SUSTAINABLE STANFORD

Track 2A
Decarbonized District Energy Network for New Stanford Campus

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CampusEnergy2020
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INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Stanford Energy Operations

- Main Campus Replacement CEF
  - Electric-driven heat recovery system
- Building Electrification
- Reliable Energy Supply
- Cost Effective
- Sustainable

82% By Dec 2021 when next solar plant comes online

~~68%~~ reduction in campus greenhouse gas emissions by 2016

18% By Dec 2021 when LWHE comes online

~~15%~~ reduction in campus drinking water use by 2015

$520 with Direct Access and 100% solar PPAs

~~$420~~ million saved over next 35 years

Stanford Energy Operations

- Electricity
  - 250,000,000 kWh/yr
  - 435 locations
- Low Temperature Hot Water
  - 600,000 mmBtu/yr
  - 174 locations
- Chilled Water
  - 60,000,000 ton-hrs/yr
  - 147 locations
- Steam
  - 36,000 mmBtu/yr
  - 17 locations

- Staff of 42
- $100M O&M Budget
- $28M Energy Cost
  - $26M Electricity
  - $1M Natural Gas
  - $1M Water

Stanford Energy Operations

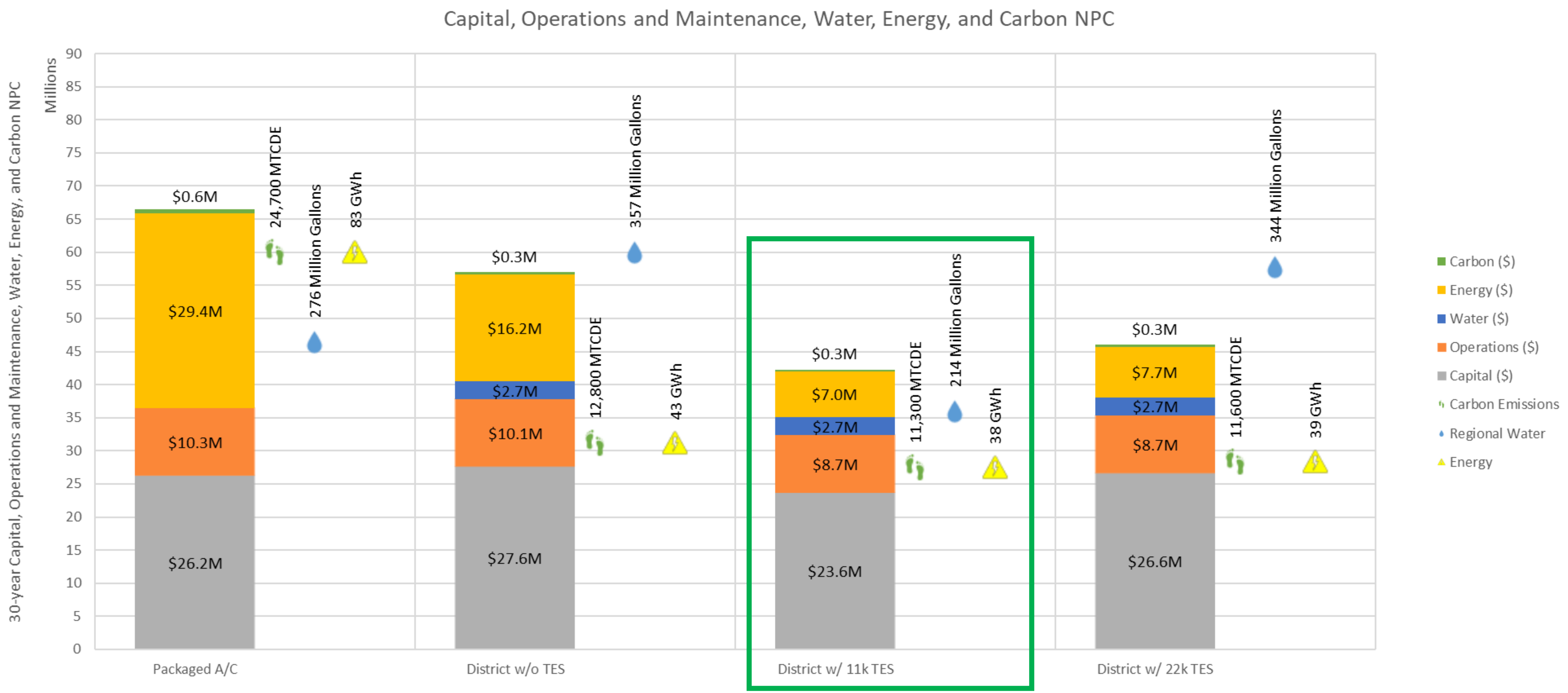
- Stanford in Redwood City
  - New campus developed for 2,700 Stanford staff members
  - Allows main campus growth
- Extension of Stanford sustainability
- Demonstrates **scalability**
- Remotely operated

Stanford in Redwood City – Initial Concept

Stanford in Redwood City – Cooling Options

- Packaged DX air-cooled units
- Packaged DX water-cooled units
- Building-level hydronic cooling
- District hydronic cooling
- District hydronic cooling with partial-shift TES
- District hydronic cooling with full-shift TES

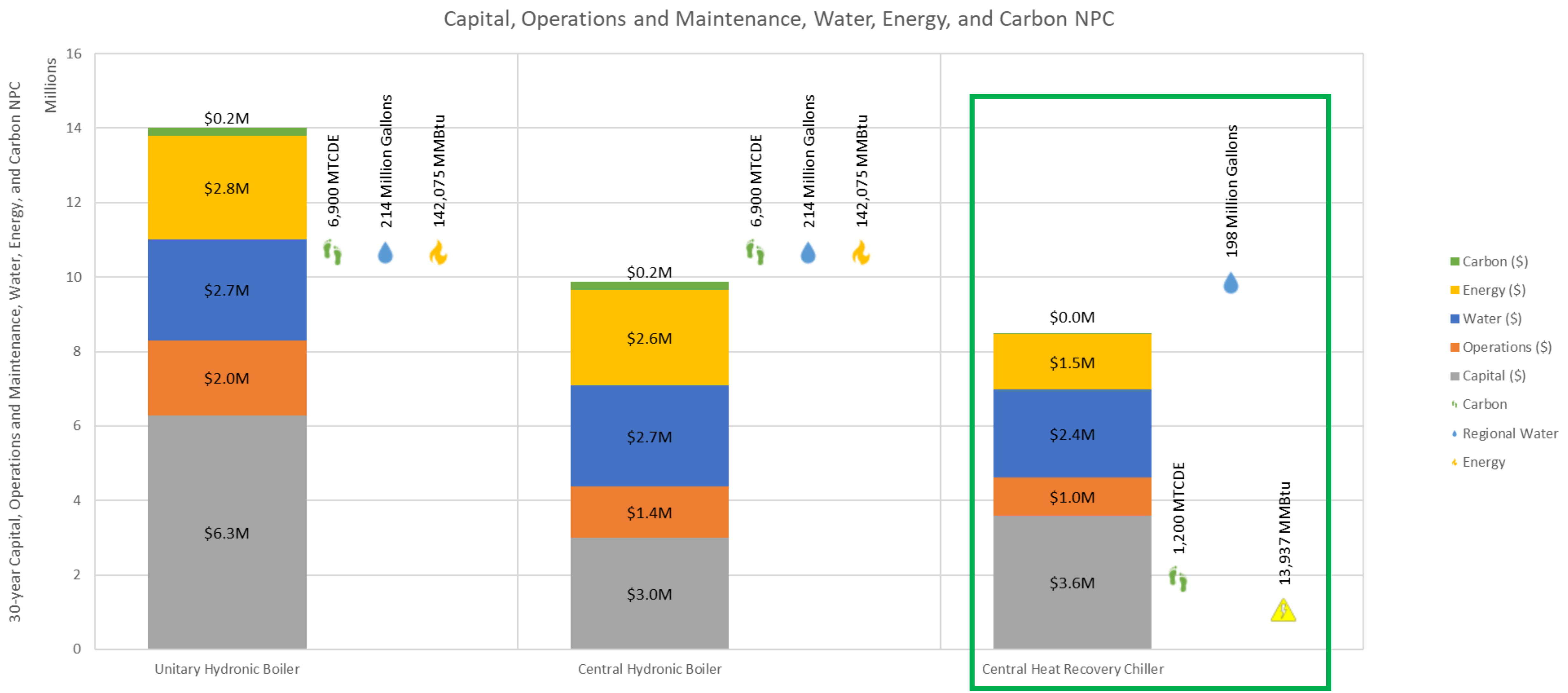
Life Cycle Cost Analysis – Cooling Options



