NERSC, Energy Efficiency & Facility Side Power Management

Norm Bourassa
Building Infrastructure Group

July 15, 2021 – NERSC User Group Monthly Meeting

NERSC Machine Generations:
1st Level of EE Improvement

Edison: ~2 MW

Cori: 5x Edison, ~4 MW

Perlmutter: 3x Cori, ~6 MW

Scientific Computing Energy Efficiency

- **Avoid Compute Jobs failing**
  - A SysAdmin challenge for facilities with many users like NERSC

- **Site Specific Facility Design**
  - Dissipate HPC waste heat directly to outside environment (or another use) as much as possible, and
  - avoid vapor-compression based air conditioning as much as possible

- **Operational tools providing high resolution real-time performance monitoring & analysis**
  - Supporting all operational activities

Shyh Wang Hall (B59) Completed June 2015

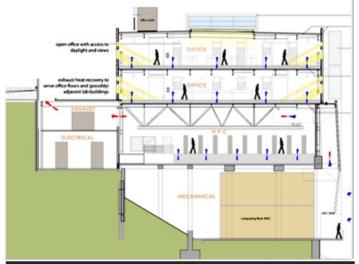- **Four-Story 150,000 GSF**
  - Two 20k sf office floors, 300 offices
  - 20k -> 28k sf HPC floor
  - 21.5 MW
  - Current demand ~10 MW
- **Energy Efficient**
  - Year-round compressor-free air and water cooling
  - LEED Gold Rated Building
  - High resolution monitoring
  - **PUE 1.08** annual avg
- **Room Air & Cooling Water**
  - Most hours, single pass air
  - Cooling Towers can provide 75ºF or colder water all hours of year
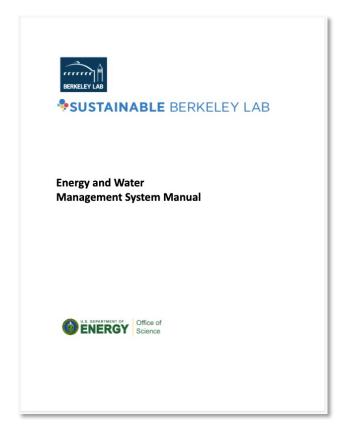
NERSC – Significant Energy User

At ~40% of campus energy demand, NERSC is a designated SEU and participates within the Core Team of the LBNL Energy & Water Management Program

LBNL Receives DOE's 50001 Ready & ISO 50001

Photo Credit: LBNL. Shyh Wang Hall, home of NERSC, the Lab's high performance computing center.

After nearly three years of development and implementation, Lawrence Berkeley National Laboratory (LBNL) received DOE's 50001 Ready recognition in June 2020, and was subsequently ISO 50001 certified in September 2020 with zero non-conformities. ISO 50001 is an international standard for managing and improving energy management and DOE's 50001 Ready Program is a free, self-guided approach based on the principles of the ISO guidance. LBNL pursued 50001 as a way to ensure both its energy and water management activities and efficiency savings were strategic, effective, and persistent.

SUSTAINABLE BERKELEY LAB

Energy and Water Management System Manual

U.S. DEPARTMENT OF ENERGY | Office of Science

NERSC EE - LBNL Division Collaboration

BERKELEY LAB — Bringing Science Solutions to the World

El Elements

News for Employees at Berkeley Lab

Monday, Feb. 24

Groundbreaking Step Toward Efficient Data Centers

Berkeley Lab's decades of expertise in energy-efficient data centers is now being applied to NERSC resources via the Efficiency Optimization Project, a partnership between NERSC, ETA, and Sustainable Berkeley Lab that uses operational data analytics to optimize cooling systems and save electricity.

HPCwire

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Berkeley Lab Team Improves HPC Datacenter Efficiency with Analytics
By Oliver Peckham

February 25, 2020

As HPC datacenters scale up, improving efficiency is crucial to avoiding correspondingly large energy use (and the ensuing high costs and large carbon footprints). Now, a team at Lawrence Berkeley National Laboratory's National Energy

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- Journal Cover Stories
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LESS IS MORE: LBNL BREAKS NEW GROUND IN DATA CENTER OPTIMIZATION

NERSC efficiency metrics project leverages Lab's decades-long expertise in energy management

FEBRUARY 18, 2020
Contact: Kathy Kincade, kkincade@lbl.gov, +1 510 495 2124

Finding ways to improve energy efficiency in high performance computing (HPC) data centers is not a new challenge but it is an evolving one, driven by increasing data creation, changes in the world's climate, and pressure to reduce energy consumption and carbon footprints. Together these factors dramatically influence the design and maintenance of HPC facilities and the hardware and software resources within them.

