Saving Water and Operating Costs at NREL's HPC Data Center

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4A-District Energy & Water Strategies for Sustainable Operation

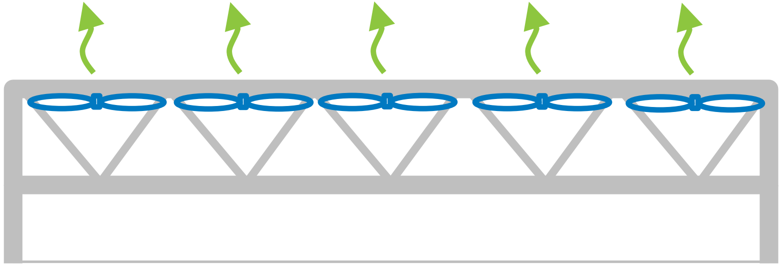
Outline/Agenda

- Traditional and hybrid choices for heat rejection
- Description and operation of the thermosyphon cooler (TSC)
- Description of the National Renewable Energy Laboratory's (NREL's) Energy Systems Integration Facility (ESIF) High Performance Computing (HPC) Data Center and installation of the TSC
- Initial system modeling
- Initial results/conclusions.

Air- and Water-Cooled System Options

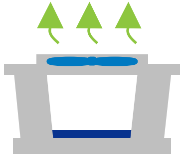
Air-Cooled System

- Design day is based on **DRY BULB** temperature
- Consumes no water
  (no evaporative cooling)
- Large footprint/requires very large airflow rates.



Water-Cooled System

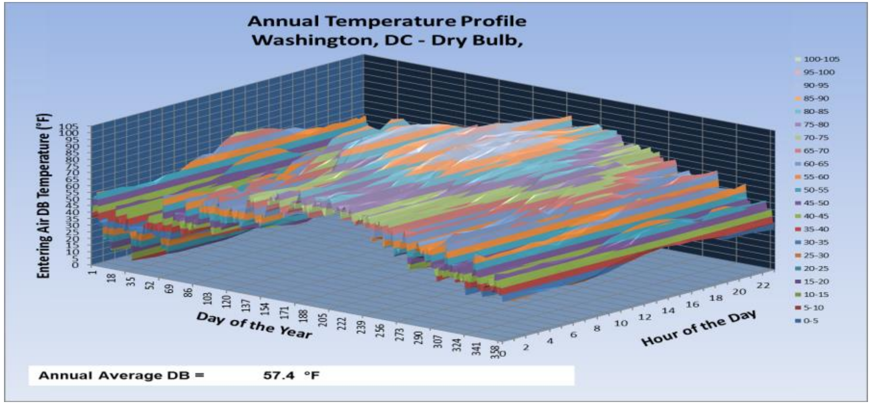
- Design day is based on the lower **WET BULB** temperature
- Evaporative cooling process uses water to improve cooling efficiency
  - **80% LESS AIRFLOW → lower fan energy**
  - Lower cost and smaller footprint.
- Colder heat-rejection temperatures improve system efficiency.

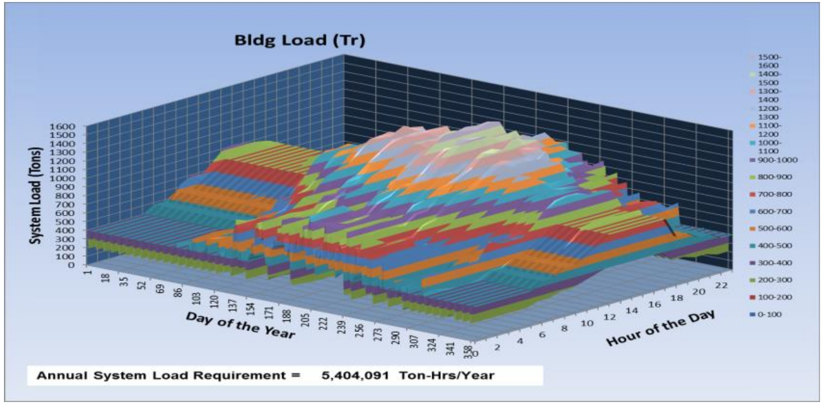


However, water-cooled systems depend on a reliable, continuous source of low-cost water.

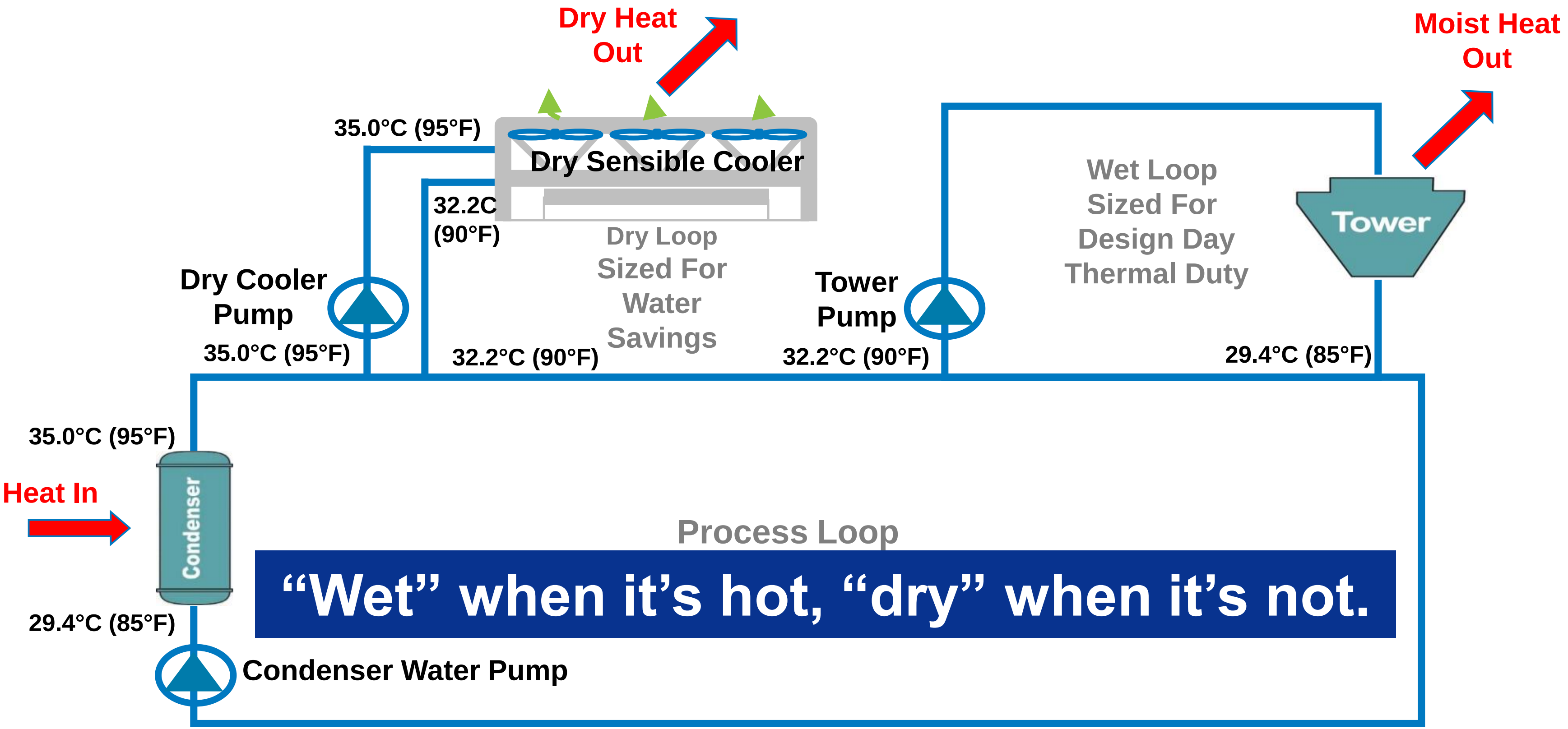
Basic principles:

- Operates **wet** during peak design periods to save energy (high temperatures and loads)
- Operates **dry** during low design periods to save water (lower temperatures and loads)
- Depending on the design, system might operate either as **wet** or **dry** or might be able to operate both **wet** and **dry.**



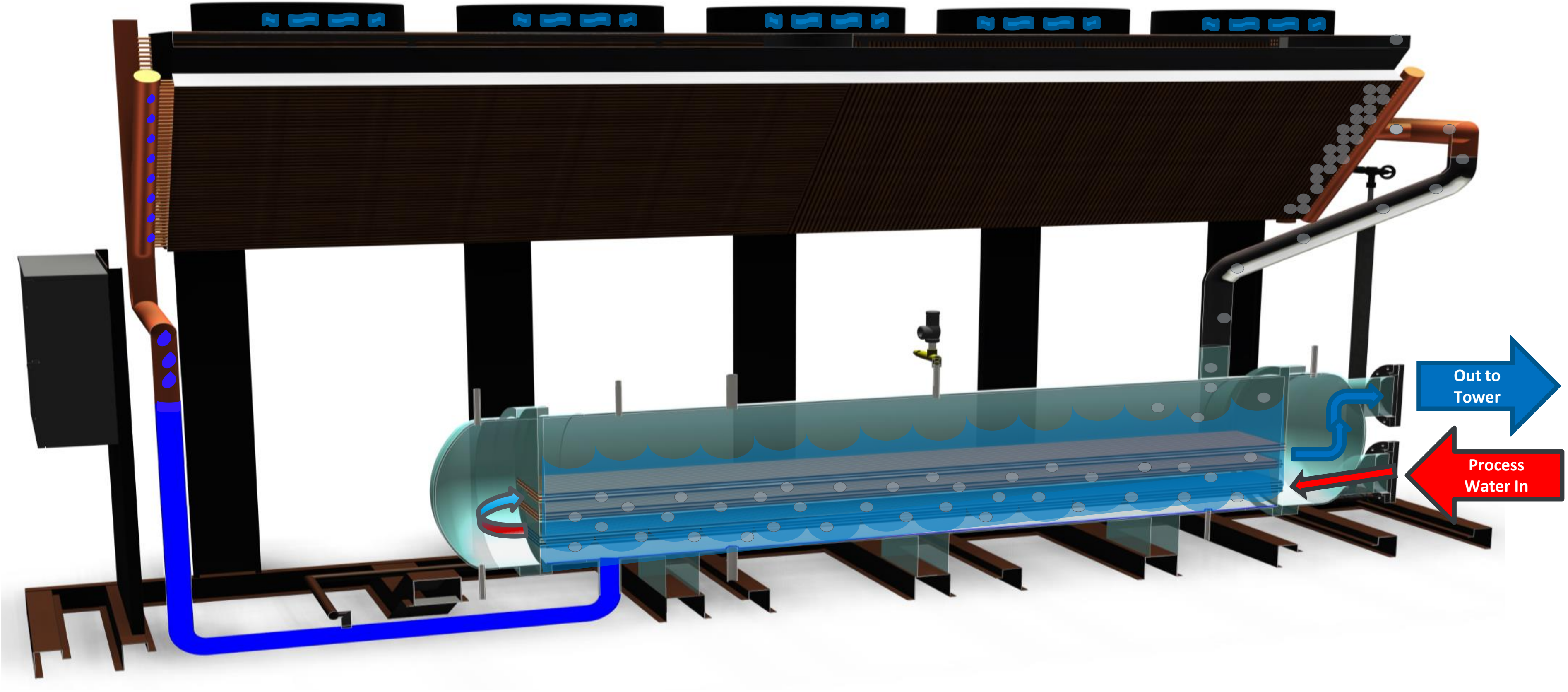


Basic Hybrid System Concept



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

Thermosyphon Cooler



NREL Campus


Cooling Towers
Lab Wing
HPC Data Center
Office Wing
Photo by Dennis Schroeder, NREL 30743

ESIF HPC Data Center

- Annualized average power usage effectiveness (PUE) rating of better than 1.06 since opening in 2012
- Based on industry/tech trends, committed to direct liquid cooling at the rack
  - No mechanical chillers
  - High-power-density racks, more than 60 kW per rack.
- Holistic approach—integrate racks into the data center, the data center into the facility, and the facility into NREL's campus
- Capture and use data center waste heat: office and lab space (now) and export to campus (future).

Two key design parameters:

- IT cooling supply: 24°C (75°F) on hottest day of year, ASHRAE "W2" class
- IT return water: required 35°C (95°F) to heat facility on coldest day of the year.

