U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Liquid in the Rack: Liquid Cooling Your Data Centers

Dale Sartor, PE, Lawrence Berkeley National Laboratory DASartor@LBL.gov
Otto Van Geet, PE, National Renewable Energy Laboratory Otto.VanGeet@nrel.gov

FEMP
Federal Energy Management Program

Agenda

- Introduction to Liquid Cooling
- NREL Case Study

Benefits of Liquid Cooling

- **Higher compute densities**
- **Higher efficiency**

➢ Vision: Eliminate compressor based cooling and water consumption

Moving (Back) to Liquid Cooling

- As heat densities rise, liquid solutions become more attractive
- Volumetric heat capacity comparison:

(1.5 m^3)

Water

=

(5,380 m^3)

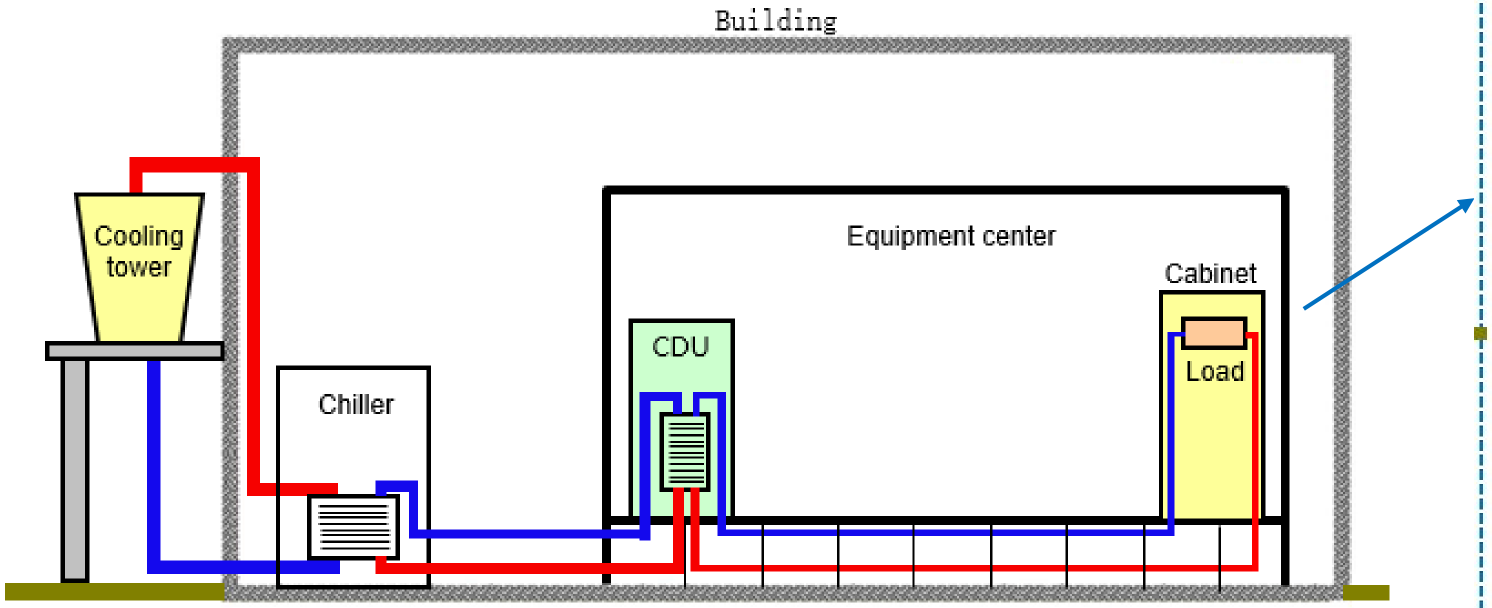
Air

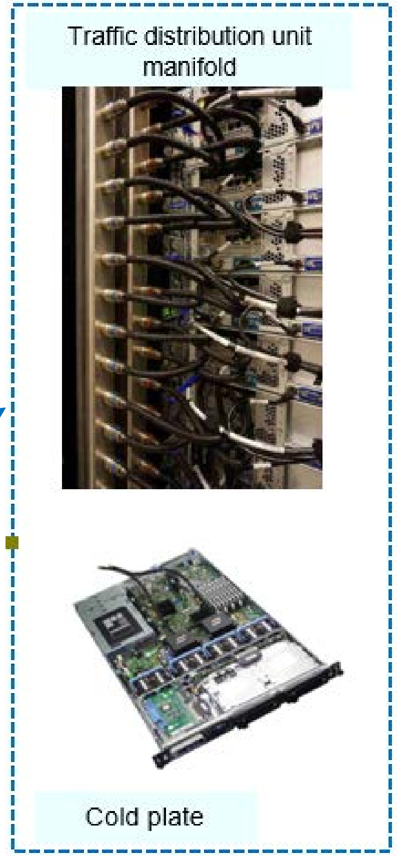
Why Liquid Cooling?

- **Liquids can provide cooling at higher temperatures**
  - Improved cooling efficiency
  - Increased economizer hours
  - Potential use of waste heat
- **Reduced transport energy:**

Heat Transfer		Resultant Energy Requirements			
Rate	ΔT	Heat Transfer Medium	Fluid Flow Rate	Conduit Size	Theoretical Horsepower
10 Tons	12°F	Forced Air	9217 cfm	34" Ø	3.63 Hp
		Water	20 gpm	2" Ø	.25 Hp

