Energy Exchange℠

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AUGUST 21-23, 2018 • CLEVELAND, OHIO

Liquid in the Rack: Liquid Cooling Your Data Center

NREL ESIF Data Center

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NREL/PR-7A40-72046

NREL's Dual Computing Mission

- Provide HPC and related systems expertise to advance NREL's mission, *and* push the leading edge for data center sustainability
- Demonstrate leadership in liquid cooling, waste heat capture, and re-use
- Holistic "chips-to-bricks" approaches to data center efficiency
- Showcase data center at NREL's Energy Systems Integration Facility (ESIF)

Critical Topics Include:

- Liquid cooling and energy efficiency
- Water efficiency

Planning for a New Data Center

- Started planning for new data center in 2006
- Based on HPC industry/technology trends, committed to direct liquid cooling
- **Holistic approach**: integrate racks into the data center, data center into the facility, the facility into the NREL campus
- Capture and use data center waste heat: office and lab space (now) and export to campus (future)
- Incorporate high-power density racks—more than 60 kW per rack
- Implement liquid cooling at the rack, no mechanical chillers
- Use chilled beam for office/lab space heating. Low-grade waste heat use.
- Considered two critical temperatures:
  - Information technology (IT) cooling supply—could produce 24ºC (75ºF) on hottest day of the year, ASHRAE "W2" class
  - IT return water—required 35ºC (95ºF) to heat the facility on the coldest day of the year

Build the World's Most Energy Efficient Data Center

NREL Data Center

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) is 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 60- to 80-kW compute racks

Compared to a Typical Data Center

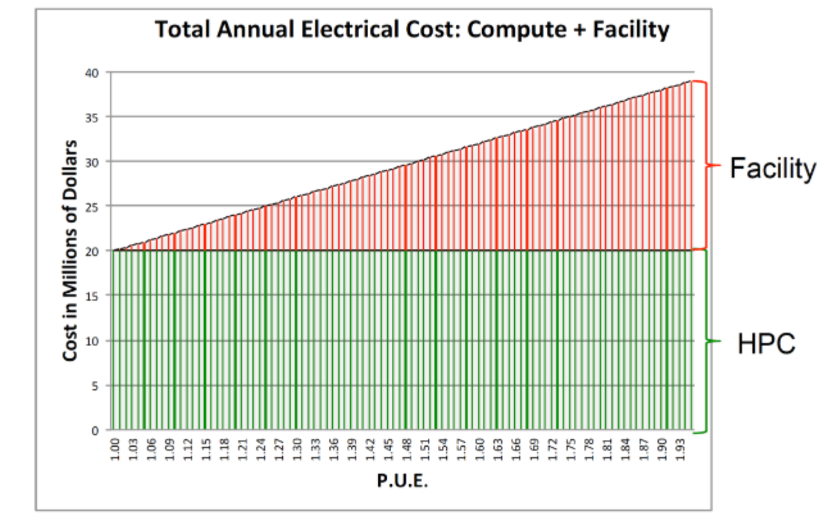
- Lower CapEx—costs less to build
- Lower OpEx—efficiencies save

