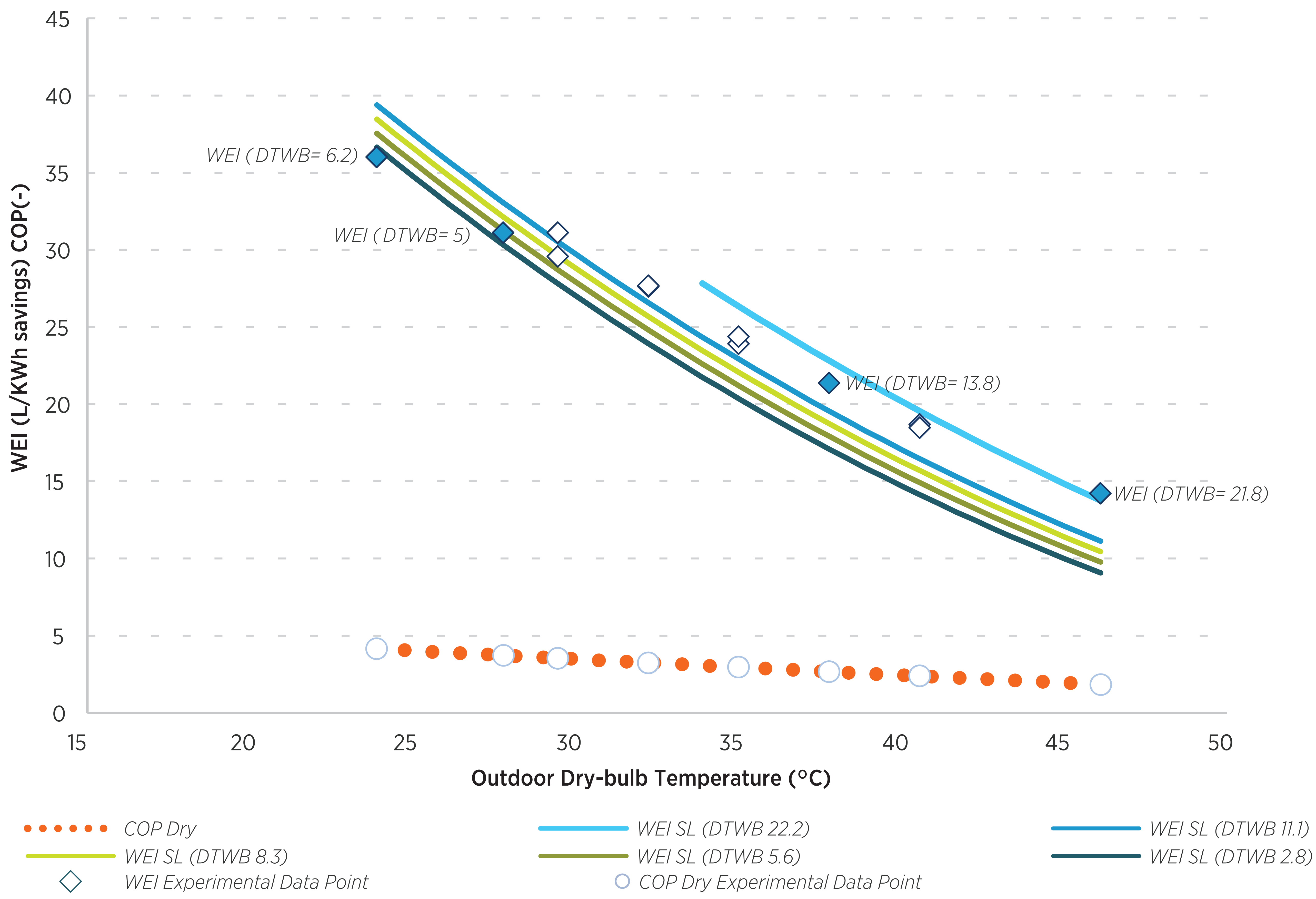
Does Evaporative Cooling Make Sense in Arid Climates?

Explores the trade-off between water use and energy savings, using three different water alternatives—by employing energy and cost analyses of small-scale evaporative cooling technologies.



Water Energy Index (WEI)

Experimental data collected from retrofitted 4-ton York RTU air cooled condensing unit with flow rate of 0.13 cubic meter per second per kW cooling used to calculate WEI. WEI includes: volume of water for evaporation and an additional 15% maintenance water:

WEI=W$_L$/E$_L$ × 1.15

$$W_L\left[\frac{L}{kWh_{Cooling}}\right] = EE \times (W_{Sat.} - W_{in}) \times Q_c \times \frac{\rho_{air}}{\rho_{water}} \times \frac{hr}{3600\ s}$$

Water Consumption

$$E_L\left[\frac{kWh_{Electricity\ saving}}{kWh_{Cooling}}\right] = \left[\frac{1}{COP_{Base}}\right] - \left[\frac{1}{COP_{Pre-cool}}\right]$$

Normalized Electricity Savings

PROJECT RESULTS:
Does Evaporative Cooling Make Sense in Arid Climates?

Energy Base Analysis

Desalination produces 80-280 liters of potable water for 1 kWh consumed

- Evaporative cooling consumes 9-40 liters of water per 1 kWh saved
- Equivalent to getting back 2-30 kWh for investing 1 kWh (electricity multiplier)
- Desalinization can operate at night and evaporative cooling reduces peak demand during the day

Economic Assessment

Desalination rate $1.65 per 1000 liters produced

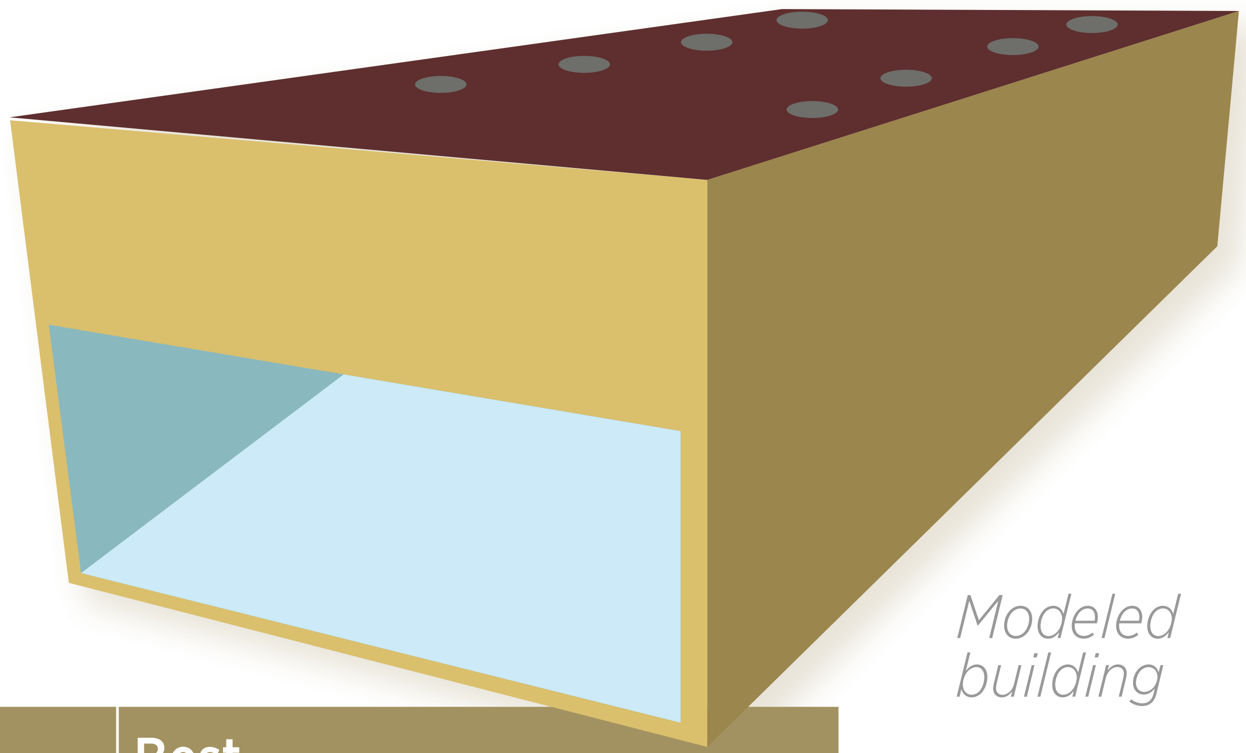
- Electricity costs of $0.08-$0.37 per kWh
- $1 in desalination water yields $1.20-$25 in electricity cost savings, depending upon the technology employed and the local cost of electricity