Stanford in Redwood City – Heating Options

- Building-level hydronic boiler
- Central hydronic boiler
- Central heat recovery chiller

Life Cycle Cost Analysis – Heating Options

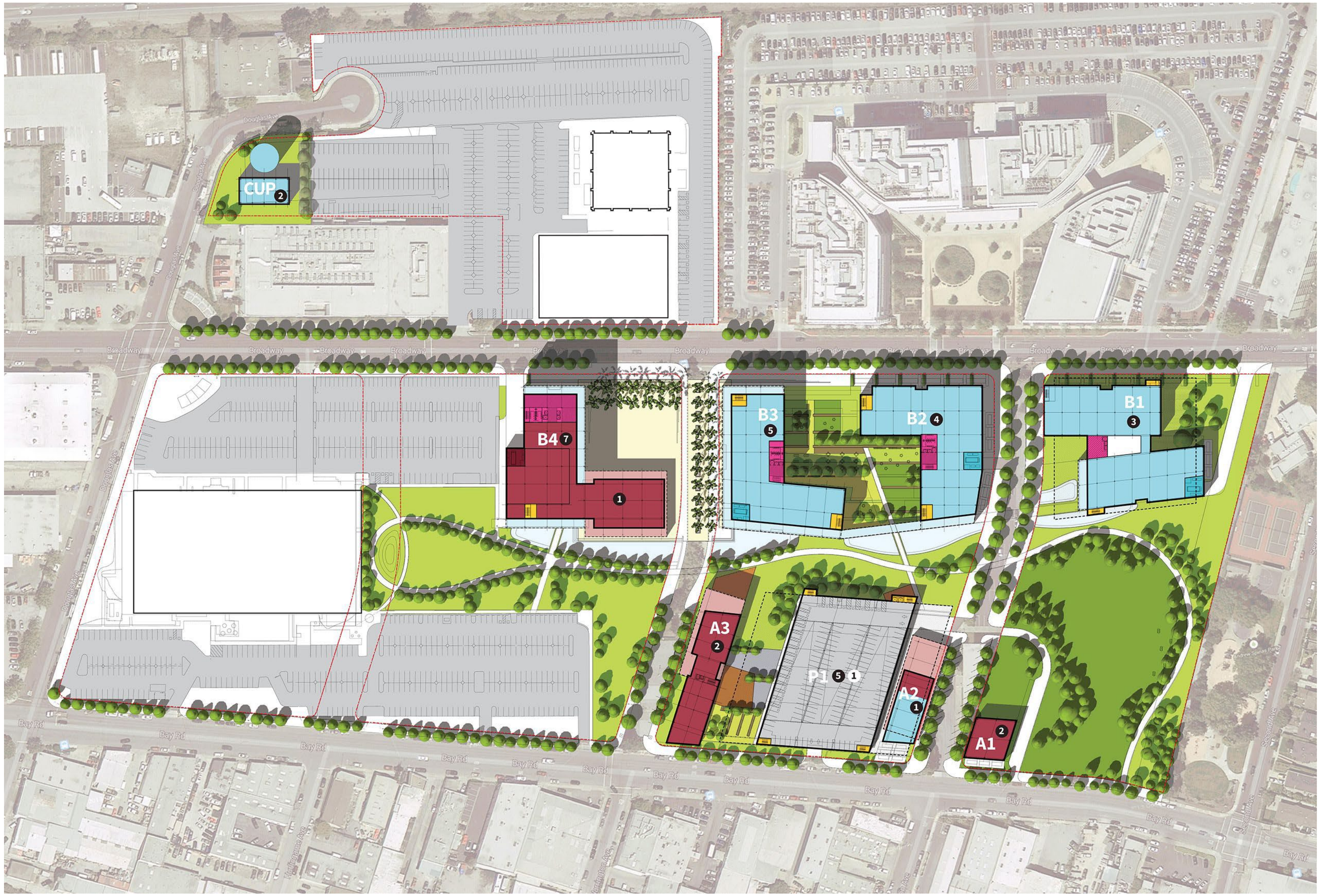


Comparison of BAU to Selected Option

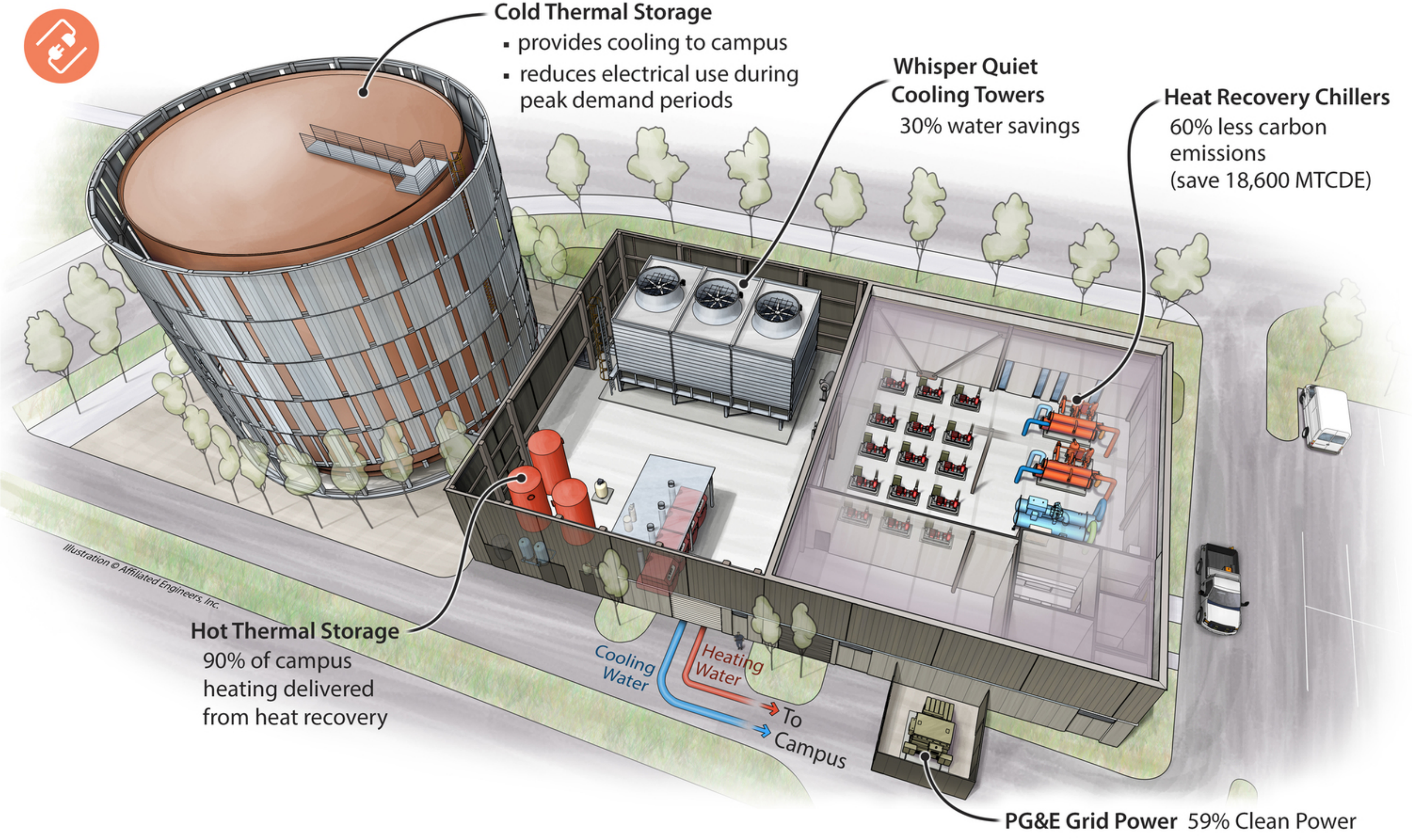
	Packaged DX Cooling Units and Unitary Hydronic Boilers	District Combined Heating and Cooling System with TES
Lifecycle Carbon Emissions	31,600 MTCDE (Scope 1 and 2)	Scope 1 and 2 near zero carbon within two years when offsite green power is online Minimal Scope 1 emitted by natural gas cooking and backup heating
Present Value of Capital	$32.5M	$30.2
Total Present Cost	$77.8M	$48.1 38% Savings
Lifecycle Energy Consumption	430,000 MMBtu	140,000 MMBtu 67% Reduction
Average COP	3.02	8.96