Integrated "Chips-to-Bricks" Approach

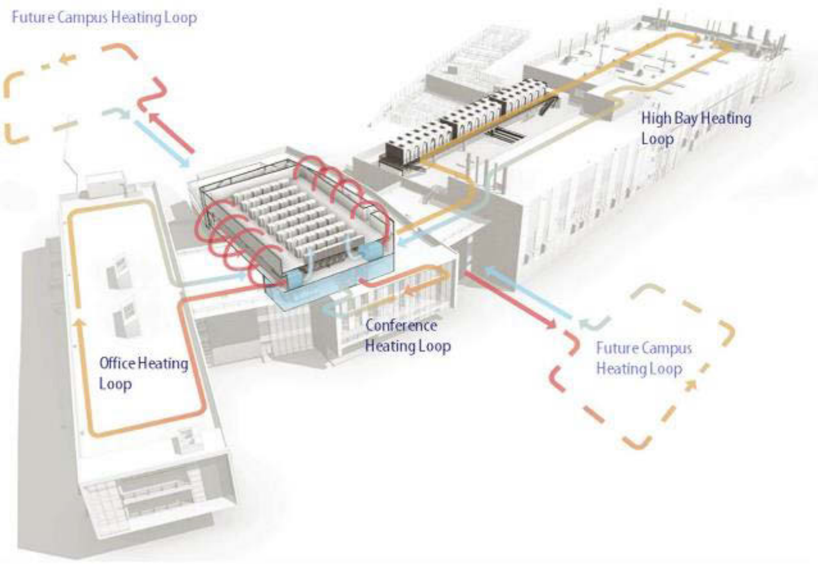
Metrics

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

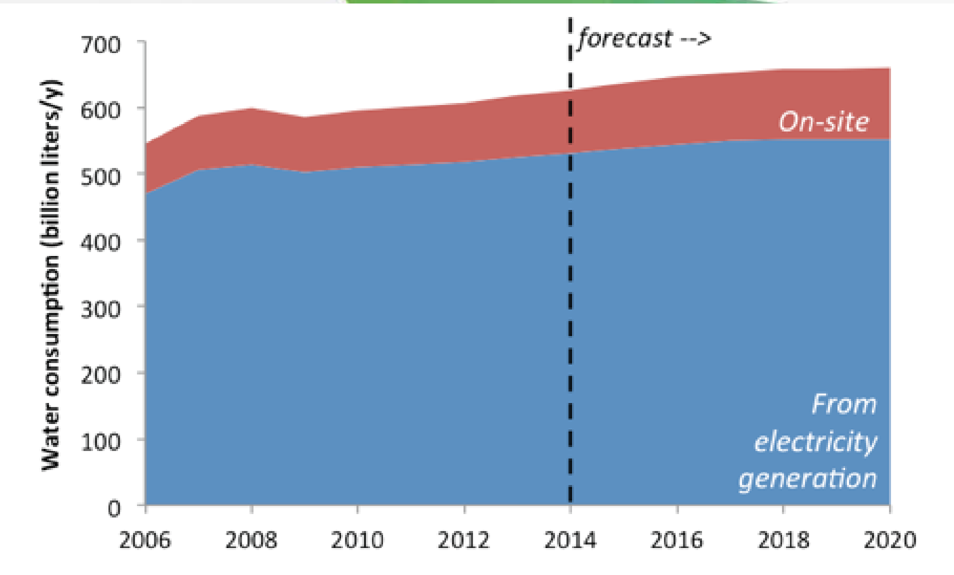
$$ERE = \frac{\text{"Facility energy"} + \text{"IT energy"} - \text{"Reuse energy"}}{\text{"IT energy"}}$$