Liquid Cooling Solution



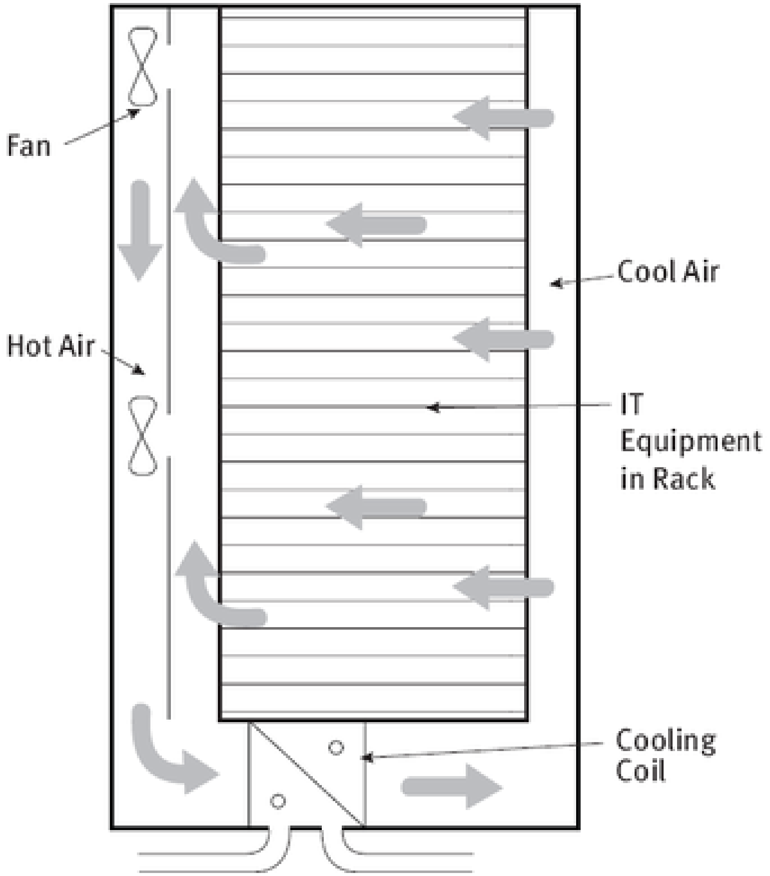


Typical liquid cooled equipment room, with external coolant distribution units (CDUs)

- For most locations data centers may be operated without chillers in a water-side economizer mode

In-Rack Liquid Cooling

- Racks with integral coils and full containment:



Rear-Door Heat Exchanger

- Passive technology:
  relies on server fans for airflow
- Active technology:
  supplements server fans with external fans in door
- Can use chilled or higher temperature water for cooling

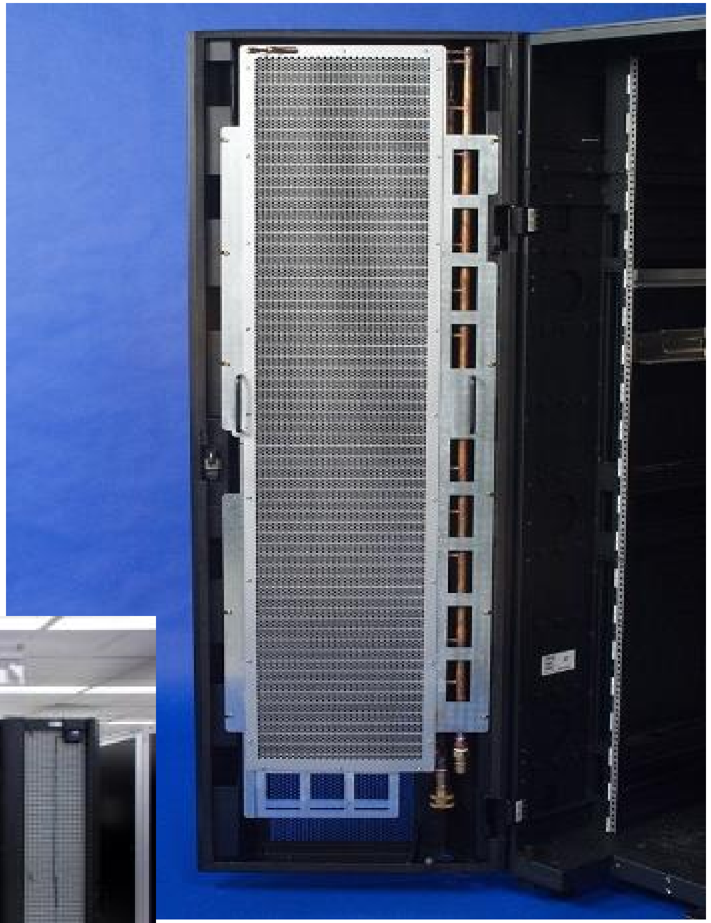
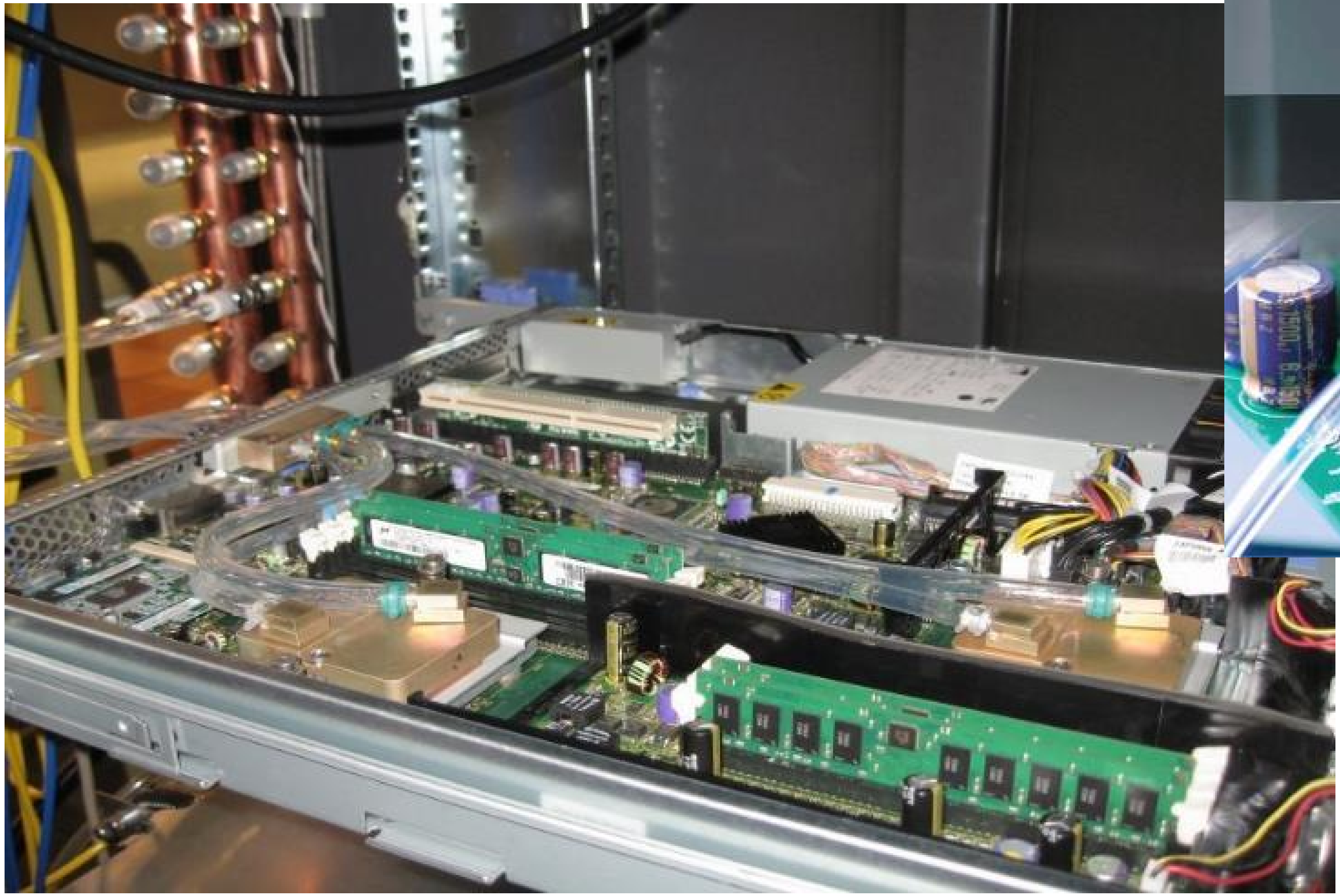


