ASHRAE VIRTUAL ANNUAL CONFERENCE

June 28-30, 2021

Seminar #8 - Energy Management Best Practices, Case Studies and Lessons Learned from Real-world Data Center Operation

Harnessing the Power of Data Analytics for Reliable and Efficient Data Center Operations at LBNL's High Performance Computing (HPC) Center

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Learning Objectives

- Learn ***key design features*** that make the NERSC data center highly energy efficient and the operational challenges they bring;
- Learn ***how data analytics*** can be used to improve the design and operation decision-making in existing data centers.
- Describe how Power BI can be leveraged for constructing basic analytics and energy performance dashboards that users can then gain actionable insights
- Identify several types of data center intelligent HVAC controls and their practical applications
- Explain why operational choices are as important as the design in achieving effective and efficient data center cooling and why poor IT equipment installation/physical configuration impacts risk, effectiveness, efficiency and capacity

Acknowledgements

We would like to acknowledge the Federal Energy Management Program (FEMP) Office of the U.S. Department of Energy for funding this work.

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Outline/Agenda

- Background
- NERSC Facility Design & Operational Challenges
- Ongoing Commissioning
- Data Collection & Analytics Platform
- Use Cases for Data Analytics
- Continuously Improving Energy Management Process
- Key Takeaways

About LBNL HPC Data Center

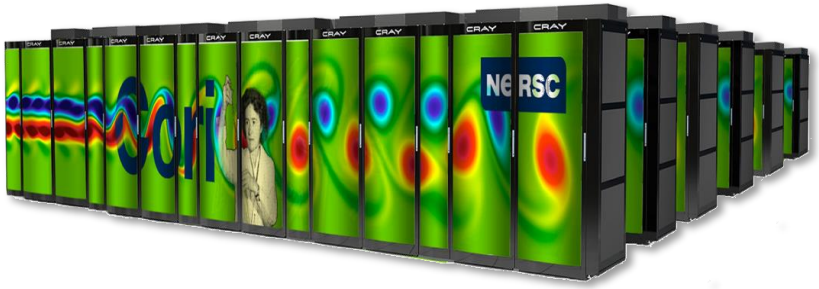
National Energy Research Scientific Computing (NERSC) Center

- Founded in 1974
- DOE Office of Science's *User Facility*
- Located at Lawrence Berkeley National Laboratory (LBNL)
- High Performance Computing (HPC) Center

High Performance Computers

Cori (Generation-8) since July 2017

- Compute & data intensive workloads
- 30 petaflops[1] system



Perlmutter (Generation-9) since May 2021

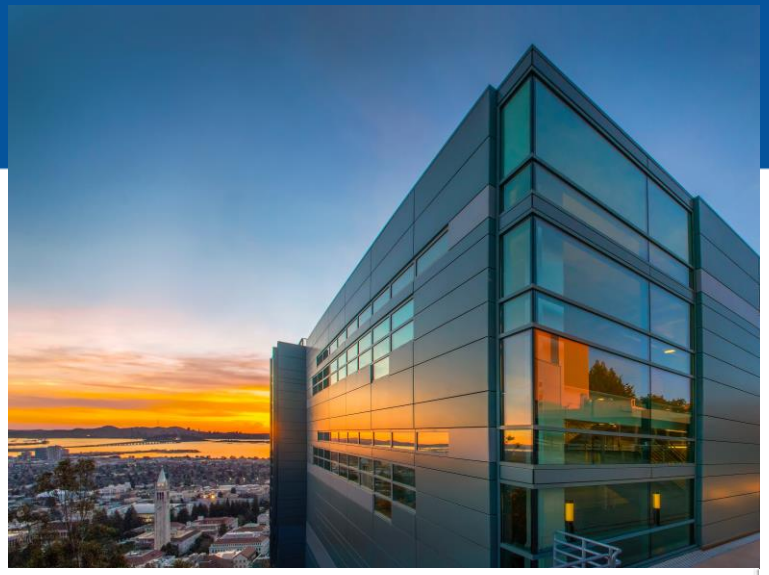
- Pre-exascale[2]
- 3-4 times capability of Cori
- Facility upgrade from 12.5 MW to 25 MW electrical service
- 100% liquid cooled system