Power Usage Effectiveness Metric

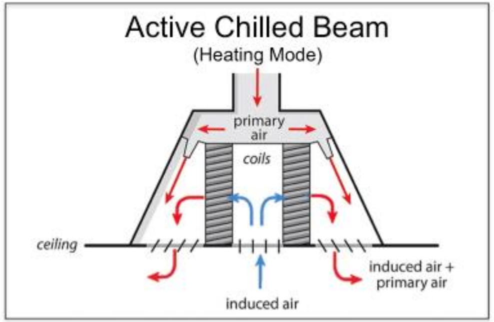
- PUE is the ratio of the total amount of power used by a computer data center facility to the power delivered to the computing equipment:

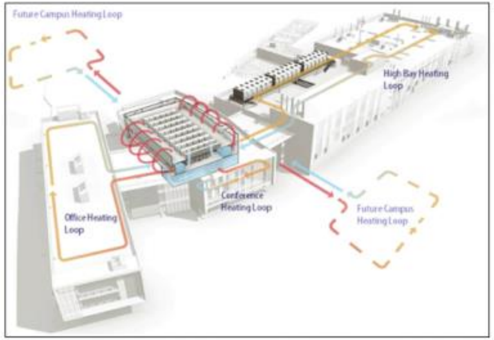
$$PUE = \frac{Lights\&Plugs + Cooling + Pumps + HVAC + IT\ Equipment}{IT\ Equipment}$$

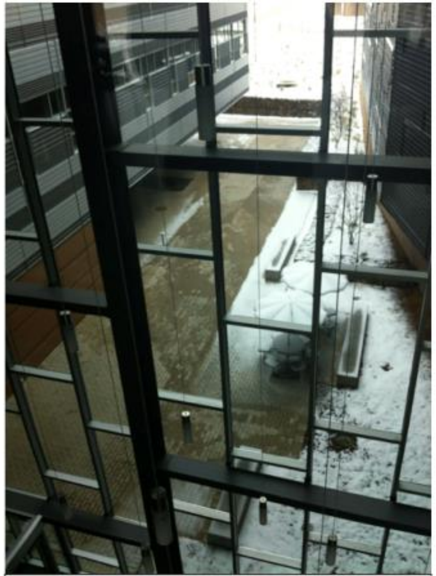
- PUE values cover a wide range for data centers, with an overall average of approximately 1.8.
  - Data centers focusing on efficiency are achieving PUE values of 1.2 or less.
  - NREL's HPC Data Center achieved an annualized PUE rating of 1.04 in 2016.

Waste Heat (Energy) Reuse

- Heat energy in the energy recovery water (ERW) loop is available to heat the ESIF's process hot water (PHW) loop through the use of heat exchangers.
- Once heated, the PHW loop supplies:
  - Active chilled beams to heat office space
  - Air handling units to heat the conference and high-bay spaces
  - Snowmelt loop in the courtyard approaching the ESIF's main entrance
  - District heating loop.