Demand Response with Evaporative Pre-Coolers

- Evaporative pre-coolers provide the largest impact at peak demand times
- Water use efficiency is highest at peak times
- Planning project to test evaporative pre-cooler response time

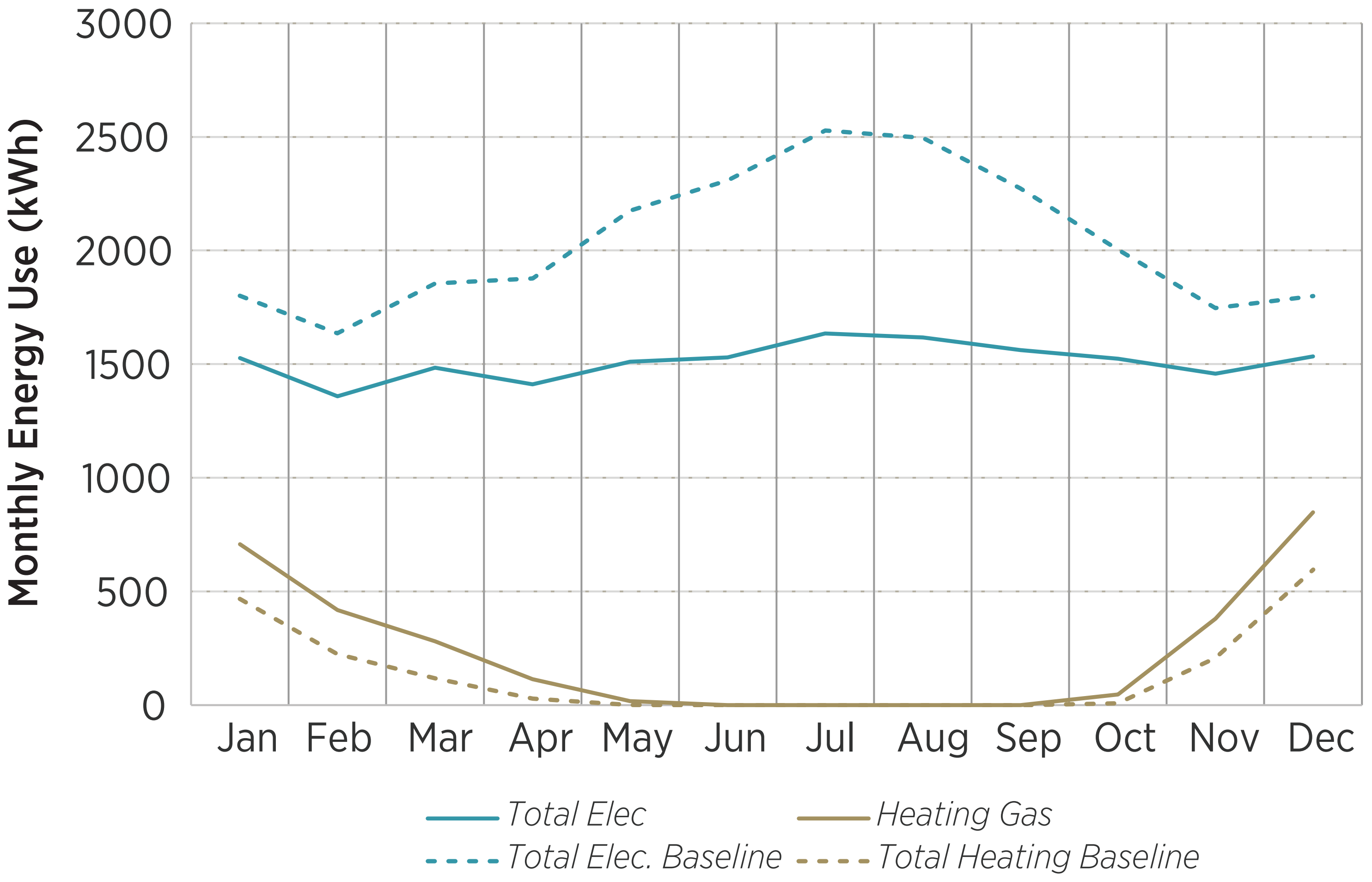
PROJECT RESULTS:
Multi-Tenant Light Commercial—Modeling

