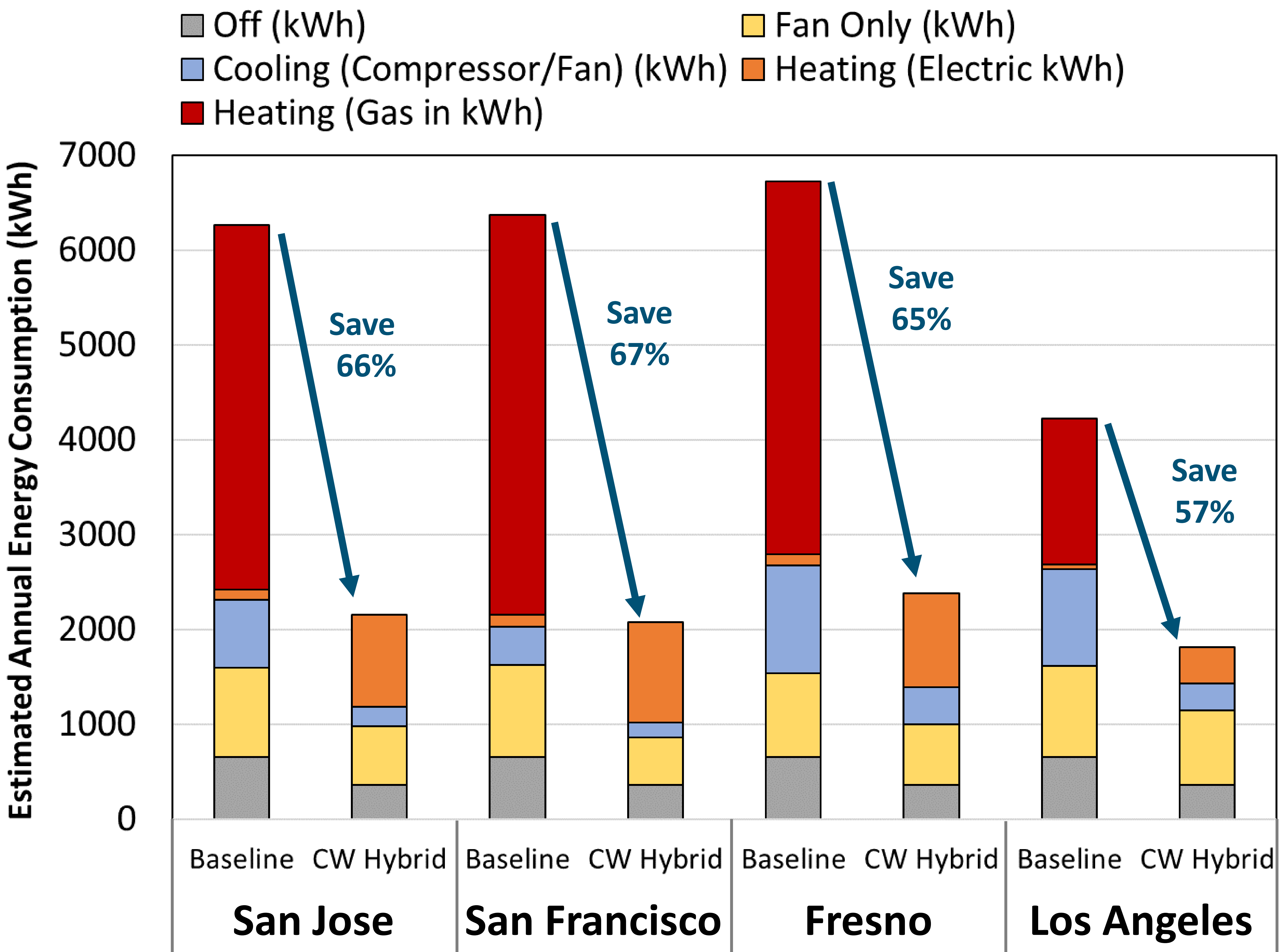

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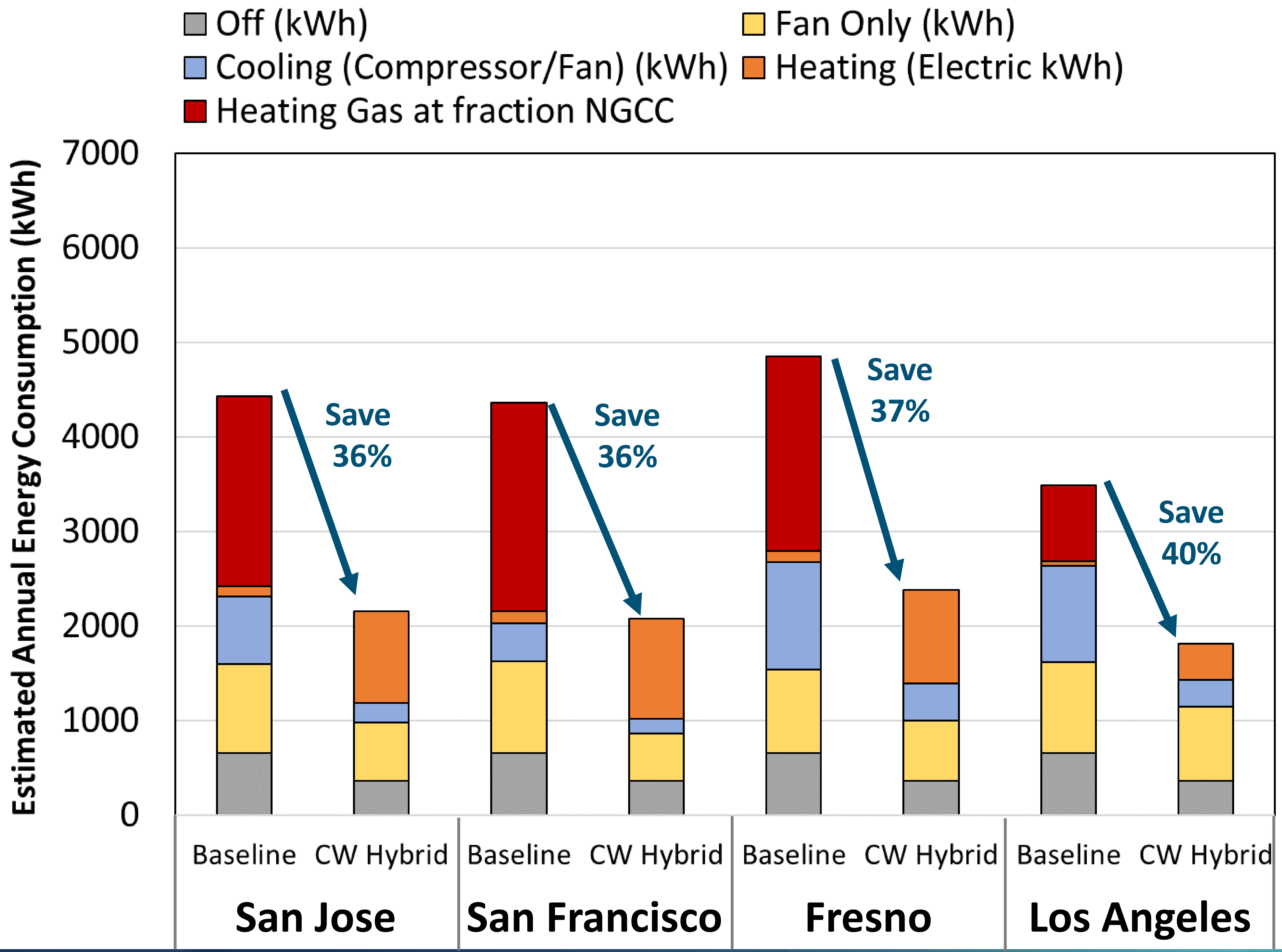
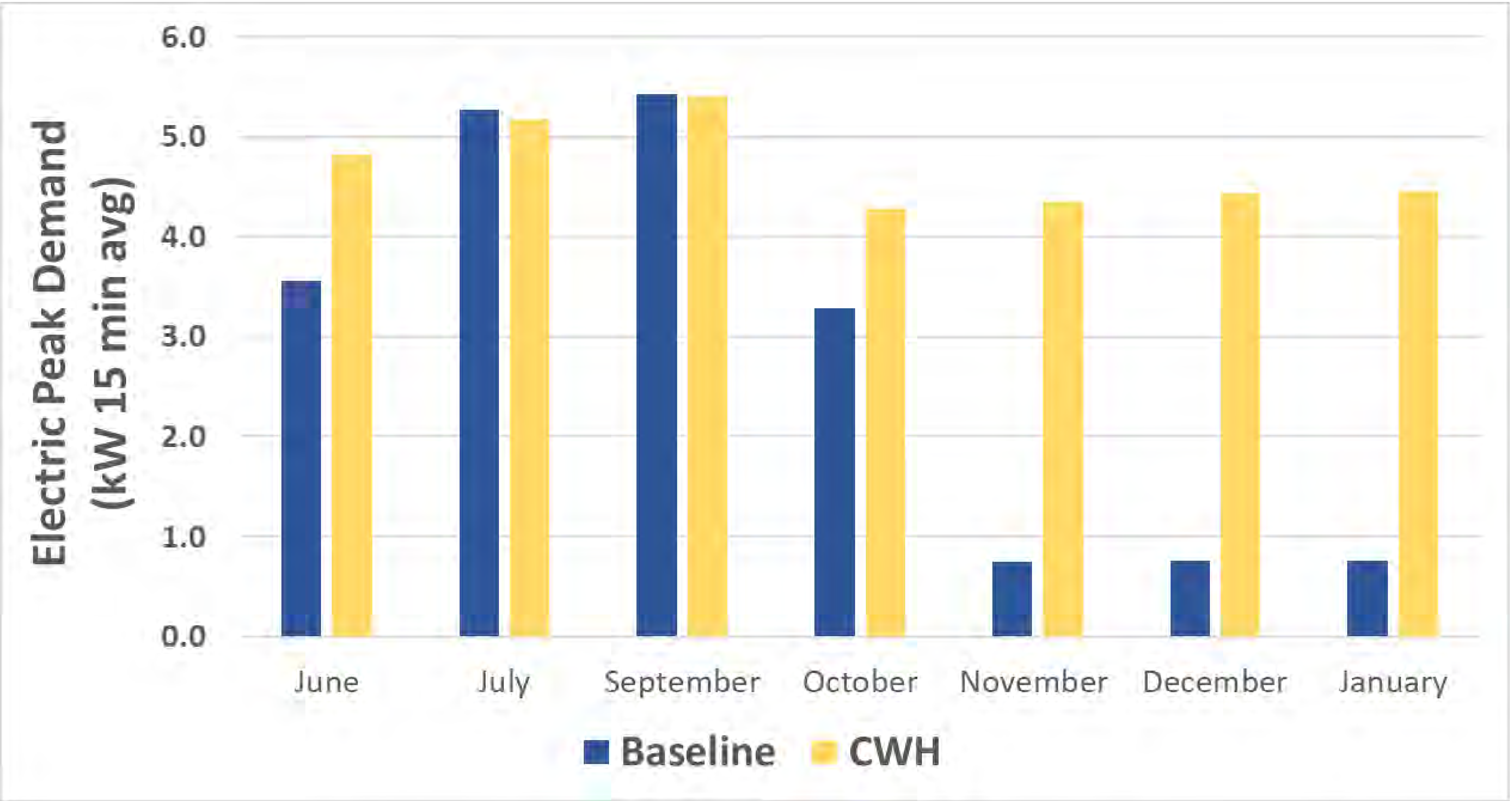




Electric Peak Demand (kW 15 min avg)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
June
July
September
October
November
December
January
Baseline
CWH

Indoor Air Quality

- Climate Wizard Hybrid increases ventilation by 25% to 60% depending on climate zone while still achieving the energy savings shown

