U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Data Center Optimization Strategies

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NREL/PR-7A40-74841

FEMP
Federal Energy Management Program

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)

- **Data Center Features**
  - Direct, component-level liquid cooling, 24°C (75°F) cooling water supply
  - 35°C–40°C (95°F–104°F) 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

Utilize the bytes and the BTUs!

Liquid Cooling – Considerations

- **Liquid cooling essential at high-power density**
- **Compatible metals and water chemistry is crucial**
- **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**

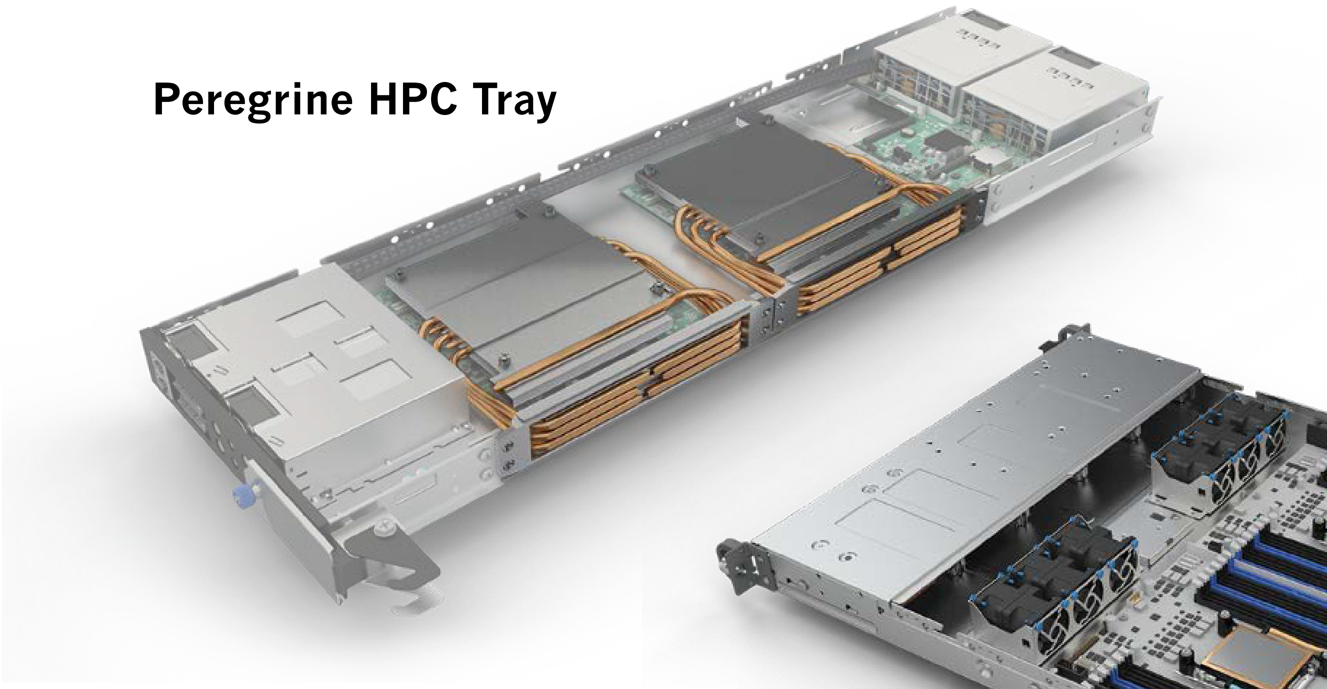
Air-Cooled to Liquid-Cooled Racks

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

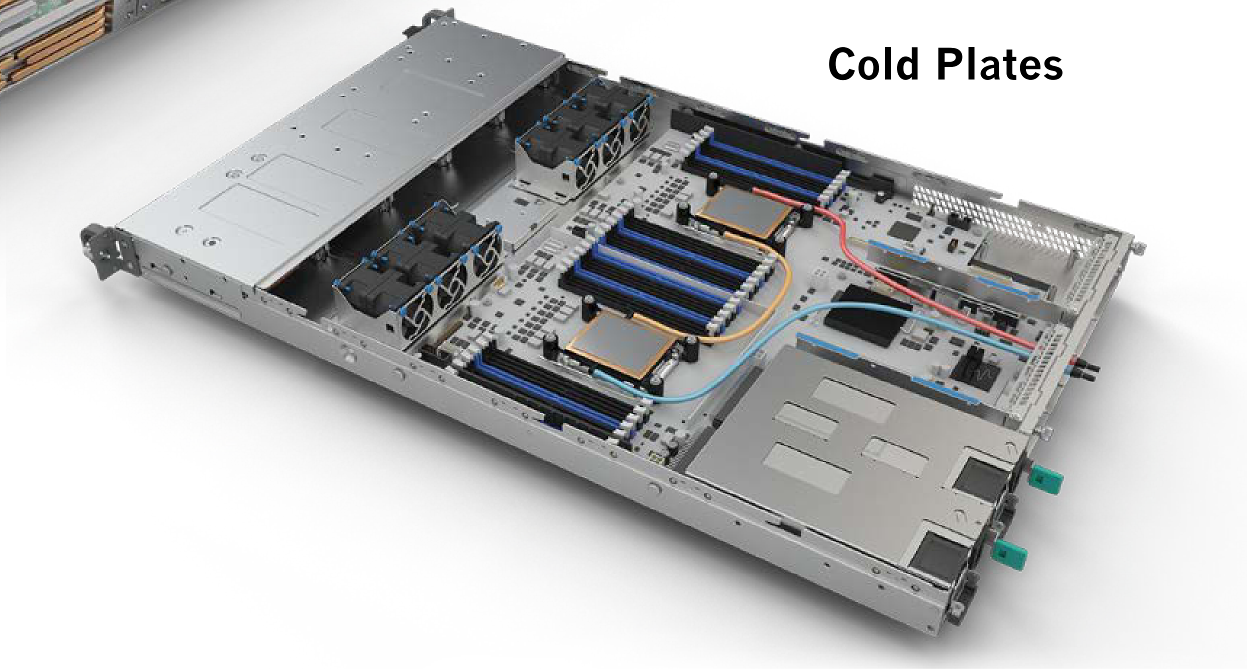
Liquid-cooled when rack power densities in 5kW–80kW range, have several options