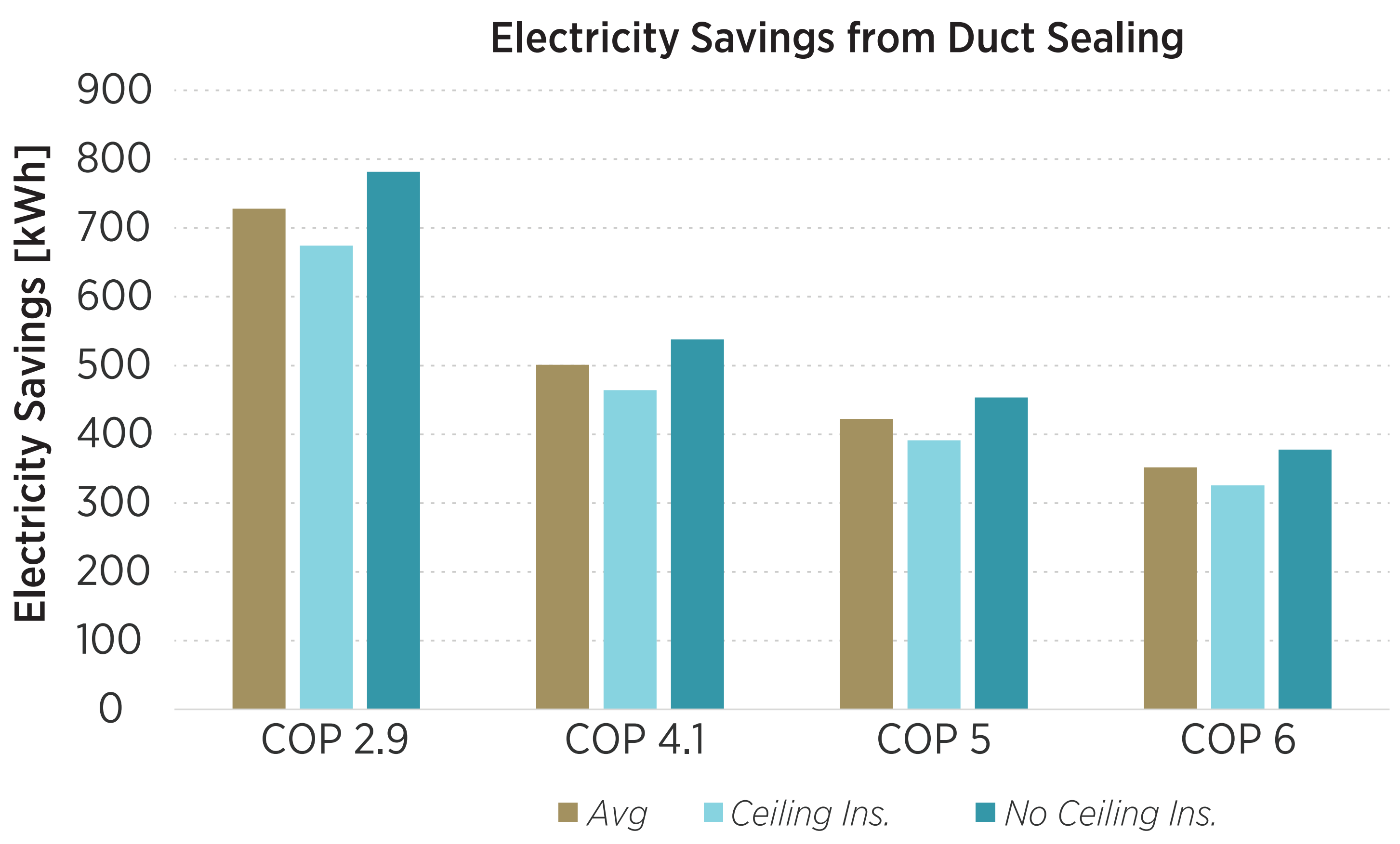
- The MTLC prototype building was modeled with 18 variable parameters
- The parametric analyses consisted of approximately 500,000 simulations



Modeled building

Parameter	Baseline	Best
RTU Efficiency	COP = 2.9	COP = 6
Evaporative Pre-Cooler	No	Yes
HVAC Economizer	No	Yes
Cool Roof	No	Yes
Windows	SHGC = 0.38 U-Factor = 4.088	SHGC = 0.25 U-Factor = 3.236
Skylights	None	SHGC = 0.8 U-Factor = 3.24
Lighting	Linear fluorescent T8 lighting LPD (retail) = 1.14 W/sf	LED LPD = 0.87 W/sf
Daylight Harvesting Control System	None	Continuous dimming

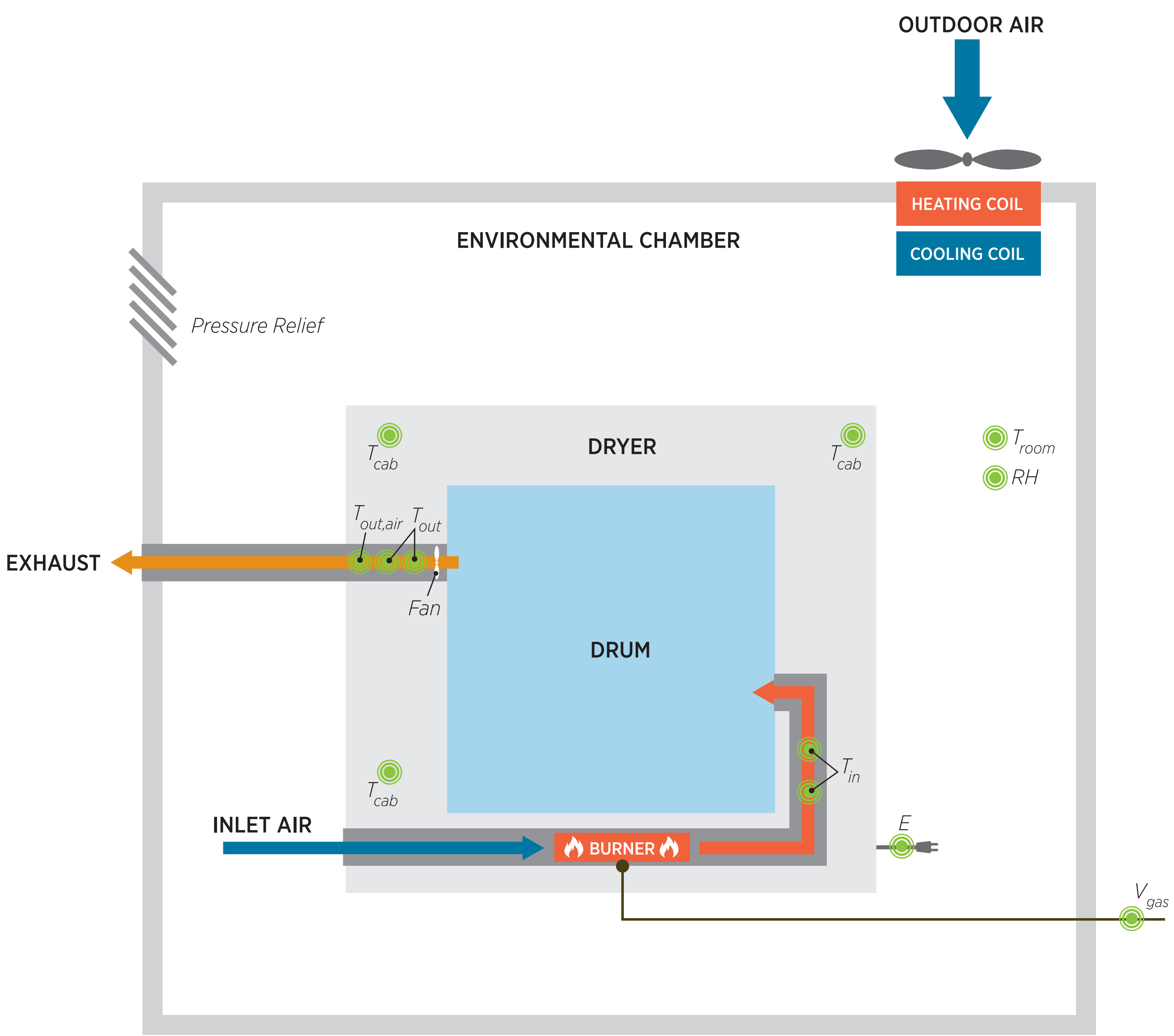




The parameters that were common among the top 10 performing configurations saves 27% electricity annually over the baseline configuration.