Water Consumption

- Estimated at an average use of 8.5 gallons per kWh saved
- Cost of water is a small fraction of utility cost savings (typically less than 20%)

Next Steps

» Continue San Jose field test monitoring to:
  - Test peak demand reduction control strategies

» Field Tests and or Laboratory Tests to:
  - Validate savings estimates in more climates for Seely Climate Wizard Hybrid
  - Develop savings estimation model and validate for Air_2O Hybrid CRS

» Field tests at larger number of sites to:
  - Familiarize designers and trades
  - Prove reliability
  - Identify any additional market barriers

CASE STUDIES | PRESS ARTICLES | NEWS | HVAC PRESENTATIONS | NEWSLETTER | REPORTS | PUBLICATIONS | INTERVIEWS | RESEARCH | EDUCATION | DEMONSTRATION BRIEFS | OVERVIEW | OUTREACH | MISSION | CONTACT | TECHNICAL SERVICE AGREEMENTS |

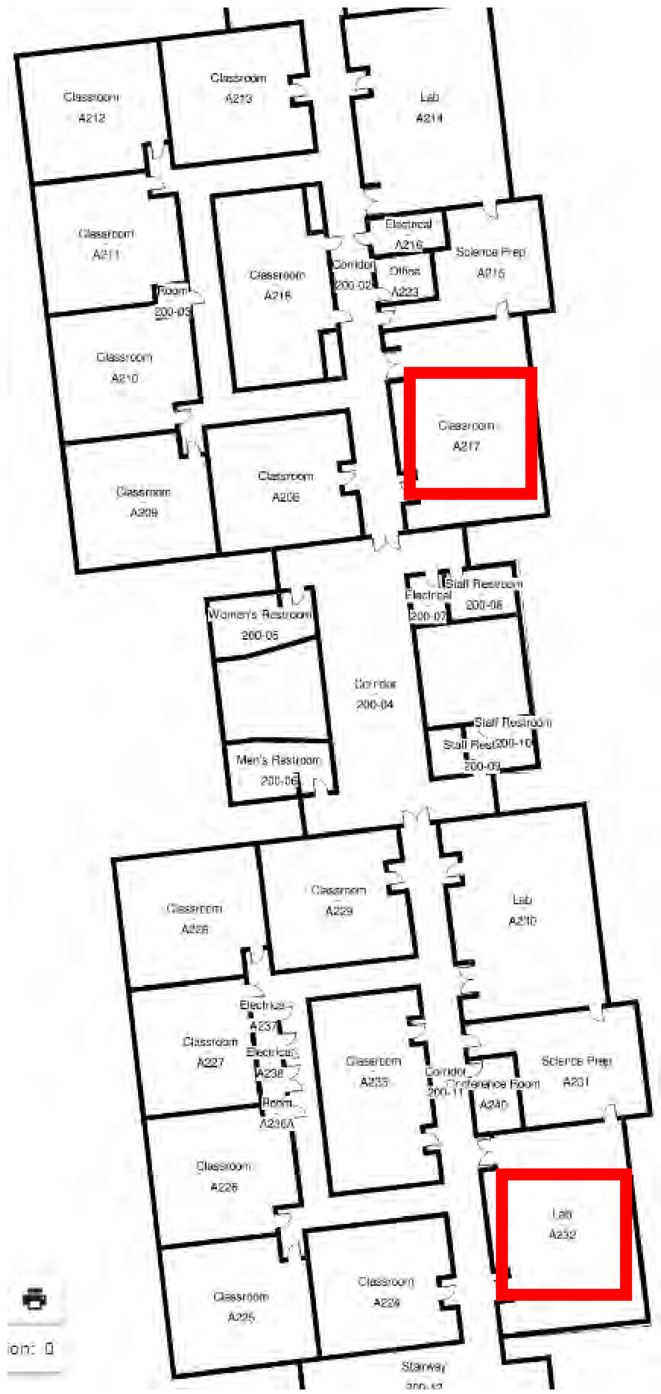
wcec.ucdavis.edu

TECHNOLOGY TOPICS | SECTOR RESEARCH | BEHAVIORAL RESEARCH | SYSTEMS INTEGRATION | CONTROLS | DEMAND SIDE MANAGEMENT | EVAPORATIVE TECHNOLOGIES | RADIANT COOLING | TITLE 24 | VIDEO PRODUCTION | MARKET TRANSFORMATION |

Extra slides for answering questions below here

Classroom Selection Details

- Similar building locations to hopefully get equivalent loads
- Located in San Jose
- HS classrooms monitored without occupants using electric