Stanford in Redwood City – Master Plan

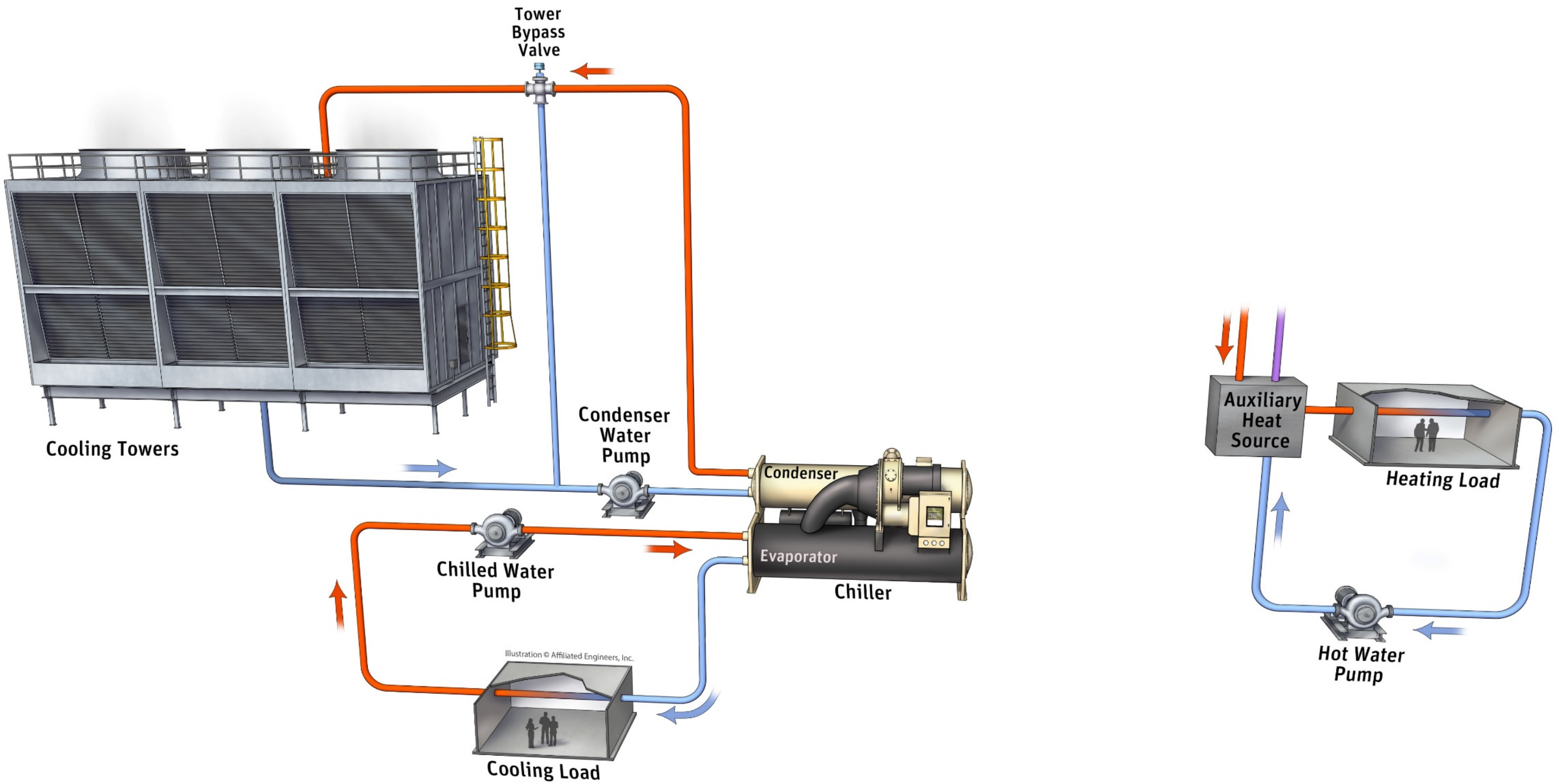
Stanford in Redwood City – Initial Development