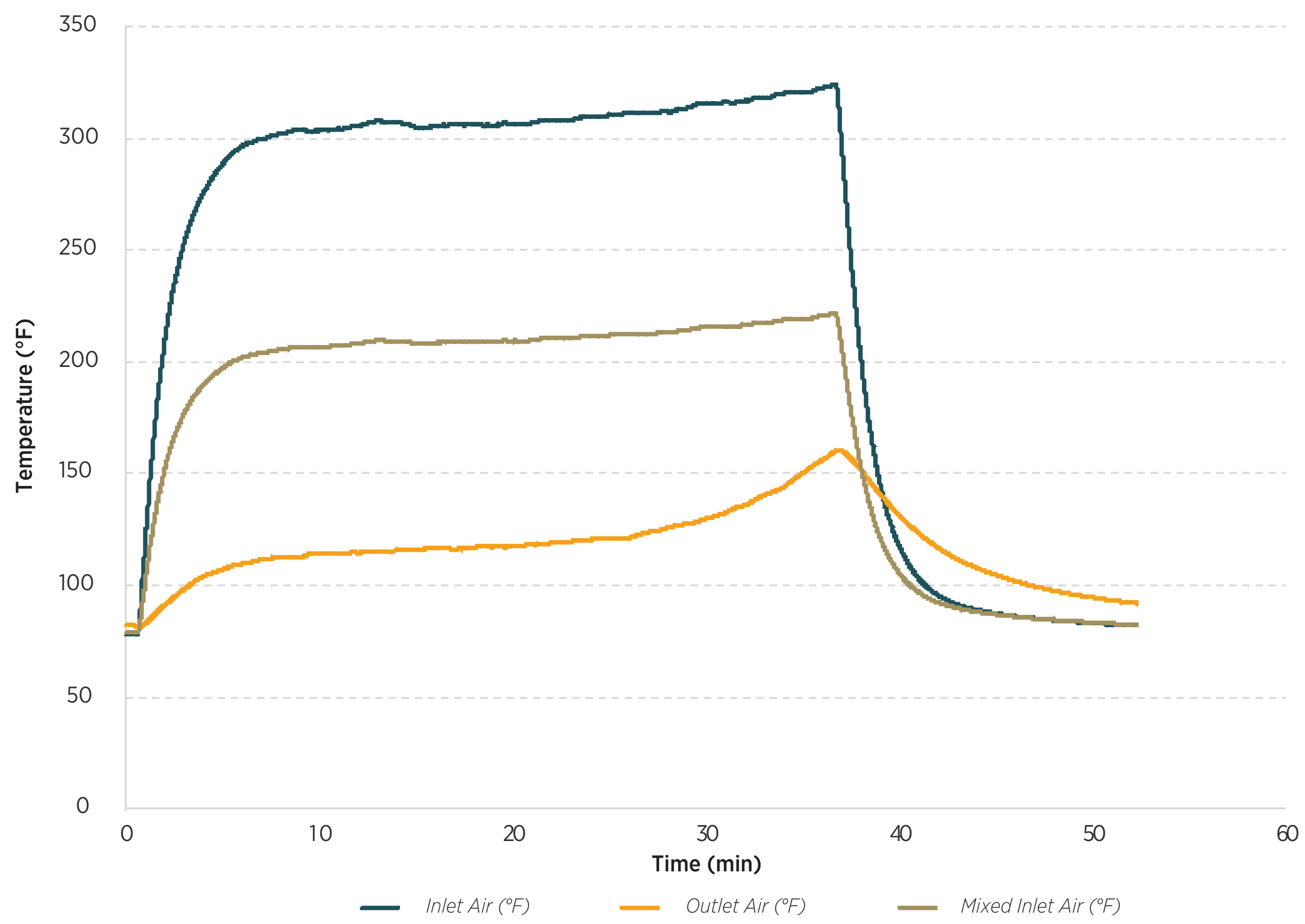
PROJECT RESULTS:
A New Termination Control Method for a Clothes Drying Process in a Clothes Dryer

Clothes Dryer Testing Diagram

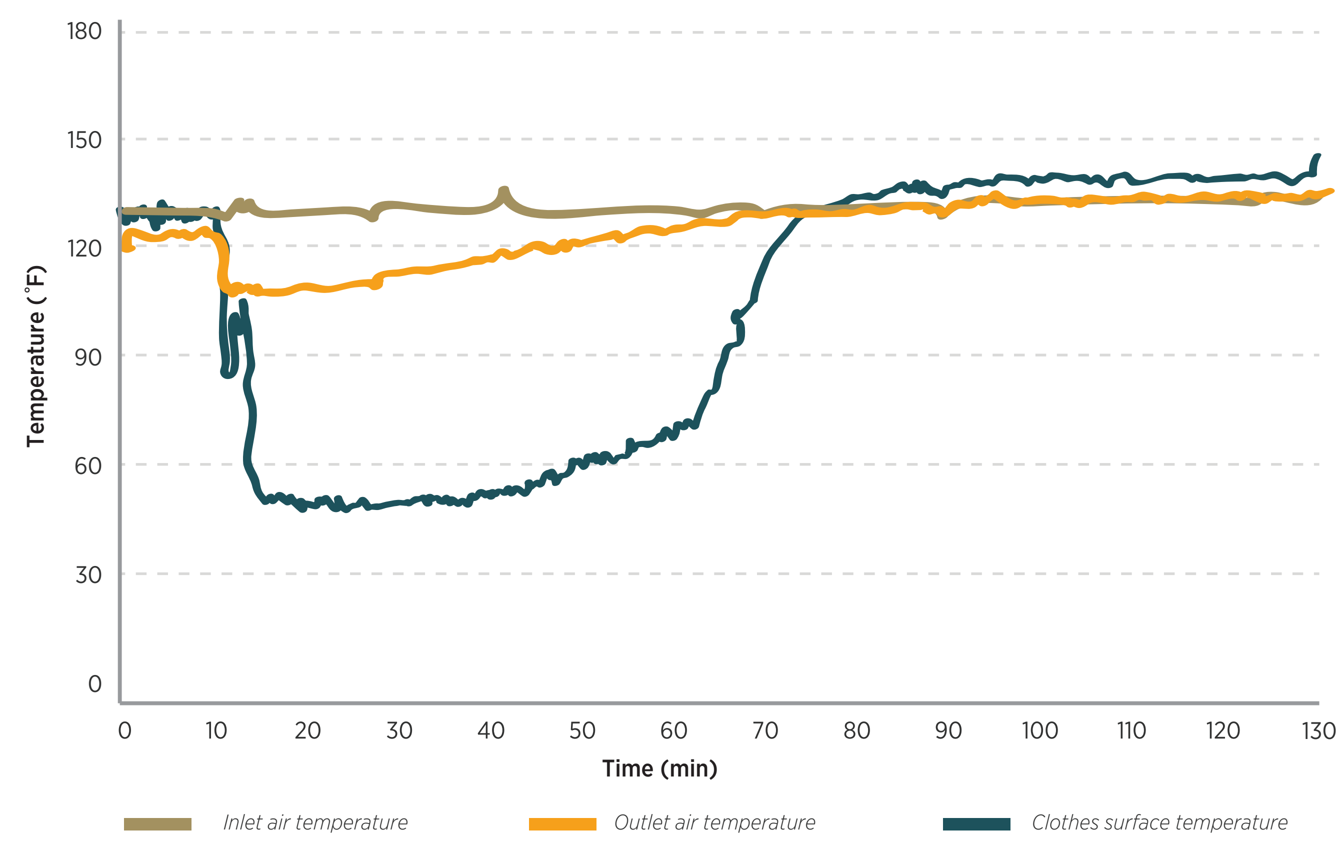


- DOE estimates that energy savings between 4 – 62% are possible with improved dryer controls
- Achieving 20% savings in natural gas dryers with 10% market penetration would save 6 million therms annually in California
- WCEC testing has shown that typical natural gas dryers run with inlet temperatures above 300°F and a significant amount of the air bypasses the burner

