Energy Exchange℠

Be Efficient And Resilient

U.S. Department of Energy

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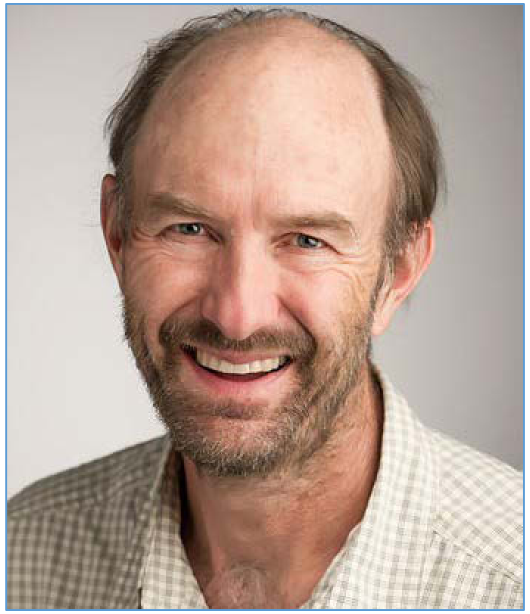

Data Center Optimization Strategies

NREL ESIF Data Center Energy and Water Savings

NREL Data Center Design

- **Showcase Facility**
  - ESIF 182,000 ft.^{2} research facility
  - 10,000 ft.^{2} data center
  - 10 MW at full buildout
  - LEED Platinum facility, PUE ≤ 1.06
  - No mechanical cooling (eliminates expensive and inefficient chillers)

Utilize the bytes and the BTUs!

- **Data Center Features**
  - Direct, component-level liquid cooling, 24ºC (75ºF) cooling water supply
  - 35–40ºC (95-104ºF) return water (waste heat), captured and used to heat offices and lab space
  - Pumps more efficient than fans
  - High voltage 480 VAC power distribution directly to high power density 60kW–80 kW compute racks
- **Compared to a Typical Data Center**
  - Lower CapEx—costs less to build
  - Lower OpEx—efficiencies save

Integrated "Chips to Bricks" Approach

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Liquid Cooling – Considerations

- Liquid cooling essential at high-power density
- Compatible metals and water chemistry is crucial
- Cooling distribution units (CDUs)
  - Efficient heat exchangers to separate facility and server liquids
  - Flow control to manage heat return
  - System filtration (with bypass) to ensure quality
- Redundancy in hydronic system (pumps, heat exchangers)
- Plan for hierarchy of systems
  - Cooling in series rather than parallel
  - Most sensitive systems get coolest liquid
- At least 95% of rack heat load captured directly to liquid