Liquid-Cooled Server Options

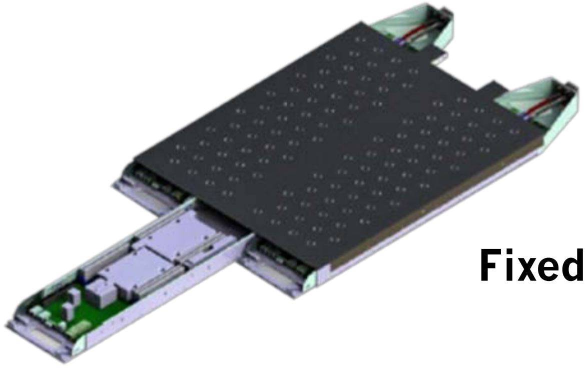
Peregrine HPC Tray

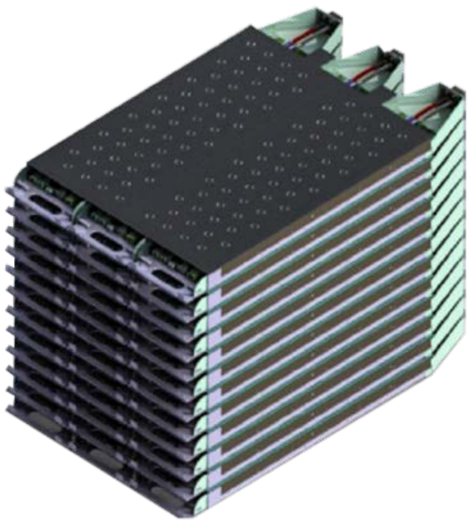


Cold Plates

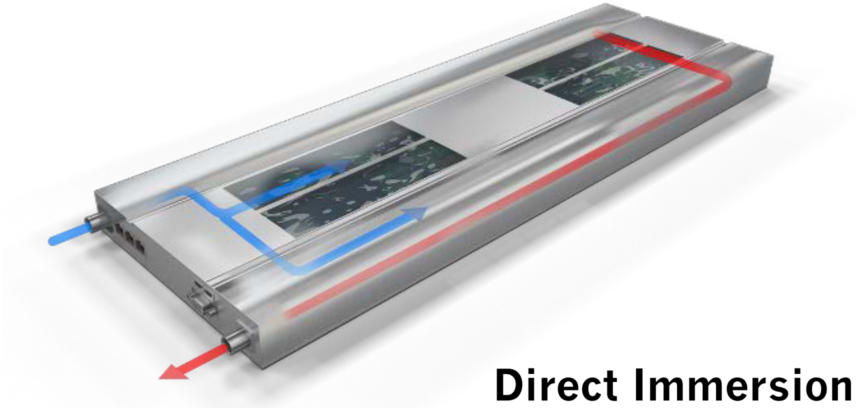


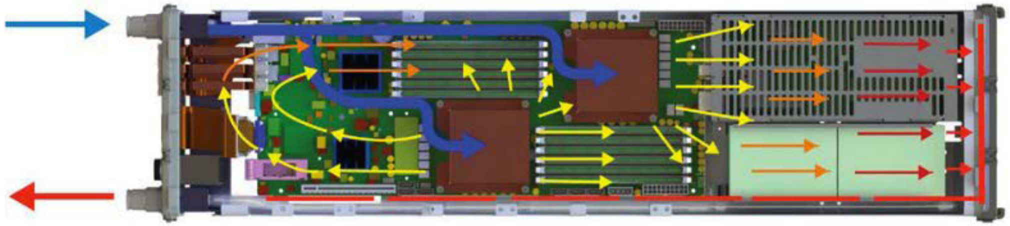
Fanless Liquid-Cooled Server Options





Fixed Plate



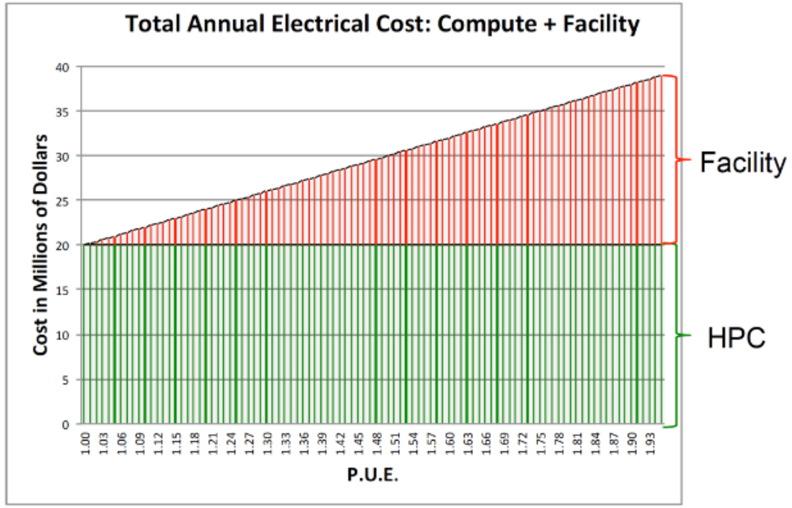


Direct Immersion

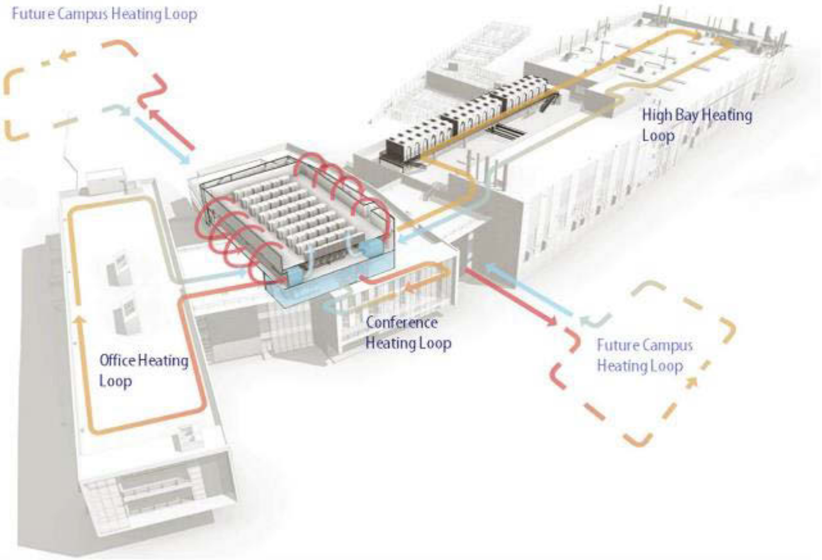
Metrics

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

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