WCEC Laboratory Findings



Control Scheme Proof of Concept



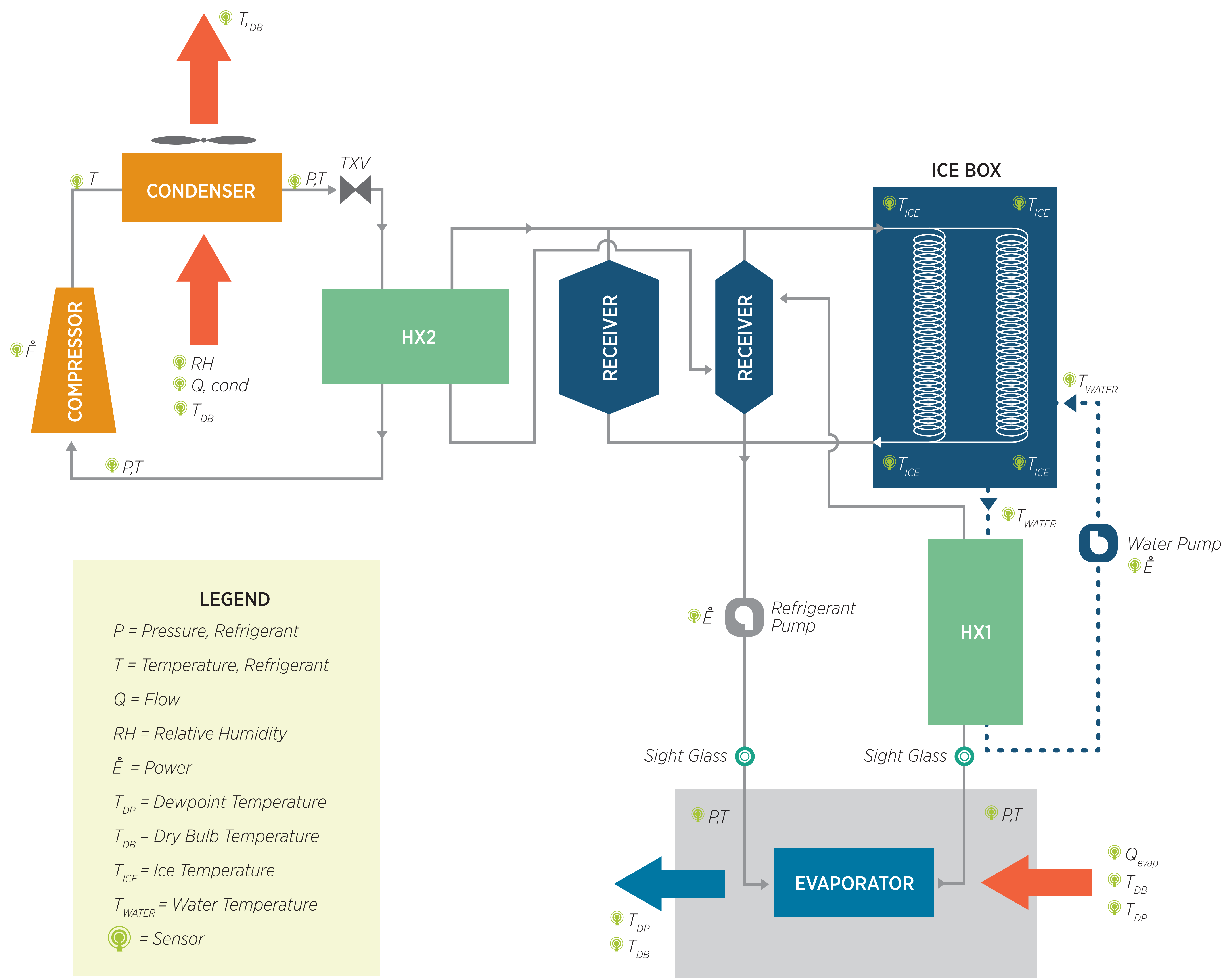
Researchers at Hong Kong Polytechnic University (Ah Bing Ng, Shiming Deng, 2008) have demonstrated control scheme proof of concept in a laboratory setup

PROJECT RESULTS:

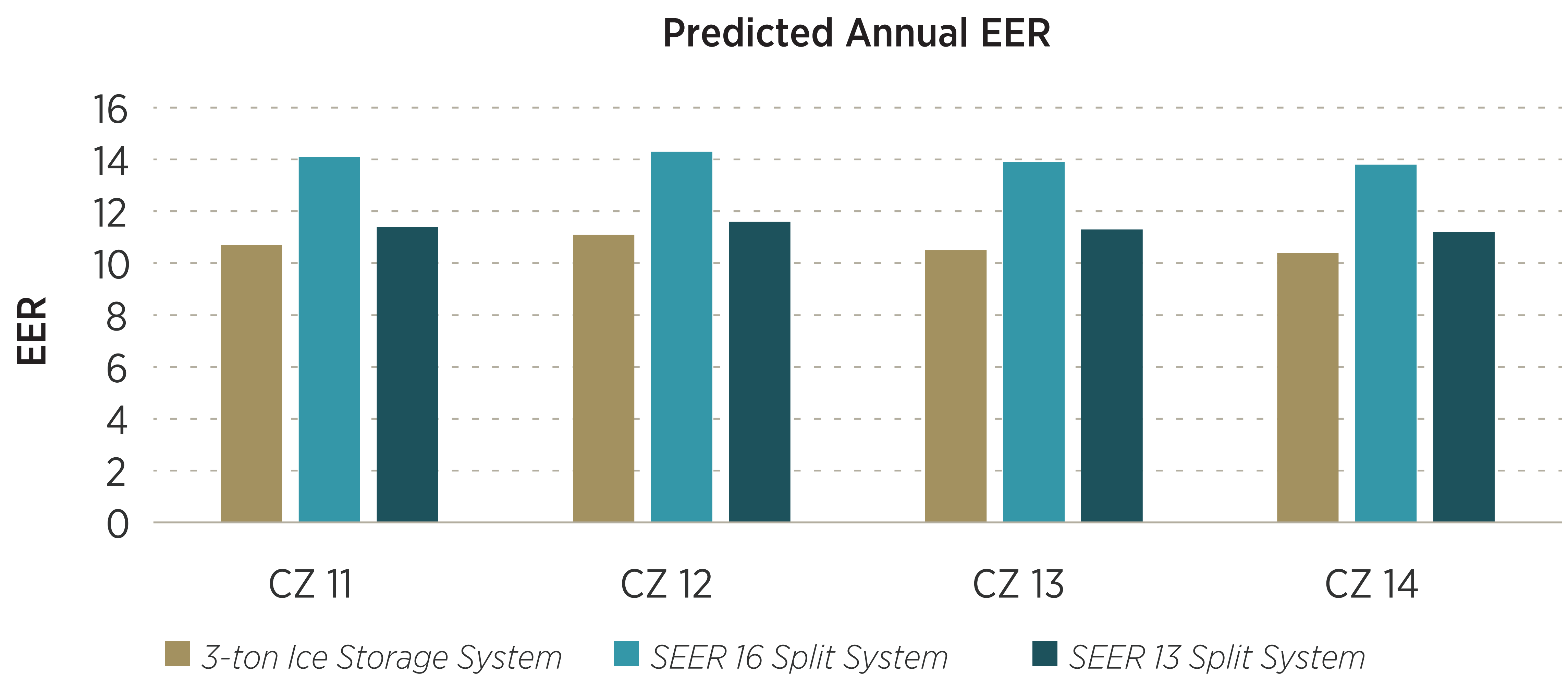
Performance Evaluation of a Thermal Storage Solution