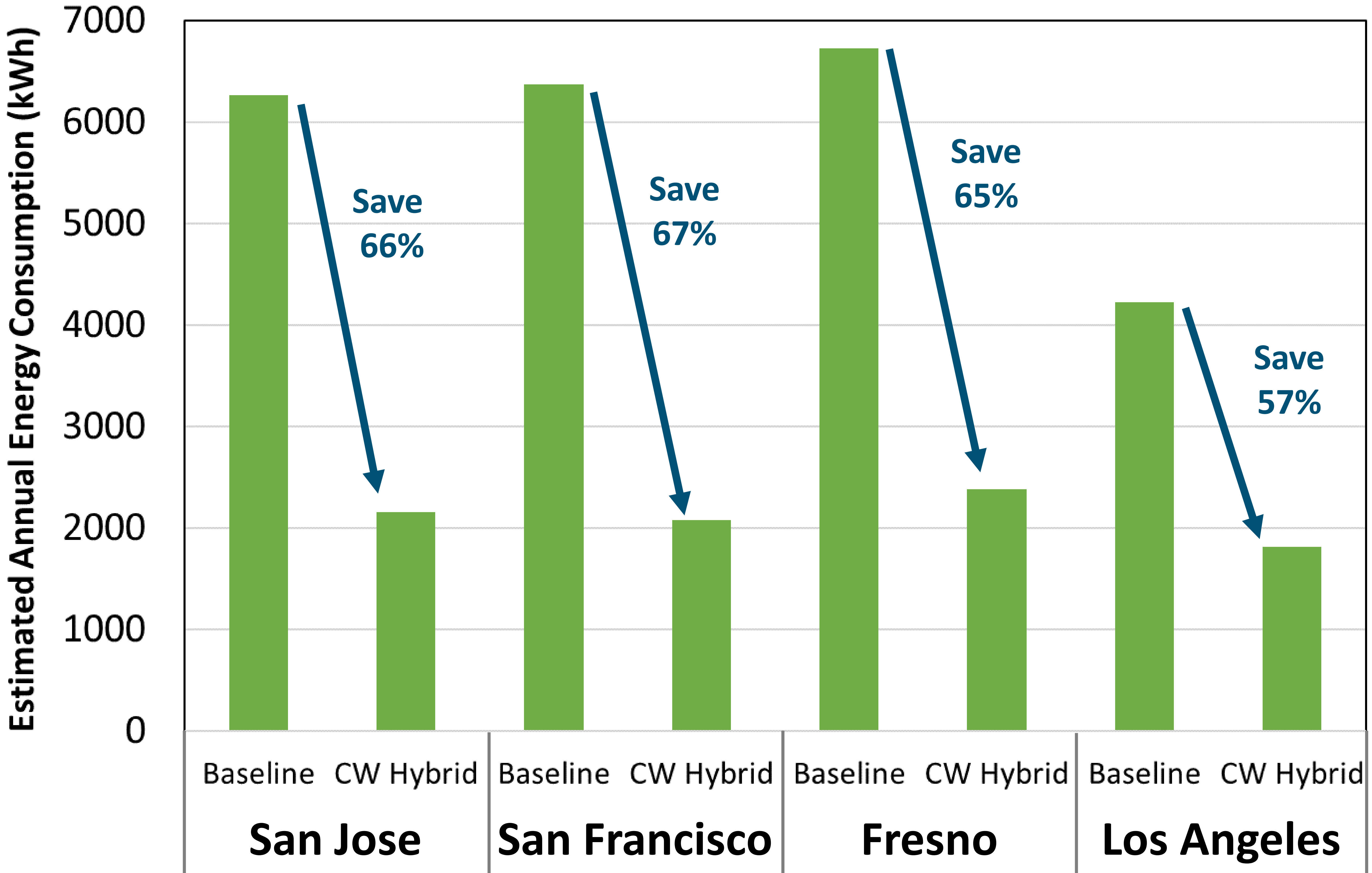


Classrooms Photos

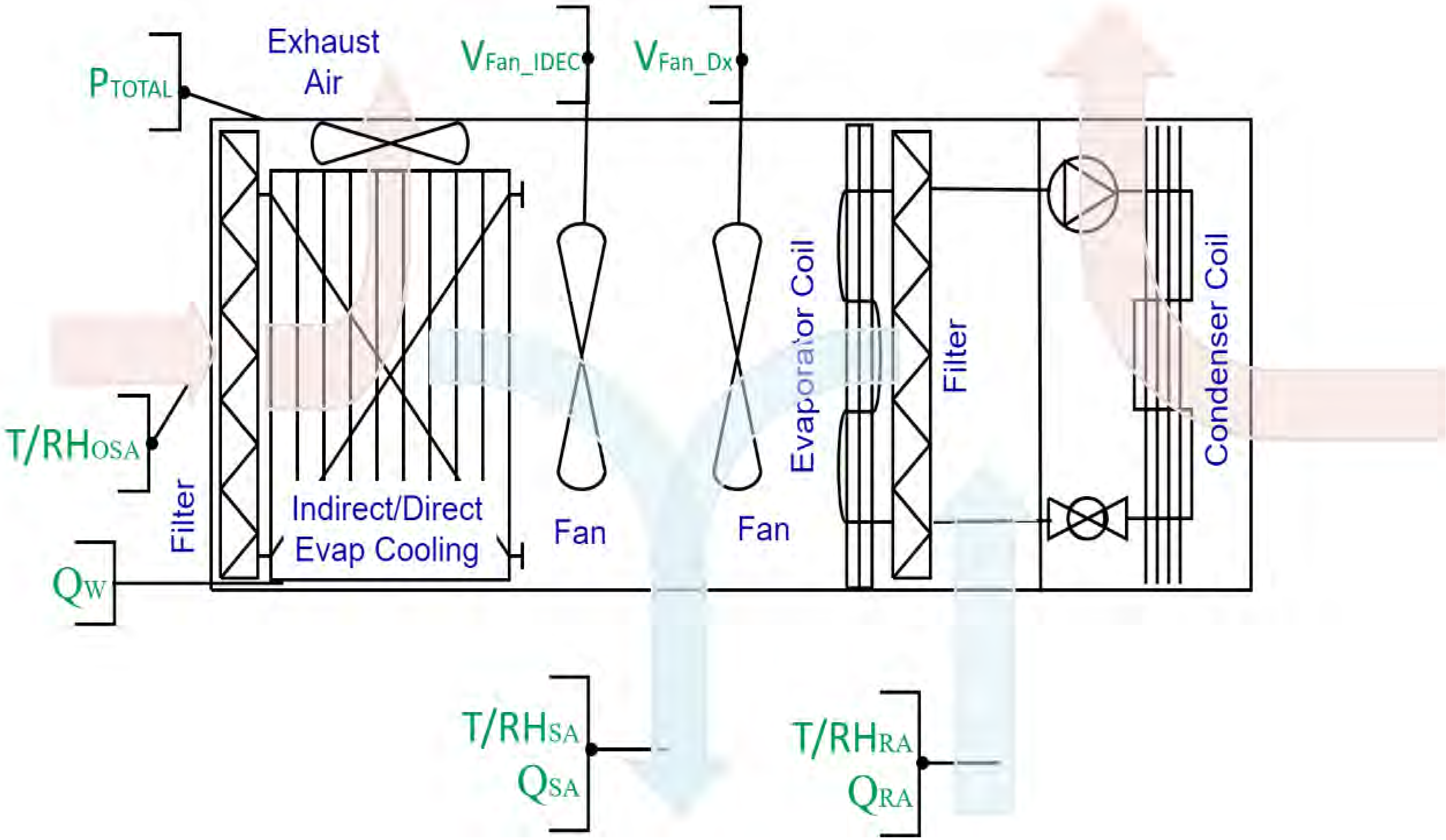
Seeley CW Heat Pump

Lennox - Baseline

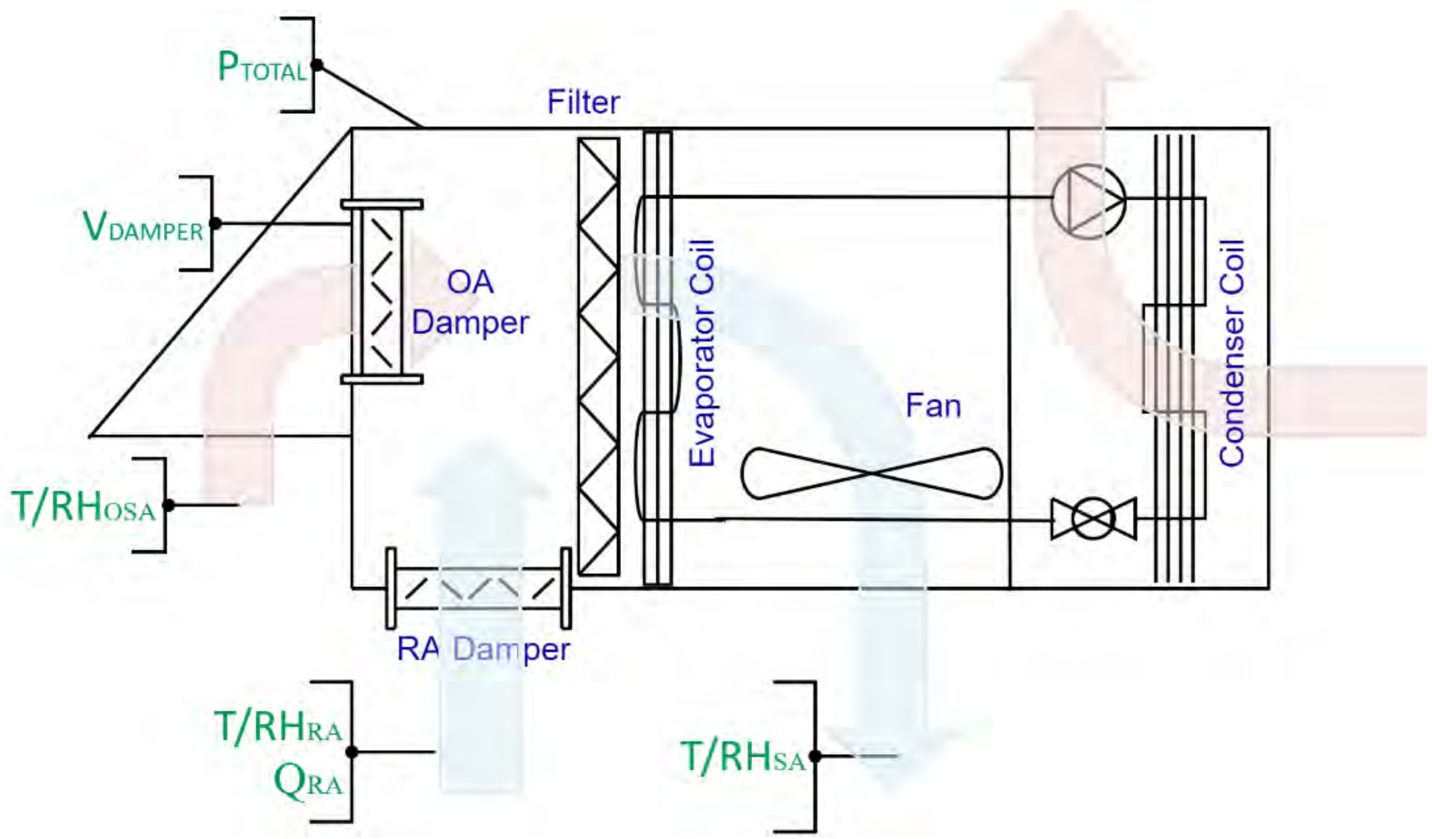
San Jose Field Test: Hybrid Unit Vs Existing Roof Top Unit

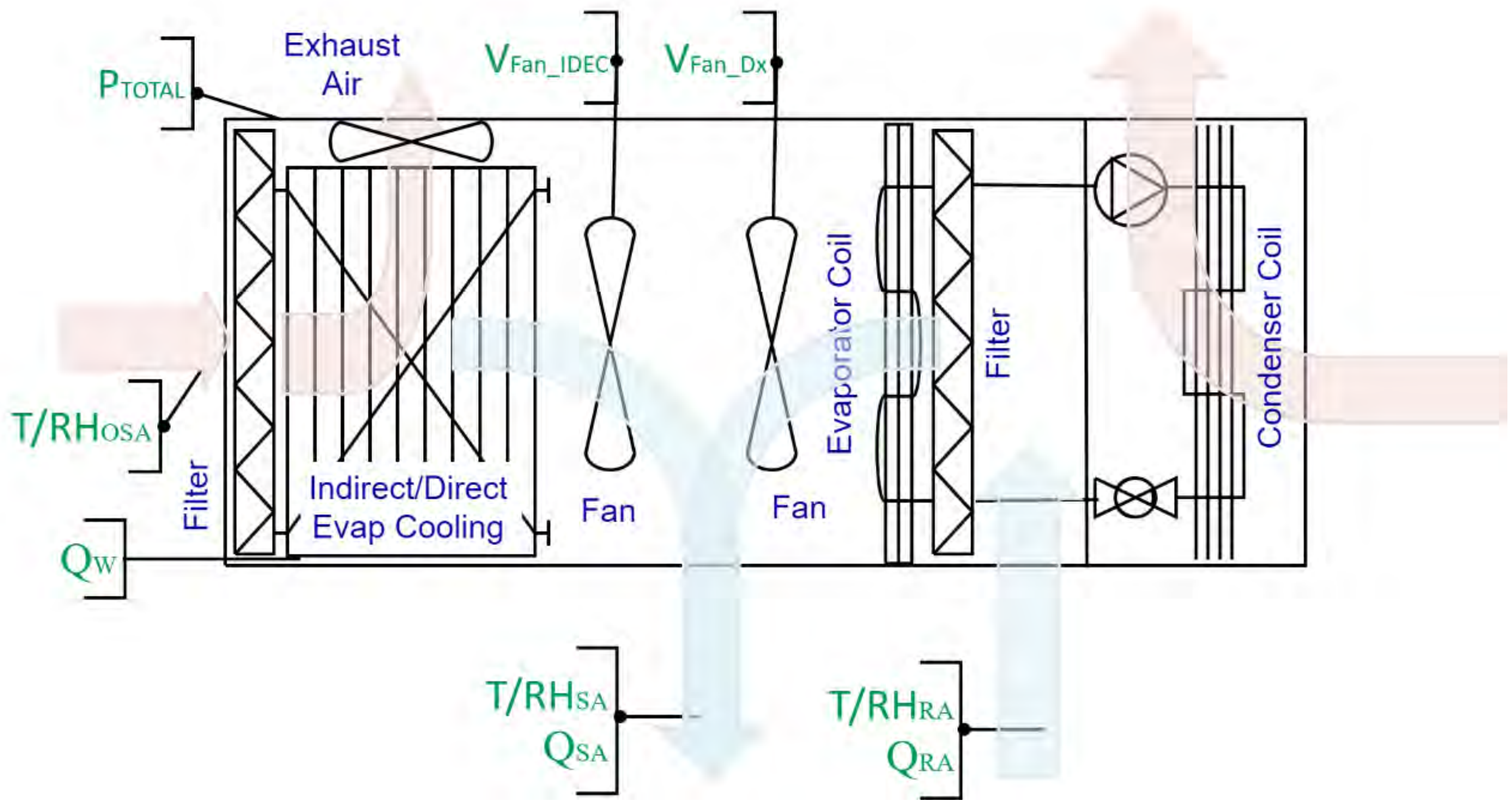


Climate Wizard Hybrid



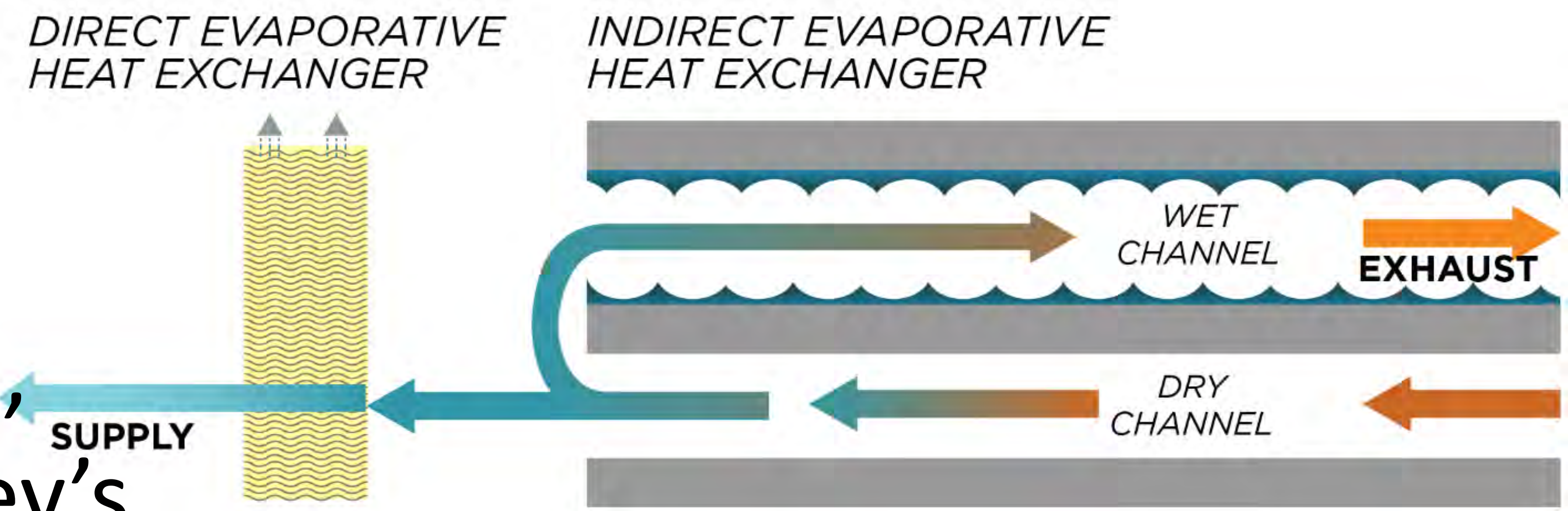
Baseline and Climate Wizard Hybrid Units