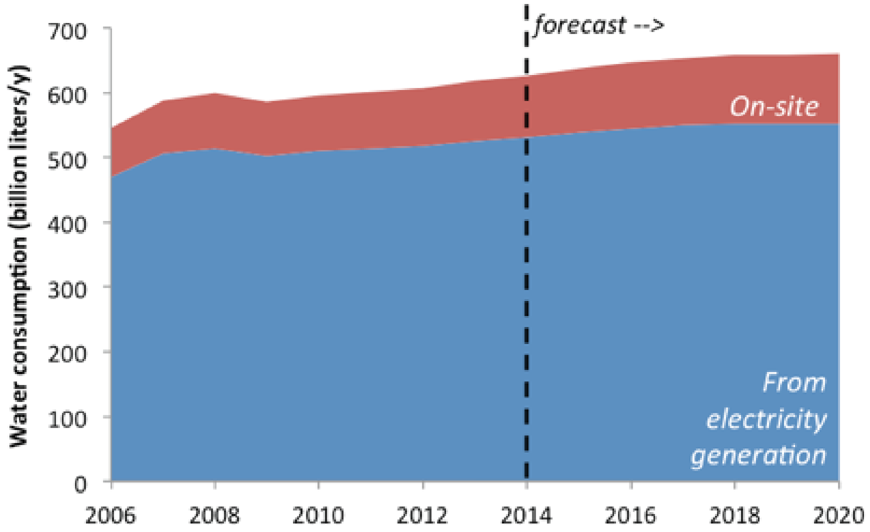
Assume ~20MW HPC system & $1M per MW year utility cost.



Metrics

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

the units of WUE are liters/kWh



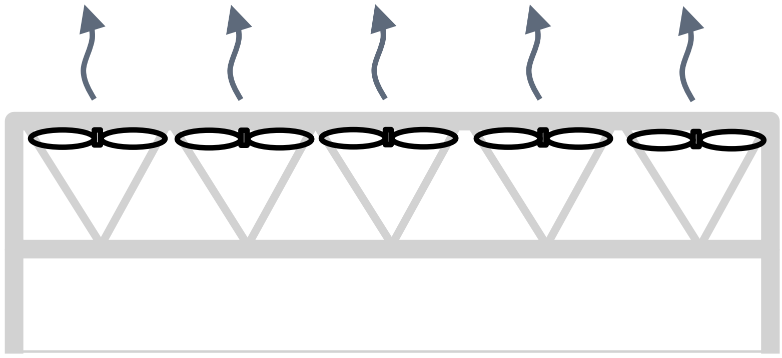
$$WUE_{SOURCE} = \frac{\text{“Annual Site Water Usage”} + \text{“Annual Source Energy Water Usage”}}{\text{“IT energy”}}$$

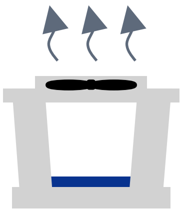
$$WUE_{SOURCE} = \frac{\text{“Annual Site Water Usage”}}{\text{“IT energy”}} + [EWIF \times PUE]$$