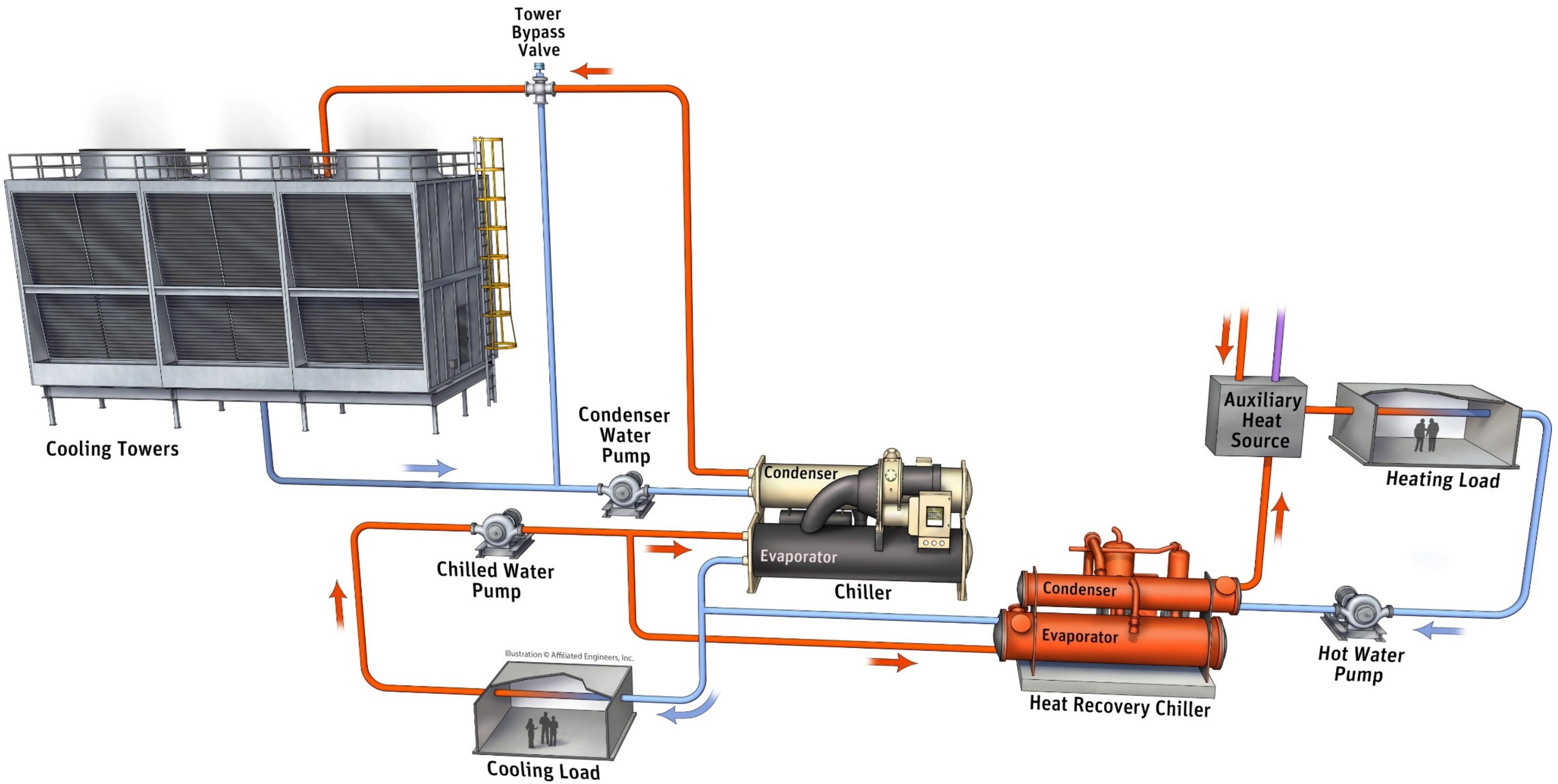
Central Energy Facility



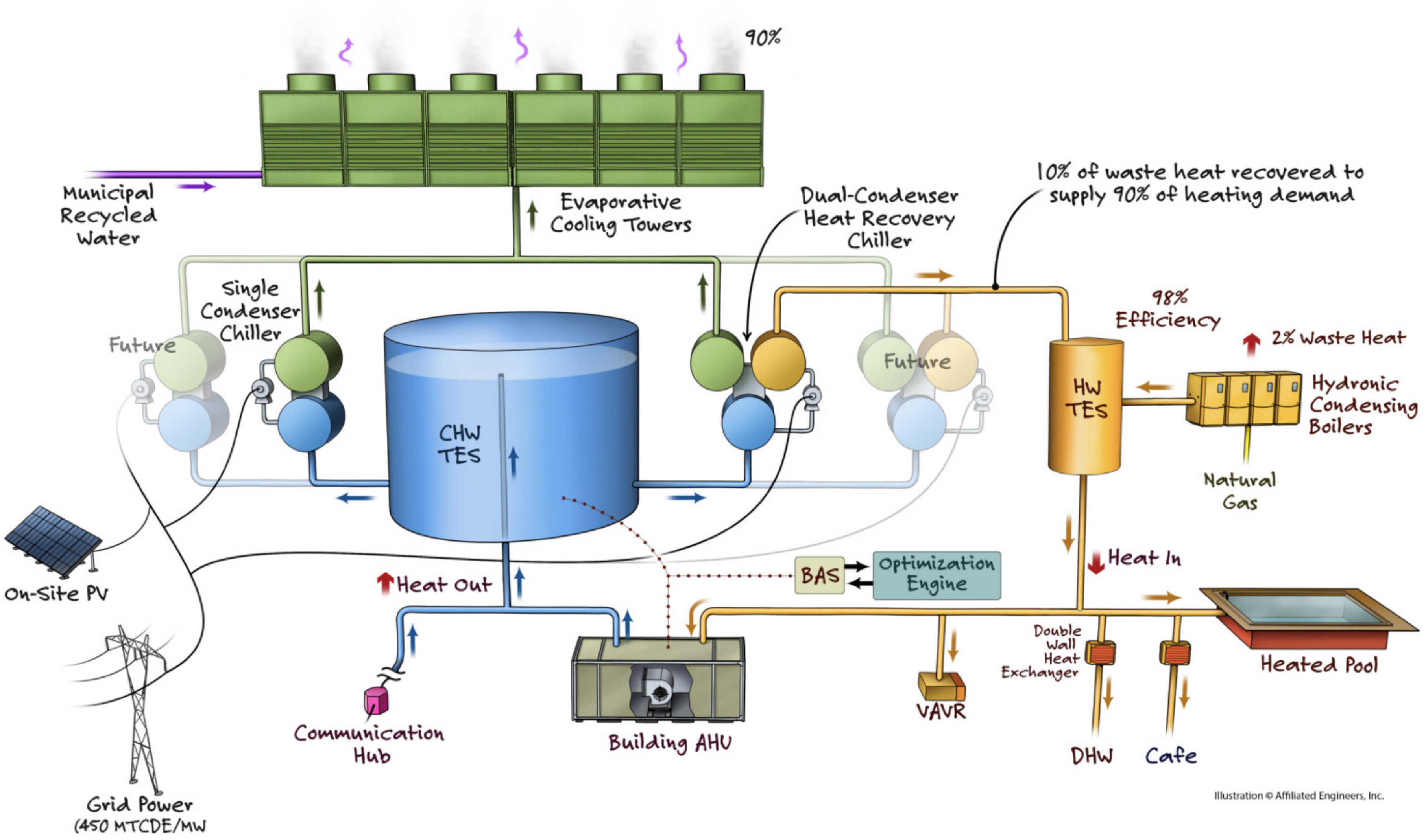
Separate Heating and Cooling (SHC)



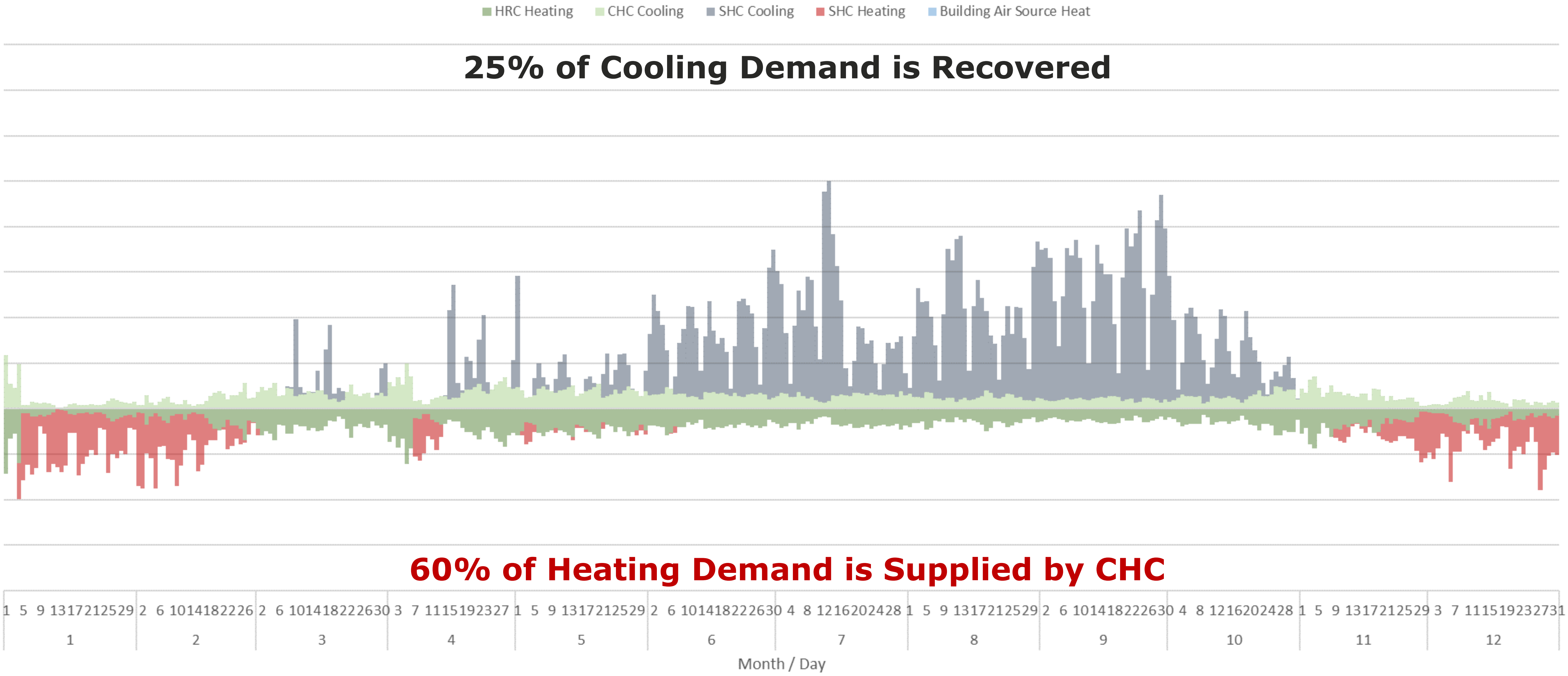
Combined Heating and Cooling (CHC)