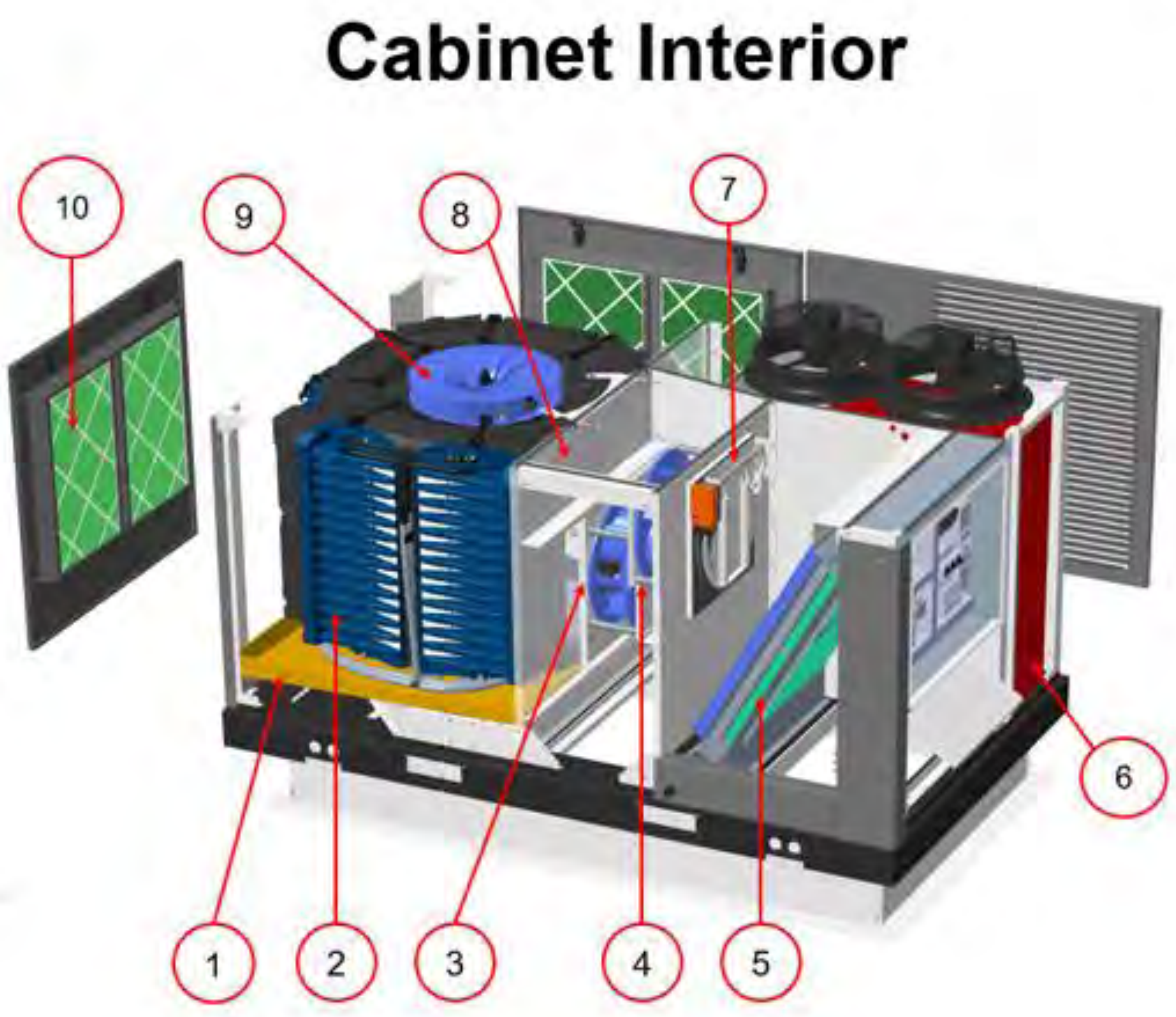


Evaporative Cooling of CWH

- Has separate water loops to enable both Indirect, and Direct Evaporative Cooling.
- Can also run in Hybrid modes which runs DX cooling along with Evaporative. This is controlled through variable speed fans, dampers, and Seeley's control logic.



CW Hybrid Details



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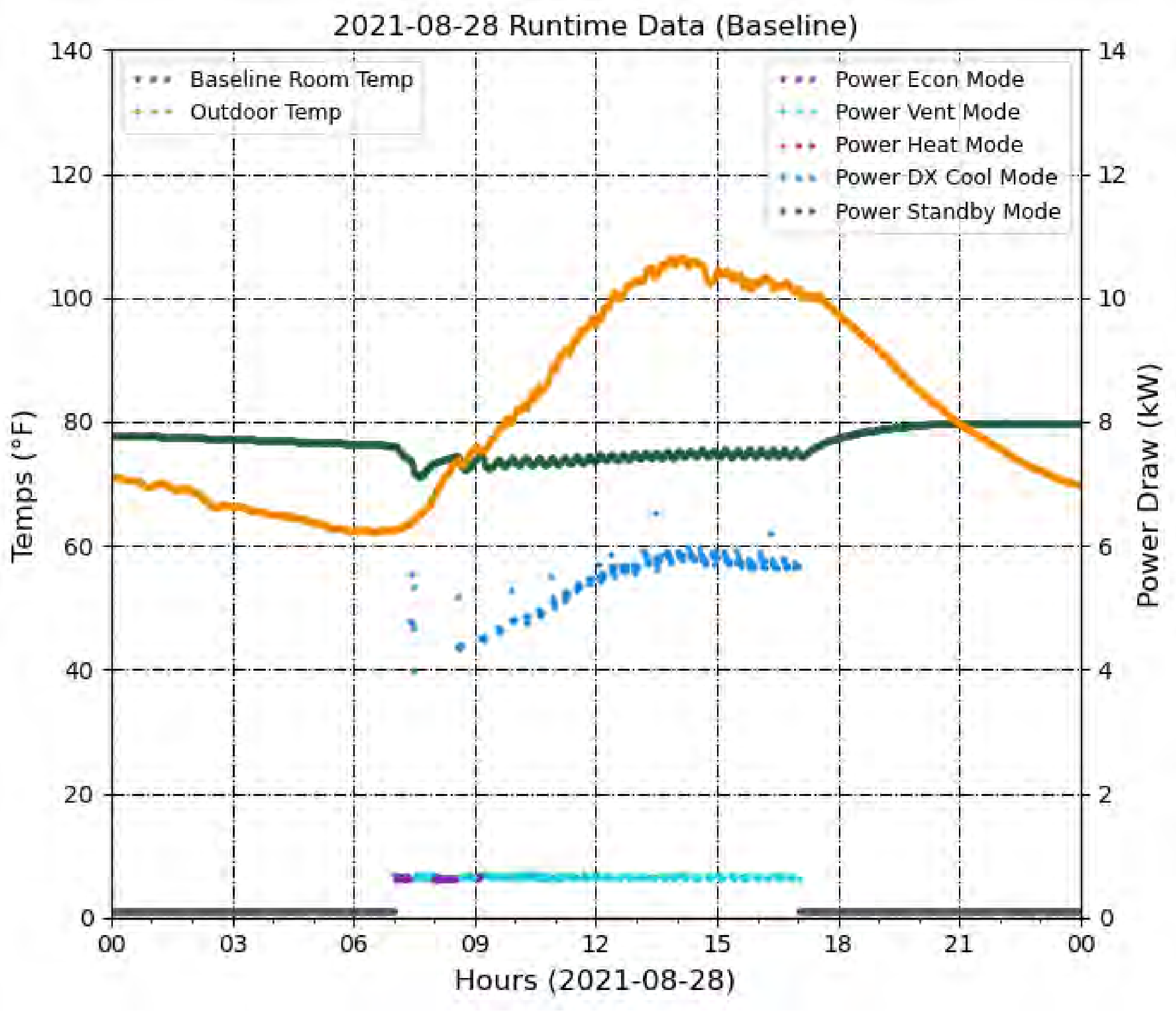
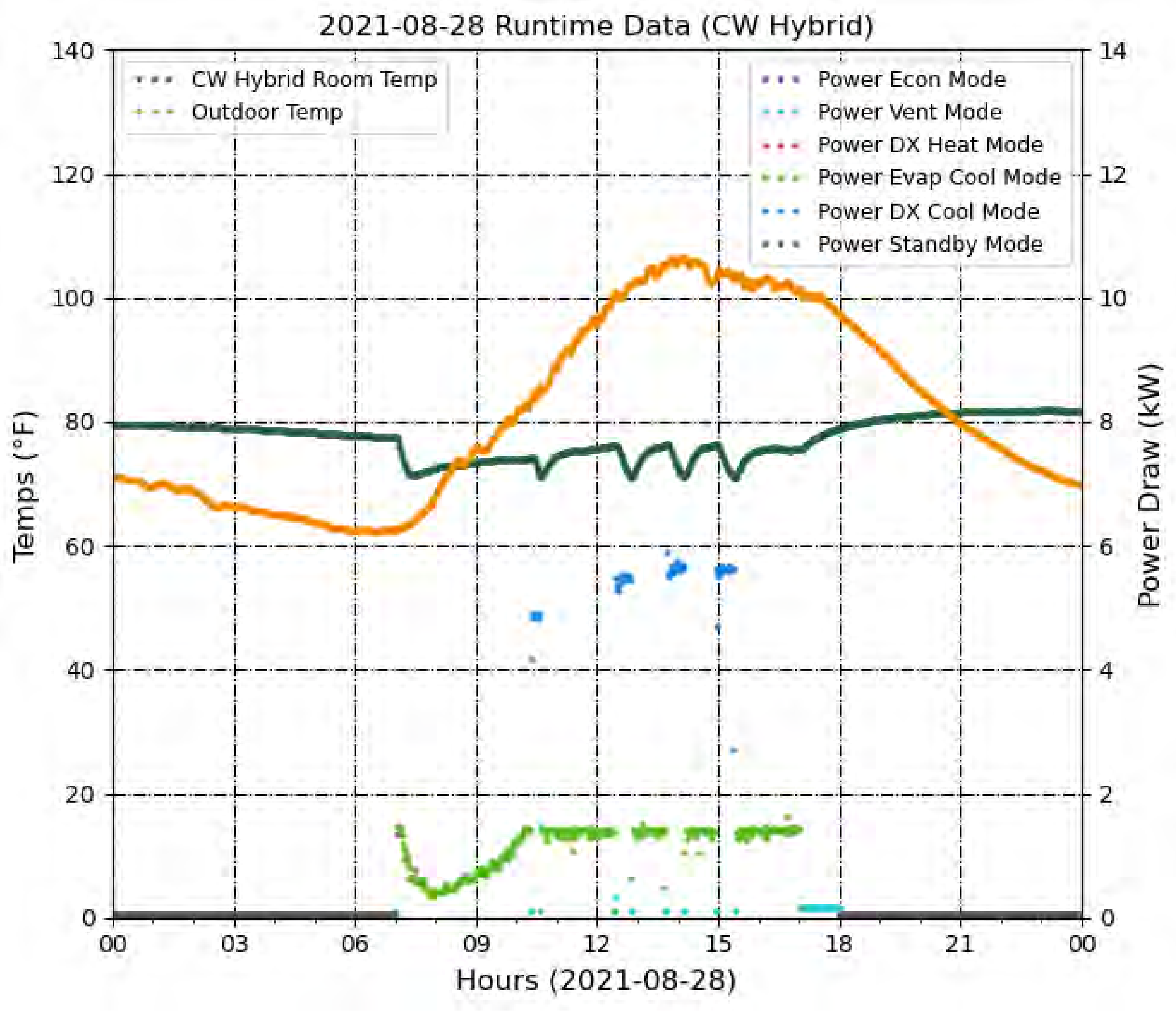
8	CW Damper (not visible)
9	CW exhaust fan
10	Outdoor air filters