Photo courtesy of Vette

Liquid On-Board Cooling



Example: Maui DOD HPC Center Warm Water Cooling

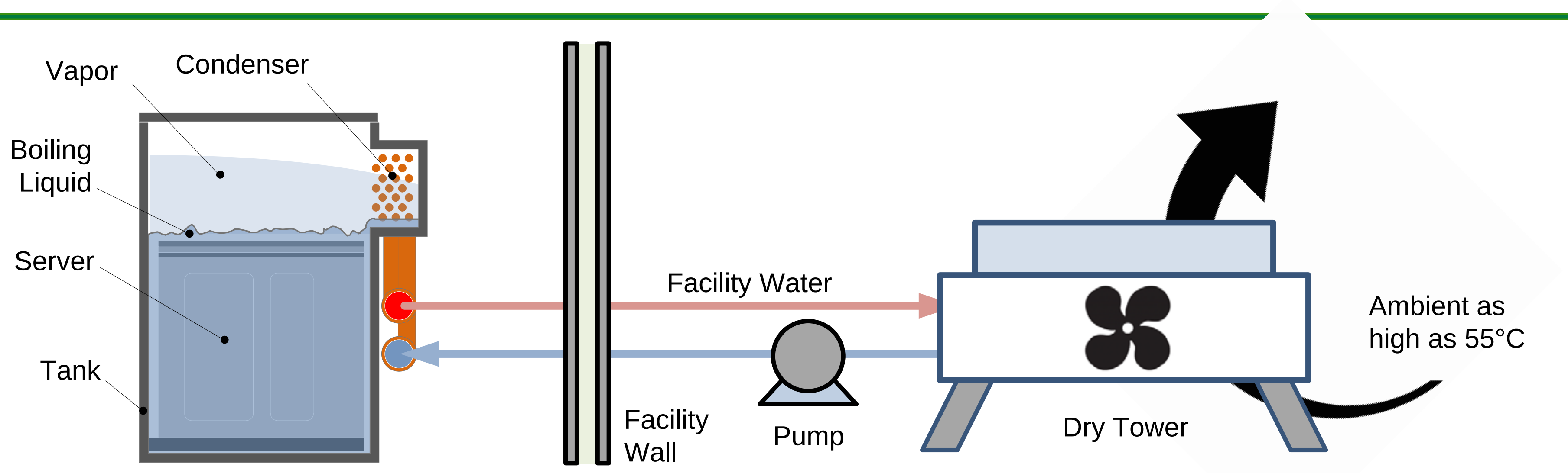
IBM System x iDataPlex

- 90% water cooled
- 10% air cooled
- Cooling water temperature as high as 44°C

Water inside

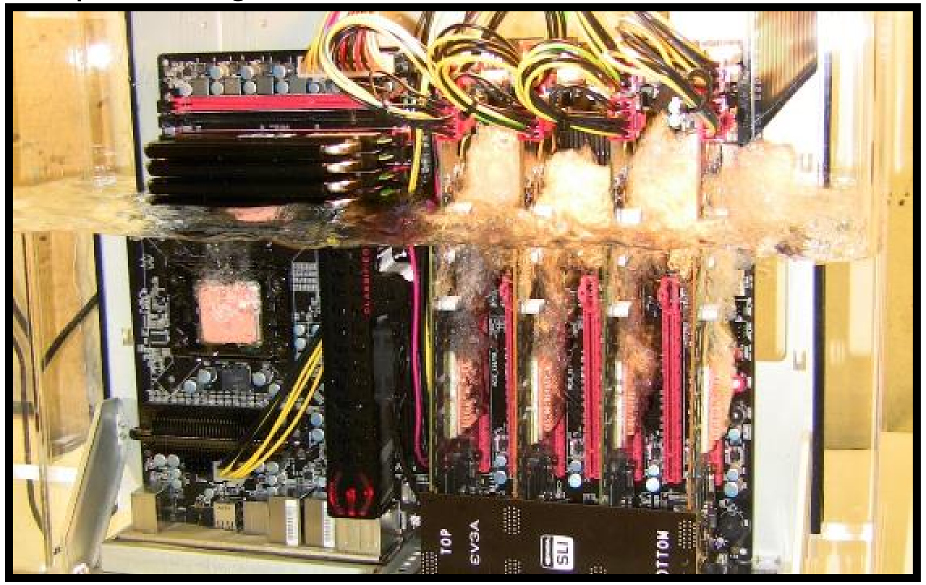
Dry Coolers, 10 kW each compared to 100 kW Chillers