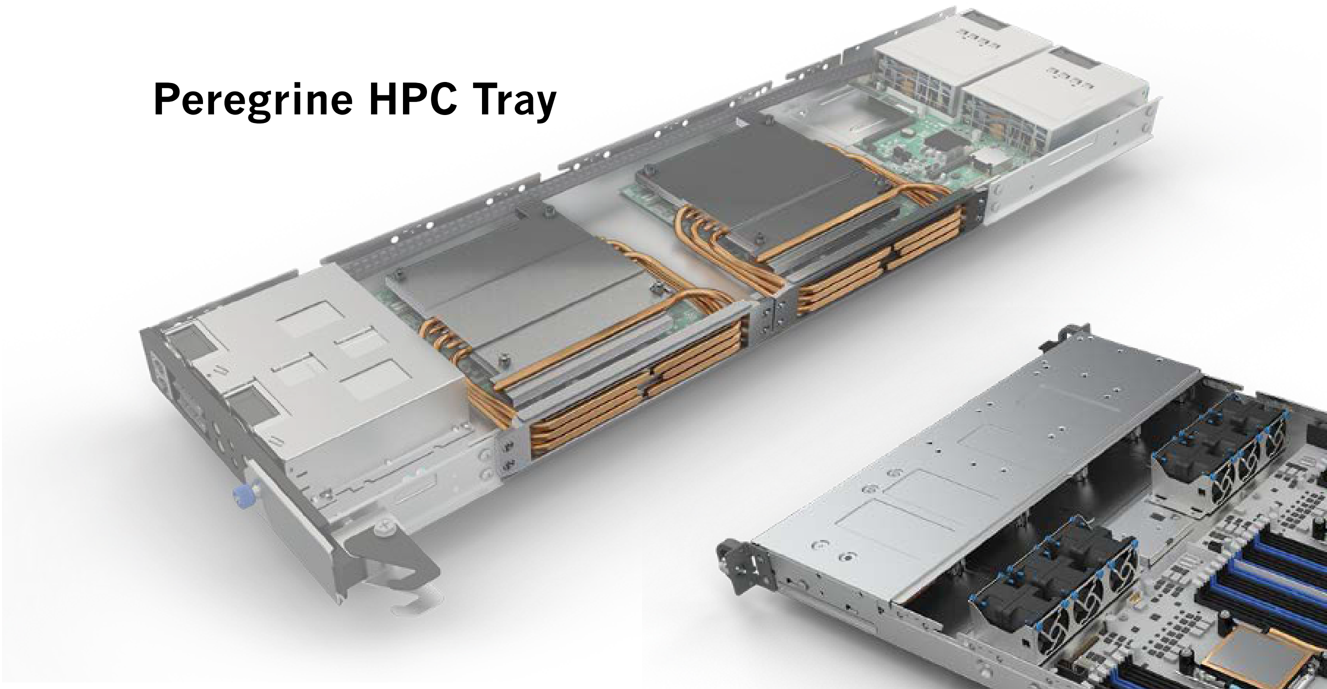
Air-Cooled to Liquid-Cooled Racks

Traditional **air-cooled** allow for rack power densities of 1kW–5kW

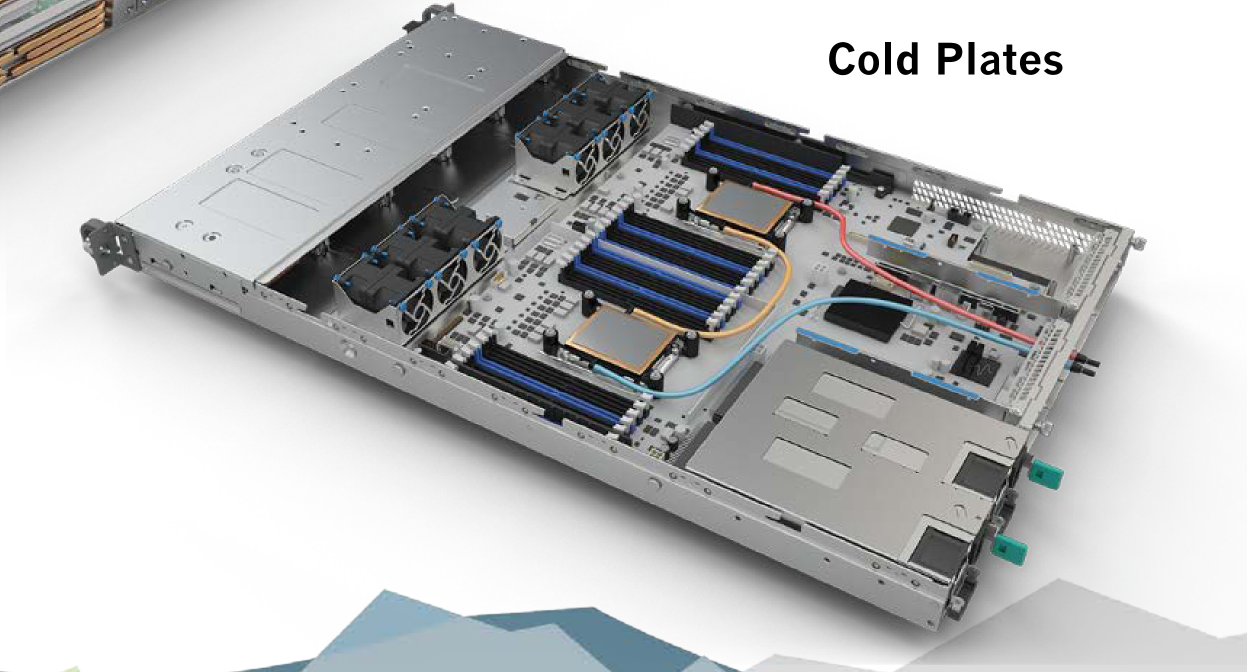
Require **liquid-cooled** when rack power densities in 5kW–80kW range, have several options