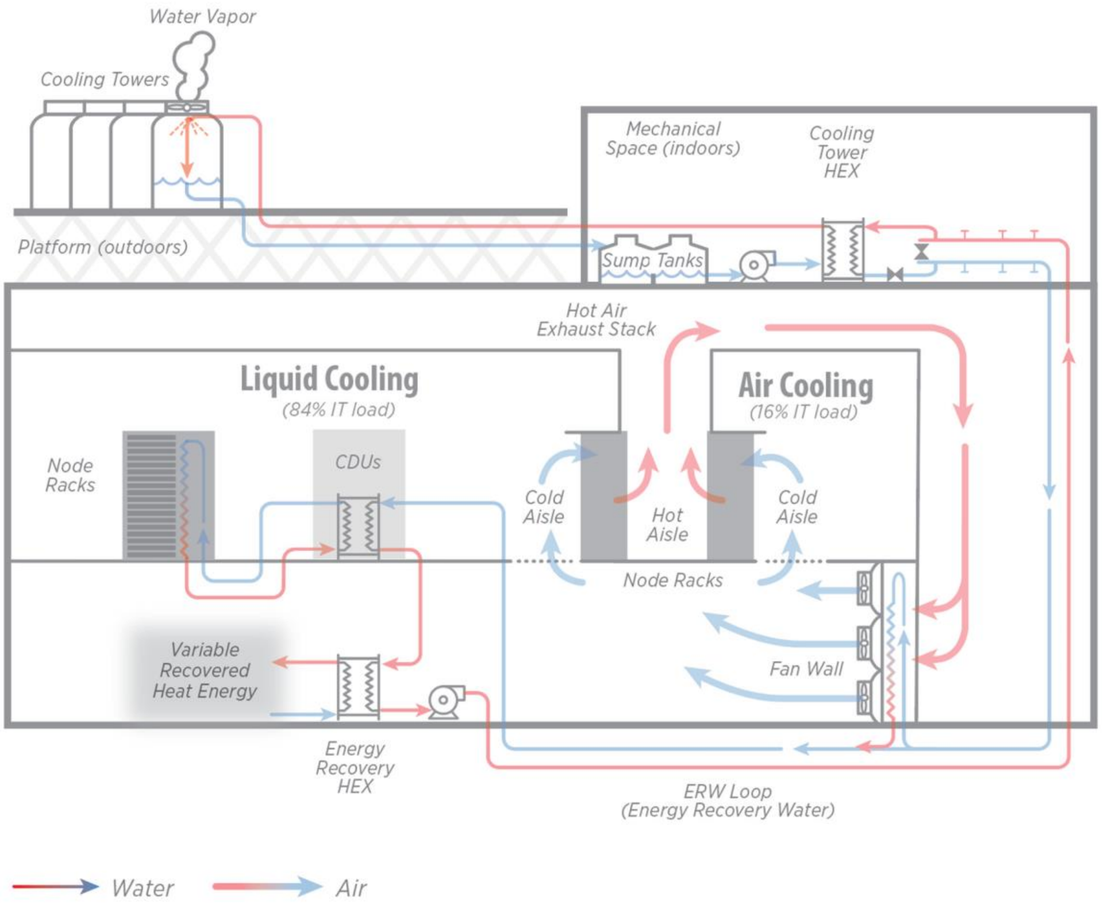






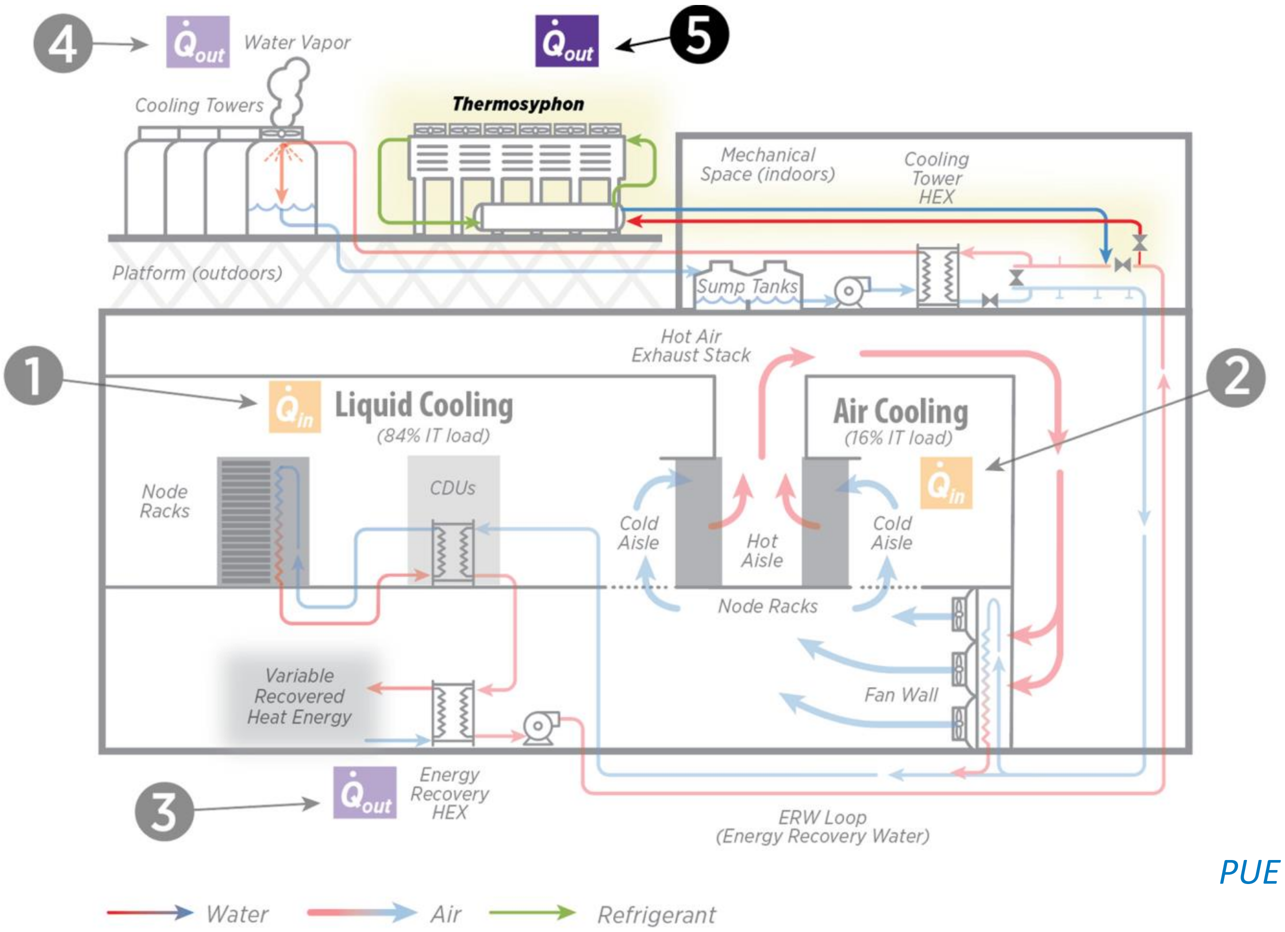
Snow melt in ESIF courtyard

System Schematic: Original Configuration



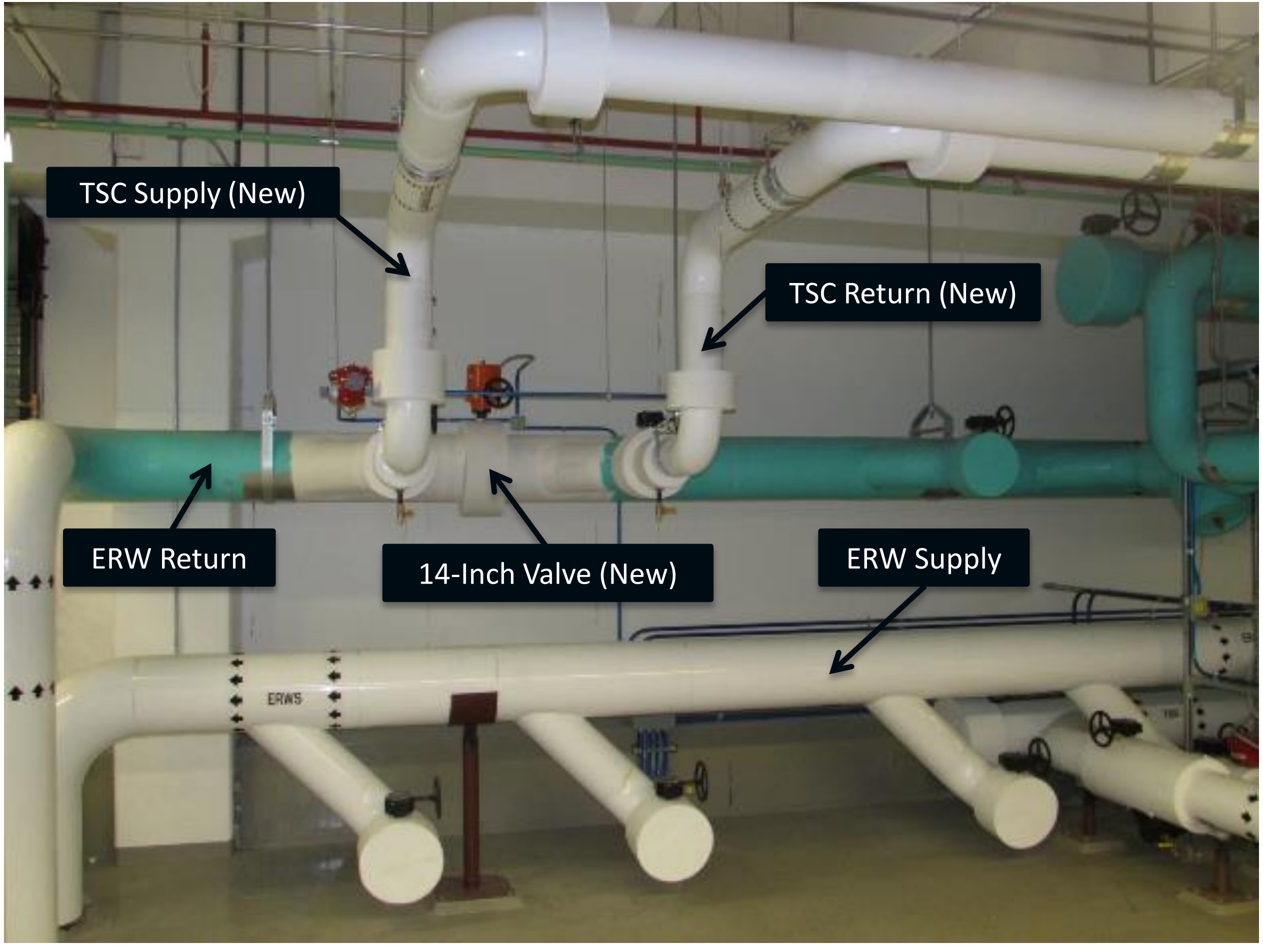
PUE ≤ 1.06

System Schematic: Current Configuration



PUE ≤ 1.06 (still)