Liquid Immersion Cooling



Cooling Power = Pump + Fan

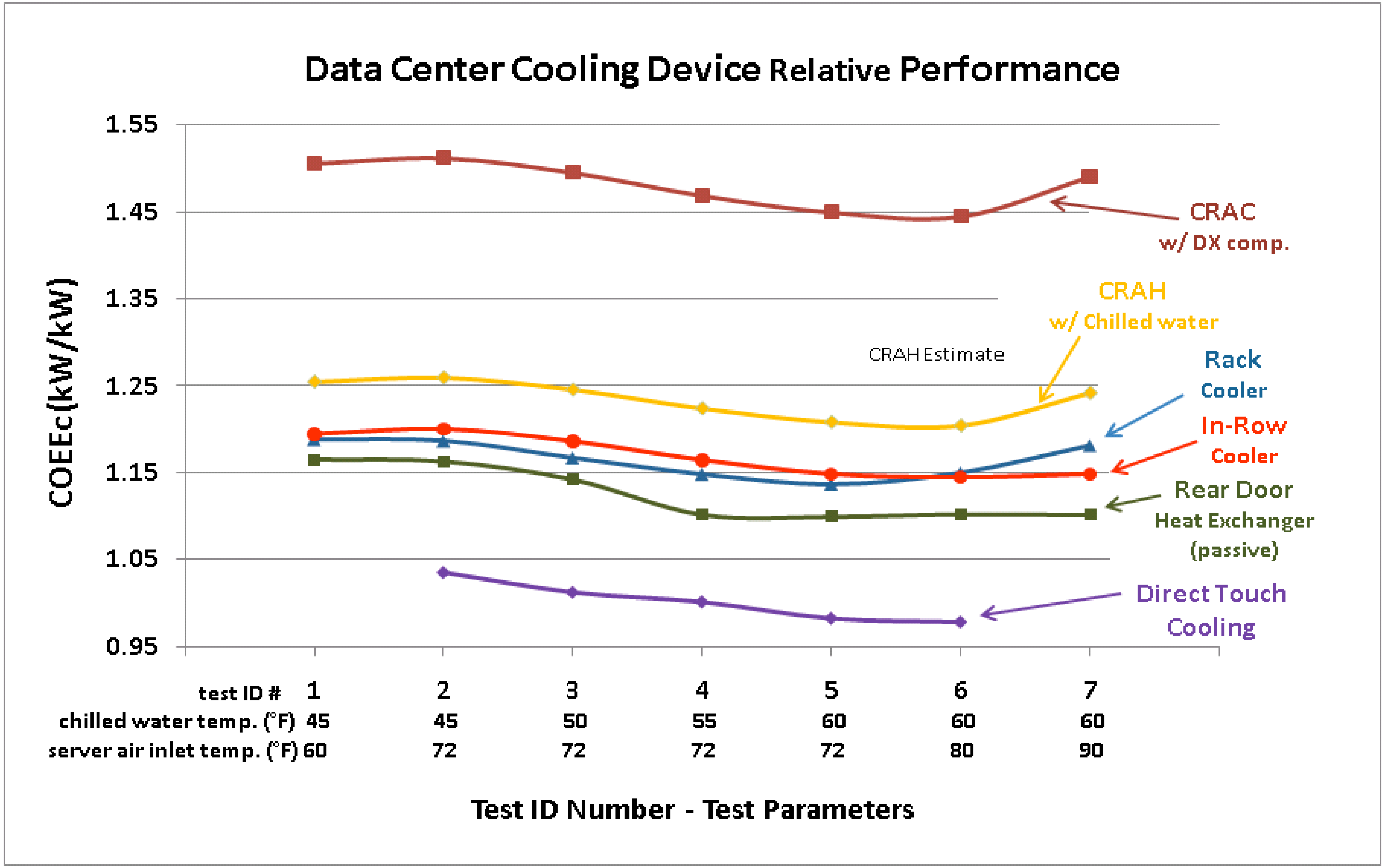
Computers in glass tank



No longer requires:

- chillers
- cooling towers
- water use
- raised floors
- CRACs
- earplugs!

"Chill-Off 2" Evaluation of Liquid Cooling Solutions



"Free Cooling" w/ Water-Side Economizers

- Cooling without Compressors
- Easier retrofit
- Added reliability (backup in case of chiller failure)
- No contamination issues
- Put in series with chiller
- Uses tower or dry cooler

No or minimum compressor cooling

Cooling tower and HX = Water-side Economizer

Re-Use of Waste Heat

- **Heat from a data center can be used for:**
  - Heating adjacent offices directly
  - Preheating make-up air (e.g., “run around coil” for adjacent laboratories)
- **Use a heat pump to elevate temperature**
  - Waste heat from LBNL ALS servers captured with rear door coolers feed a heat pump that provides hot water for reheat coils
- **Warm-water cooled computers are used to heat:**
  - Greenhouses, swimming pools, and district heating systems

Resources: FEMP's Center of Expertise in Data Centers

- datacenters.lbl.gov
- datacenters.lbl.gov/technologies/liquid-cooling

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FEMP Federal Energy Management Program

NREL ESIF Data Center

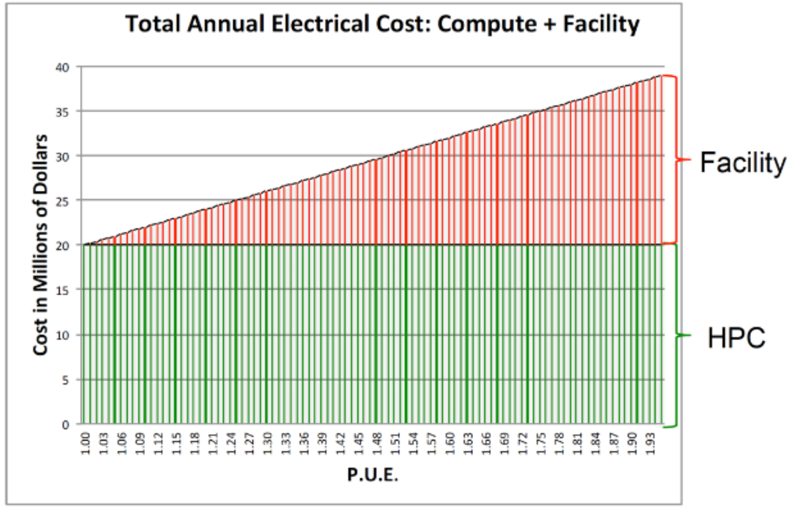
- **Showcase Facility**
  - ESIF 182,000 ft.^{2} research facility
  - 10,000 ft.^{2} data center
  - 10-MW at full buildout
  - LEED Platinum Facility, **PUE ≤ 1.06**
  - NO mechanical cooling (eliminates expensive and inefficient chillers)

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

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

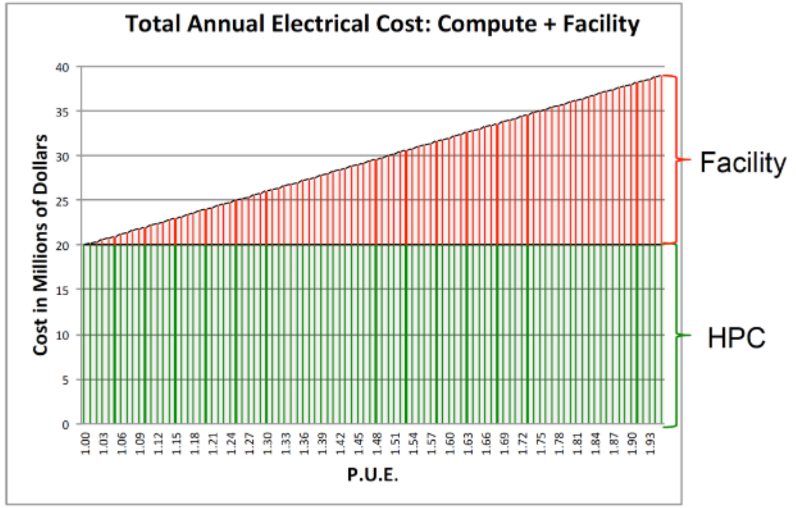


Assume ~20MW HPC system & $1M per MW year utility cost.