Liquid-Cooled Server Options

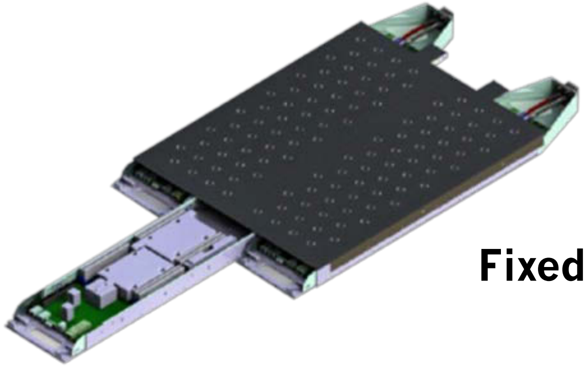
Peregrine HPC Tray



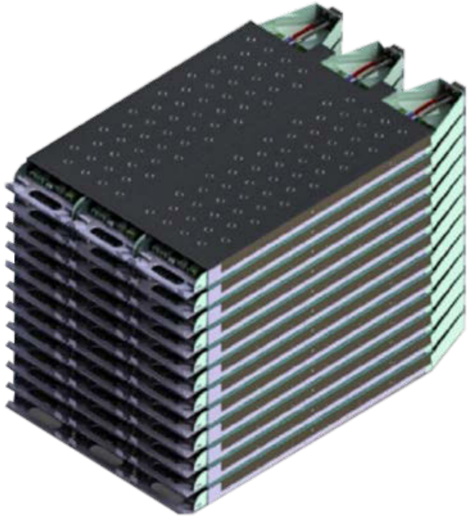
Cold Plates

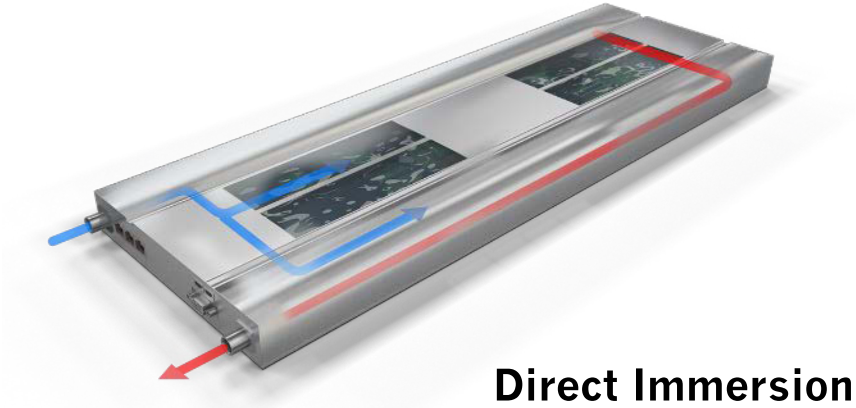


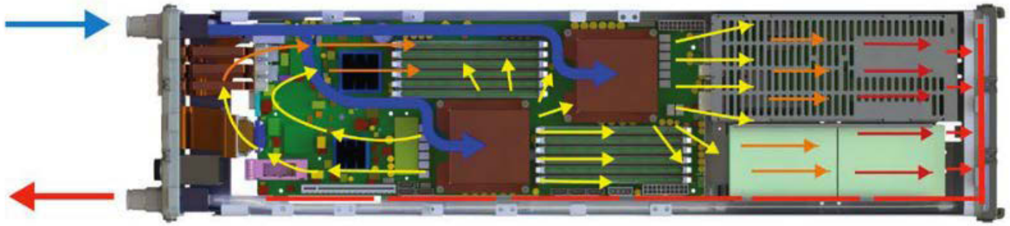
Fanless Liquid-Cooled Server Options



Fixed Cold Plate





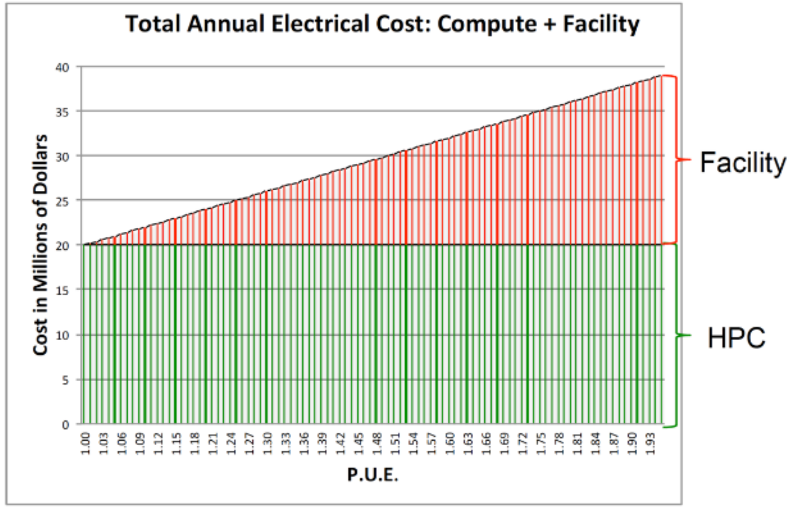


Direct Immersion

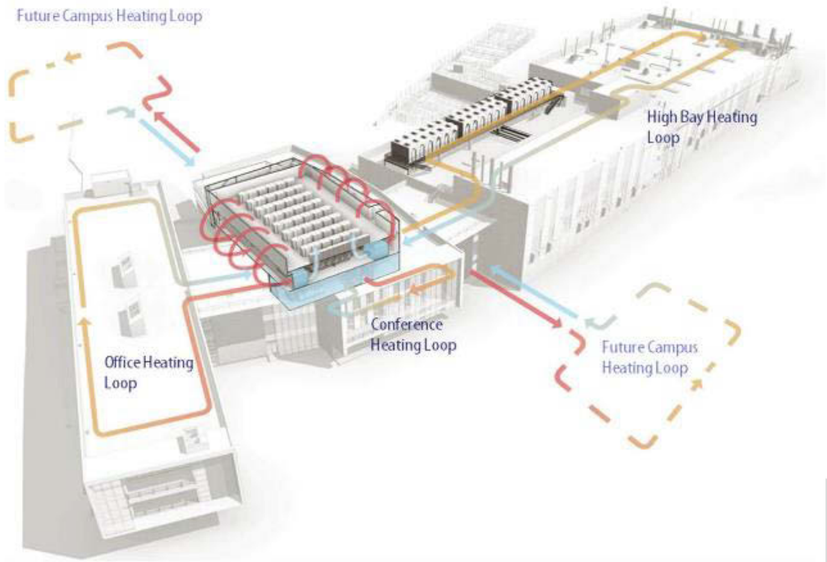
Metrics

$$PUE = \frac{\text{"Facility energy"} + \text{"IT energy"}}{\text{"IT energy"}}$$

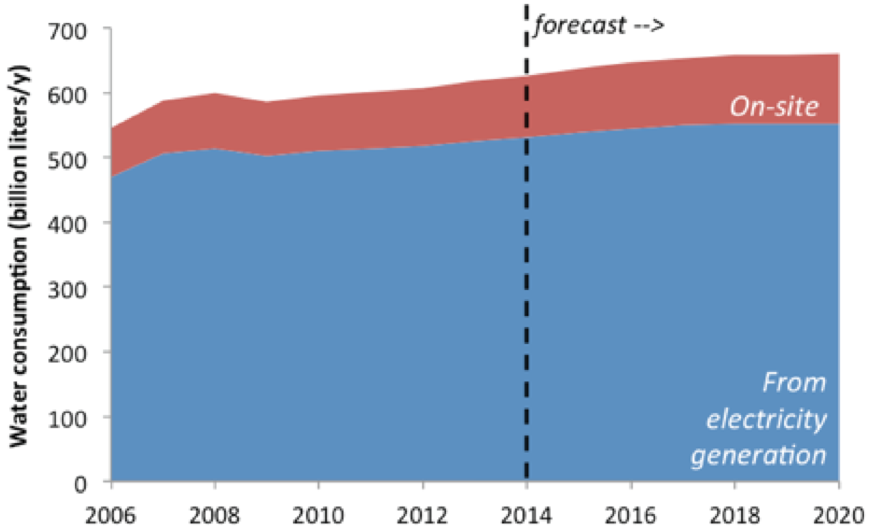
$$ERE = \frac{\text{"Facility energy"} + \text{"IT energy"} - \text{"Reuse energy"}}{\text{"IT energy"}}$$



Assume ~20MW HPC system & $1M per MW year utility cost.



Metrics



$$WUE = \frac{\text{“Annual Site Water Usage”}}{\text{“IT energy”}}$$

the units of WUE are liters/kWh

$$WUE_{SOURCE} = \frac{\text{“Annual Site Water Usage”} + \text{“Annual Source Energy Water Usage”}}{\text{“IT energy”}}$$

$$WUE_{SOURCE} = \frac{\text{“Annual Site Water Usage”}}{\text{“IT energy”}} + [EWIF \times PUE]$$

where EWIF is energy water intensity factor

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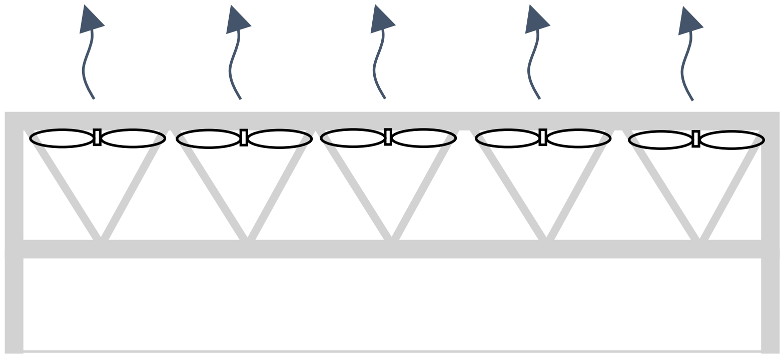
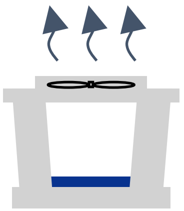
Air- and Water-Cooled System Options