[1] Unit of computing speed equal to one thousand million million (10^{15}) floating point operations per second.
[2] The scale of 10^{18}

Motivation for Energy Efficiency

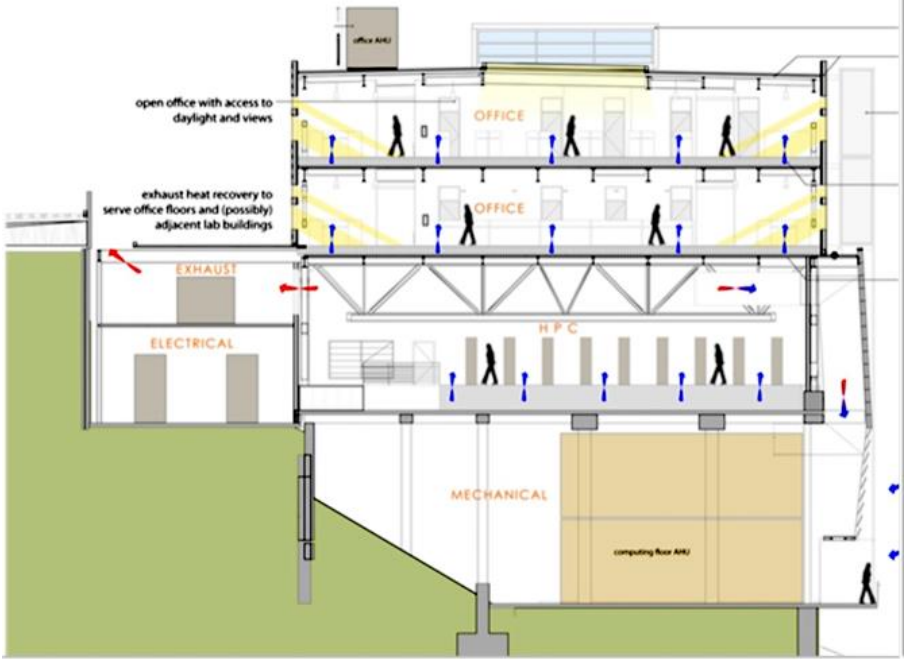
- **NERSC consumes 1/3 of LBNL's energy**
  - 4.8 GWh/mo. (2020)
  - Will increase when NERSC 9 online
- **Requirements from Federal law & the University of California**
- **A strong culture of sustainability**
- **The compressor-free cooling systems require close attention to operating conditions**

The Shyh Wang Hall



- **Occupied in summer 2015**
- **4-story 150,000 GSF, Mixed Use**
- ✓ Two office floors
- ✓ 20,000 sf HPC floor
- **LEED Gold Certified**
- **Annual PUE=1.08**

$$\text{PUE} = \frac{Total\ Facility\ Energy}{IT\ Energy}$$



Bold Design Decisions

Compressor-free Cooling

- Mild local climate
- Cooled by both outdoor air and cooling tower-generated cooling water
- Uncommon for high-availability data centers
- Modular design and build out needed tower and AHU capacity over time

Save capital & operational costs to do more science!