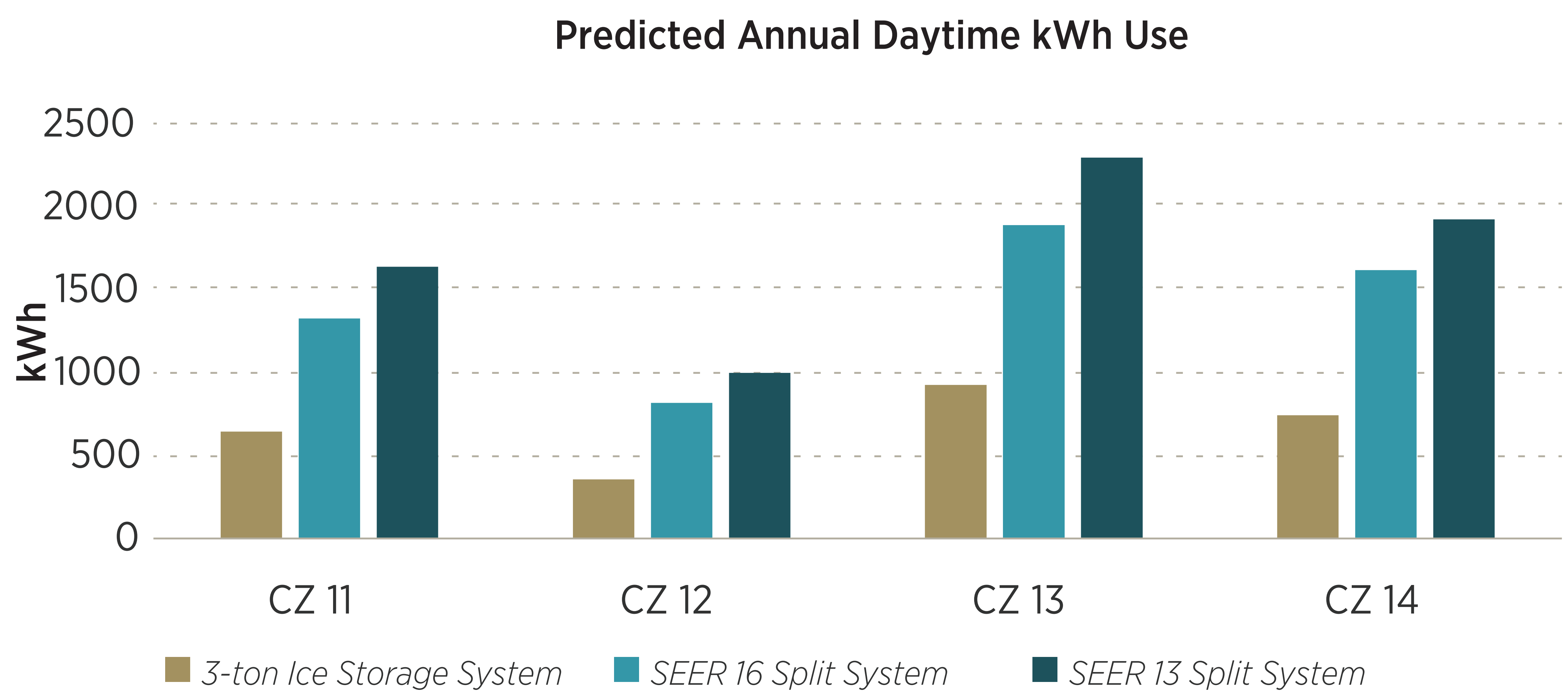
Using ice to store thermal potential

- WCEC tested a thermal storage solution in our environmental control chamber, and used the results to suggest design improvements and build a predictive performance model.
- The predictive model was used to estimate performance for a next generation thermal storage solution
- Successful completion of the tests is an example of the breadth of WCEC's expertise in energy efficient technologies



Laboratory testing diagram


Predicted Annual EER
16
14
12
10
8
6
4
2
0
EER
CZ 11
CZ 12
CZ 13
CZ 14
3-ton Ice Storage System
SEER 16 Split System
SEER 13 Split System


Predicted Annual Daytime kWh Use
2500
2000
1500
1000
500
0
kWh
CZ 11
CZ 12
CZ 13
CZ 14
3-ton Ice Storage System
SEER 16 Split System
SEER 13 Split System

PROJECT RESULTS:
High Performance Waste Heat Recuperators for Heat Recovery Cycles

Motivation and Challenges

- Waste heat recovery in ships can lead to enhanced efficiency and longer times between refueling.
- There has been recent interest in sCO2 cycles for power generation and waste heat recovery.
- Challenge is in designing a reliable recuperator,
  - Cyclic operation
  - Corrosion
  - Low pressure drop designs needed