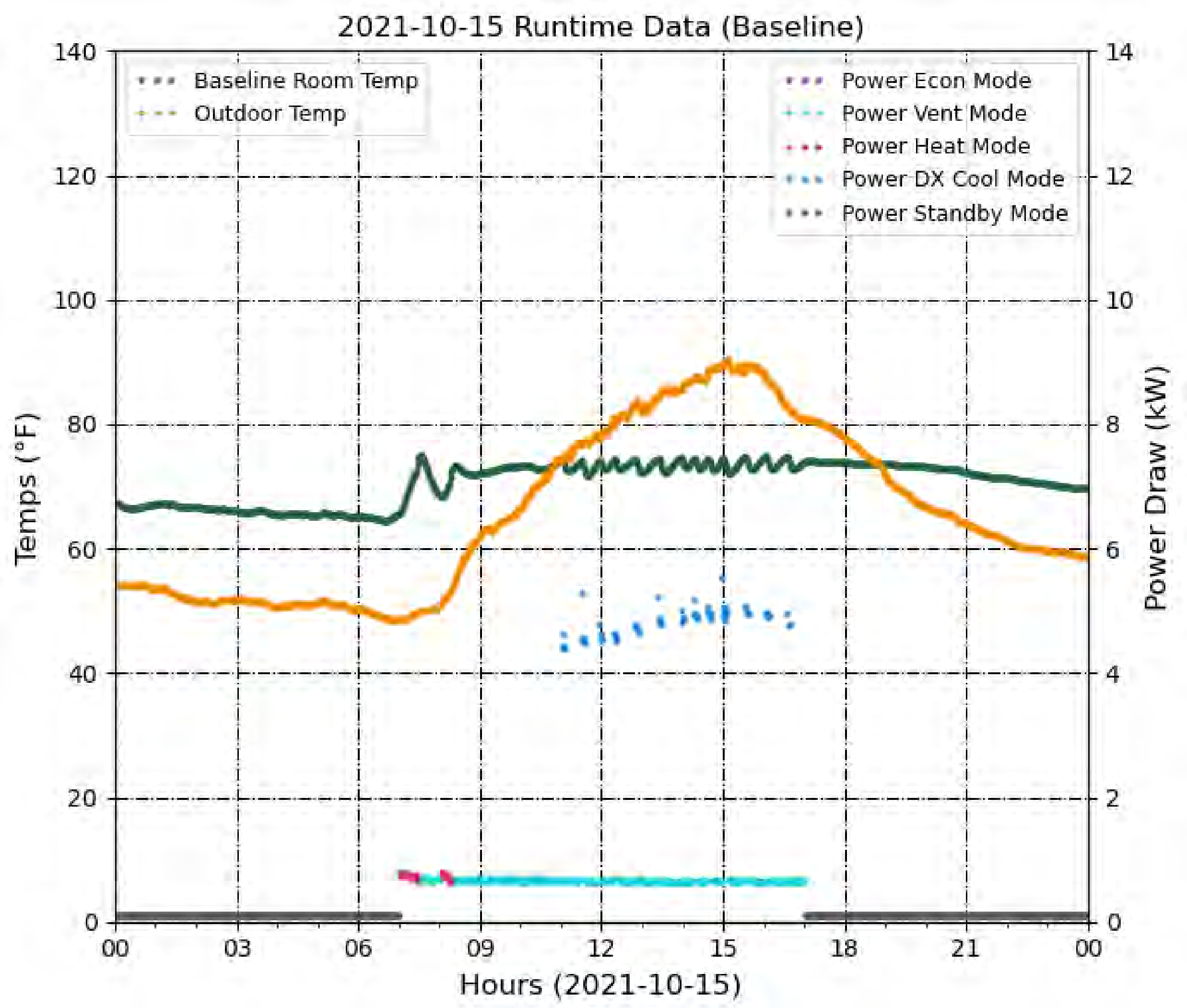
Loads

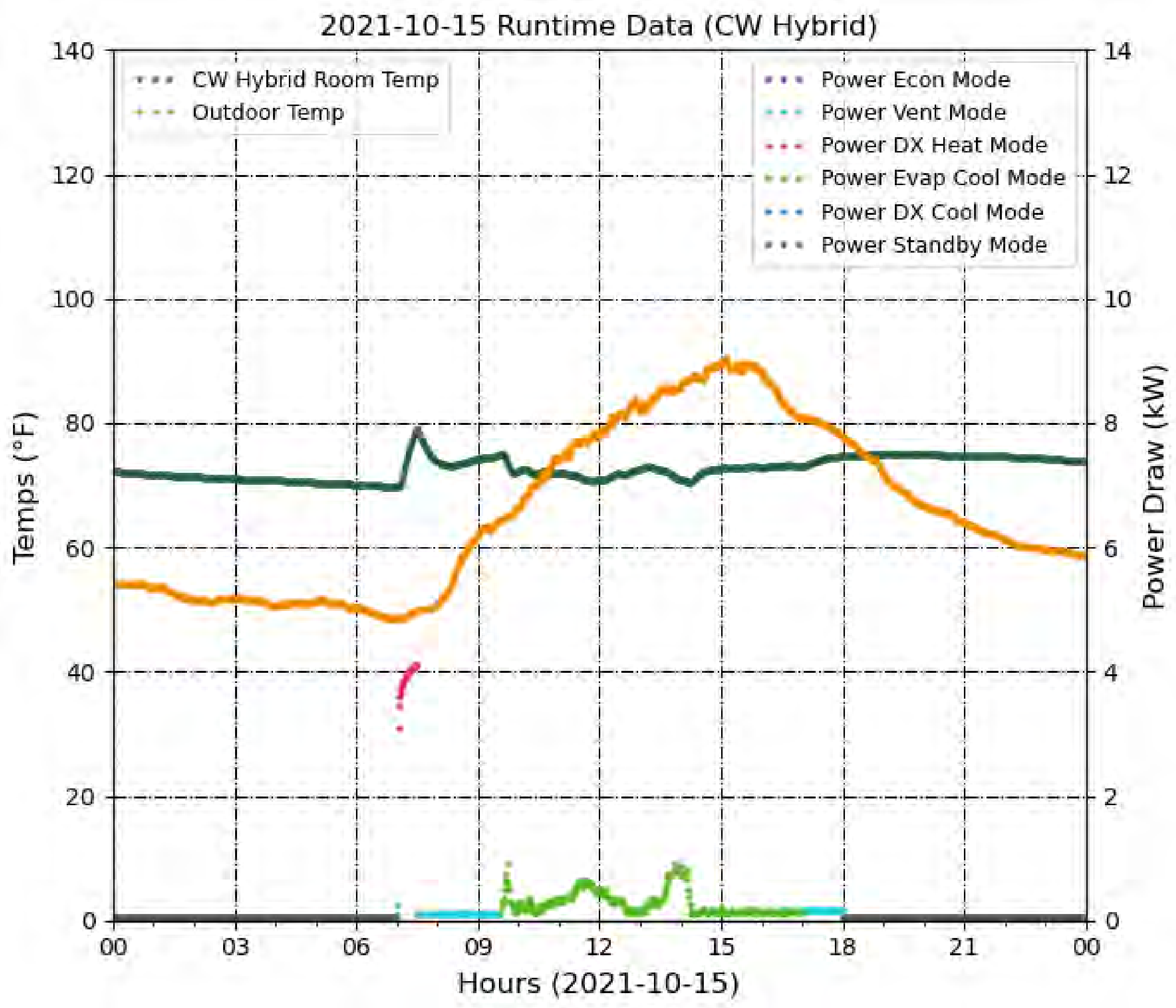
Summer Operation



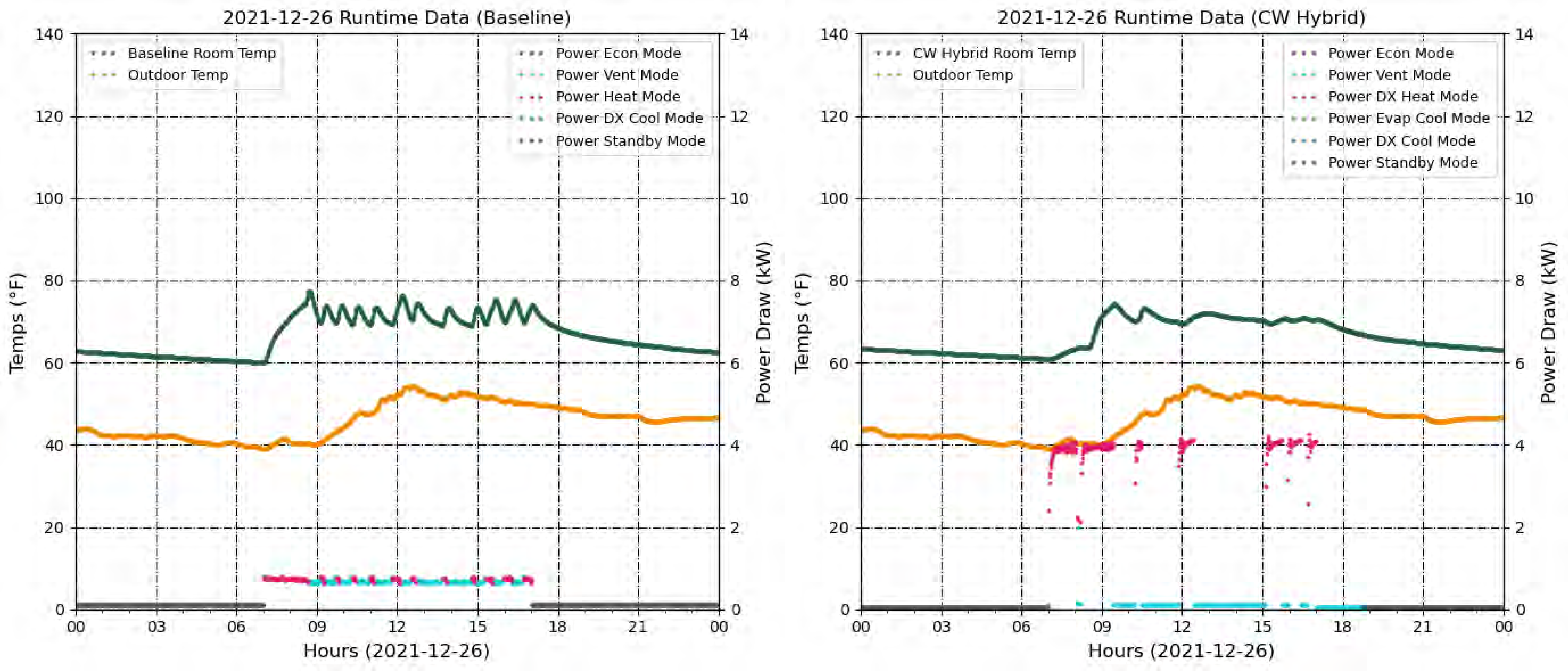


Shoulder Fall Operation

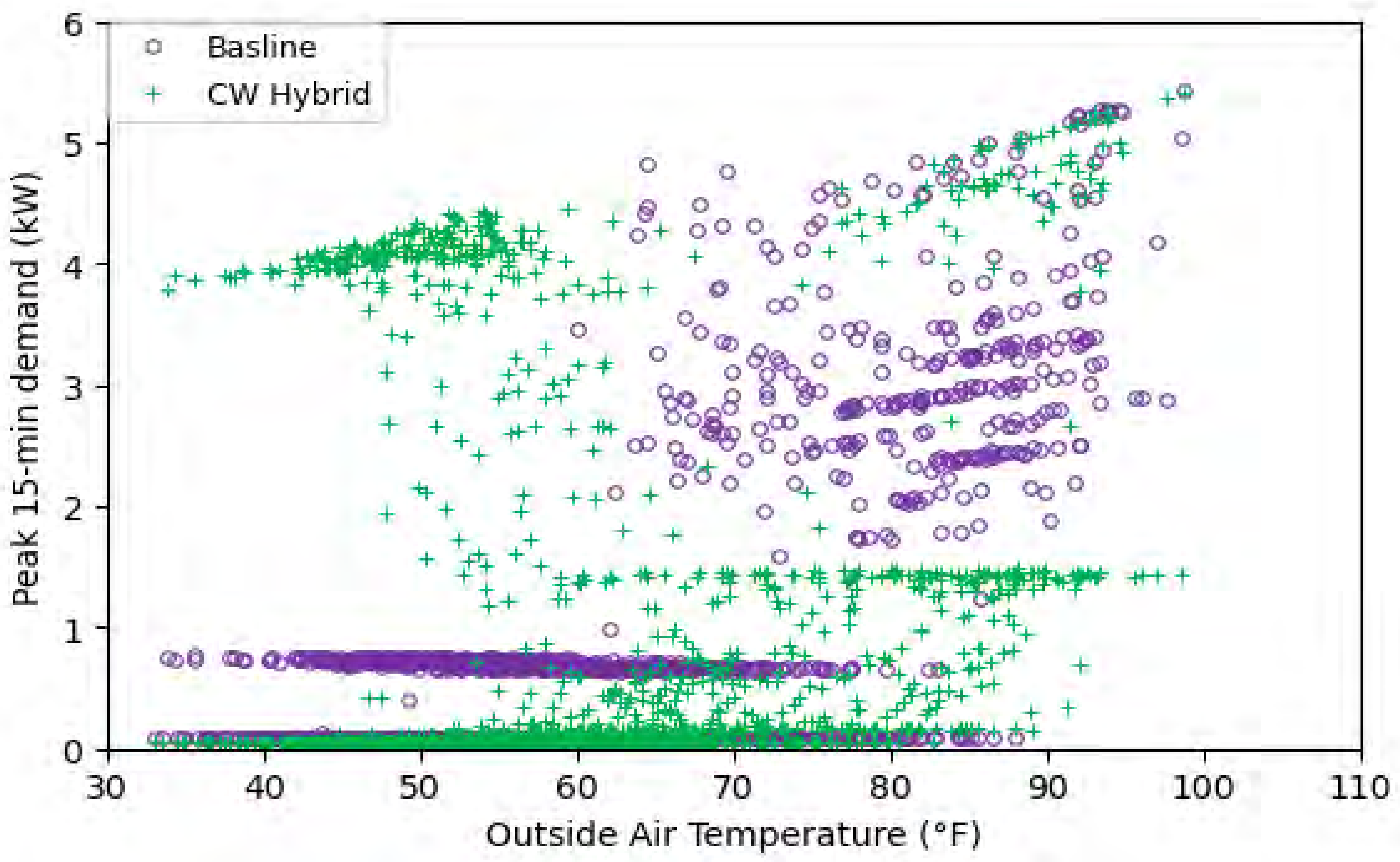




Winter Operation

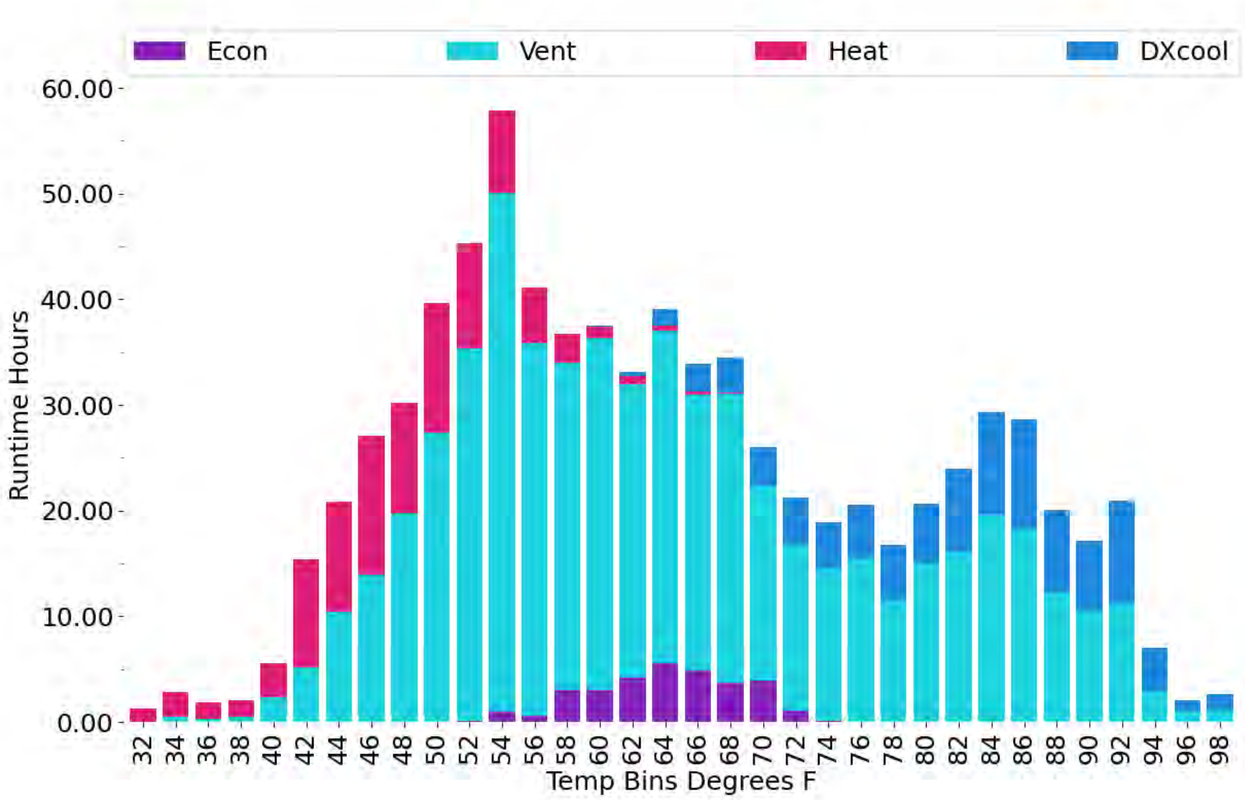


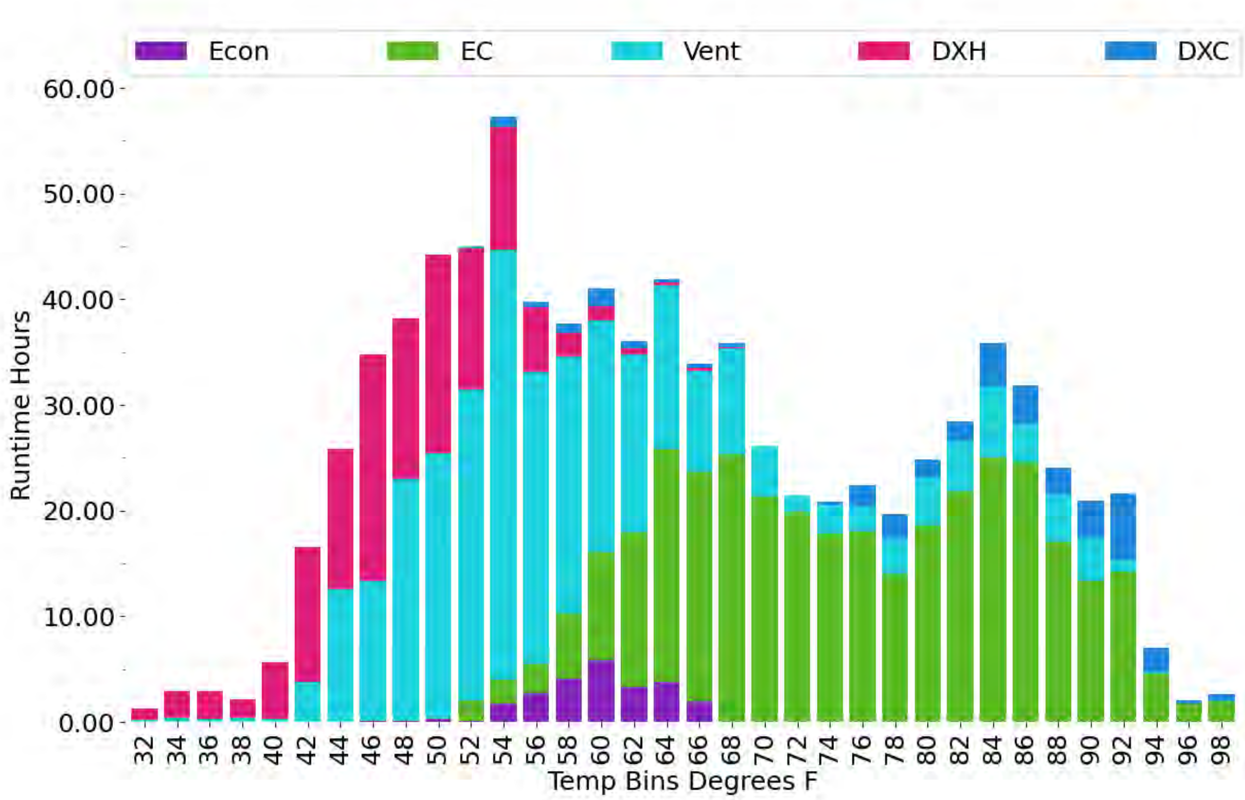
Peak Demand

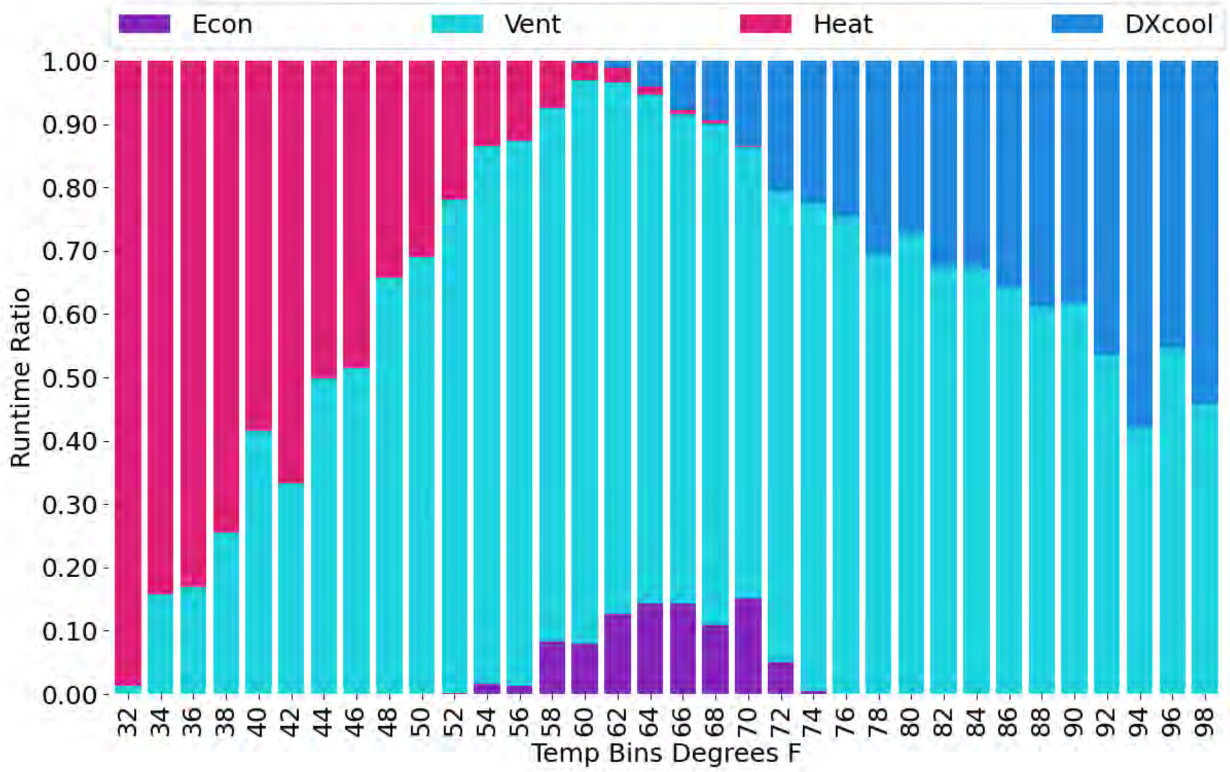


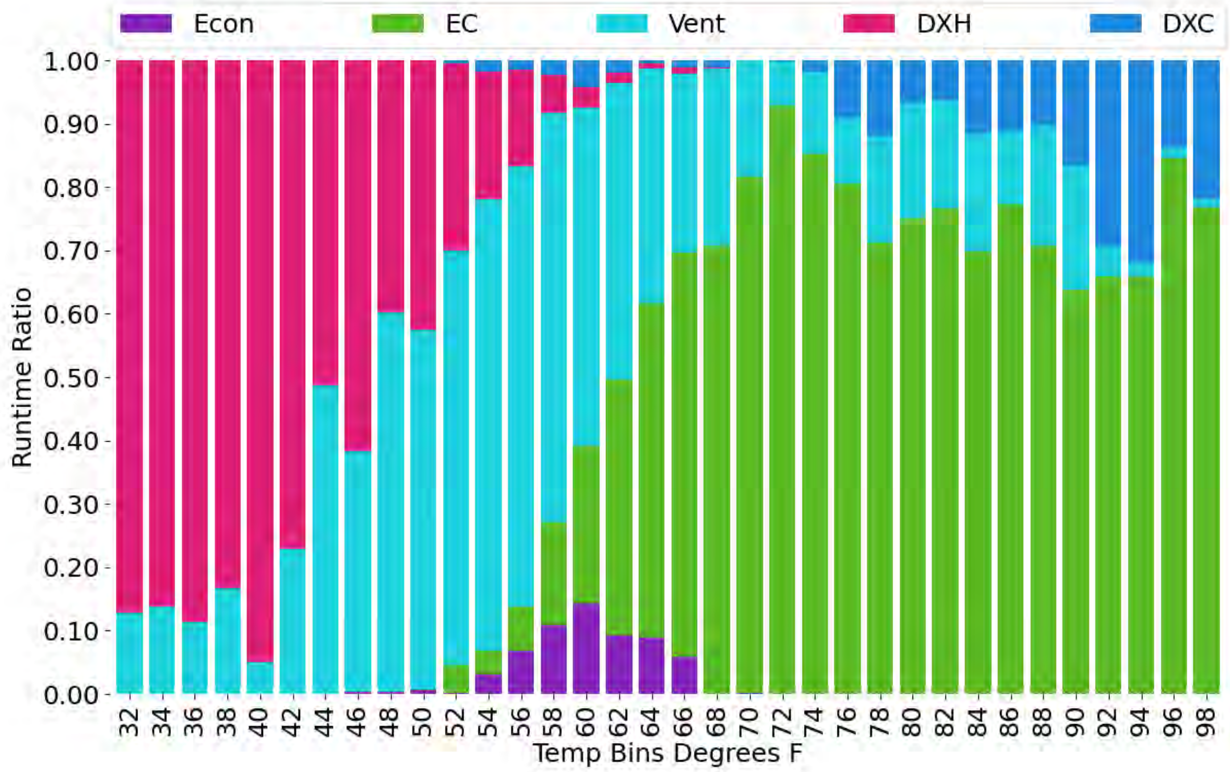
Basline