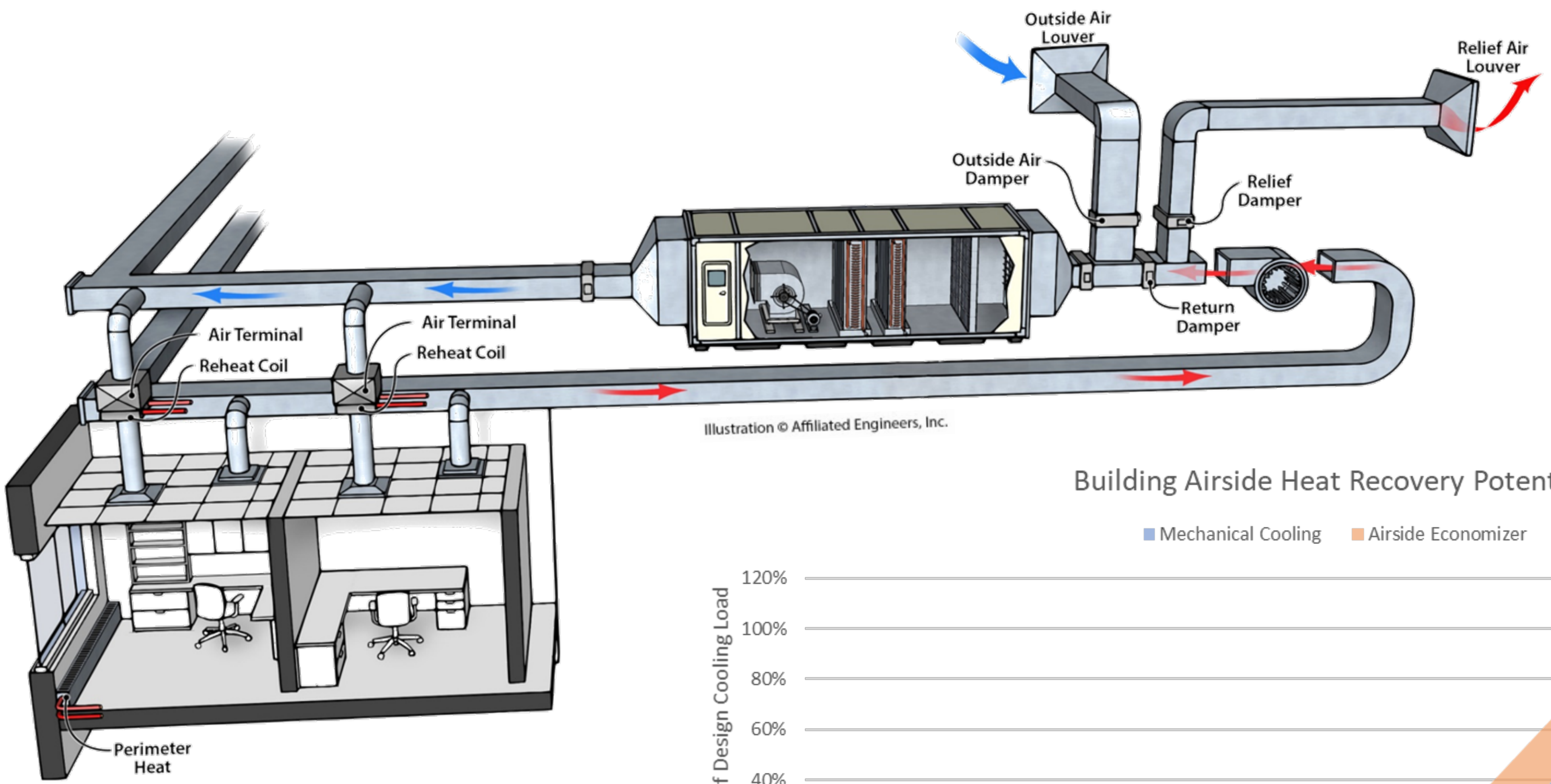
Campus Energy Flow

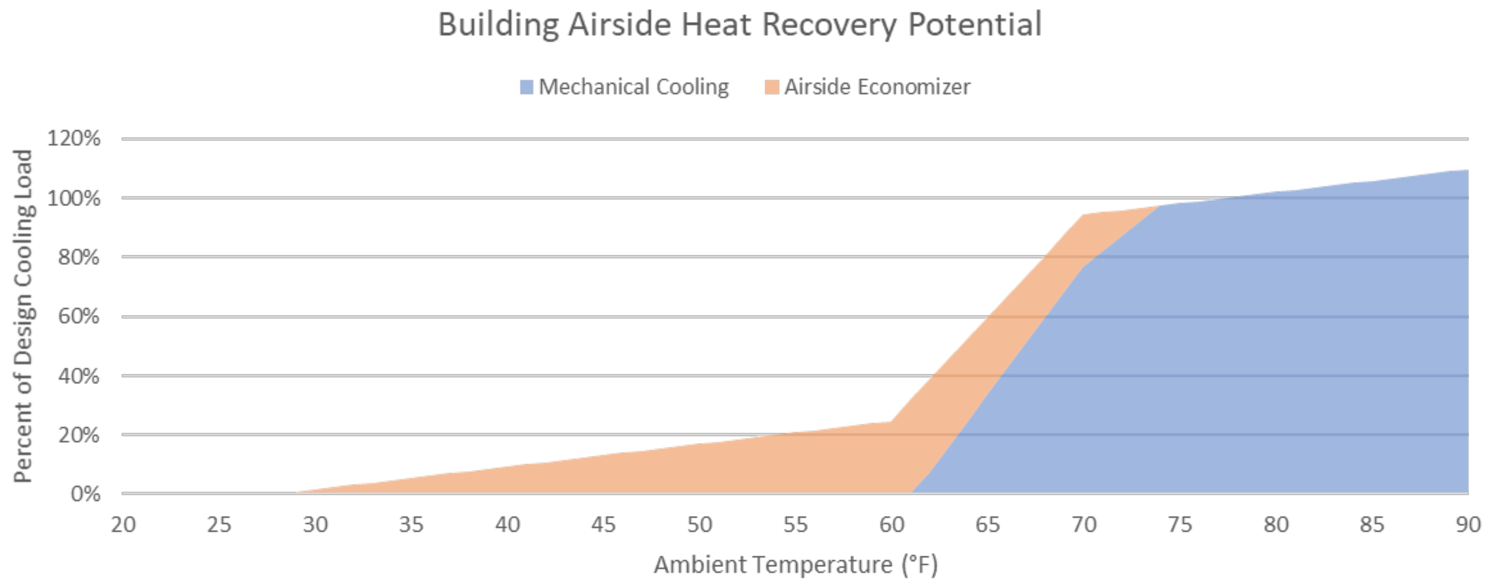


Annual Combined Heating and Cooling



Building Air Source Heat (BASH)