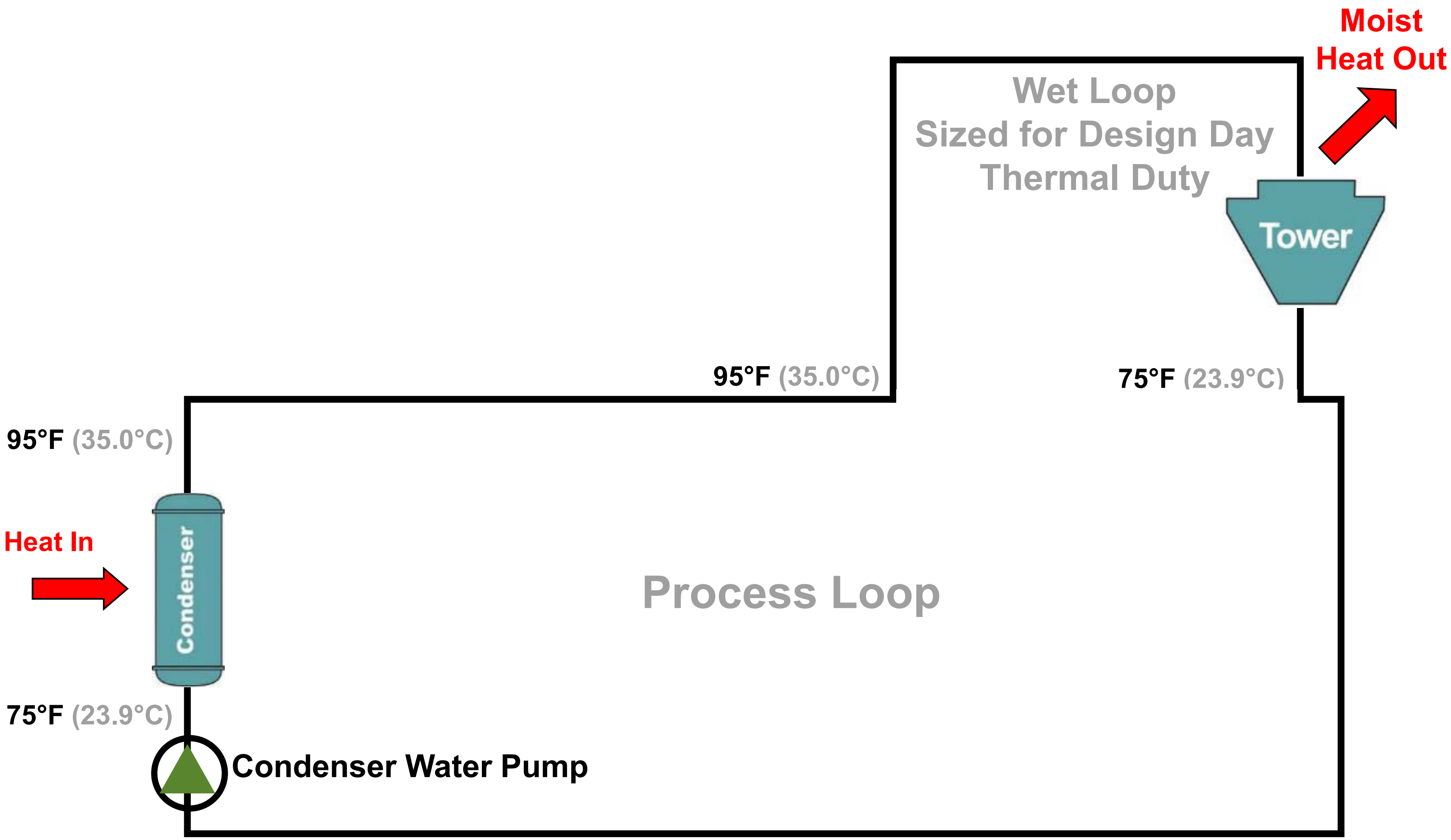
- **Air-Cooled System**
  - Operation is based on DRY BULB temperature
  - Consumes no water (no evaporative cooling)
  - Large footprint requires very large airflow rates
- **Water-Cooled System**
  - Operation is based on the lower WET BULB temperature
  - Evaporative cooling process uses water to improve cooling efficiency
    - 80% LESS AIRFLOW = lower fan energy
    - Lower cost and smaller footprint
  - Colder heat rejection temperatures improve system efficiency