where EWIF is energy water intensity factor

Air- and Water-Cooled System Options

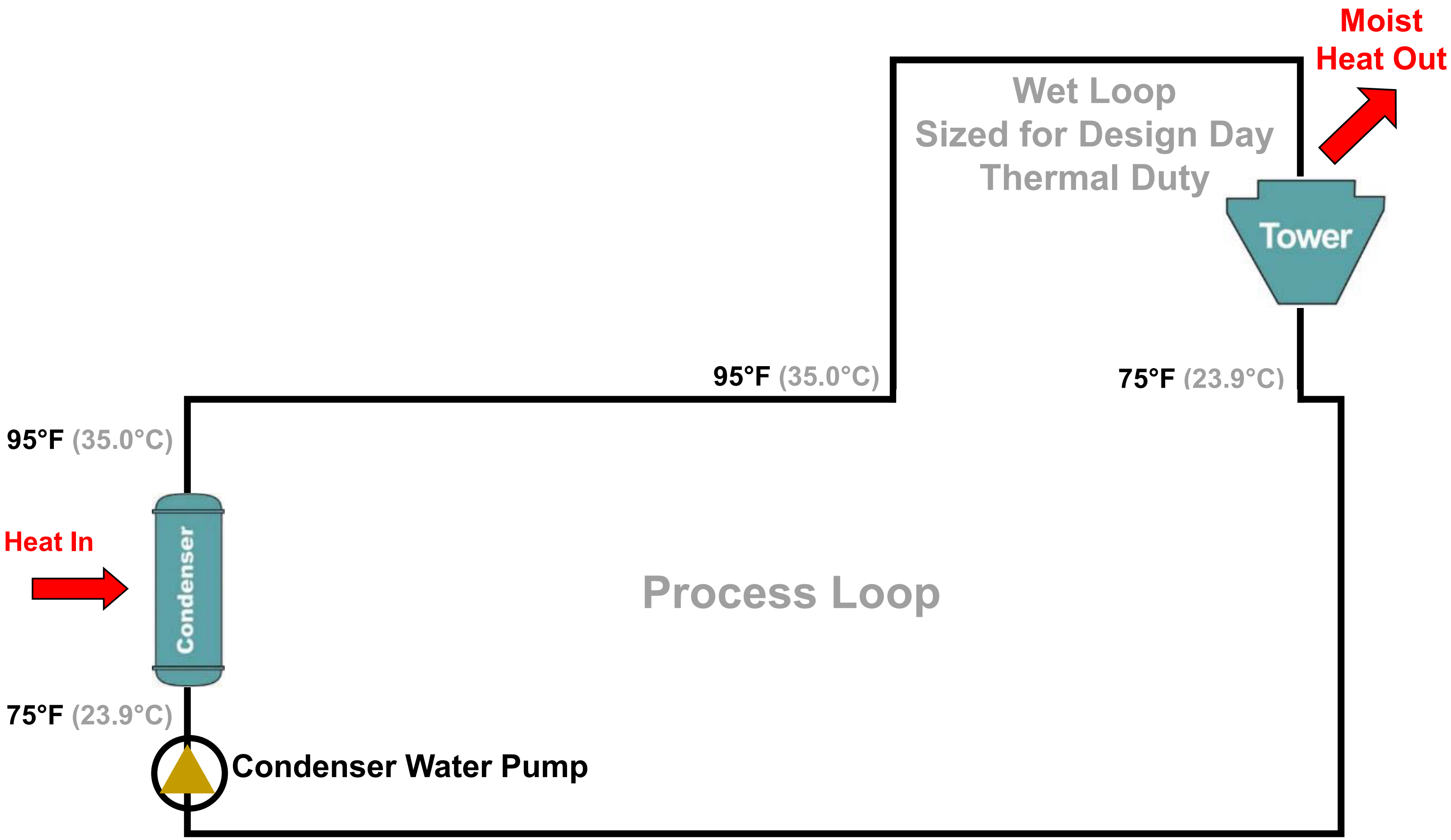
- **Air-Cooled System**
  - Operation is based on DRY BULB temperature
  - Consumes no water (no evaporative cooling)
  - Large footprint requires very large airflow rates
- **Water-Cooled System**
  - Operation is based on the lower WET BULB temperature
  - Evaporative cooling process uses water to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



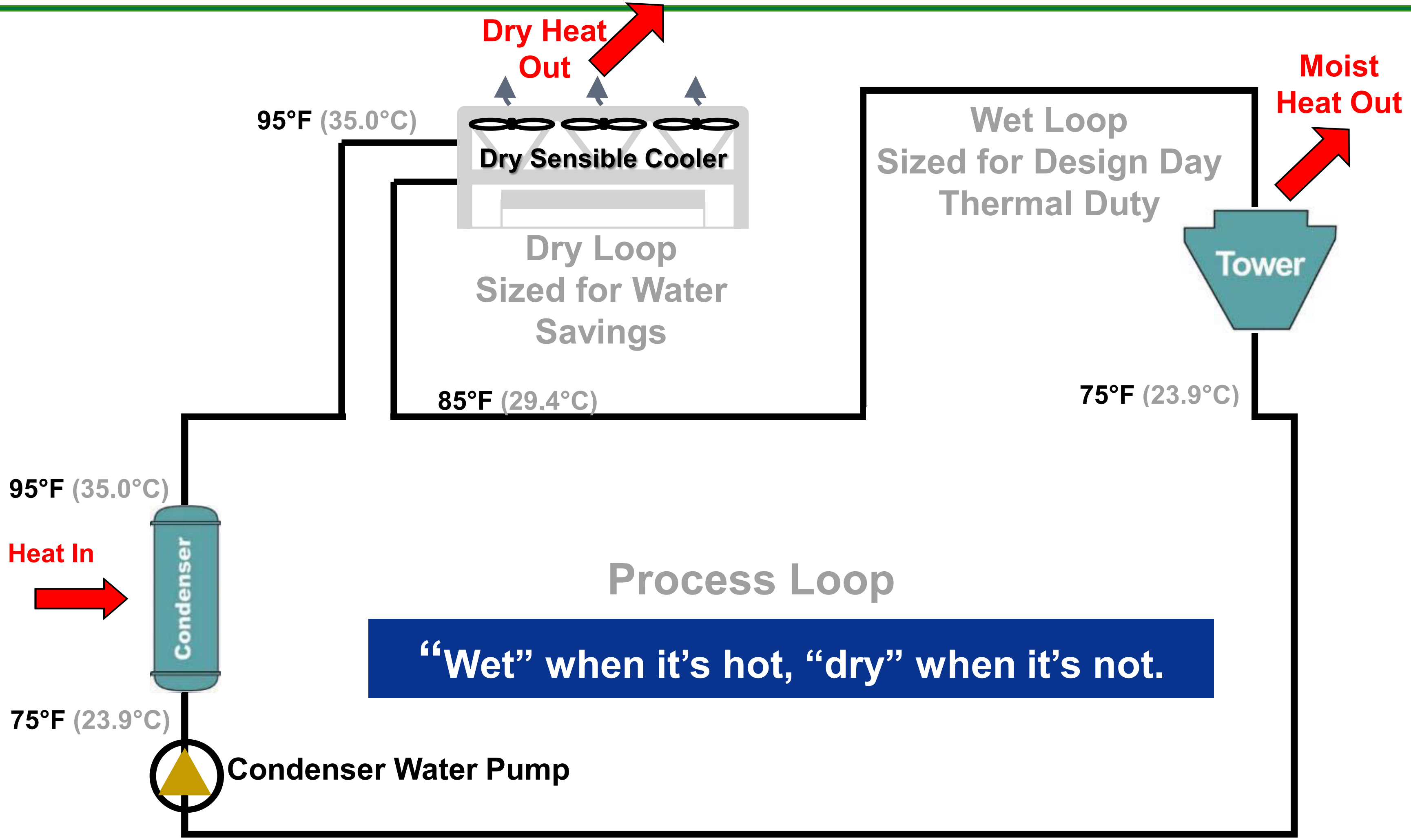


However, water-cooled systems depend on a reliable, continuous source of water.