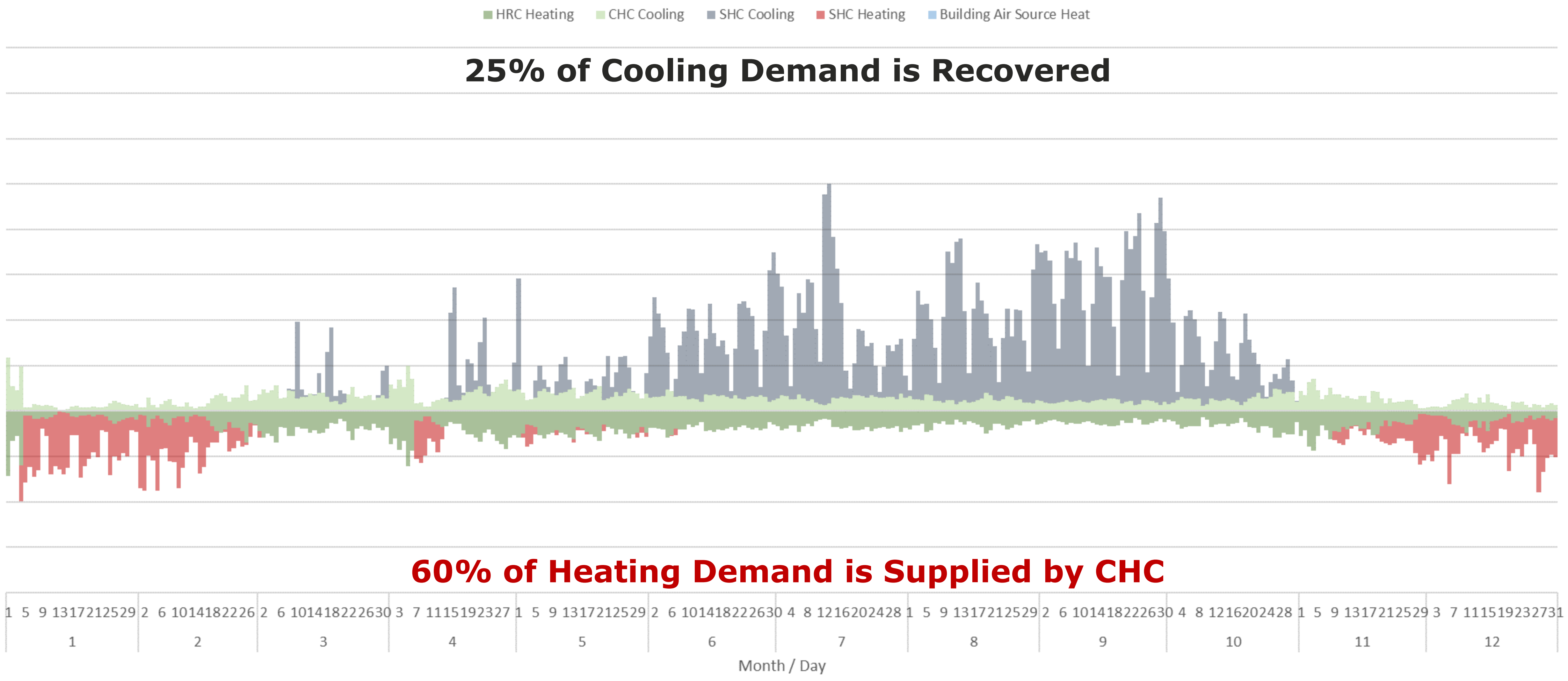


<u>Assumptions</u>

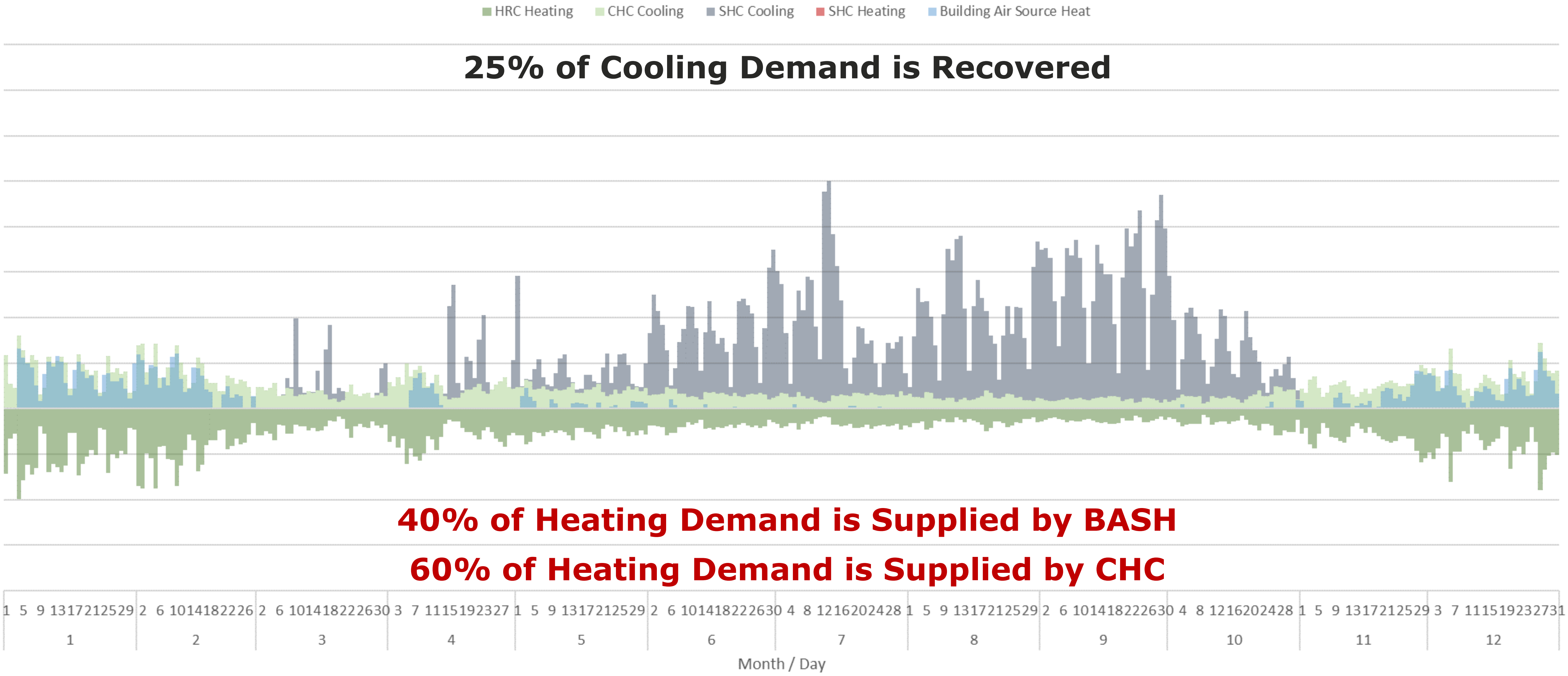
Above 70°F OADB: 55°F SAT and 74°F RAT

Below 60°F OADB: 62°F SAT and 68°F RAT

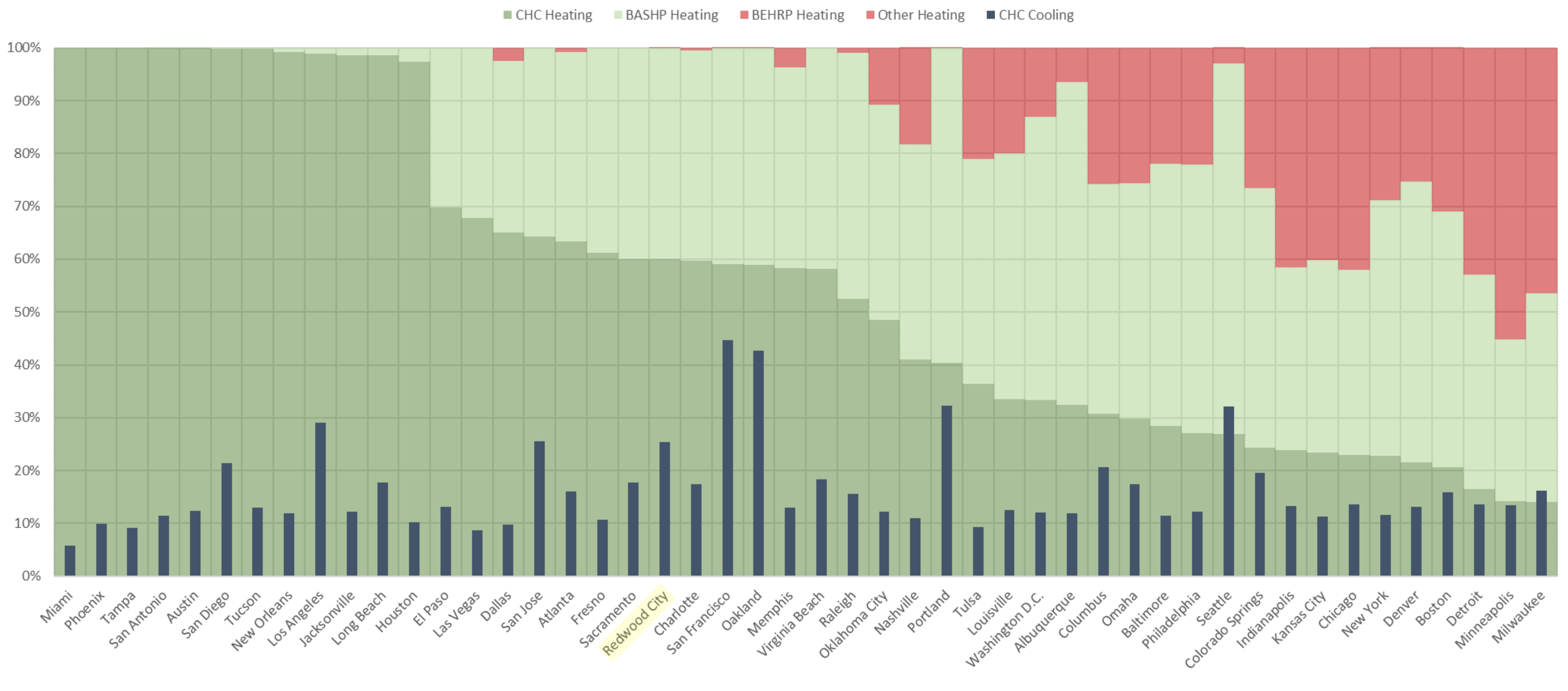