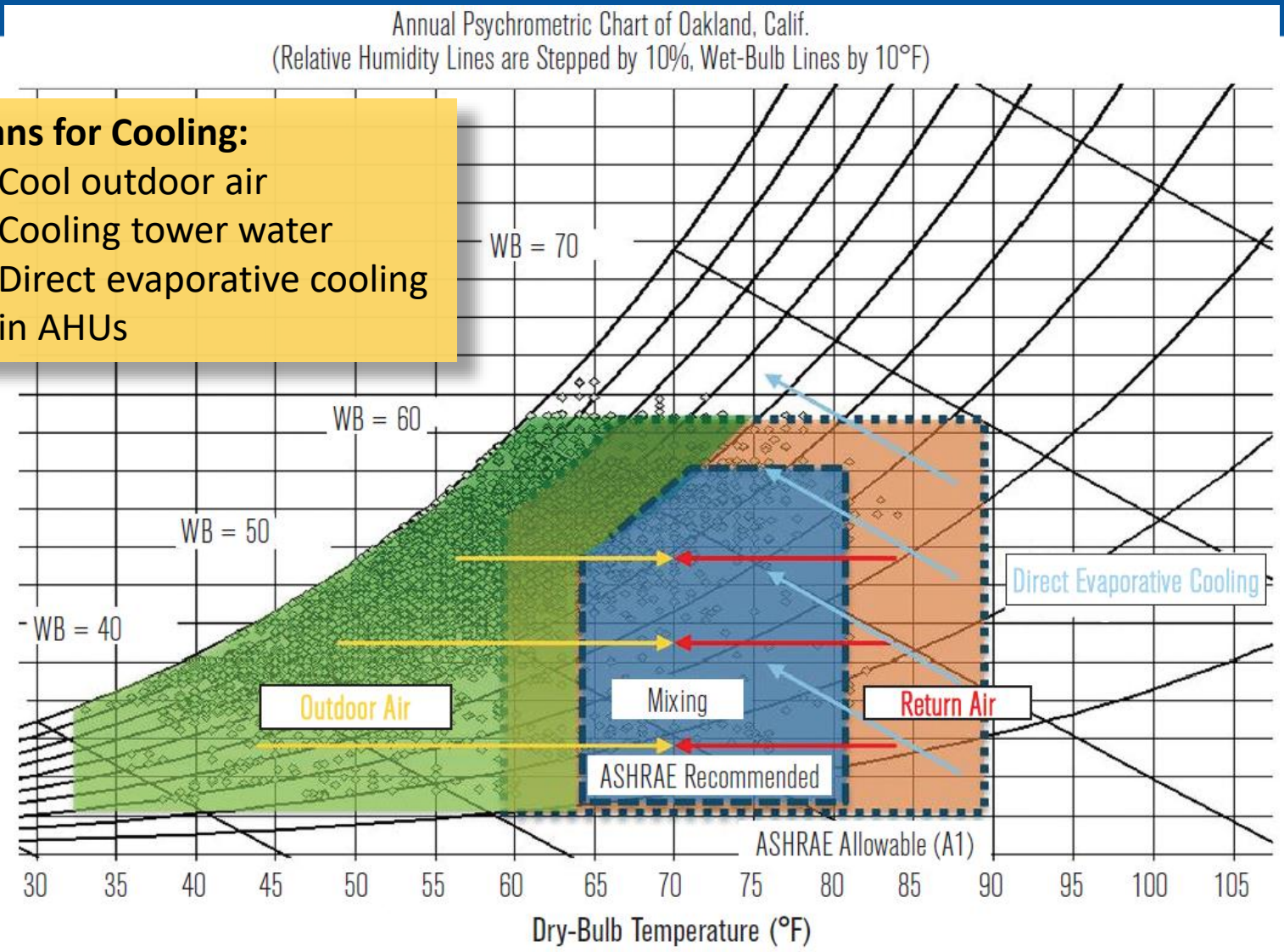
Small UPS & Generator System

- Not to back up in-process jobs;
- Only sized to transfer finished results to long-term storage;
- Carry over 1 AHU and tower until generator takes over;
- Energy saver mode retrofit

Maintaining Indoor Conditions

3 Means for Cooling:

- Cool outdoor air
- Cooling tower water
- Direct evaporative cooling in AHUs



Psychrometric Chart Showing Local Weather and Cooling Strategies (Source: reference [1])

Need for Retro-Commissioning

Retro-Commissioning (RCx)

- Systematic, operational improvements, quick payback
- Less familiar to data centers

RCx is imperative for NERSC

- Sophisticated control sequences
- Wide range of outdoor conditions vs. what's coved during initial Cx
- Challenge with IT intake air conditions control

RCx Assessment by consultant

- Has saved over 1.8 GWh/yr of electricity & 0.56 mil gallons of water![1]

RCx → Ongoing Cx

- Ongoing trouble-shooting and optimization
- High OMNI instrumentation enable operational decisions

[1] These numbers were as of Oct 2020. Two additional measures have been implemented since then and the savings are to be verified and included.