CW Hybrid
Peak 15-min demand (kW)
Outside Air Temperature (°F)
0
1
2
3
4
5
6
30
40
50
60
70
80
90
100
110

Runtime over temperature range





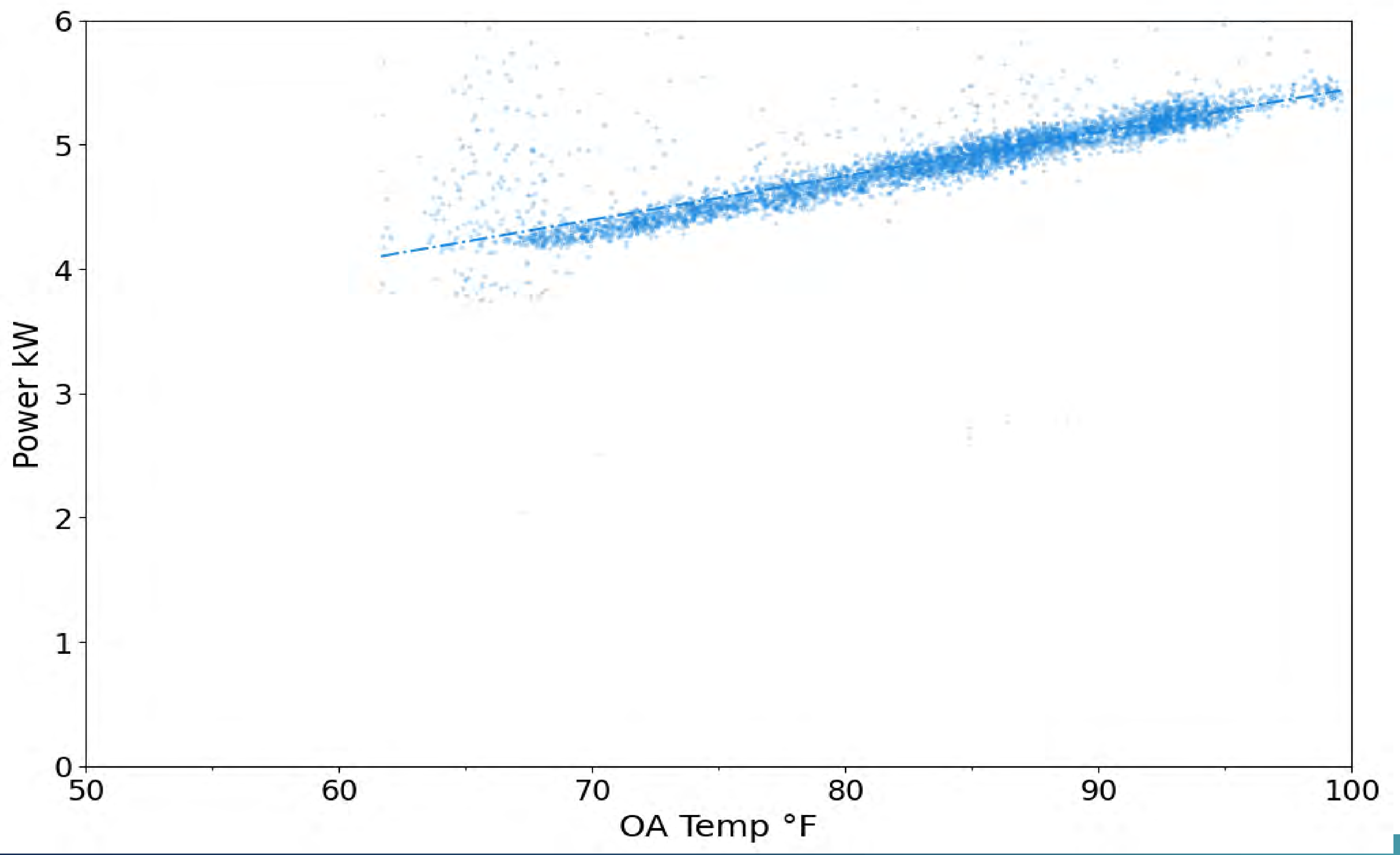




Baseline Regressions

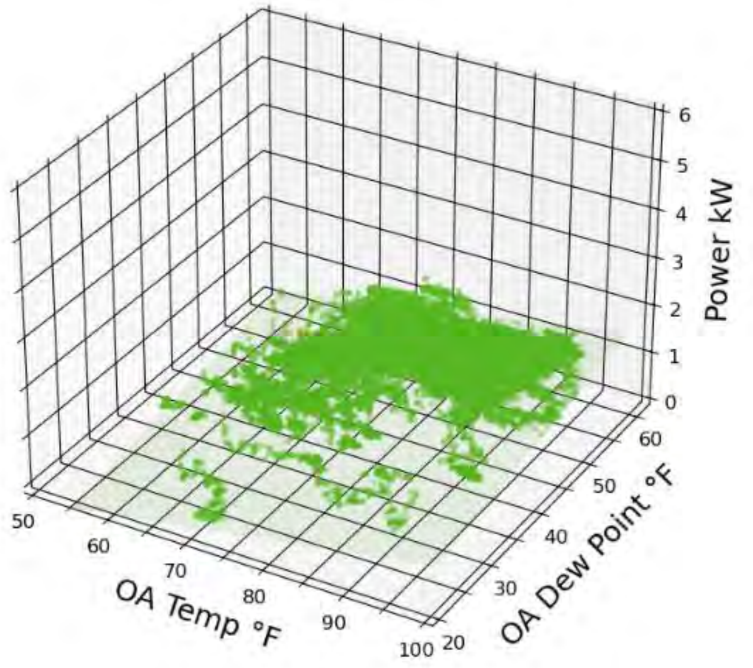
Mode	Range for Correlation	Result	Units
Off	-	0.093	kW
Vent	-	0.660	kW
Econ	-	0.632	kW
DXCool	Tdb = 60 - 100°F	0.0352*Tdb + 1.934 (R^2=0.68)	kW
Heat	-	0.729	kW
Heat	-	0.013	therms/min