Annual Combined Heating and Cooling



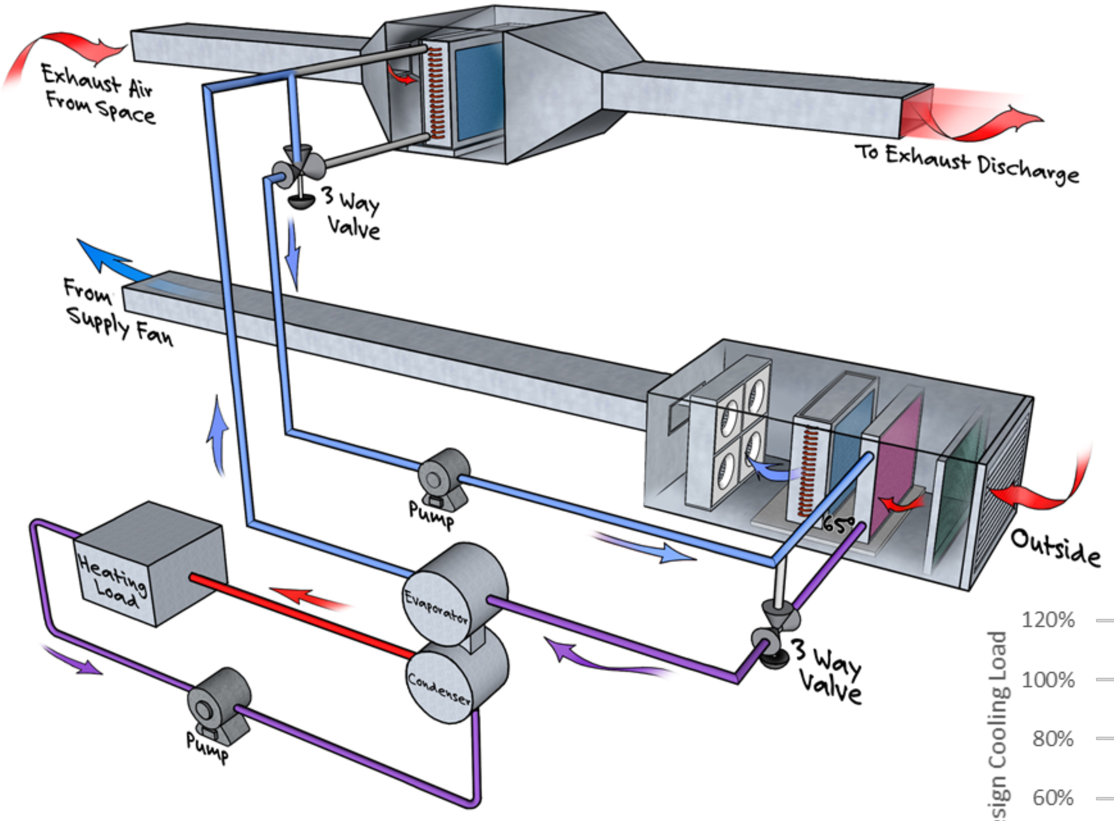
Annual Combined Heating and Cooling with BASH

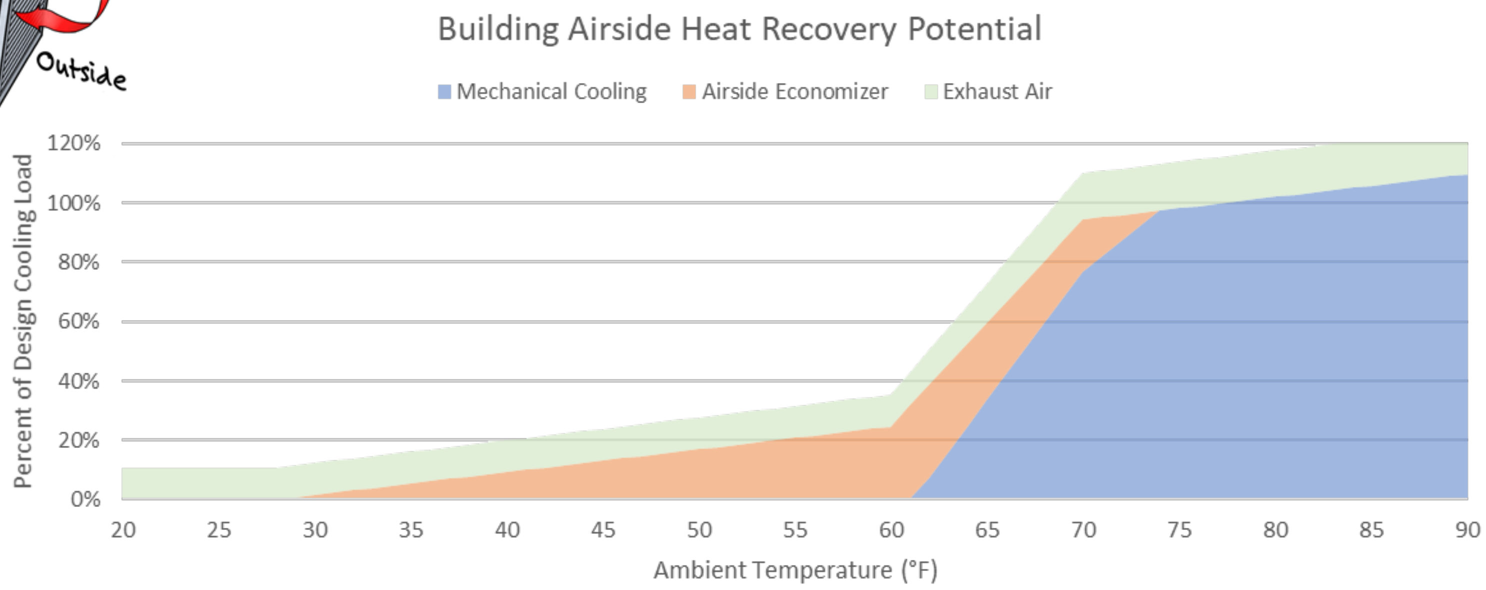


CHC and BASH Benefits Across the Country



Building Exhaust Heat Recovery (BEHR)