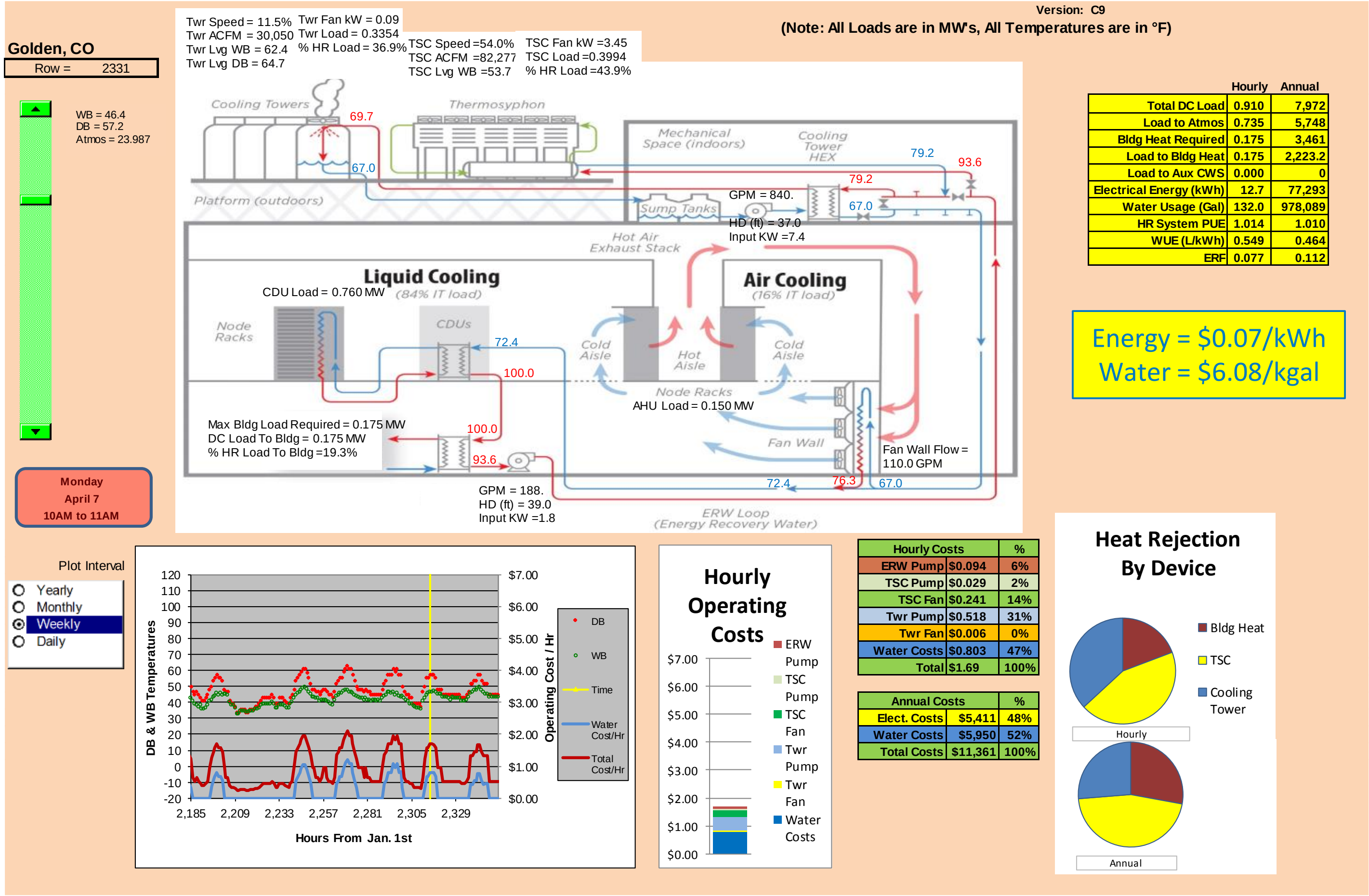
System Modification



Thermosyphon Cooler Installation

Photo by Dennis Schroeder, NREL 42001

System Modeling Program



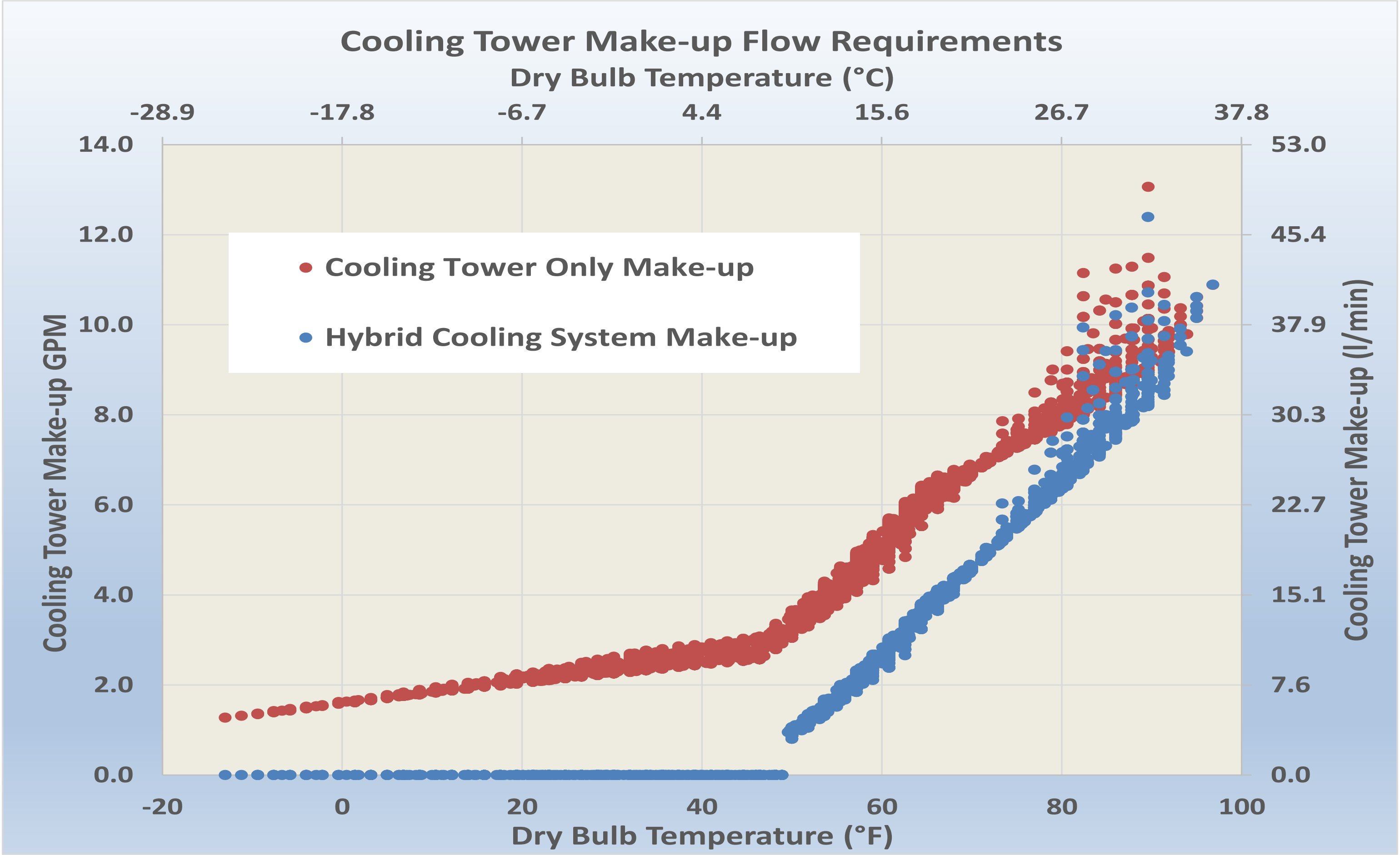