Metrics

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

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



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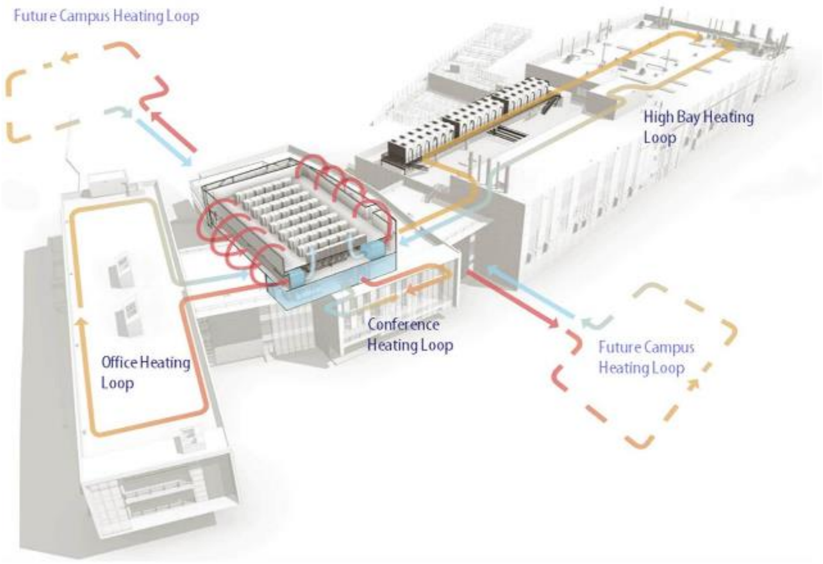
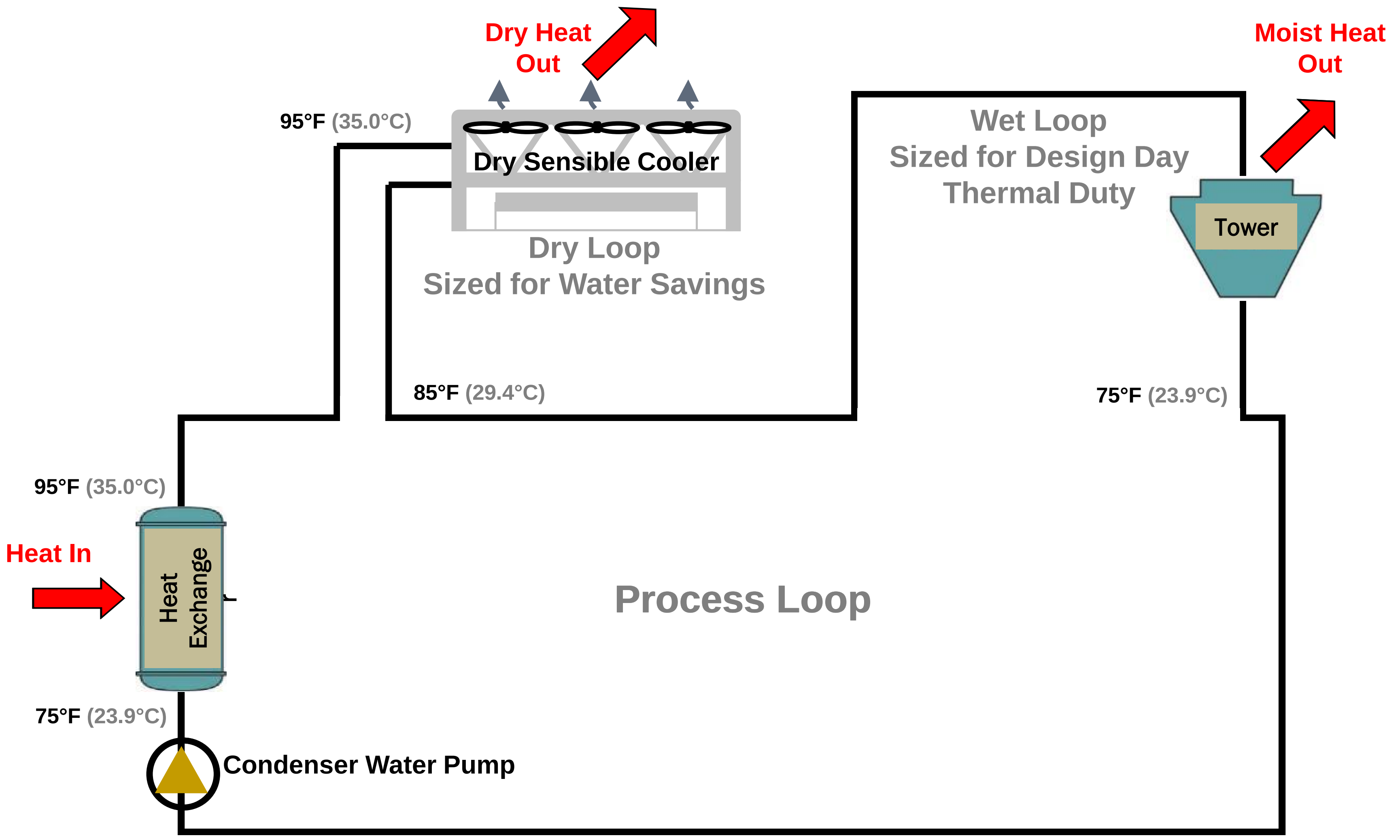