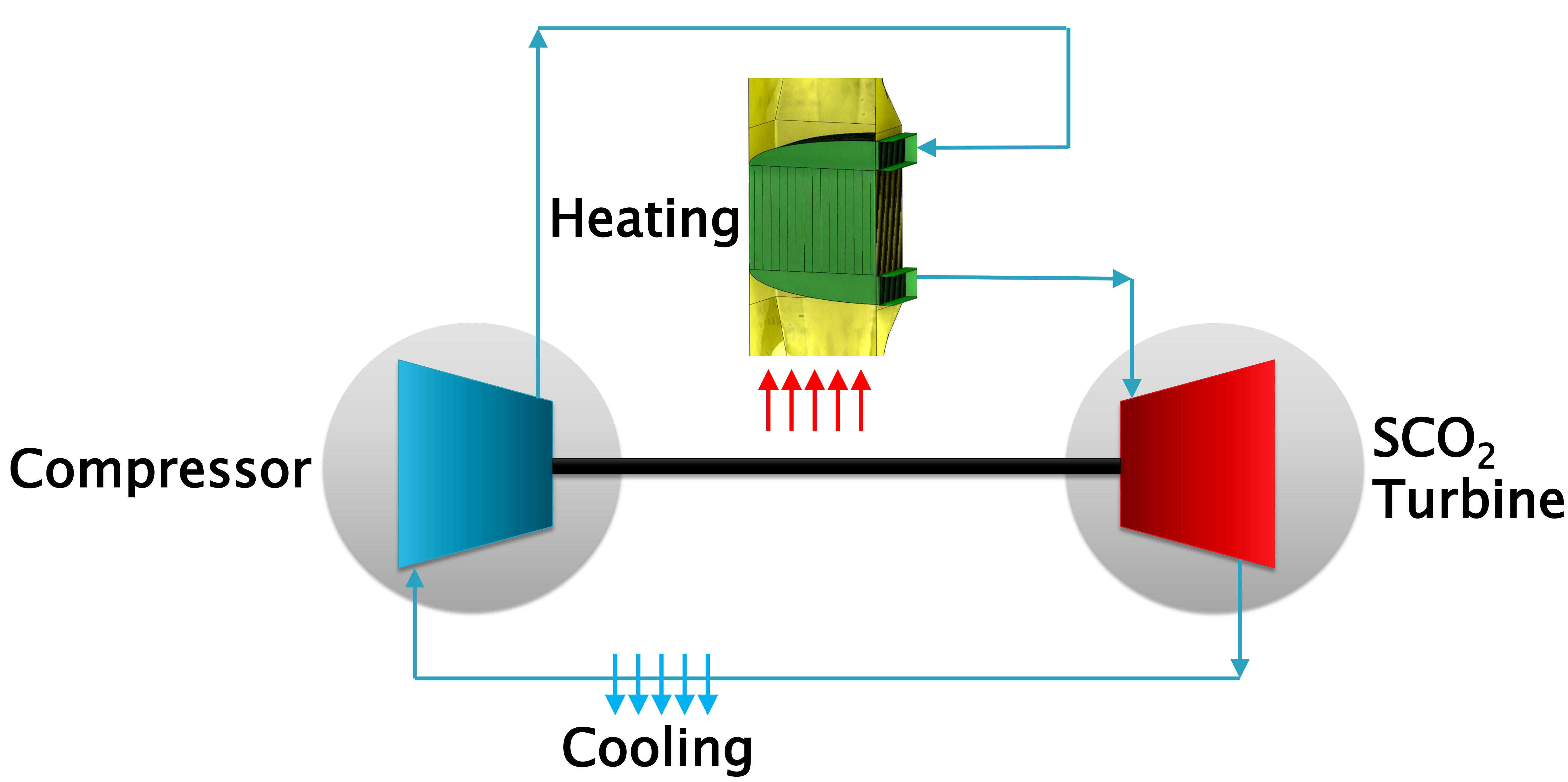
Problem Statement

Design a low pressure drop recuperator for sCO2 waste heat recovery cycle while running in system pressure as high as 200 bar (3000 psi) for a large naval ship.

Benefit to US Navy

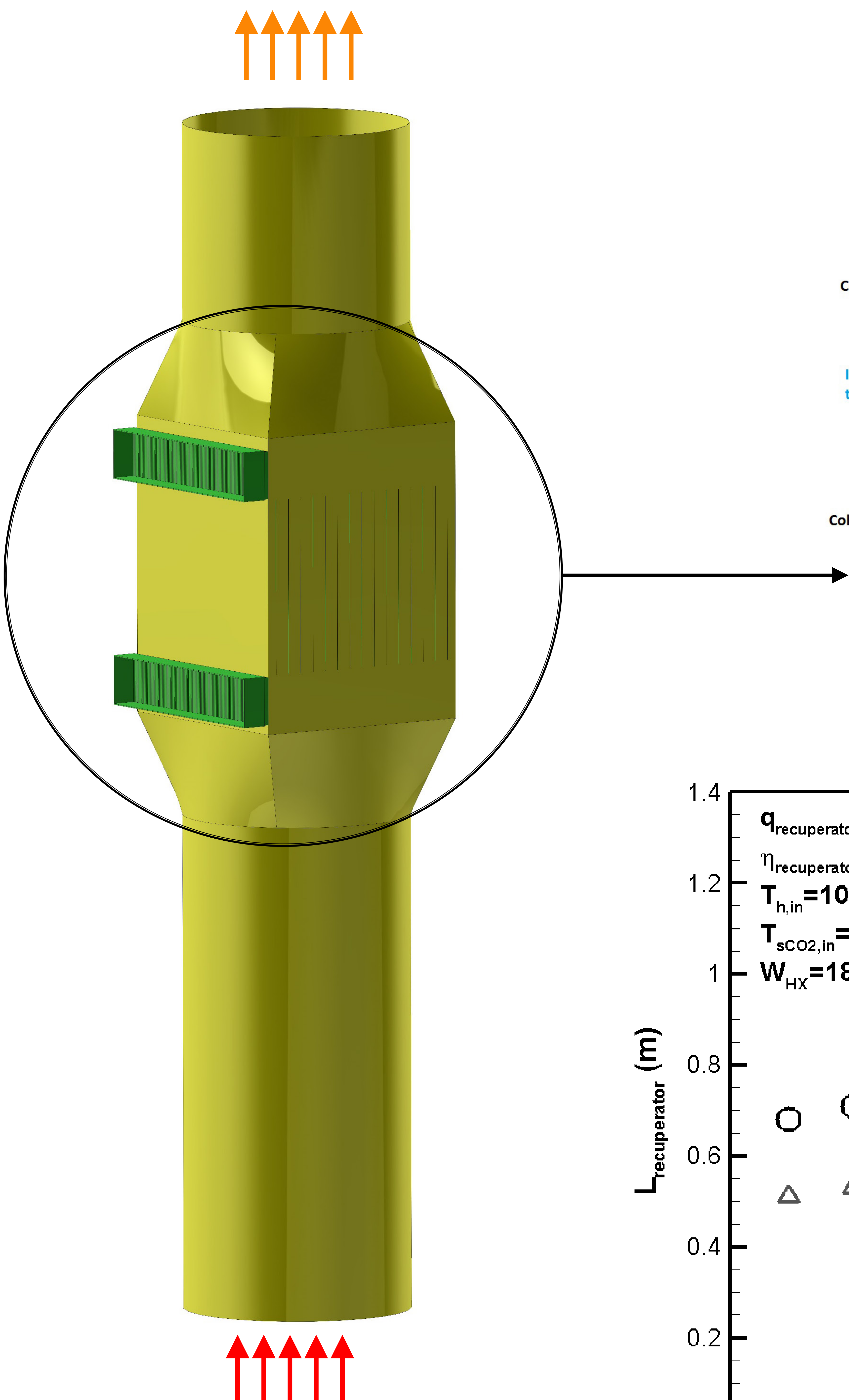
Novel recuperator designs for high pressure sCO2 waste heat recovery cycle using Additive Manufacturing:

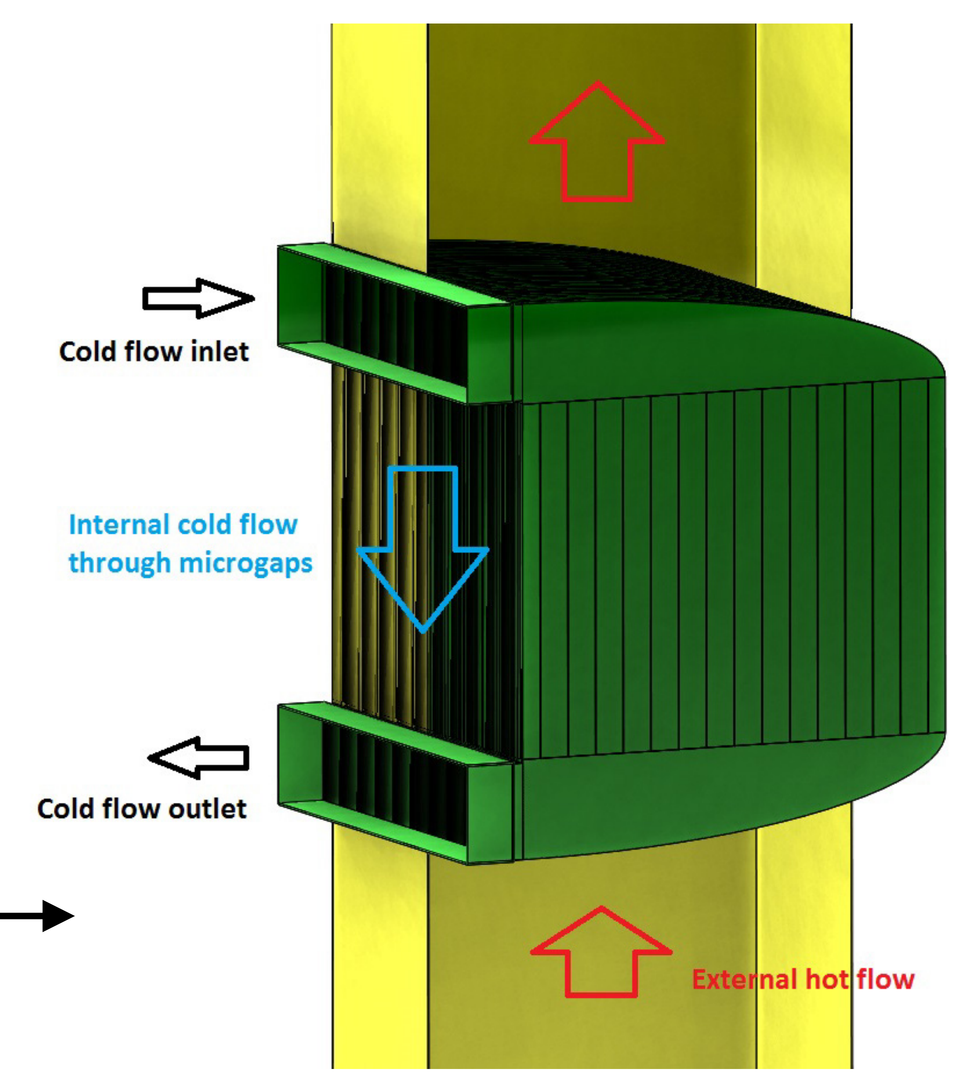
- High effectiveness recuperator
- Compact
- Low pressure drop on exhaust side
- No weld/braze joints in AM- potentially more reliable



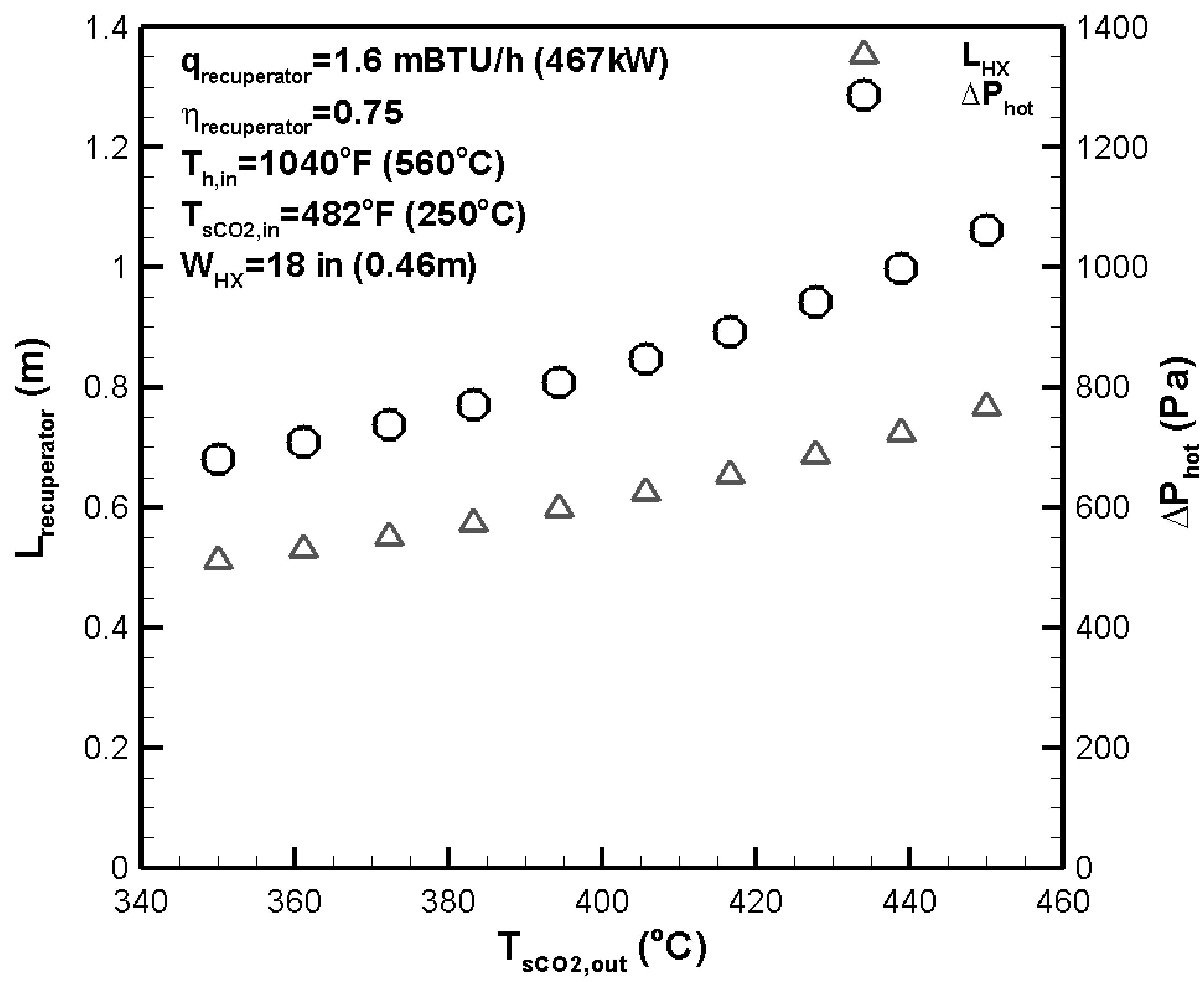
PROJECT RESULTS:
High Performance Waste Heat Recuperators for Heat Recovery Cycles

Low temperature exhaust gases to atmosphere





Hot exhaust gases from Generator



Variation of recuperator length and pressure drop of exhaust gases with sCO2 exit temperature based on the model developed for designing the recuperator