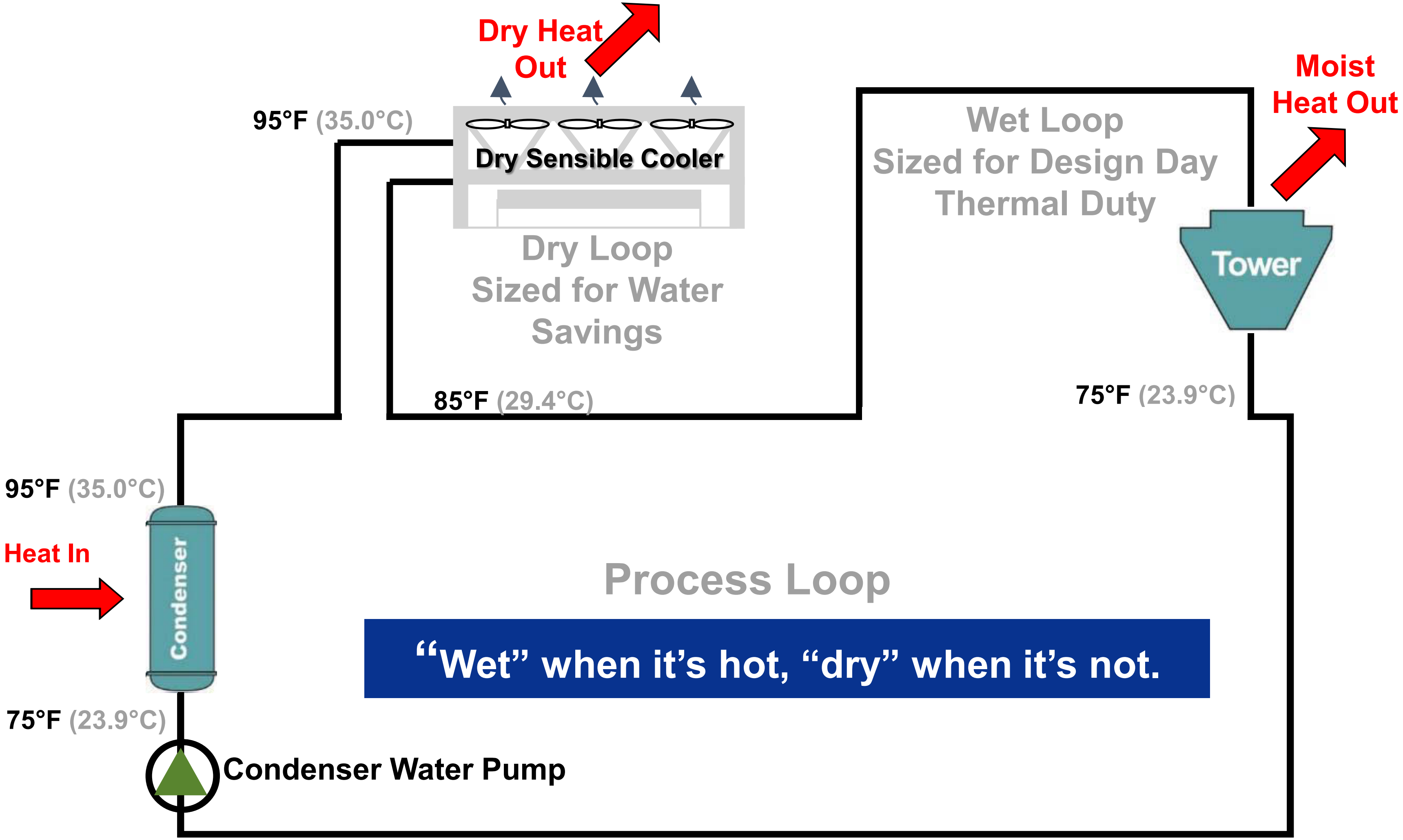


However, water-cooled systems depend on a reliable, continuous source of water.