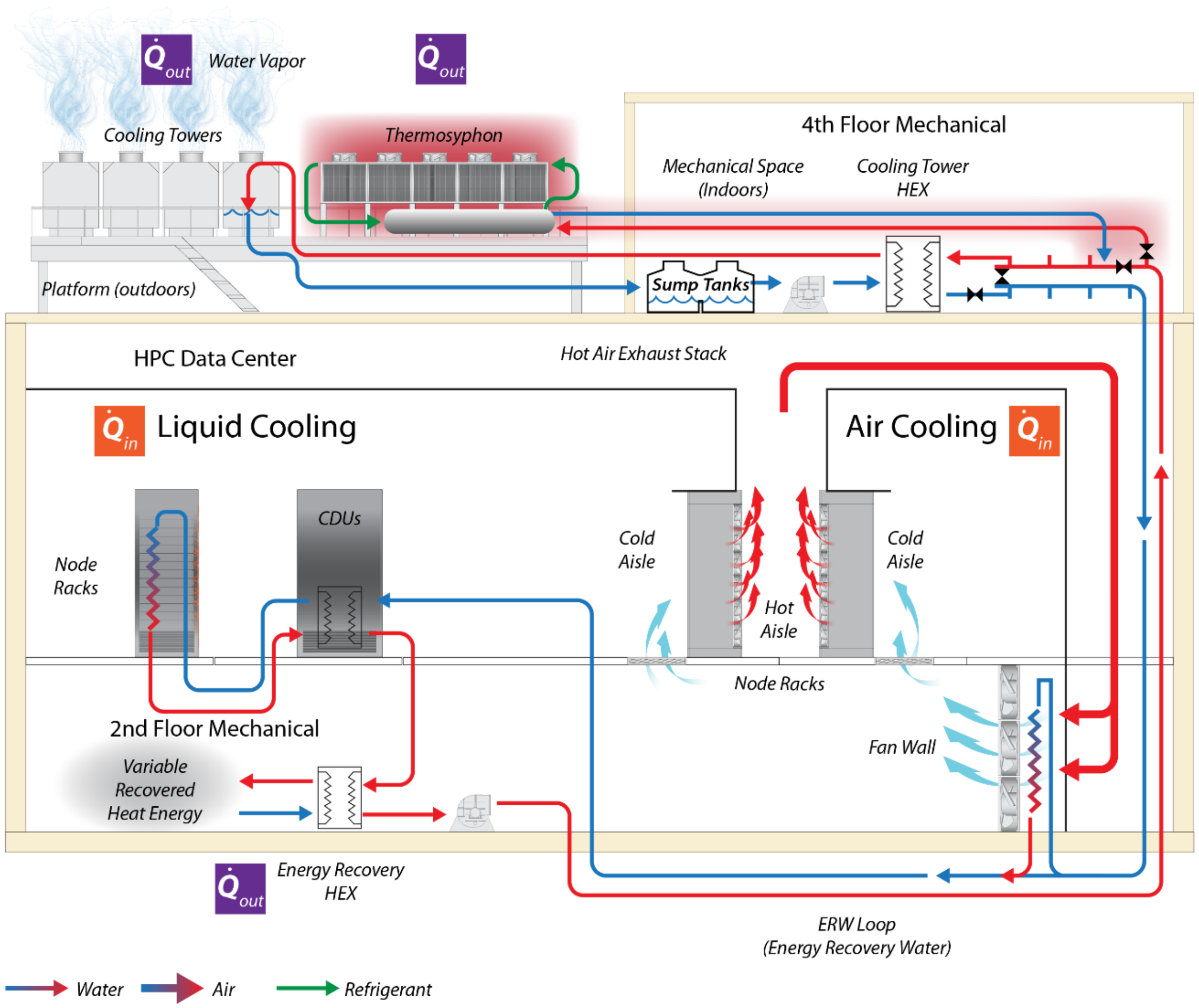
Traditional Wet Cooling System

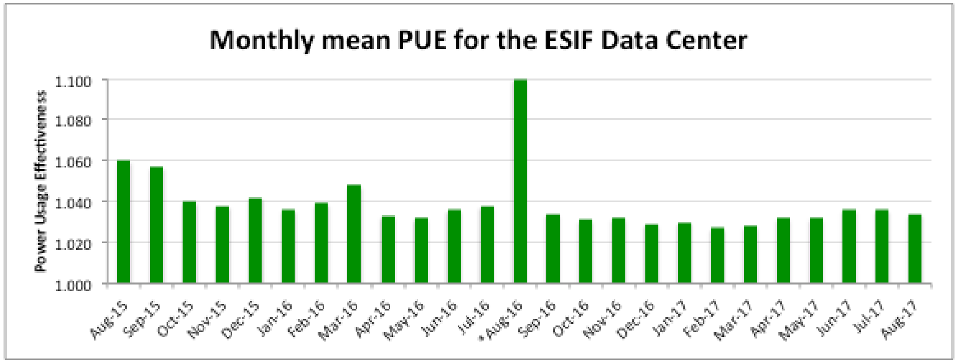


Basic Hybrid System Concept



Improved WUE—Thermosyphon





NREL NATIONAL RENEWABLE ENERGY LABORATORY

Johnson Controls

Sandia National Laboratories

ESIF Data Center Efficiency Dashboard

NREL NATIONAL RENEWABLE ENERGY LABORATORY

ESIF HIGH PERFORMANCE COMPUTING DATA CENTER

As of Thu Aug 1 16:04:11 MDT 2019

OUTDOOR		