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

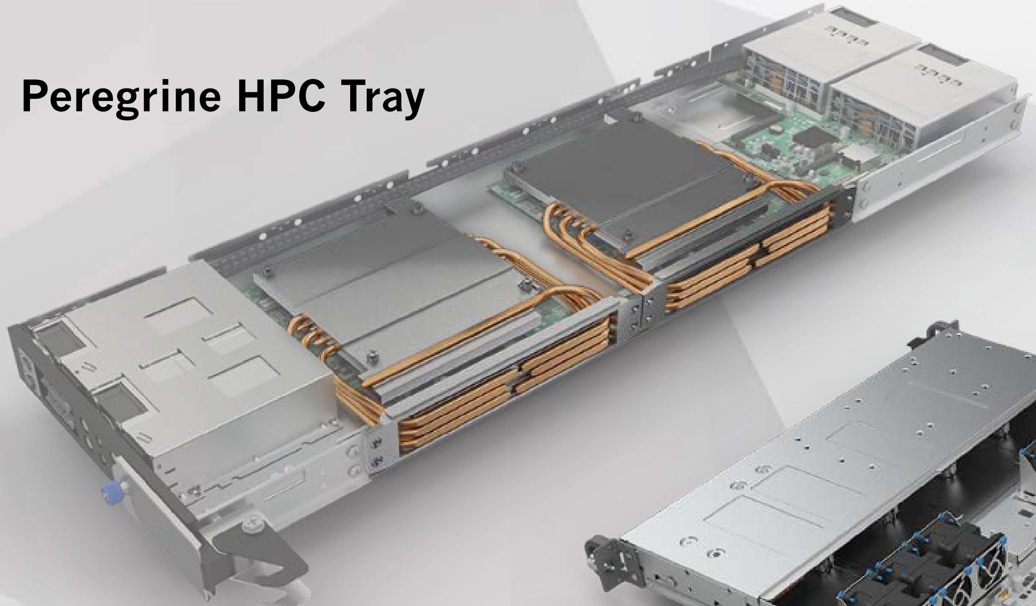
Air-Cooled to Liquid-Cooled Racks

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

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

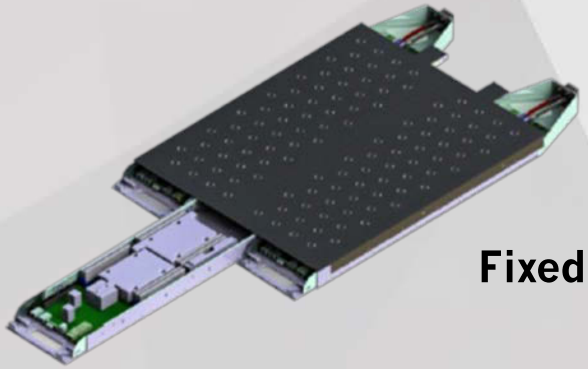