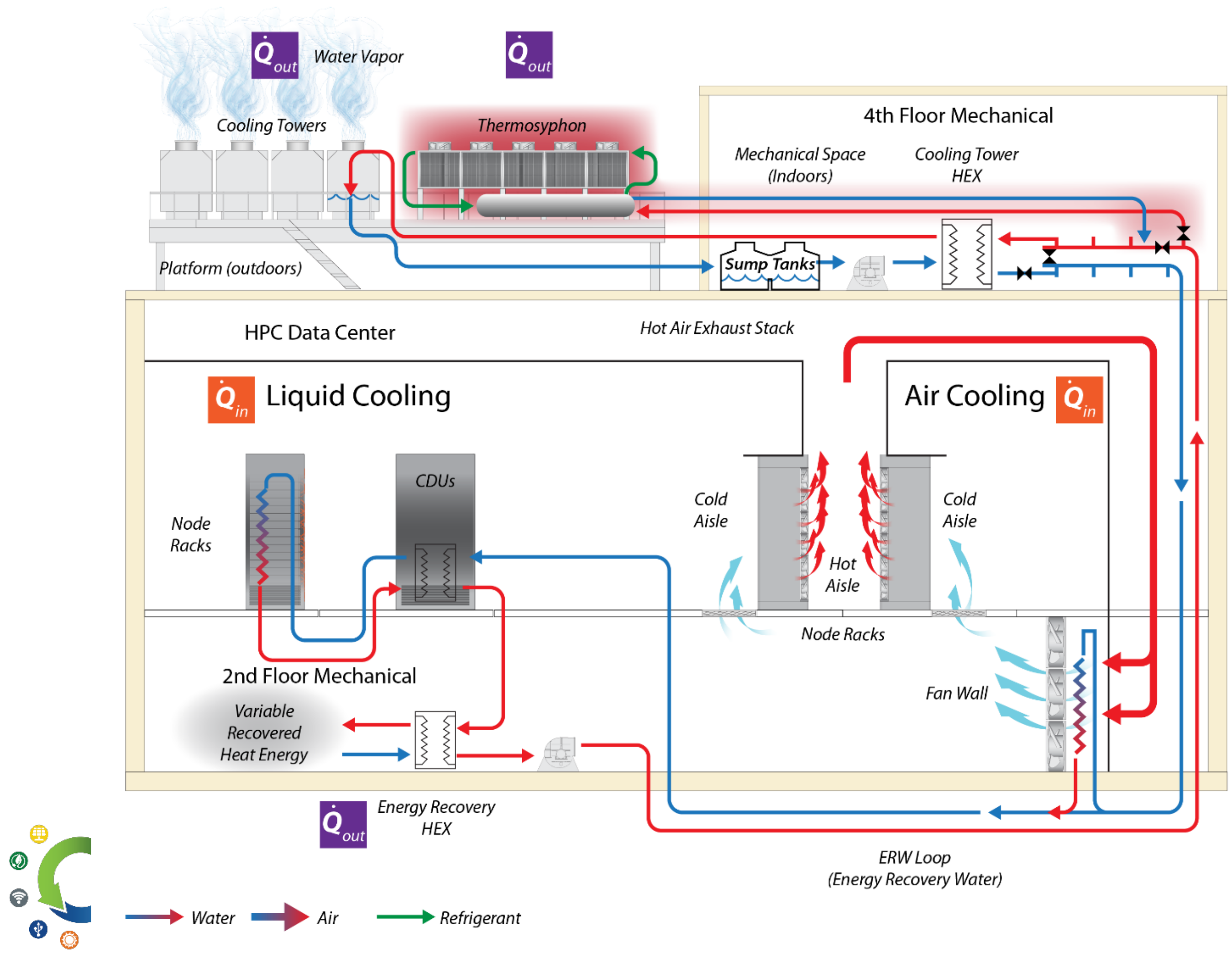
Traditional Wet Cooling System

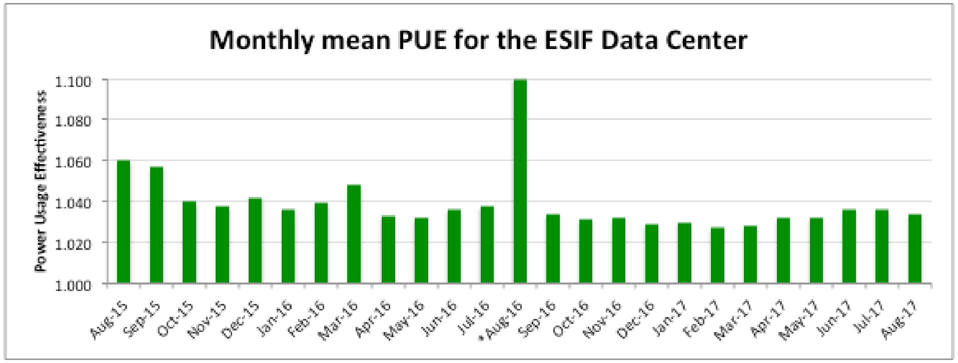


Basic Hybrid System Concept



Improved WUE—Thermosyphon





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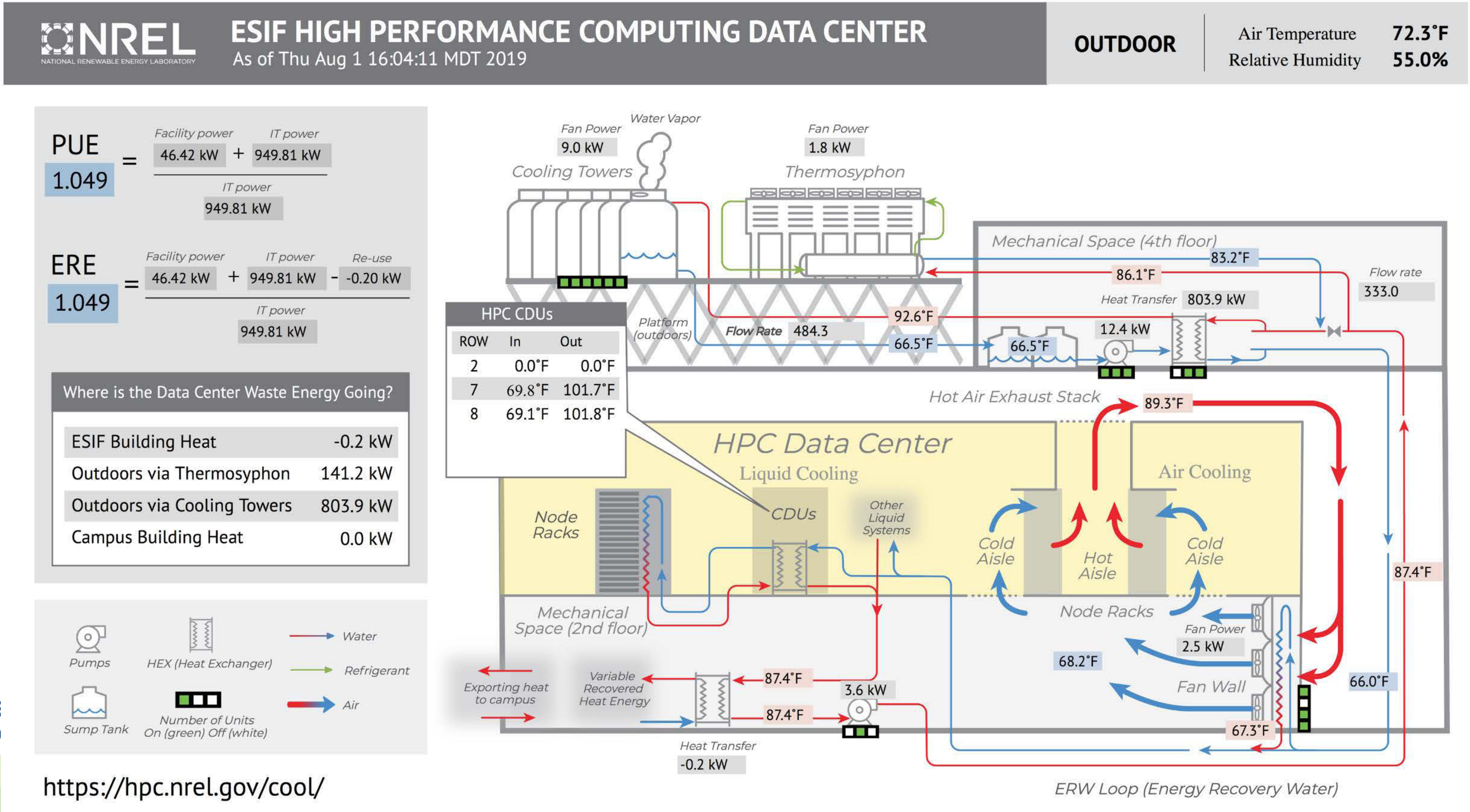
ESIF Data Center Efficiency Dashboard



Applications

Any application using an open cooling tower is a potential application for a hybrid cooling system, but certain characteristics will increase the potential for success.