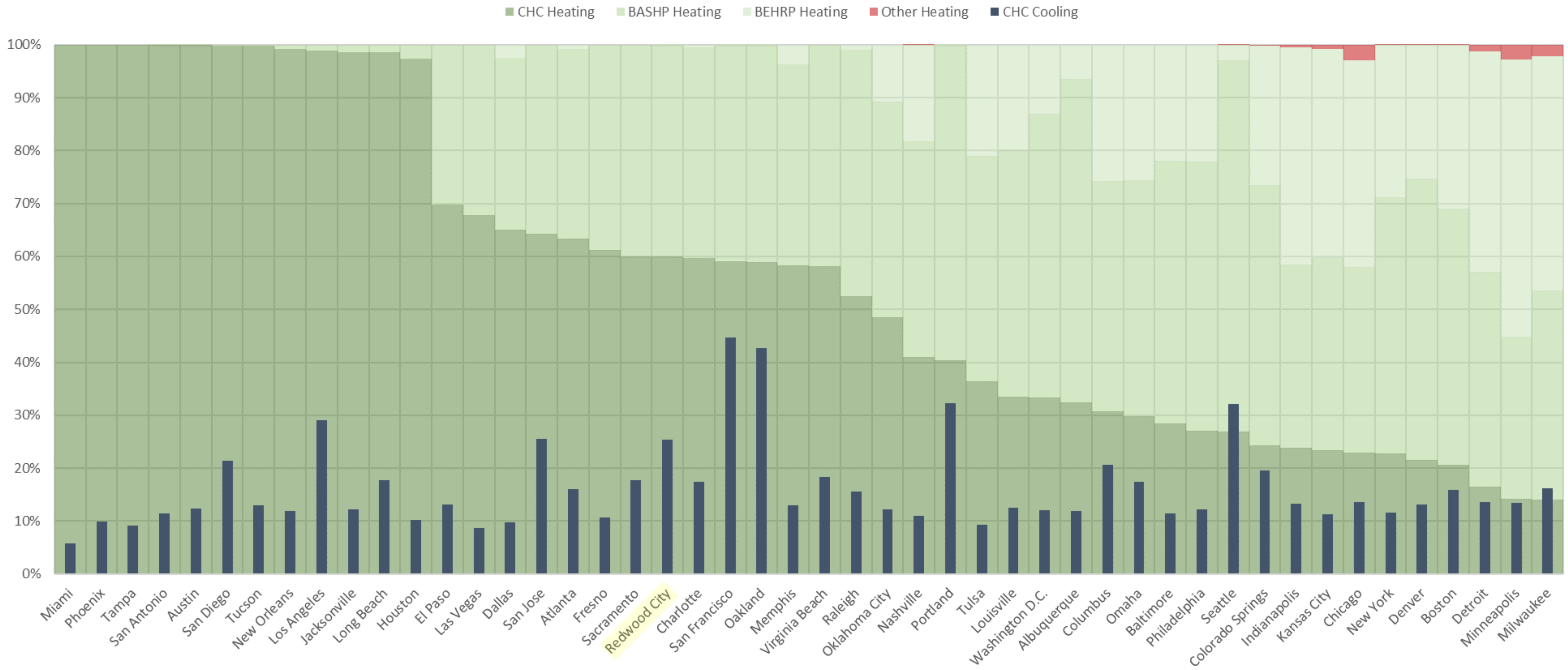


<u>Assumptions</u>

Above 70°F OADB: 55°F SAT and 74°F RAT

Below 60°F OADB: 62°F SAT and 68°F RAT

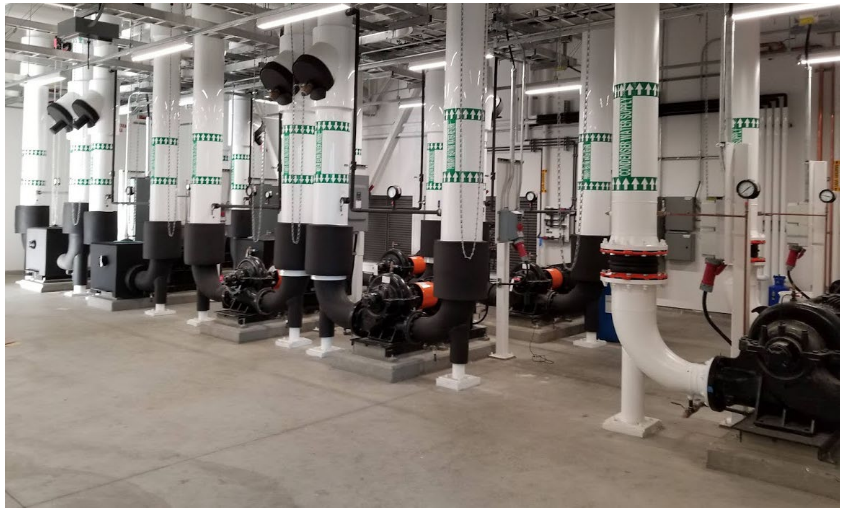
CHC and BASH+BEHR Benefits Across the Country

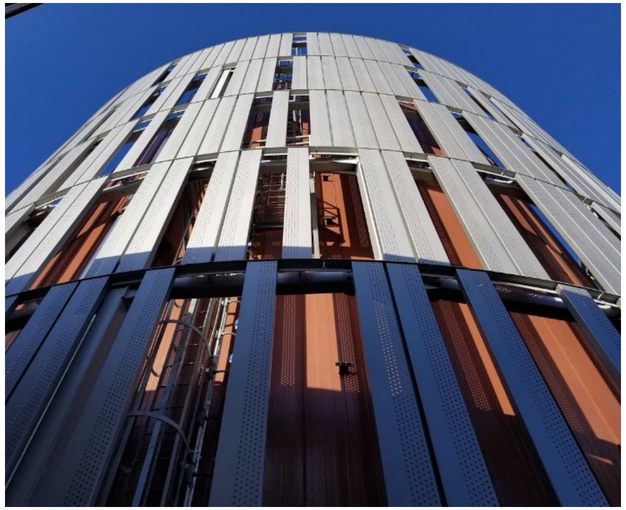


Other Low Grade Heat Sources

- **Building Air Source Heat (people, computers, lights, etc.)**
- Lower temperature refrigeration on campus
- Engine coolant
- **Building Exhaust Heat Recovery**
- Irrigation or domestic water flow
- Wastewater influent/effluent flow
- Ambient air
- Solar thermal
- Electricity
- Adjacent industry
- Surface water
- Geothermal

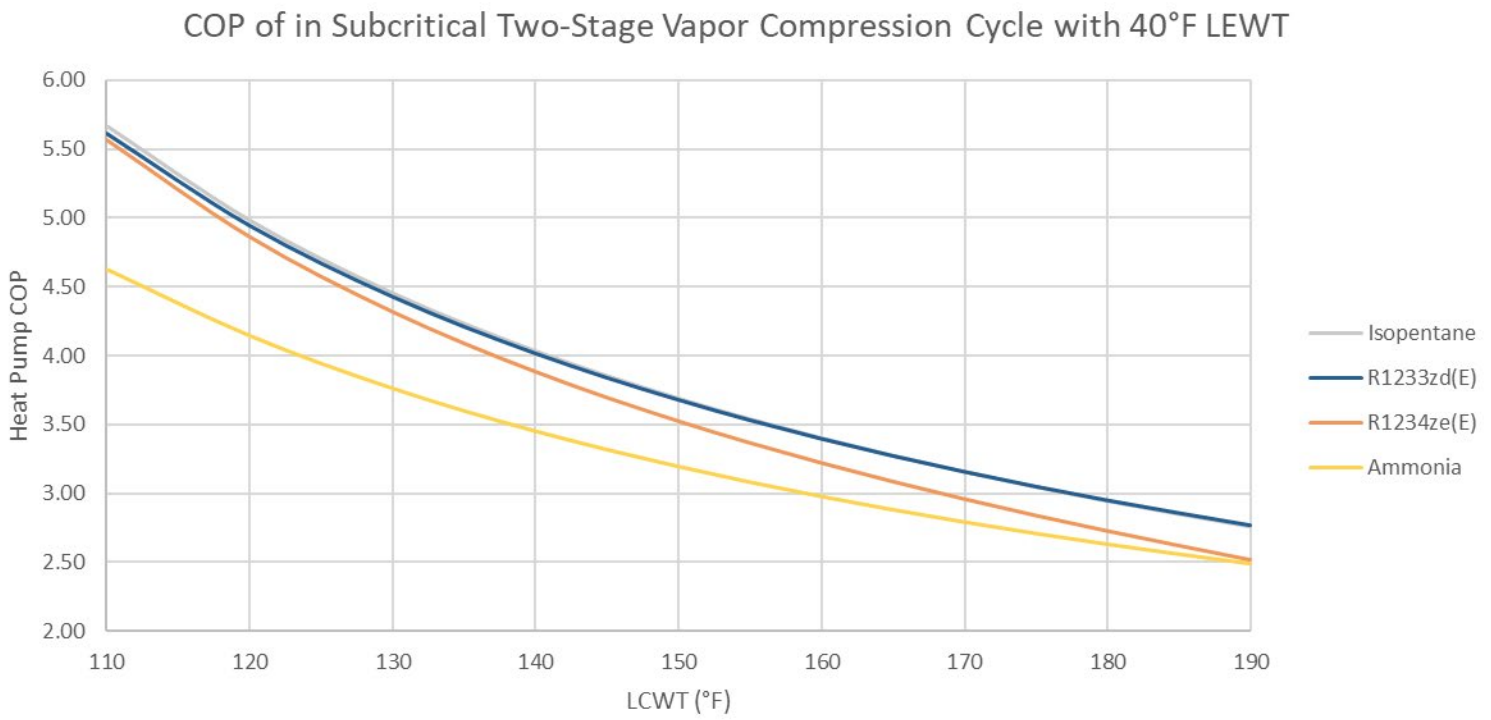
Construction Completed in 2019





Lessons Learned

- **Ultra-low 110°F heating water supply temperature**
  - VAV reheat system control
  - VAV reheat system selection
  - Alternative building heating strategies
  - Domestic hot water
  - Other heat sinks
- **Any heat pump system**
  - Refrigerant compressors
  - Differential temperature
  - Supply to return bypasses
  - Three way valves
  - Low-grade heat sources
  - Thermal storage



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Questions?

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