Liquid-Cooled Server Options

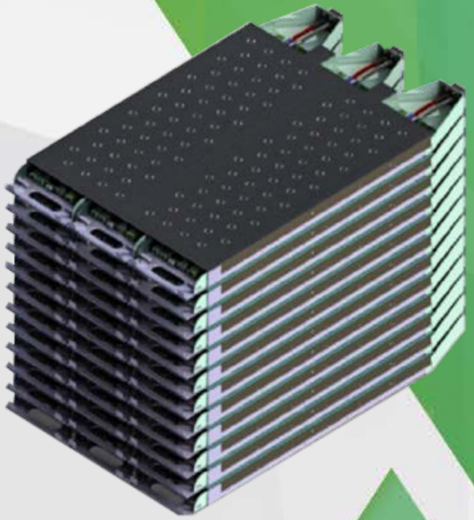
Peregrine HPC Tray



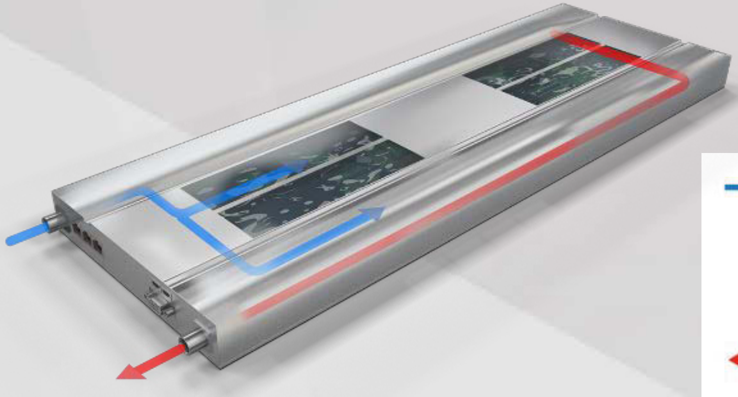
Cold Plates

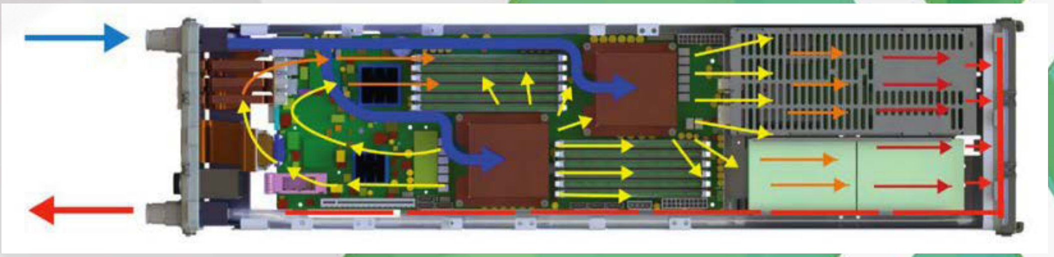
Fanless Liquid-Cooled Server Options





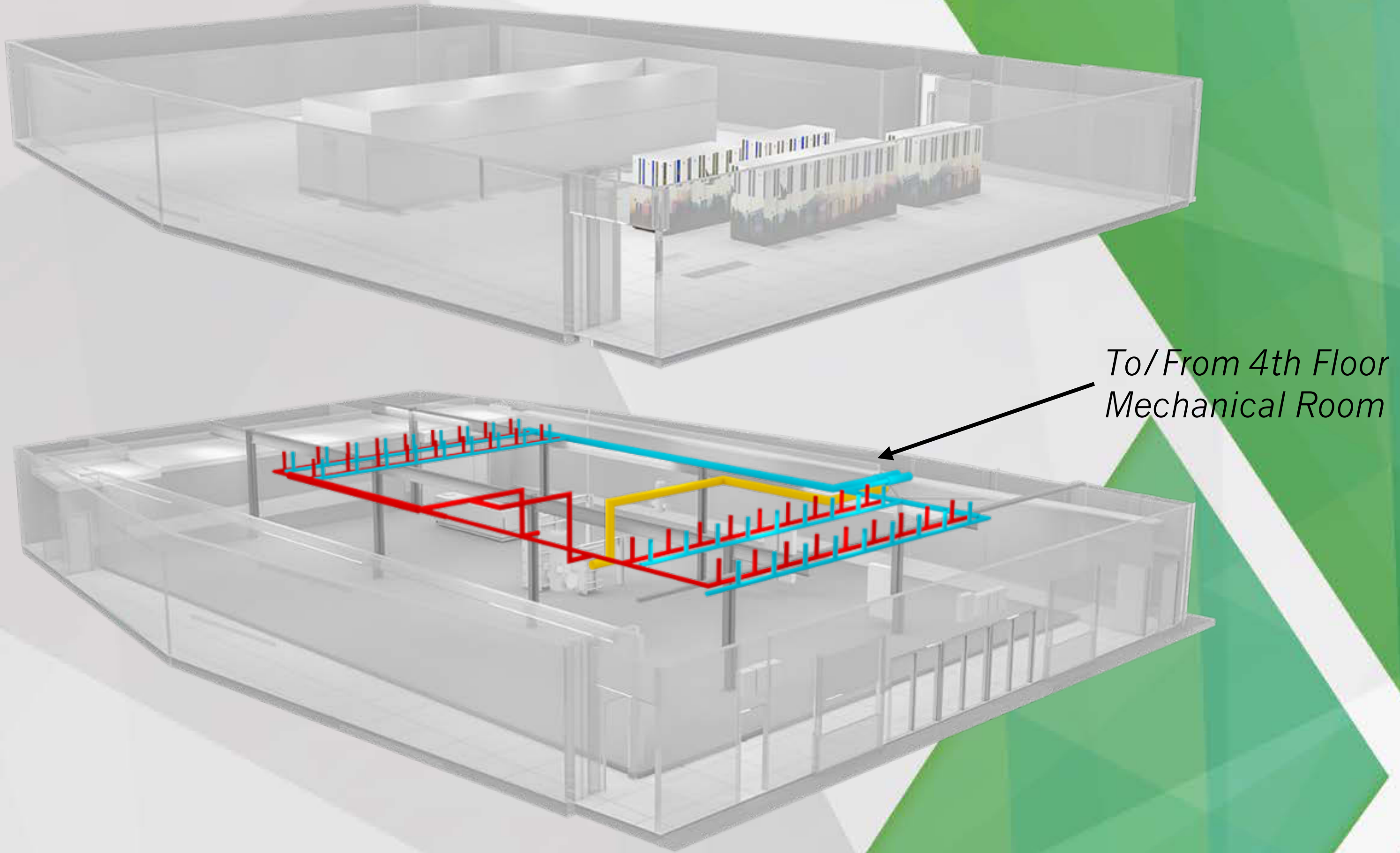
