Data Center Optimization Strategies

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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
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

\[ WUESOURCE = \frac{\text{"Annual Site Water Usage"} + \text{"Annual Source Energy Water Usage"}}{\text{"IT energy"}} \]

\[ WUESOURCE = \frac{\text{"Annual Site Water Usage"}}{\text{"IT energy"}} + [EWIF \times PUE] \]
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

- **Process Loop**: Heat In
- **Condenser Water Pump**: 75°F (23.9°C)
- **Wet Loop**: Sized for Design Day Thermal Duty
- **Moist Heat Out**: 95°F (35.0°C)
- **Tower**

Temperatures:
- **Heat In**: 75°F (23.9°C)
- **Process Loop**: 75°F (23.9°C)
- **Condenser**: 95°F (35.0°C)
- **Wet Loop**: 95°F (35.0°C)
- **Moist Heat Out**: 75°F (23.9°C)
Basic Hybrid System Concept

“Wet” when it’s hot, “dry” when it’s not.
Improved WUE—Thermosyphon

Monthly mean PUE for the ESIF Data Center

Monthly mean PUE for the ESIF Data Center
ESIF Data Center Efficiency Dashboard

ESIF HIGH PERFORMANCE COMPUTING DATA CENTER
As of Thu Aug 1 16:04:11 MDT 2019

PUE = 1.049

ERE = 1.049

OUTDOOR
Air Temperature 72.3°F
Relative Humidity 55.0%

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

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

Loads and Heat Sinks for 2-Days (*October 4-5, 2016*)

Outdoor Dry Bulb Temperature (*October 4-5, 2016*)
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

WUE = 0.7 liters/kWh
with only cooling towers, WUE = 1.42 liters/kWh

Annual Heat Rejection

Building Heat 11%
Cooling Towers 47%
Thermosyphon 42%

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

Site Water Usage and Estimated Water Savings

WUESOURCE = 5.4 liters/kWh
WUESOURCE = 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

Cumulative Estimated TSC Operational Cost & Water Savings At The NREL ESIF Installation

As of Aug 01, 2019 05:58 PM
Total TSC Heat Rejected = 11,249,663 kWh's
Total Water Saved = 3,681,375 Gallons
Total Operational Cost Savings = $10,605
Contact

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Notice

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