- **Favorable Application Characteristics**
  - Year-round heat rejection load (24/7, 365 days is best)
  - Higher loop temperatures relative to average ambient temperatures
  - High water and wastewater rates or actual water restrictions
  - Owner’s desire to mitigate risk of future lack of continuous water availability (water resiliency)
  - Owner’s desire to reduce water footprint to meet water conservation targets

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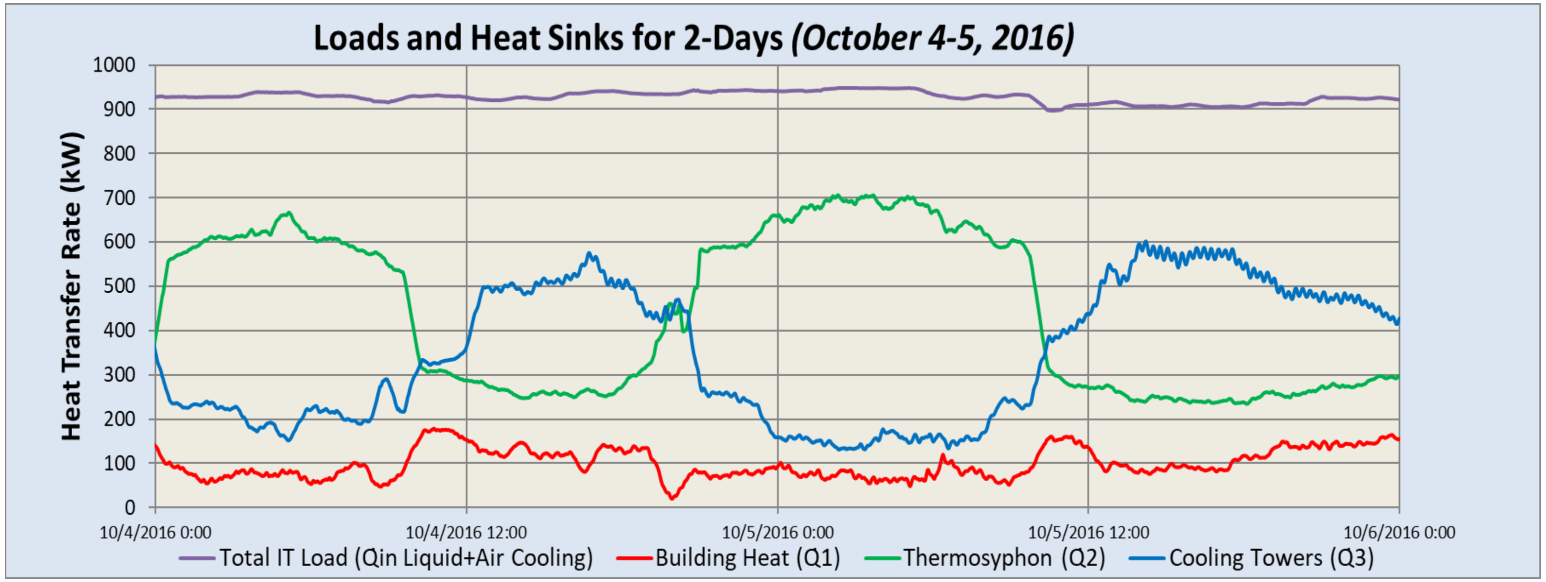
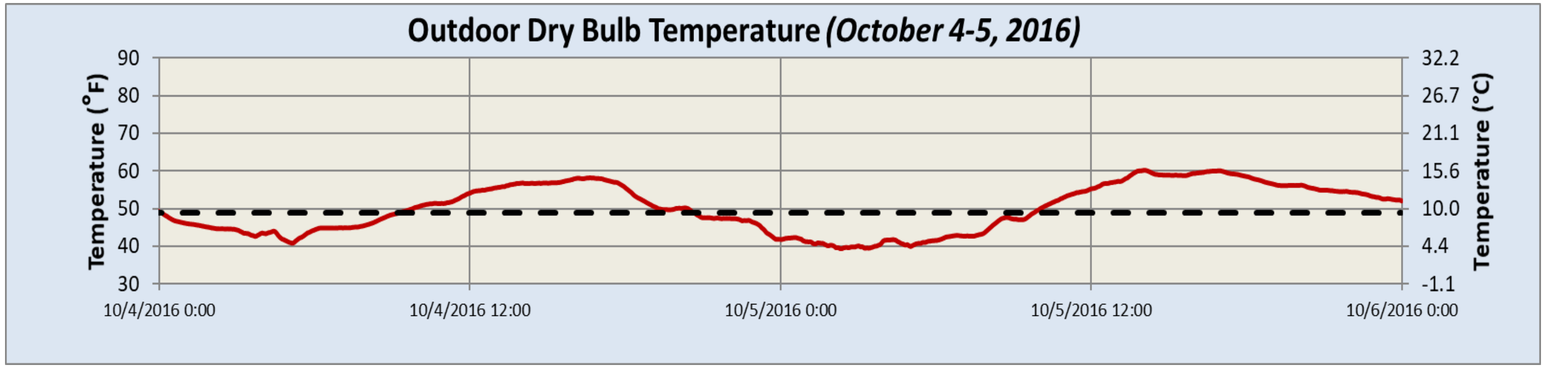
Sample Data: Typical Loads and Heat Sinks





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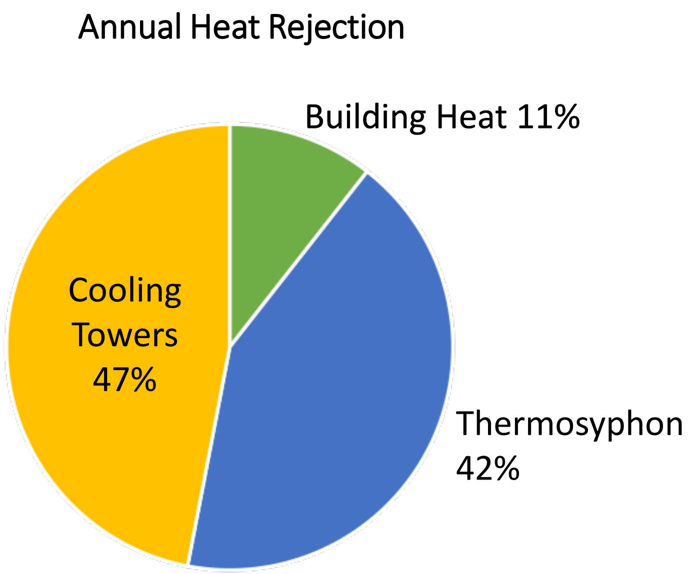
Data Center Metrics

First Year of TSC Operation (9/1/16–8/31/17)