Favorable Application Characteristics

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.

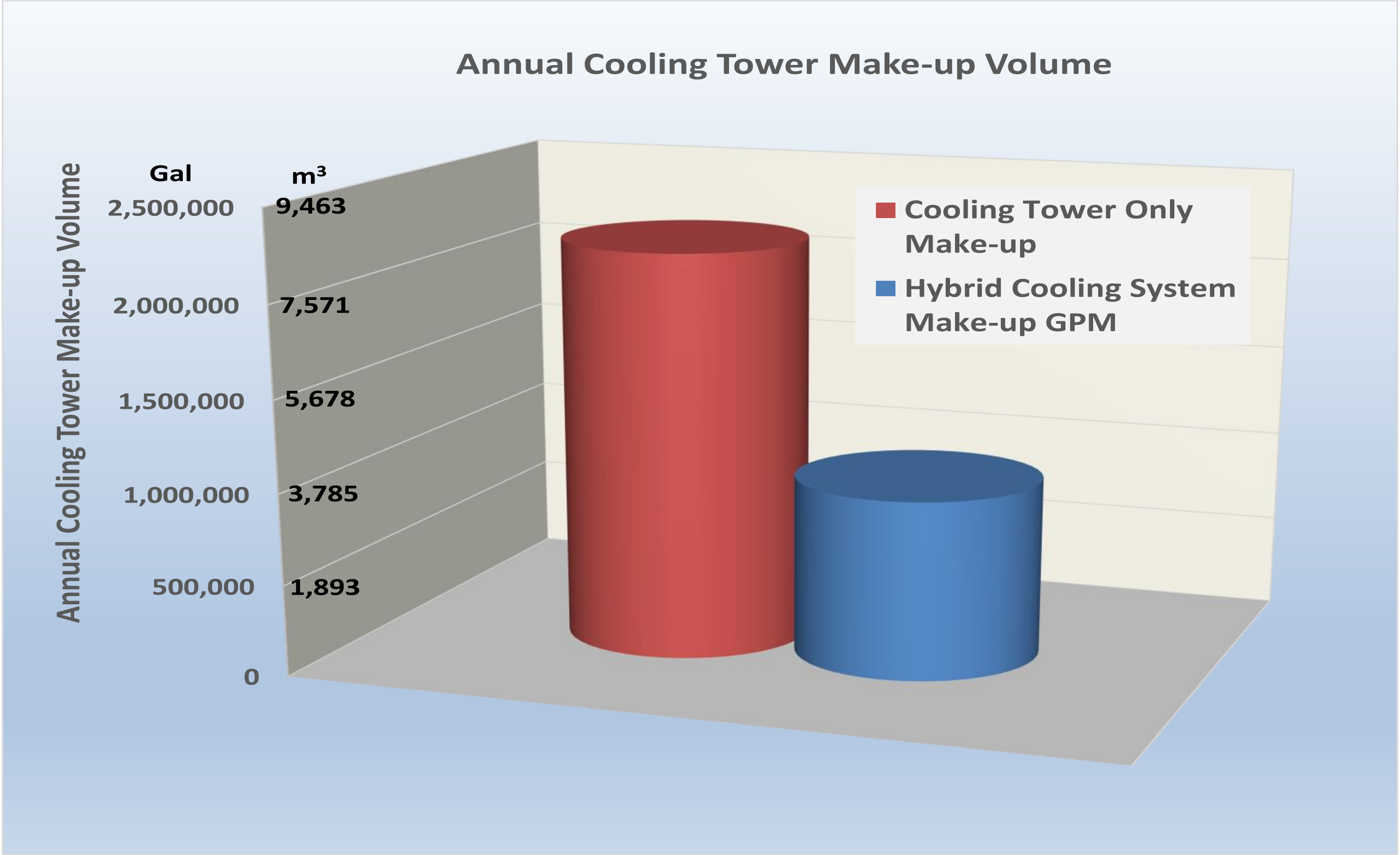
Favorable application characteristics:

- 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.