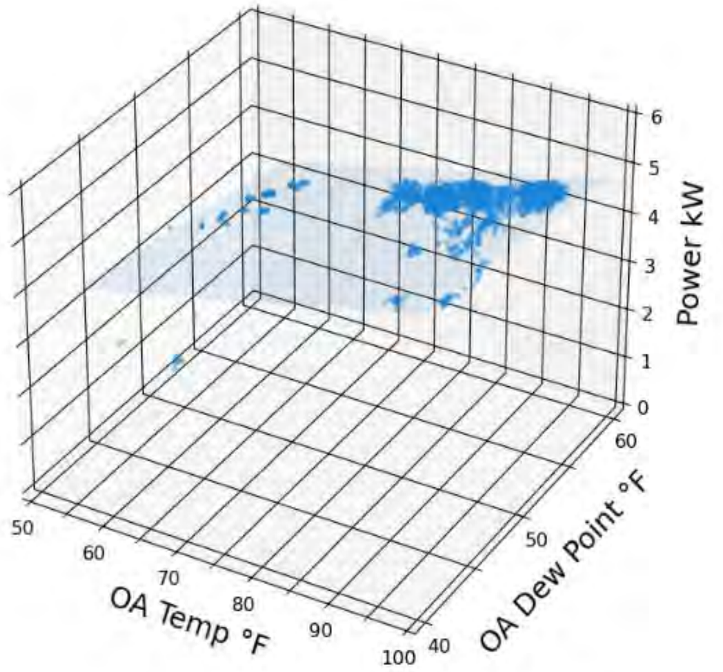
- We performed regressions on all variables for the baseline relative to Dry Bulb Temp
- For values



CWH Power Regressions

Mode	Range for Correlation	Result	Units
Econ	-	0.752	kW
EC	Tdb = 52 - 100°F Tdp = 22 – 60°F	0.0261*Tdb + 0.0241*Tdp - 2.4315 (R^2=0.41)	kW
DXCool	Tdb = 52 - 100°F Tdp = 40 – 60°F	0.0352*Tdb - 0.0459*Tdp + 4.1037 (R^2=0.71)	kW
DXHeat	Tdb = 32 - 60°F	4.049	kW