Liquid Cooling – Considerations

- **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**

Basic Hybrid System Concept



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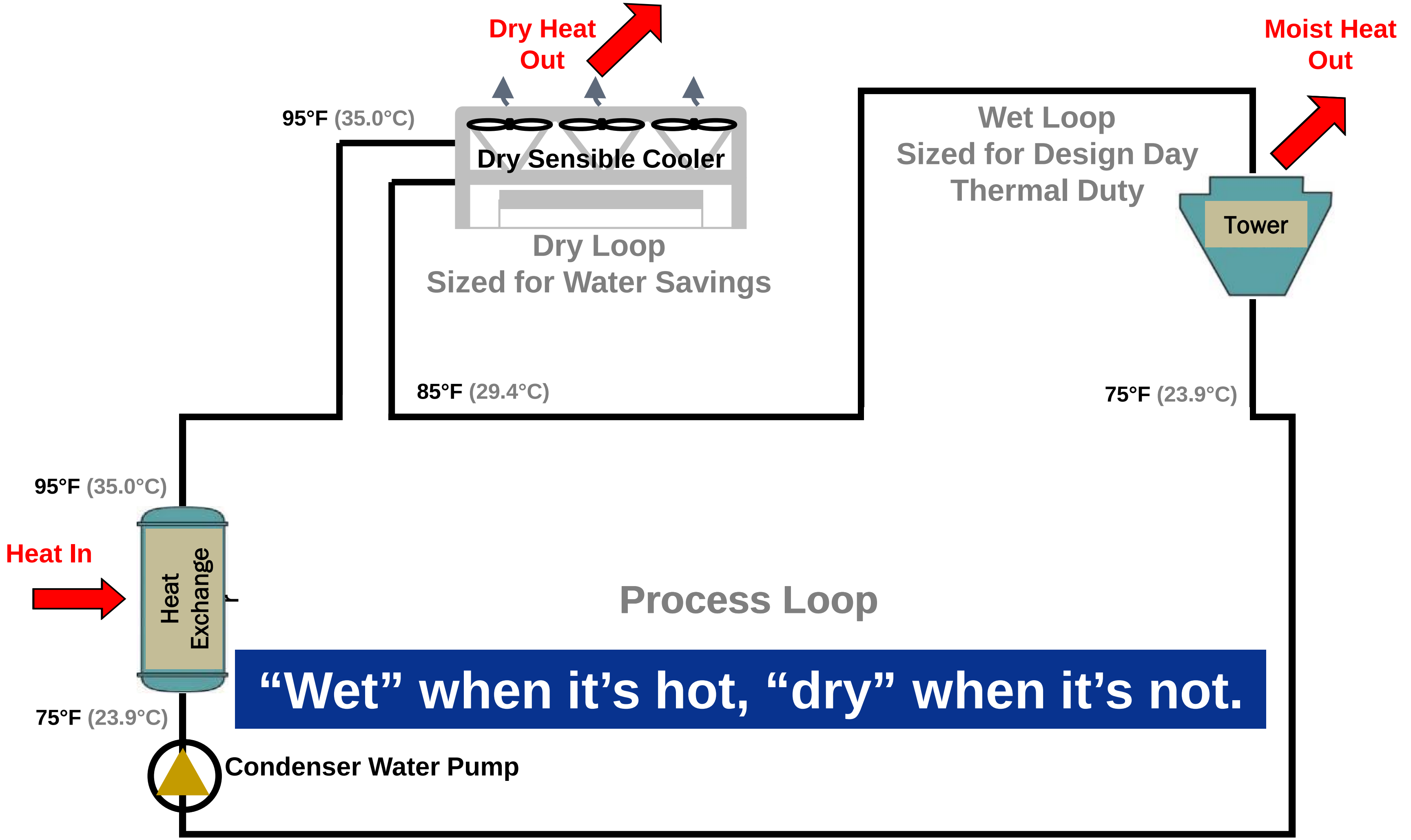
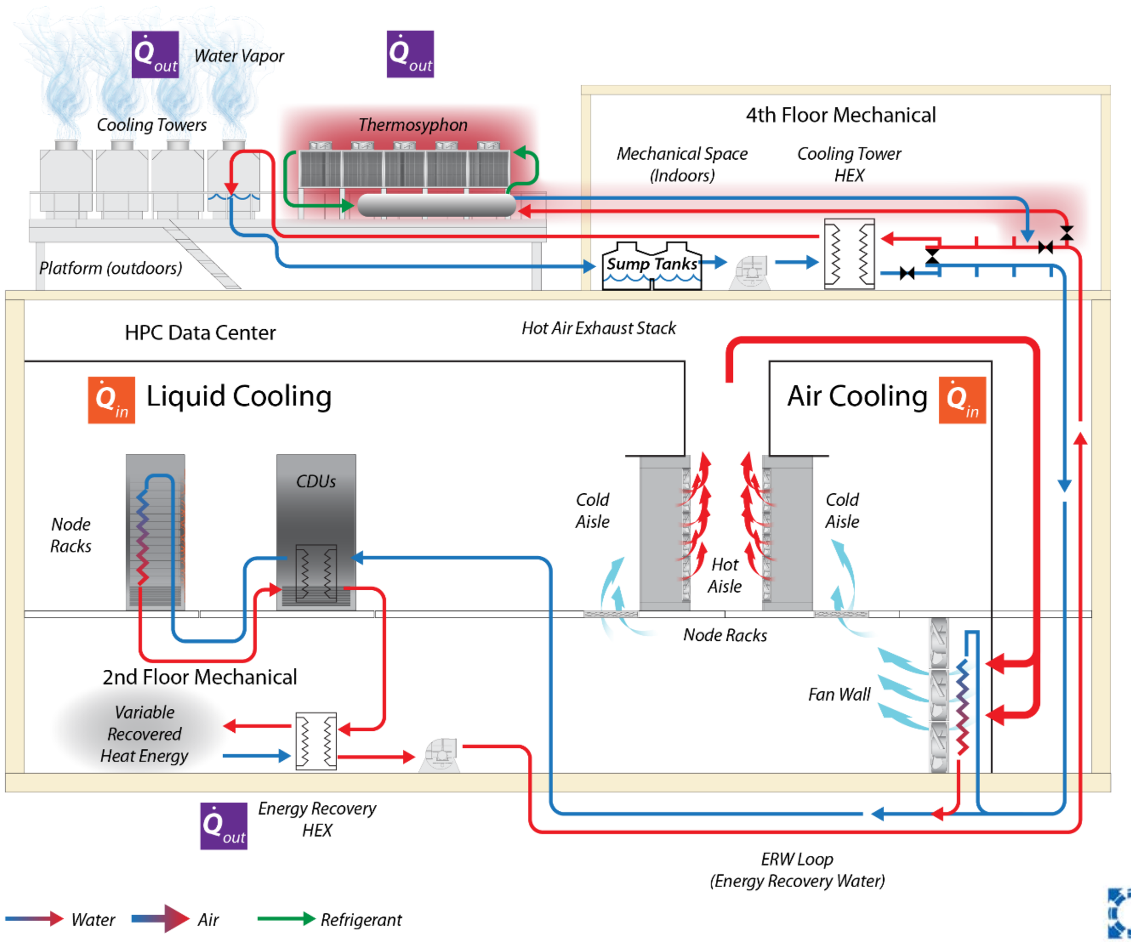
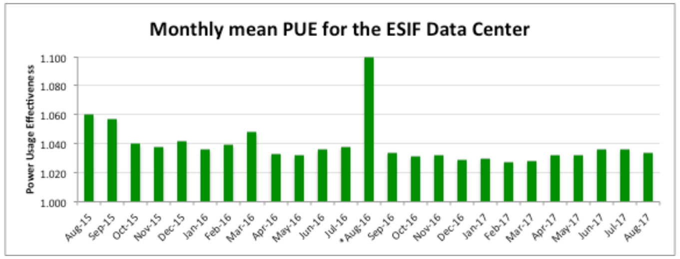