Modeling Results: Makeup GPM vs. Dry Bulb Temperature



Modeling Results: Overall Water Use



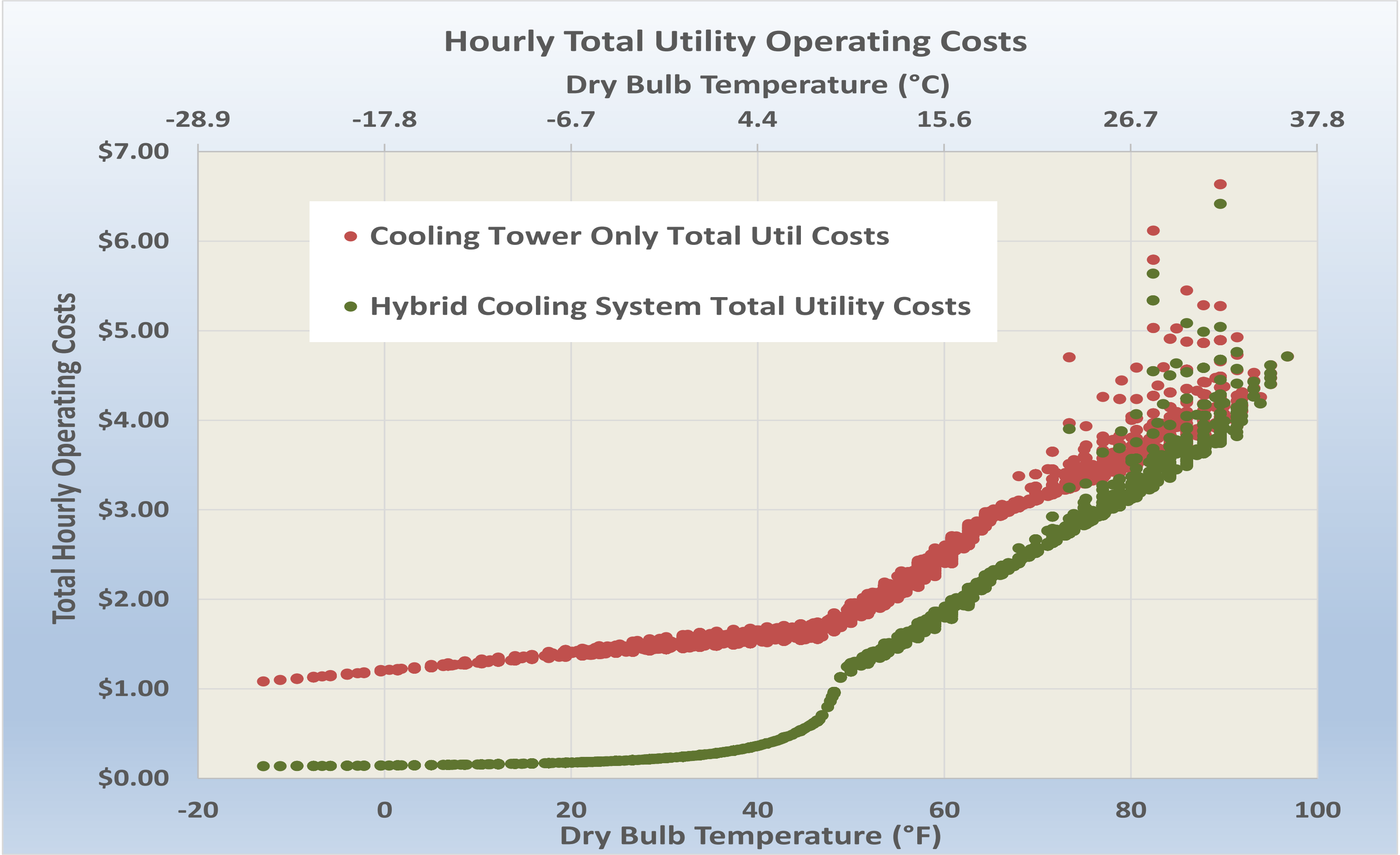
Controls Allow for Saving Both Water and Operational Costs

WECER = Water-to-Energy Cost Equivalence Ratio:

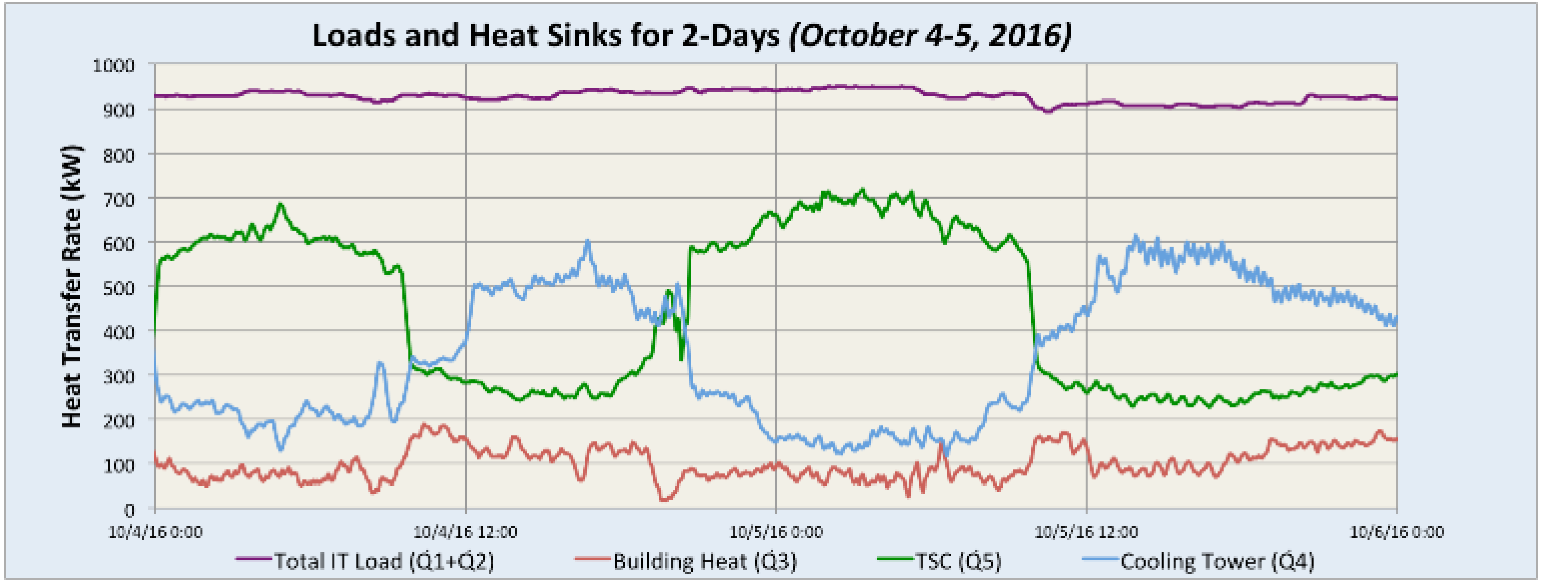
- **WECER = cost of water/cost of electricity**
- **WECER = ($/1,000 gal water) / ($/kWh)**
- **WECER = kWh/1,000 gal.**