Energy & Water Savings from Retro-Commissioning

	Energy Savings (kWh)		Water Savings (gal)		Cost Savings	PUE
Measure Title	Estimated	Verified	Estimated	Verified	$	Reduction
Install Firmware to Enable ESS Mode for UPSs		350,000		140,000	$21,930	0.007
Implement Tower Water Supply Temperature Reset and Reduced Tower Water Pump Speed		380,000		0	$22,040	0.008
Reset Cooling Water Temperature Setpoint and Enable Cray Dynamic Fan Control		275,000		110,000	$17,230	N/A
Install New Heat Exchanger		760,000		300,000	$47,570	0.016
Install Bypass Valves		35,000		10,000	$2,150	0.001
Reset Cray Air Temperature Setpoint	100,000	Installed	40,000	Installed	$5,800	N/A
Install Booster Pump	50,000	Installed	20,000	Installed	$2,900	0.001
Install Cold Aisle Temperature Sensors and Optimize AHU SAT and Flow Control	200,000		80,000		$11,600	0.004
PUE = 1.08 (avg.) Total[1]	350,000	1,800,000	140,000	560,000	$131,220[2]	0.037

[1] These numbers were as of Oct 2020. Two additional measures have been implemented since then and the savings are to be verified and included.

[2] The onsite electricity price is low compared to the region.

Large-Scale Data Collection & Analytics Platform

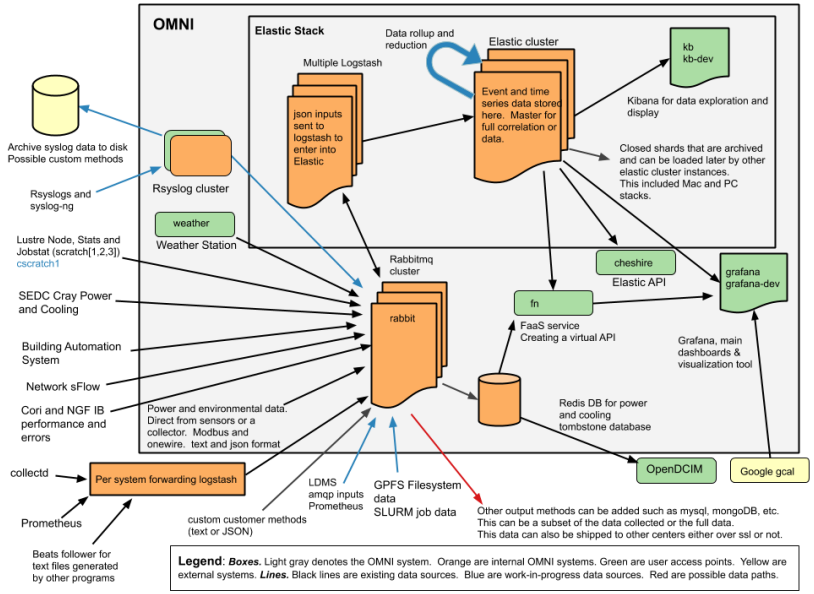
Operations Monitoring and Notification Infrastructure (OMNI)

- Extensive instrumentation & data storage system
- Original motivation: meet DOE's requirement for monthly metrics
- Open-source distributed search & analytics software suite with powerful visualization modules

"Collect all the data"

to enable data-informed business decision-making

- Deep insights from breaking silos
  - ✓ Facility and environmental data
  - ✓ Compute machine metrics
  - ✓ Job scheduler information
  - ✓ Network errors



OMNI Integrated Operational Data Collection and Analytics Architecture (Source: reference [2])