	Air Temperature	72.3°F
	Relative Humidity	55.0%

PUE 1.049 = (Facility power 46.42 kW + IT power 949.81 kW) / IT power 949.81 kW

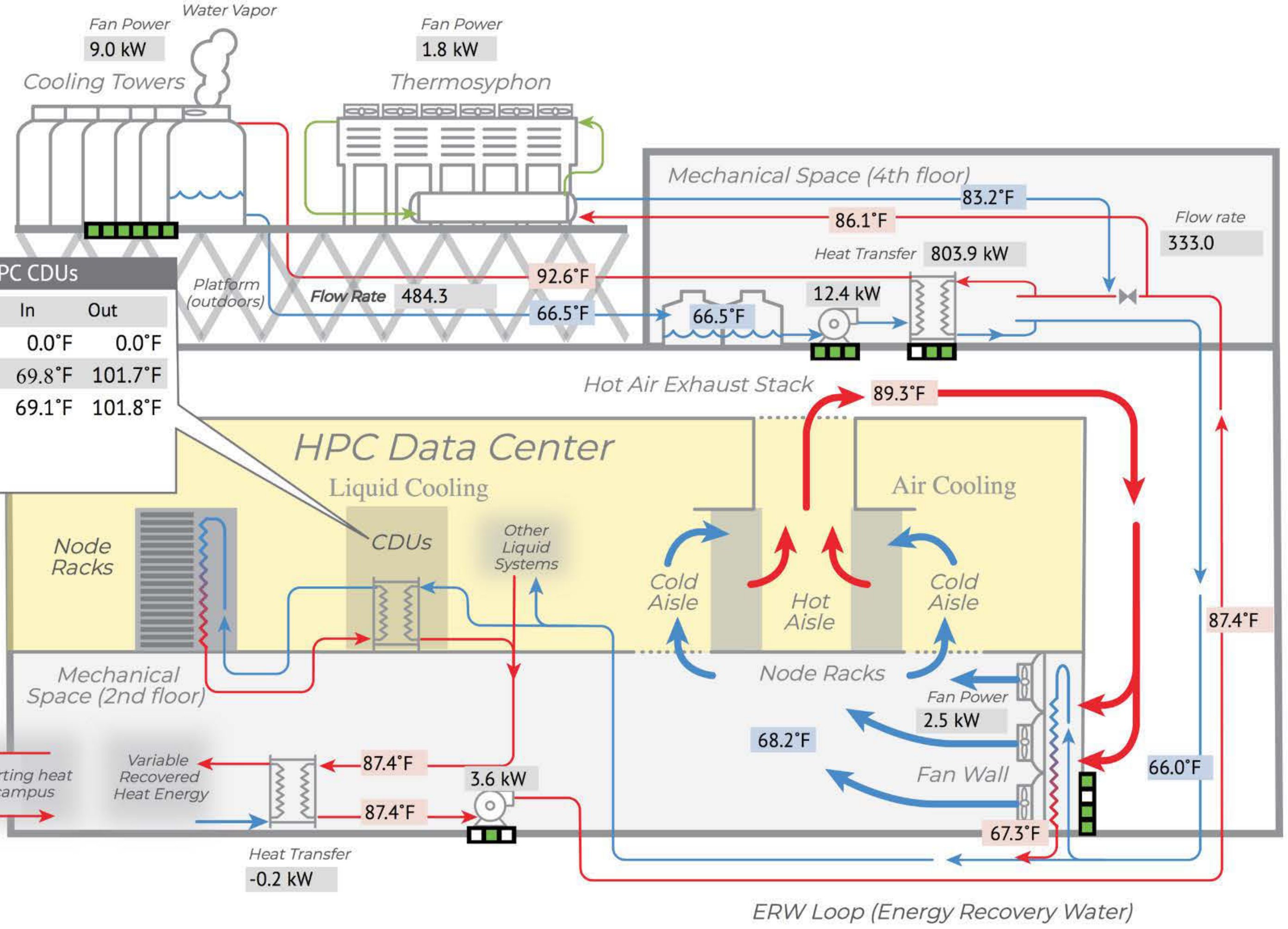
ERE 1.049 = (Facility power 46.42 kW + IT power 949.81 kW − Re-use -0.20 kW) / IT power 949.81 kW

Where is the Data Center Waste Energy Going?

ESIF Building Heat	-0.2 kW
Outdoors via Thermosyphon	141.2 kW
Outdoors via Cooling Towers	803.9 kW
Campus Building Heat	0.0 kW