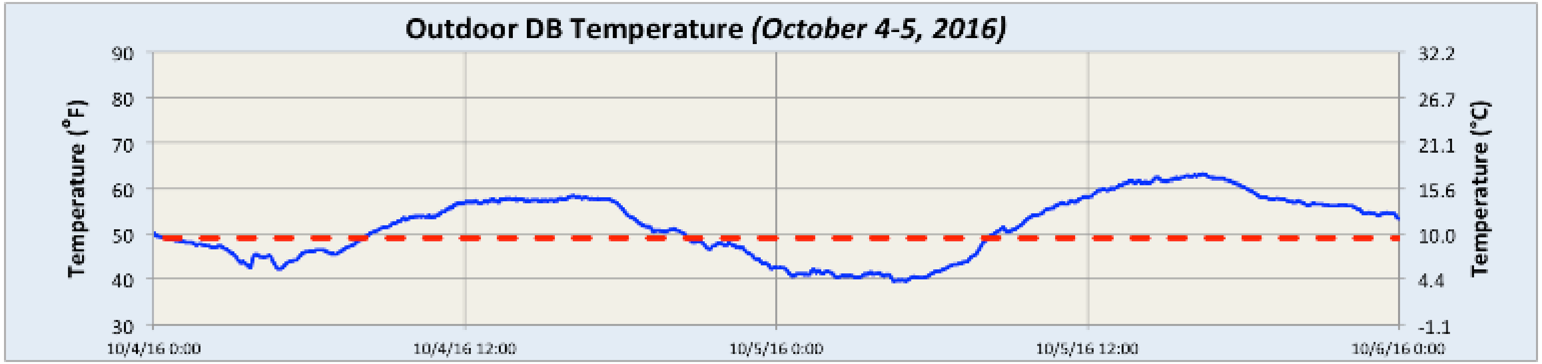
TSC fan speed = *f* (WECER and (entering water–DB)).

Modeling Results: Operational Cost

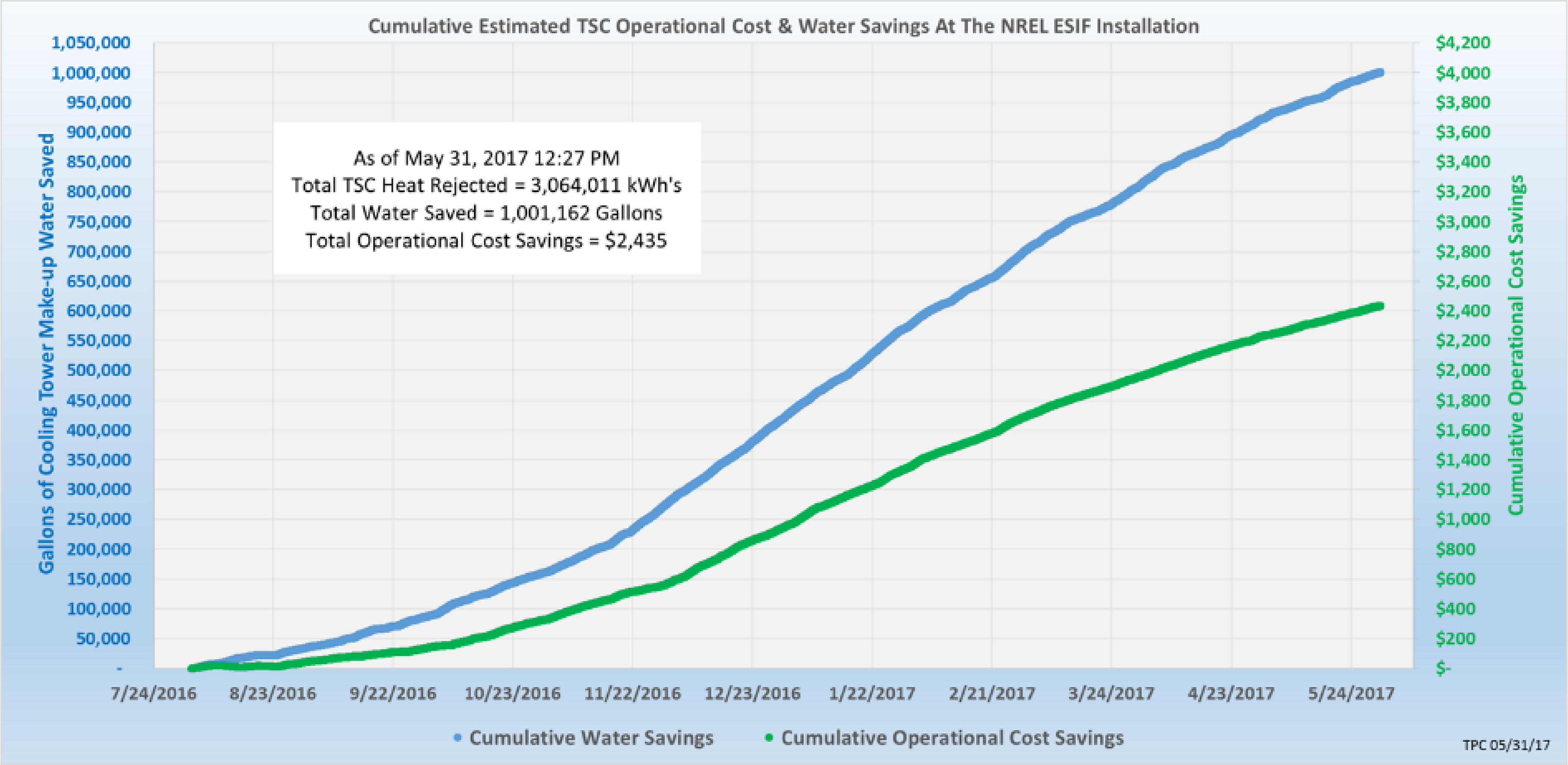


Sample Data: Typical Loads and Heat Sinks





Early Data: Cumulative Water and Cost Savings



Conclusions

- Warm-water liquid cooling has proven very energy efficient in operation.
- Initial modeling of a hybrid system showed that it was possible to save significant amounts of water while simultaneously reducing total operating costs.
- System modification was straightforward.
- Initial data indicate that the system water and operational cost savings are in line with modeling.

Bibliography

Carter, T.; Liu, Z.; Sickinger, D.; Regimbal, K.; Martinez, D. 2017. Thermosyphon Cooler Hybrid System for Water Savings in an Energy-Efficient HPC Data Center: Modeling and Installation. (LV-17-C005) Presented at the ASHRAE Winter Conference, Las Vegas, NV, January 28 – February 1, 2017.

Additional resources:

- https://hpc.nrel.gov/datacenter
- www.JohnsonControls.com/BlueStream.

Thank you!

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