Use Cases of OMNI Data

Real-time: emergency response

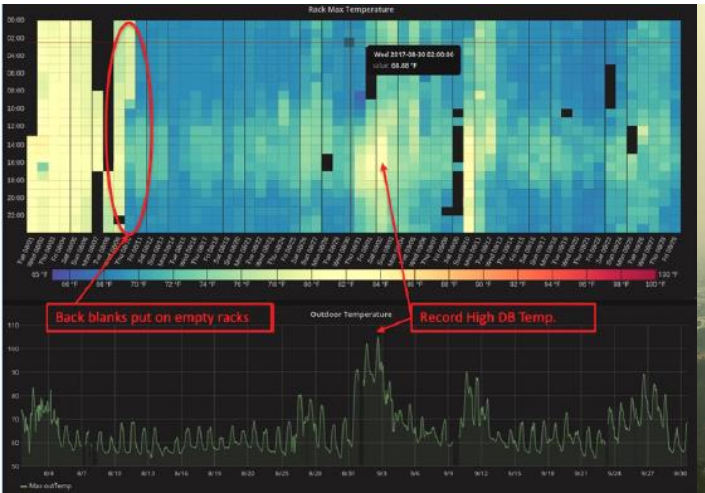
- Arch flash (temp. trend data)
- Hottest day

Short-term: review of issues

- Wildfire
- Over-voltage

Long-term: design & warranty dispute.

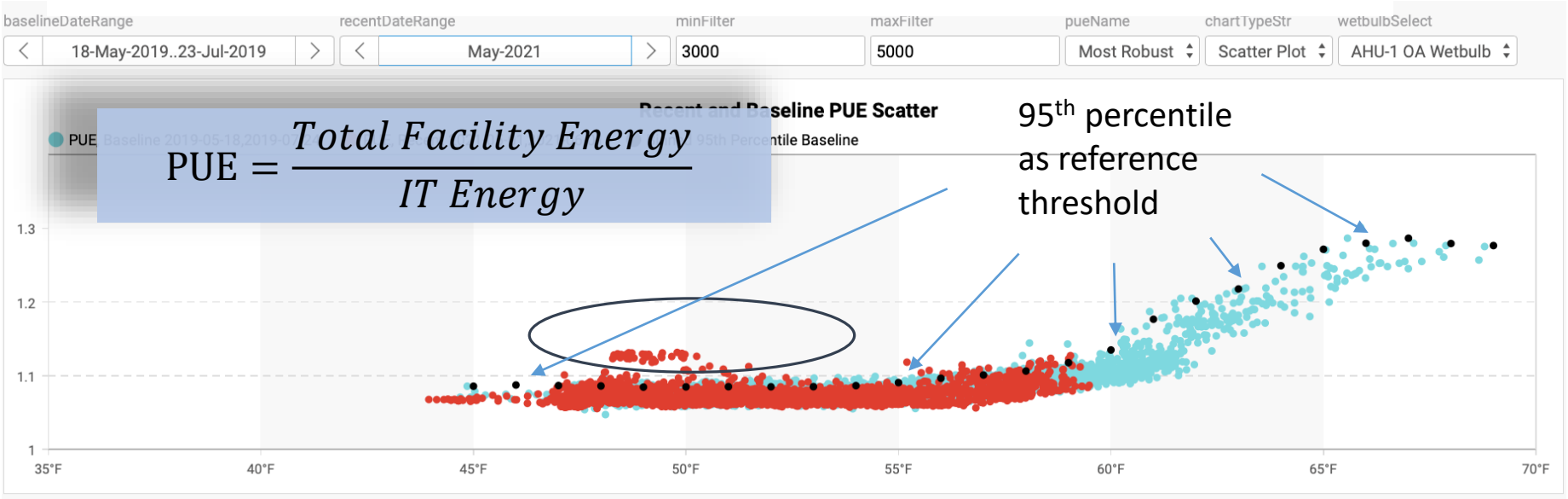
- Avoided building a new substation, saved $2M
- Warranty dispute