HPC CDUs

ROW	In	Out
2	0.0°F	0.0°F
7	69.8°F	101.7°F
8	69.1°F	101.8°F



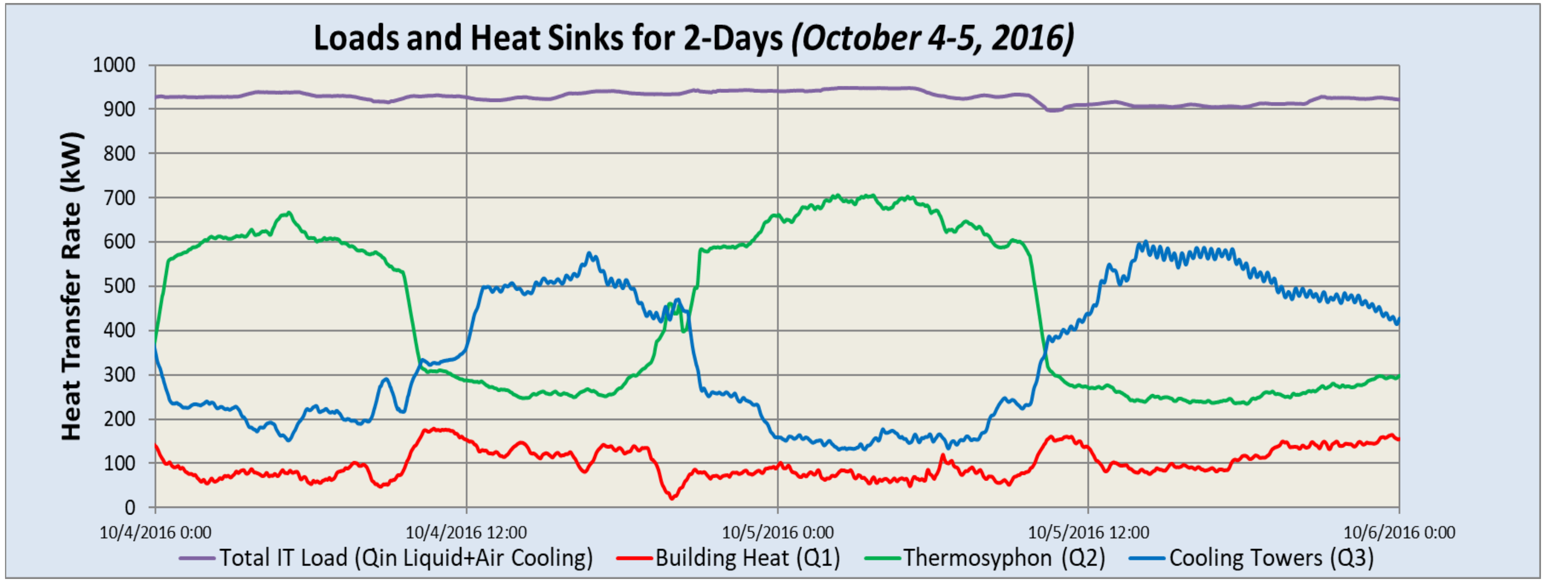
https://hpc.nrel.gov/cool/

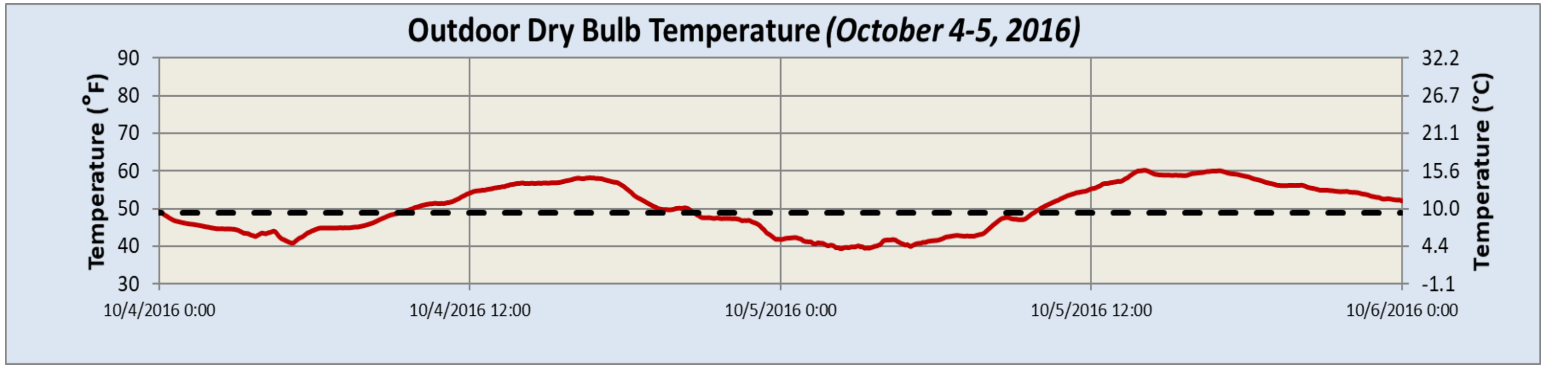
Applications

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

Sample Data: Typical Loads and Heat Sinks





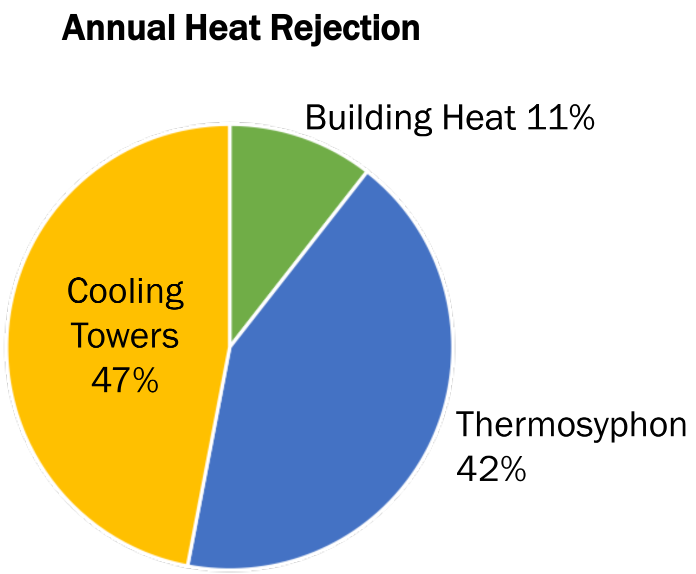
Data Center Metrics

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