“Wet” when it’s hot, “dry” when it’s not.

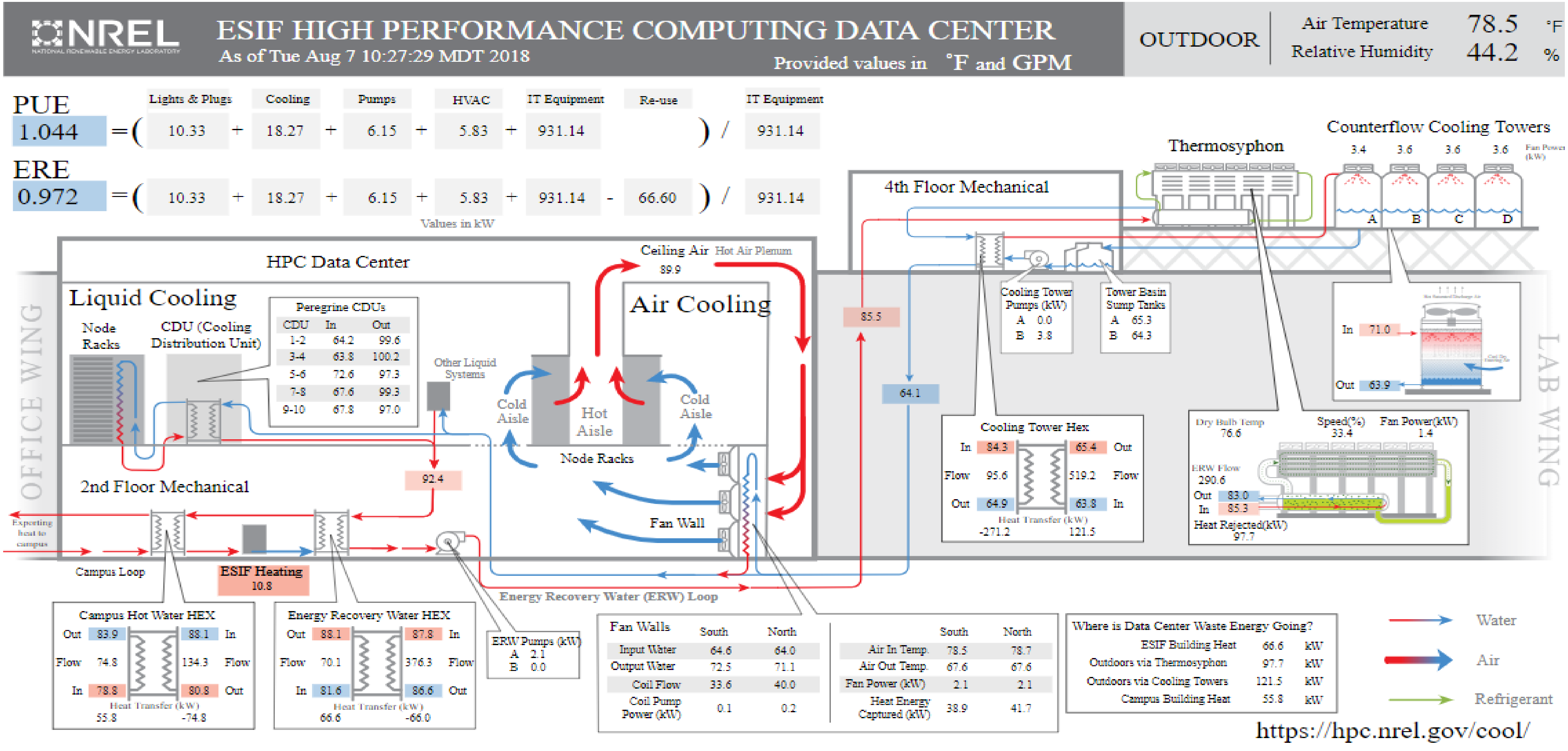
Improved WUE – Thermosyphon





NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Johnson Controls
Sandia National Laboratories

ESIF Data Center Efficiency Dashboard



Data Center Metrics

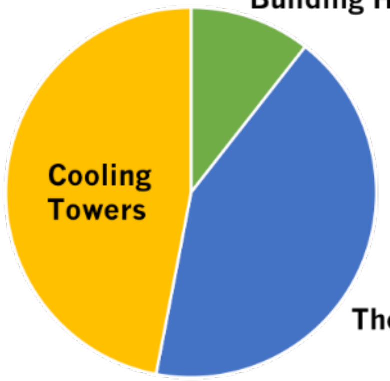
First year of TSC operation (9/1/2016–8/31/2017)