Fixed Cold Plate





Direct Immersion

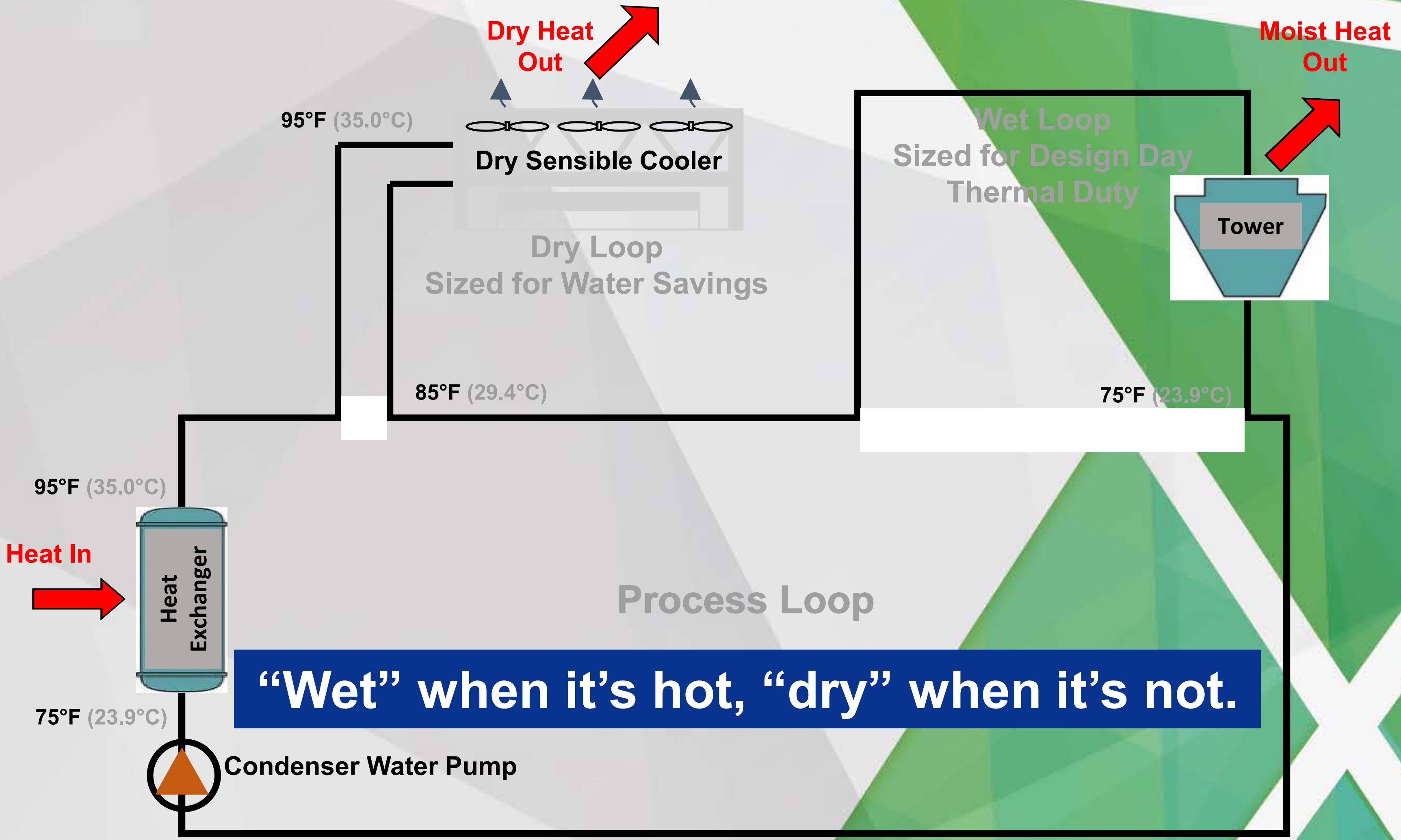
Data Center Water Distribution



Liquid Cooling—Considerations

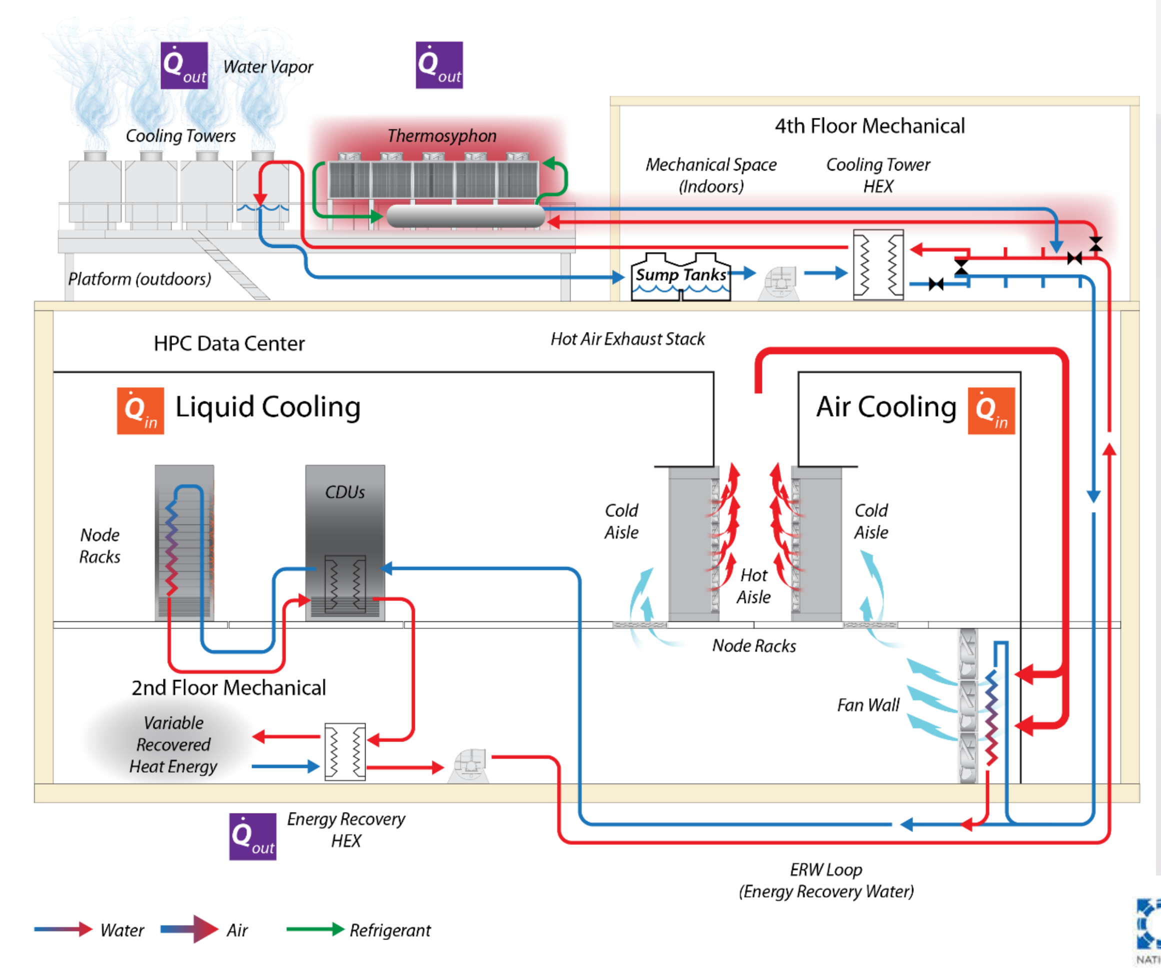
- Liquid cooling essential at high-power density
- Compatible metals and water chemistry is crucial
- Cooling distribution units (CDUs)
  - Efficient heat exchangers to separate facility and server liquids
  - Flow control to manage heat return
  - System filtration (with bypass) to ensure quality
- 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