Hourly average IT Load = 888 kW

PUE = 1.034

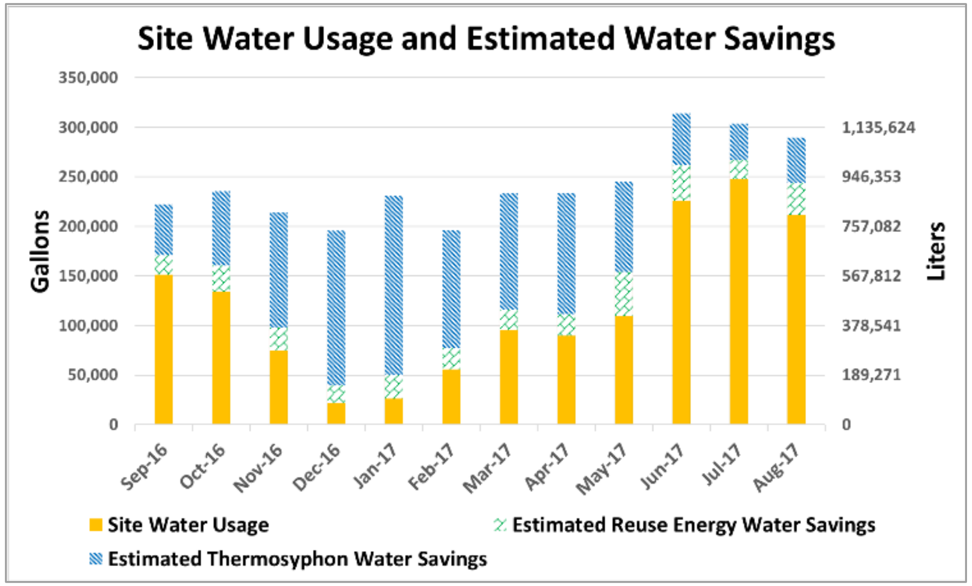
ERE = 0.929



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

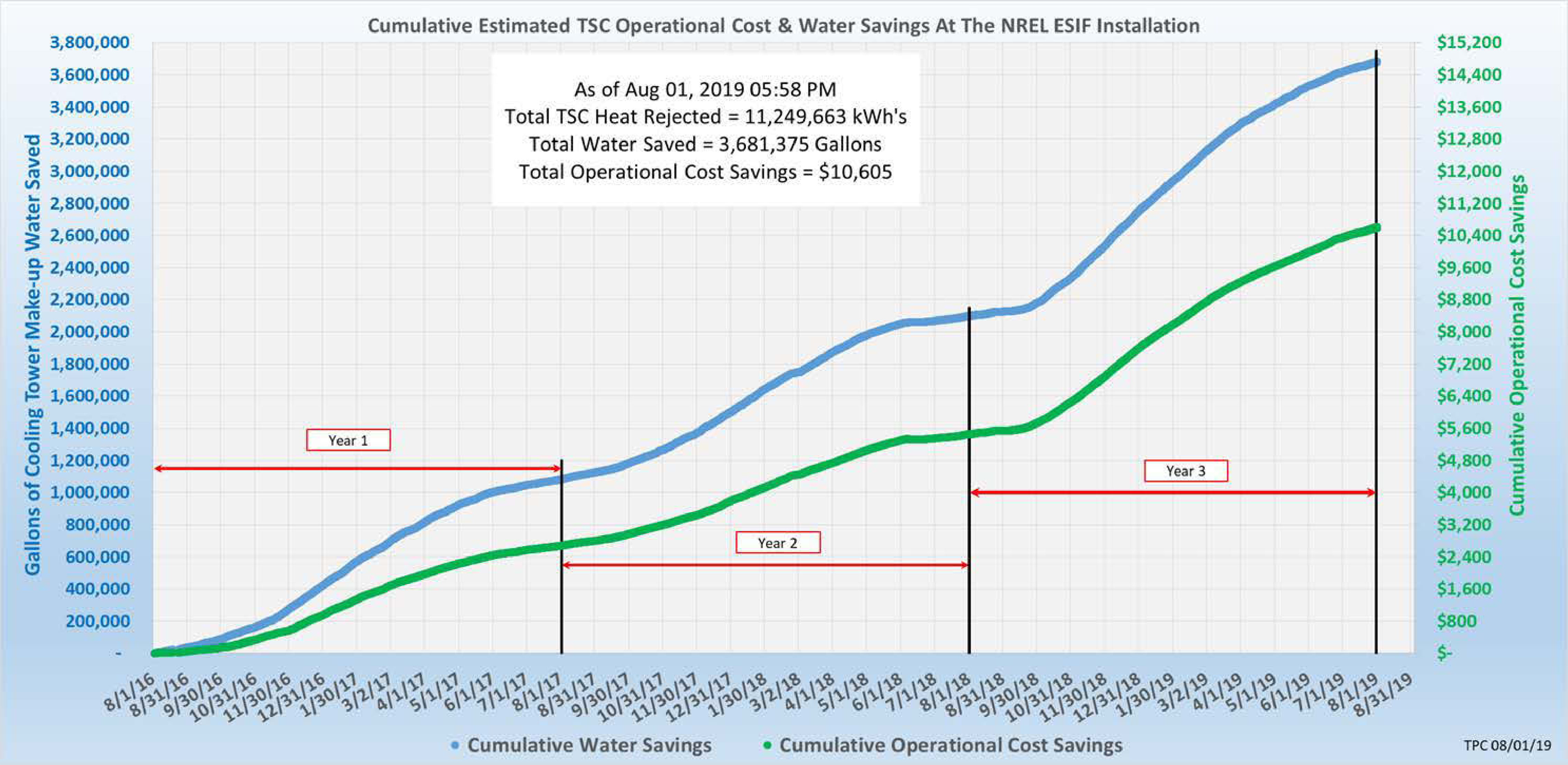
WUE = 0.7 liters/kWh

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



Contact

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Notice

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