Campus-wide Data Analytics Tool

Frame problems & trouble-shoot REAL-TIME during team meetings

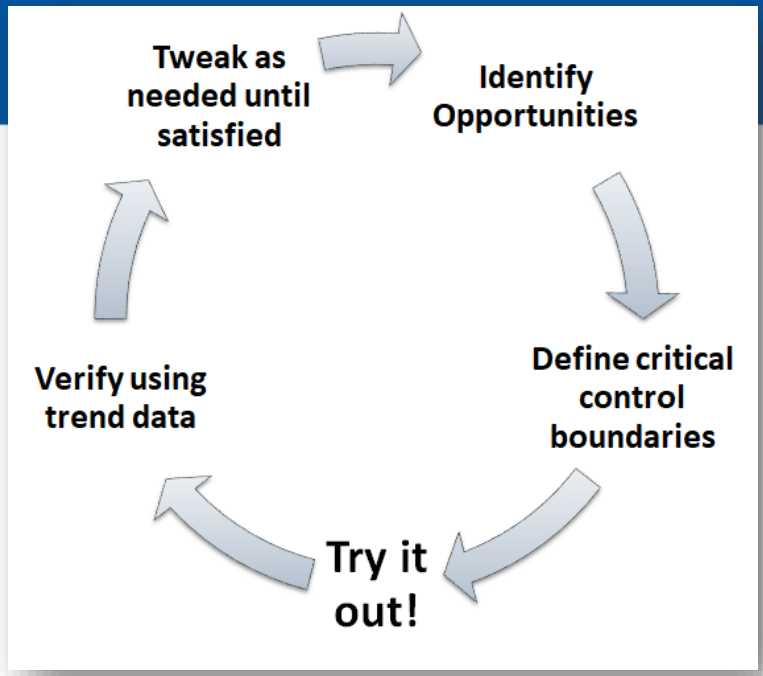
- **Interfacing with BMS (BACnet), correlate to HPC data**
- **15-min Power Usage Effectiveness (PUE) (Level 2)**
- **Great for building managers & energy engineers**
  - ✓ Correlation btw. energy consumption & weather
  - ✓ Time series datasets with different timestamps & intervals



15min Level 2[1] PUE vs. Outdoor Wet Bulb Temperature - before vs. after implementing a change

[1] Level 2 PUE: the IT load is measured at the power distribution unit (PDU) output.

Management Process Matters



NERSC EE Team meets every 2 weeks

- Led by Chief Sustainability Officer
- Cross-functional team

Senior management's support

ISO 50001 – Energy Management Systems (EnMS)

- https://iso50001.lbl.gov/ (Manual)
- Implementing ISO 50001 Standard since 2018 and certified by 3rd party in Sep. 2020
- Recognized by DOE 50001 Ready program
- "Significant Energy & Water Use" in LBNL's energy & water management system
- More rigor applied (operational controls, procurement, etc.) and improved the persistence of savings: RCx -> OCx

Key Takeaways

- **Backup power** – carefully assess the ***"true" needs*** for capital investments on UPSs & generators, which compete resources with IT investment;
- **"Free-cooling"** – effective way to lower PUE for many locations;
- **Retro-commissioning** - great deal of energy can be saved with ***control changes and low-cost measures***;
- **Data analytics** - powerful tool for ***breaking down silos***. A prioritized metering configuration can help with better operational & business decisions;
- **Holistic approach** - assemble a ***matrixed team*** & meet regularly on energy issues and use data in discussions.

References

[1] Liu, J. and Bourassa, N. (2020). *LBNL's High Performance Computing Center: Continuously Improving Energy and Water Management.* ASHRAE Journal, December 2020.

[2] N. Bourassa, W. Johnson. 2019. Presentation "Optimizing the Cooling Plant: ODA Applications at LBNL NERSC" (Aug 5, 2019). Energy Efficiency HPC State of the Practice Workshop - ICPP 2019, Kyoto, Japan.

Questions?

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