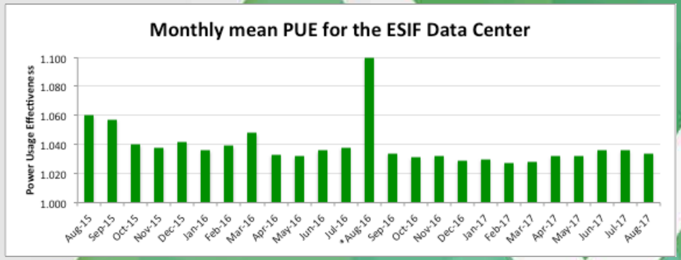
Basic Hybrid System Concept



“Wet” when it’s hot, “dry” when it’s not.

Improved WUE—Thermosyphon





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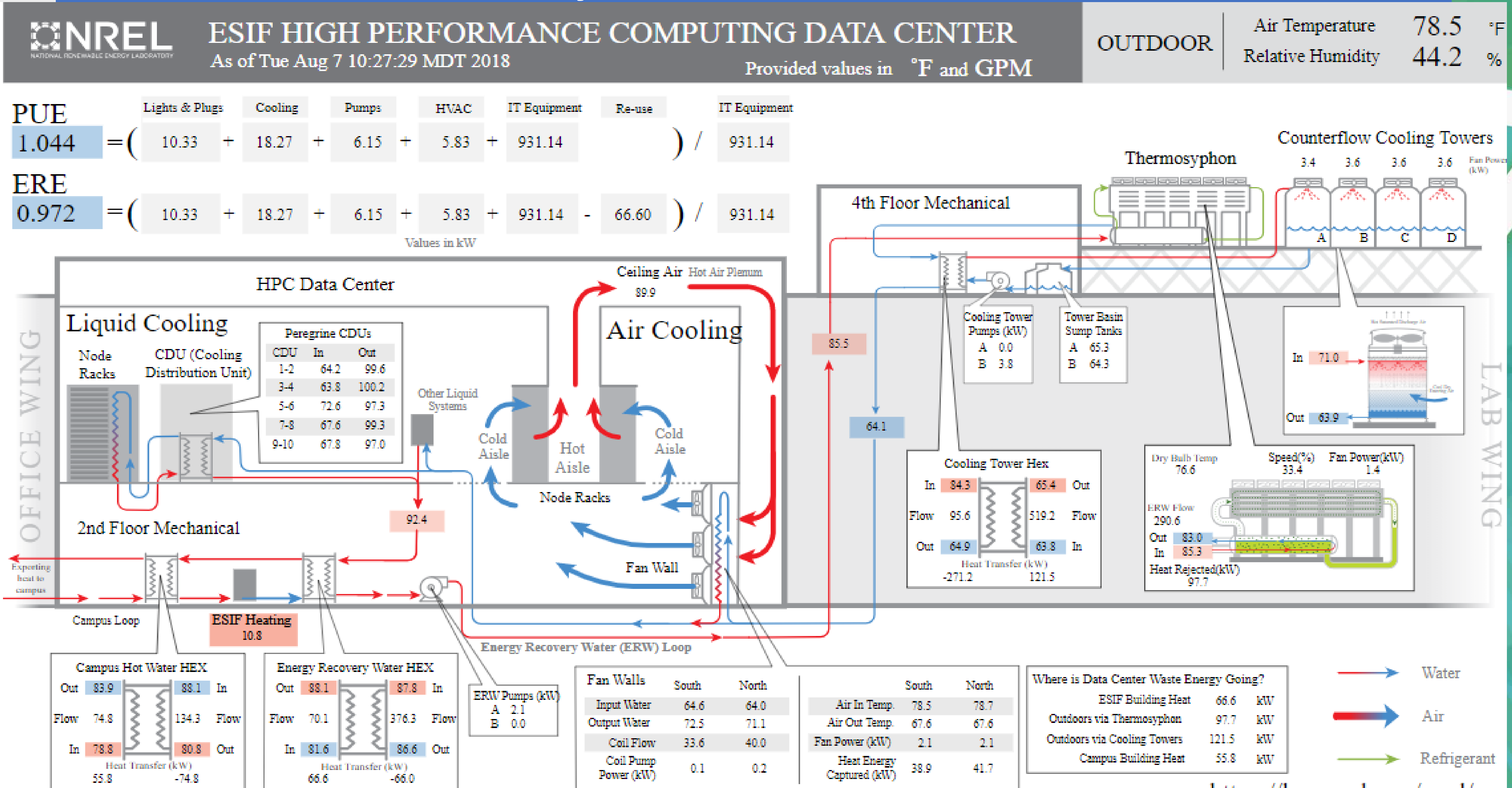
ESIF Data Center Efficiency Dashboard