Hourly average IT Load = 888 kW

PUE = 1.034

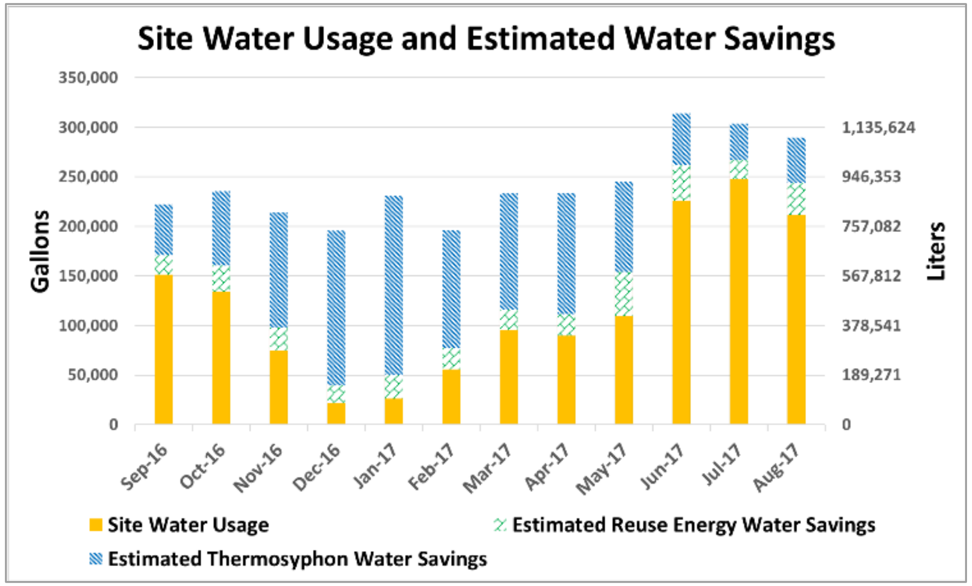
ERE = 0.929



https://www.nrel.gov/docs/fy18osti/72196.pdf

WUE = 0.7 liters/kWh

with only cooling towers, WUE = 1.42 liters/kWh

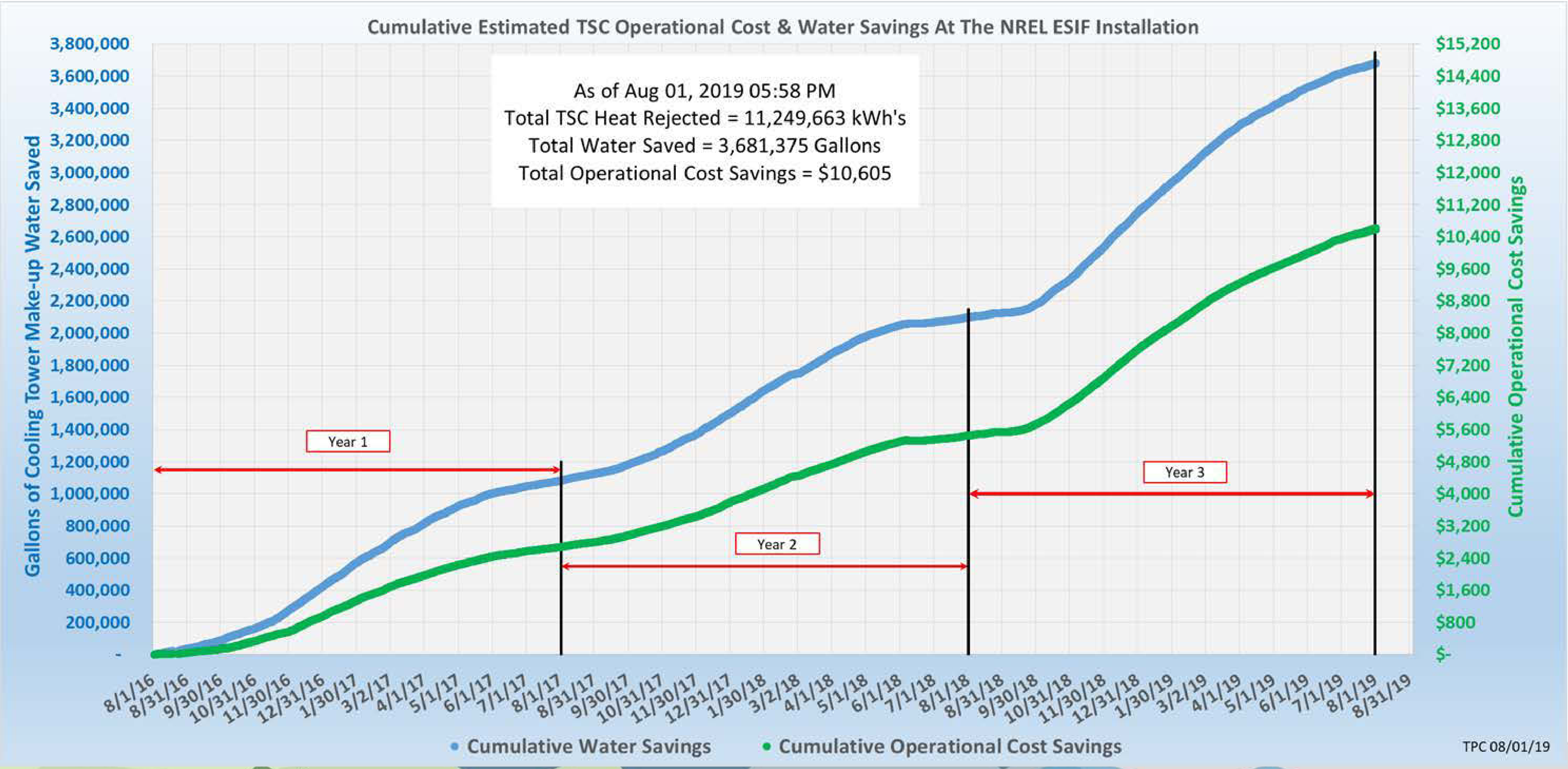


WUE_{SOURCE} = 5.4 liters/kWh

WUE_{SOURCE} = 4.9 liters/kWh if energy from 720 kW PV (10.5%) is included

using EWIF 4.542 liters/kWh for Colorado

Cost and Water Savings



Questions?

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Notice

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