Hourly average IT Load = 888 kW

PUE = 1.034

ERE = 0.929

Annual Heat Rejection



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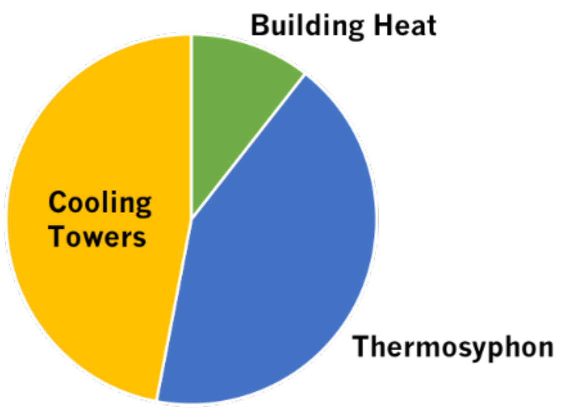
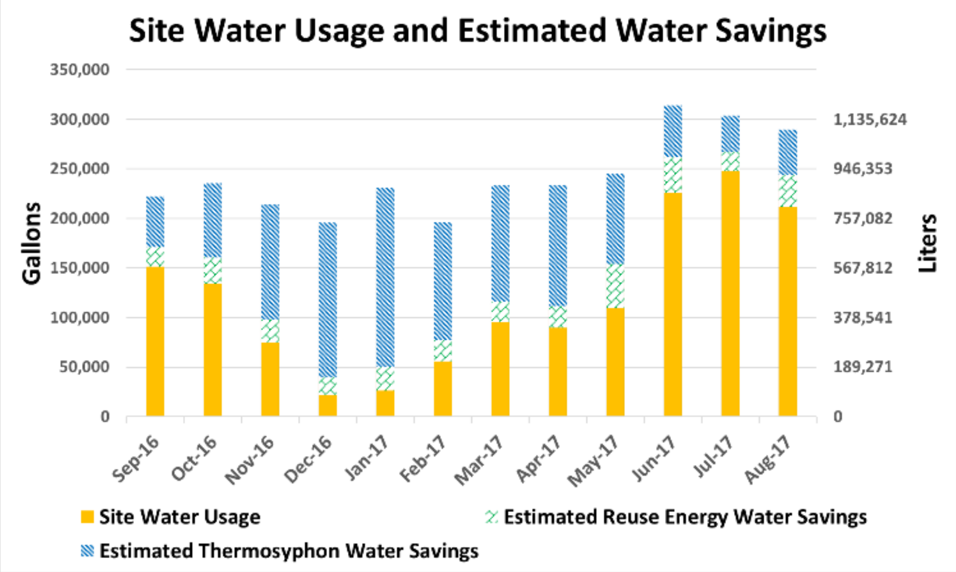


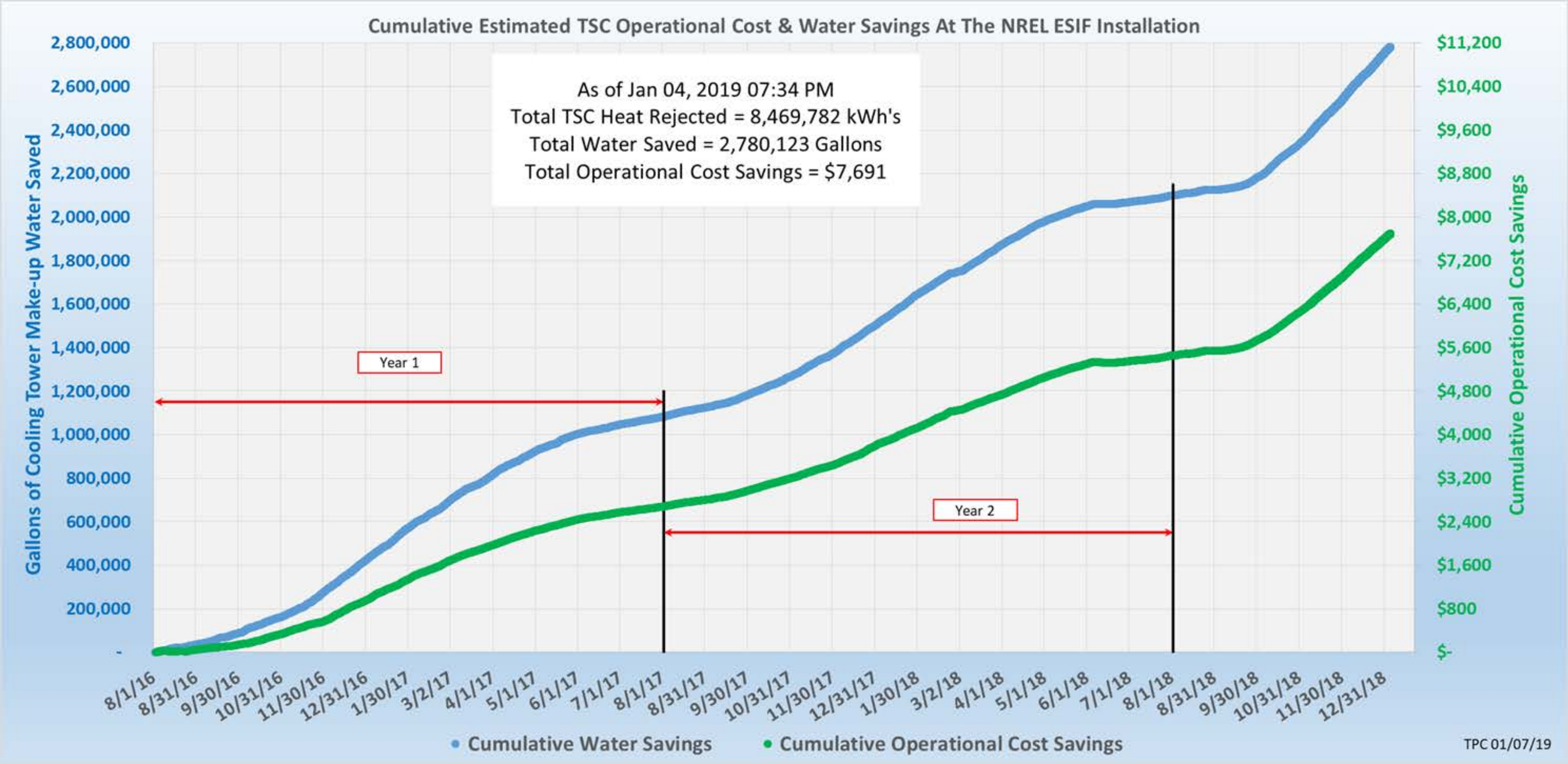
WUE = 0.7 liters/kWh

(with only cooling towers, WUE = 1.42 liters/kWh)



Cumulative Water and Cost Savings

Energy = $0.07/kWh
Water = $5.18/kgal



Questions & Contact Information

- Questions?
- Contact Information:

Dale Sartor, P.E.

DASartor@LBL.gov

BERKELEY LAB

Otto Van Geet, P.E.

Otto.vangeet@nrel.gov

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