Data Center Metrics

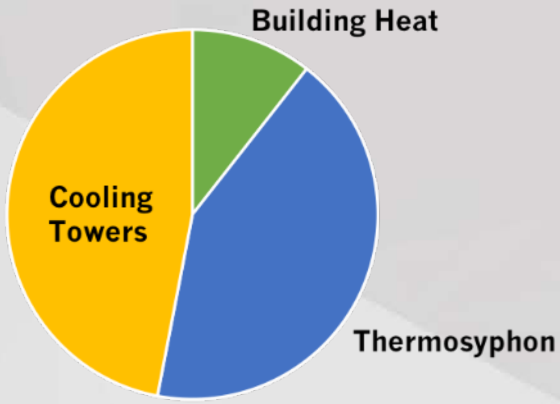
First year of TSC operation (9/1/2016–8/31/2017)

Hourly average IT Load = 888 kW

PUE = 1.034

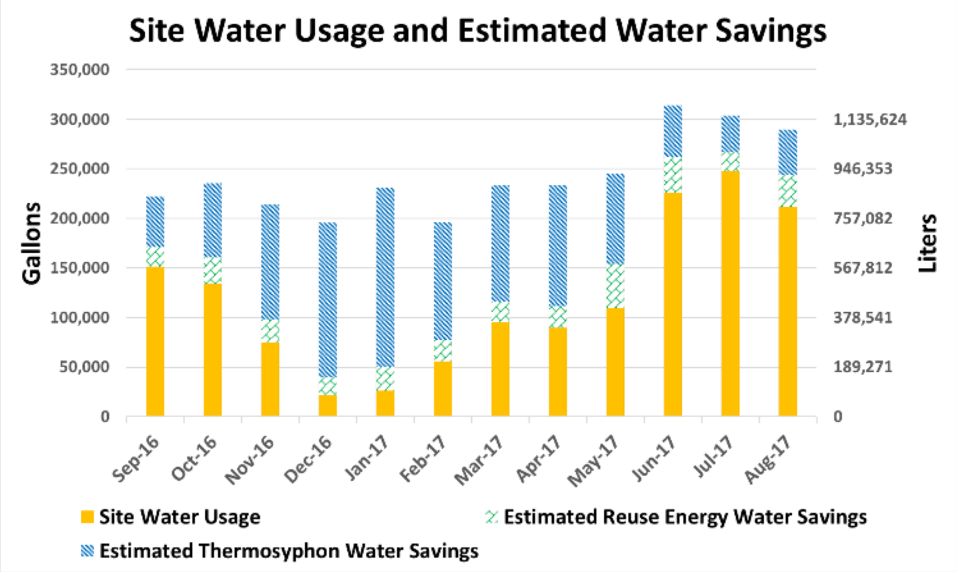
ERE = 0.929

Annual Heat Rejection



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

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Notice

This research was performed using computational resources sponsored by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy and located at the National Renewable Energy Laboratory under Contract No. DE-AC36-08GO28308. Funding provided by the Federal Energy Management Program. The views expressed in the presentation do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the presentation for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.