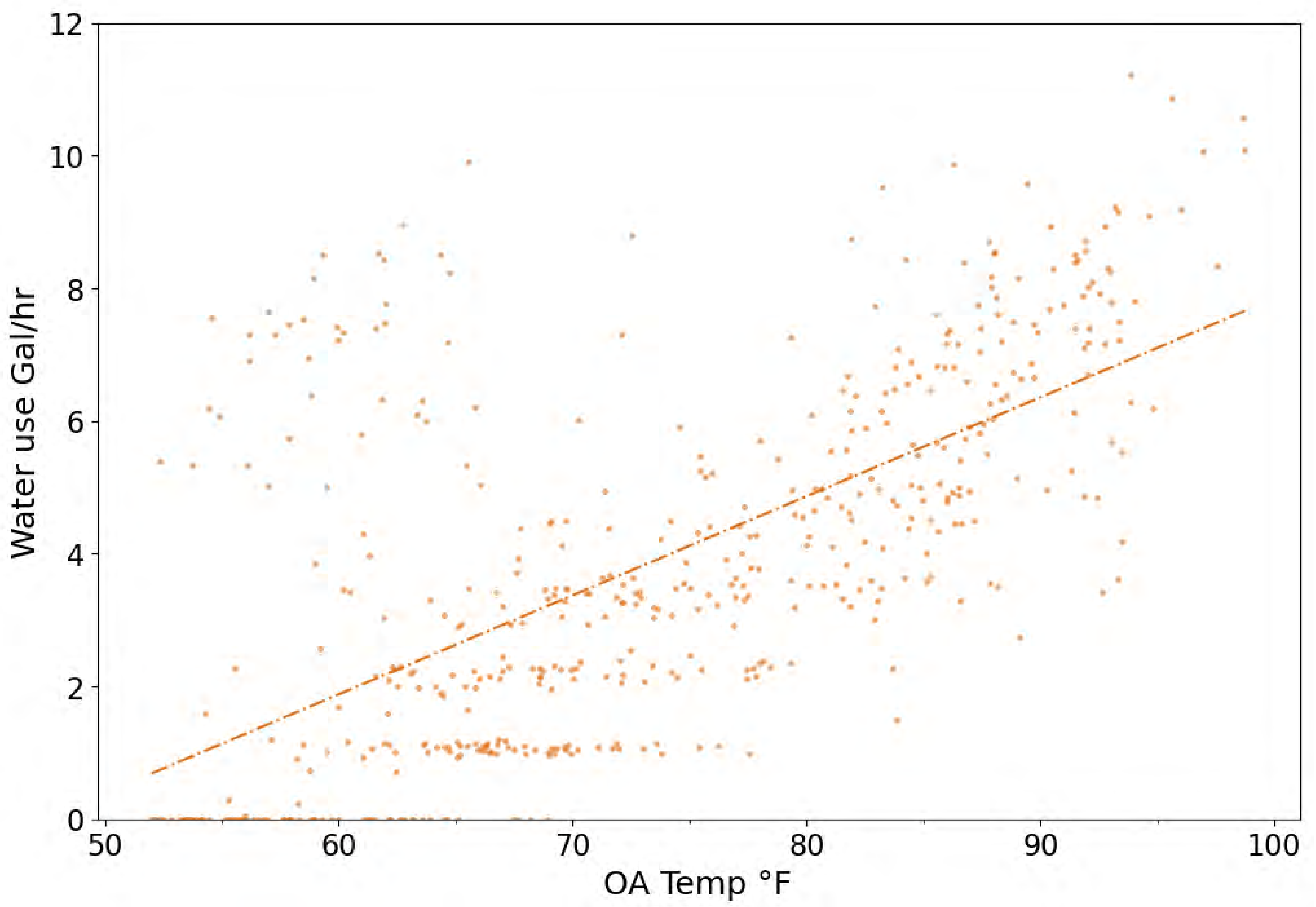


- We performed regressions on all variables for the CW hybrid relative to Dry Bulb Temp and Dew Point Temp
- For values that were basically constant over temp and humidity range a

CWH Water Regression

Mode	Range for Correlation	Result	Units
Econ and DXC	Tdb = 52 - 100°F	0.149*Tdb – 7.070 (R^2 = 0.41)	Gal/hr
All others	-	0	Ga/hr

- We performed a regression on hour data of water use on the CW hybrid relative to Dry Bulb Temp



Vent Air Regression for Modeling

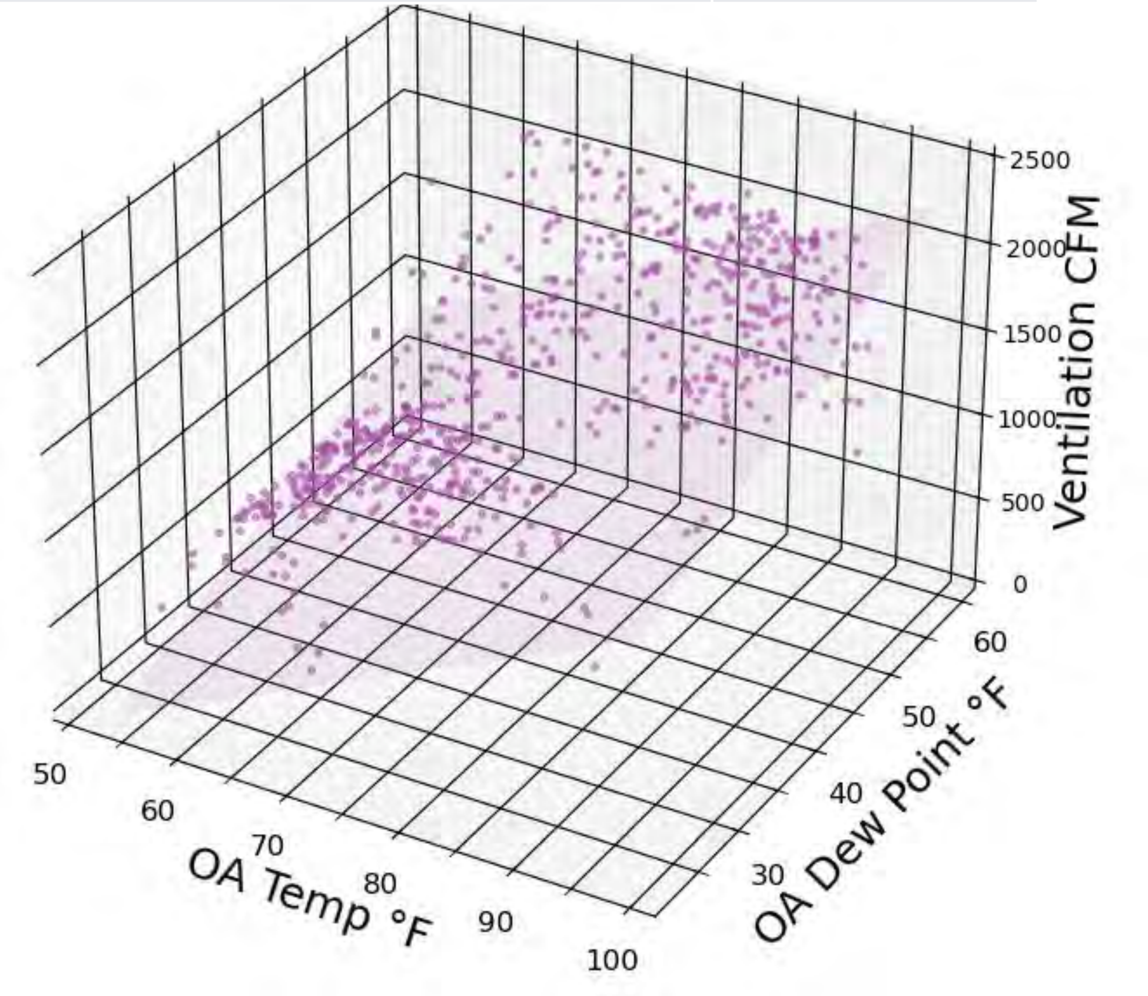
Baseline

Mode	Range	Result	Units
Econ		1238	CFM
All others		633	CFM

CW Hybrid

Mode	Range	Result	Units
Econ and DXC	Tdb = 52 - 100°F Tdp = 22 – 60°F	Greater of: 513.5 or 29.99*Tdb + 24.94*Tdp – 2197 (R^2 = 0.41)	CFM
All others		513.5	CFM

- Basline vent is based on vent and Econ runtime using fixed values measured on site.
- CW hybrid uses a regression on Dry Bulb Temp and Dew Point, with an implemented



Modeling Implementation

- Model model estimations in other climate zones were made using weather files for various locations in 2019.
- We used our percent runtime temperature binning to estimate runtimes in various modes
- Then used the weather data along with the power, and water regressions to estimate commodity use.
- Therms are estimated using runtime data and nameplate information of the baseline unit

Modeling Validation

	Baseline (Measured)	Baseline (Modeled)	Difference (%)	CW Hybrid (Measured)	CW Hybrid (Modeled)	Difference (%)
Off (kWh)	97.1	100.0	3%	49.7	55.0	11%
Vent (kWh)	349.0	333.2	-5%	34.7	30.5	-12%
Econ (kWh)	19.6	16.7	-15%	17.8	14.5	-19%
EC (kWh)				260.2	235.5	-9%
DXCool (kWh)	459.3	445.8	-3%	167.5	149.1	-11%
Heat (kWh)	63.5	58.3	-8%	501.6	502.0	0%
Gas Heat (Therms)	67.9	69.4	2%			
Total kWh	988.5	953.9	-4%	1031.4	986.6	-4%
Total Therms	67.9	69.4	2%			
Total Water (gal)				1936.7	2057.8	
Average Ventilation Rate (CFM)	776.2	734.7	-5%	1166.1	1106.9	-5%

Modeling Results for four CA cities

	SAN JOSE			SAN FRANCISCO		
Mode	Baseline	CW Hybrid	% Baseline	Baseline	CW Hybrid	% Baseline
Off (kWh)	**655**	**361**	**-45%**	**655**	**361**	**-45%**
Fan Only (kWh)	**939**	**617**	**-34%**	**968**	**501**	**-48%**
Vent (kWh)	876	84		901	97	
Cool - Econ (kWh)	63	56		67	66	
Cool - EC (kWh)		478			338	
Cooling (Compressor/Fan) (kWh)	**714**	**204**	**-71%**	**406**	**149**	**-63%**
Heating (kWh)	**109**	**973**		**123**	**1062**	
Total (kWh)	**2416**	**2155**	**-11%**	**2151**	**2072**	**-4%**
Heating (Therms)	**131**			**144**		
Total Water (gal)		**4471**			**3693**	
Average Vent Rate (CFM)	**749**	**1038**	**+39%**	**752**	**938**	**+25%**

Modeling Results for four CA cities

	FRESNO			LOS ANGELES		
Mode	Baseline	CW Hybrid	% Baseline	Baseline	CW Hybrid	% Baseline
Off (kWh)	**655**	**361**	**-45%**	**655**	**361**	**-45%**
Fan Only (kWh)	**883**	**635**	**-28%**	**954**	**779**	**-18%**
Vent (kWh)	831	72		879	68	
Cool - Econ (kWh)	52	43		75	55	
Cool - EC (kWh)		520			656	
Cooling (Compressor/Fan) (kWh)	**1137**	**391**	**-66%**	**1027**	**285**	**-72%**
Heating (kWh)	**111**	**987**		**43**	**381**	
Total (kWh)	**2787**	**2375**	**-15%**	**2678**	**1806**	**-33%**
Heating (Therms)	**134**			**53**		
Total Water (gal)		**5326**			**5722**	
Average Vent Rate (CFM)	**742**	**1046**	**+41%**	758	1206	**+59%**

Demand (Peak 15 min rolling average kW)

	BASE		CWH	
month	# of hours	pk 15 min kW 9average	# of hours	pk 15 min kW 9average
6/30/2021	144	3.561733667	144	4.819733867
7/31/2021	336	5.2747338	336	5.182400667
8/31/2021	0	nan	0	nan
9/30/2021	264	5.4294008	264	5.405200467
10/31/2021	168	3.282667	168	4.282067
11/30/2021	120	0.7482	120	4.354933933
12/31/2021	480	0.756666667	480	4.440467067
1/31/2022	360	0.764466667	360	4.454133867

NOTABLE PATENTS

TRACER GAS SYSTEM

New system that allows for accurate airflow measurement over a wide range of operating conditions.

CLOTHES DRYERS

High accuracy automatic shut-off sensors for clothes dryers.

ENVELOPE & PIPELINE SEALING

Automatically seal building envelope and low-flow gas pipeline leaks with instant verification of results.