Fortunately, for decades Lawrence Berkeley National Laboratory (Berkeley Lab) has been at the forefront of efforts to design, build, and optimize energy-efficient hyperscale data centers. The Energy Technologies Area (ETA) has supported the National Energy Scientific Research Computing Center (NERSC) and other Berkeley Lab facilities on energy issues for some 30 years, according to Rich Brown, a research scientist in ETA's Building Technologies and Urban Systems Division. In 2007, for example, Berkeley Lab was lead author on a U.S. Environmental Protection Agency (EPA) study of the national impact of data center energy use and on the resulting DOE report. In addition, ETA has been involved in EPA's Energy Star program for more than 25 years, developing specifications for servers, data storage, and network equipment.

"Berkeley Lab has been the lead institution in the U.S. on data center energy use research," Brown said. "ETA is an applied science division, and the mission here is to reduce the environmental impacts of energy use." Much of this work has been funded through the Federal Energy Management Program, including establishing a Center of
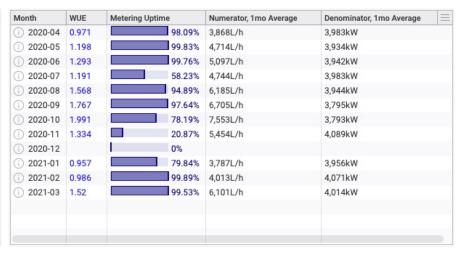
The cooling towers at NERSC, next to Shyh Wang Hall on the Berkeley Lab campus.

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BERKELEY LAB

Energy & Water Performance Tracking

- Power Usage Effectiveness (PUE) Total Data Center Energy / HPC Compute Equip. Energy
- IT-power usage effectiveness (ITUE) IT Equipment Energy / Compute Components Energy
- Water Usage Effectiveness (WUE) Water Volume Evaporated / Cooling Plant Energy (L/kWh)

E&WMP Targets for NERSC
PUE <1.1, WUE TBD

Month	PUE	Metering Uptime	Numerator, 1mo Average	Denominator, 1mo Average
2020-04	1.072	99.34%	4,240kW	3,956kW
2020-05	1.085	99.83%	4,269kW	3,934kW
2020-06	1.096	99.86%	4,321kW	3,942kW
2020-07	1.099	35.72%	4,255kW	3,871kW
2020-08	1.134	94.93%	4,472kW	3,944kW
2020-09	1.147	97.15%	4,346kW	3,790kW
2020-10	1.139	36.63%	4,209kW	3,695kW
2020-11	1.082	13.21%	4,419kW	4,082kW
2020-12		0%		
2021-01	1.086	79.33%	4,294kW	3,954kW
2021-02	1.074	100%	4,370kW	4,071kW
2021-03	1.066	99.63%	4,278kW	4,011kW

Month	WUE	Metering Uptime	Numerator, 1mo Average	Denominator, 1mo Average
2020-04	0.971	98.09%	3,868L/h	3,983kW
2020-05	1.198	99.83%	4,714L/h	3,934kW
2020-06	1.293	99.76%	5,097L/h	3,942kW
2020-07	1.191	58.23%	4,744L/h	3,983kW
2020-08	1.568	94.89%	6,185L/h	3,944kW
2020-09	1.767	97.64%	6,705L/h	3,795kW
2020-10	1.991	78.19%	7,553L/h	3,793kW
2020-11	1.334	20.87%	5,454L/h	4,089kW
2020-12		0%		
2021-01	0.957	79.84%	3,787L/h	3,956kW
2021-02	0.986	99.89%	4,013L/h	4,071kW
2021-03	1.52	99.53%	6,101L/h	4,014kW

OMNI – Monitor and Manage

Legend: **Boxes.** Light gray denotes the OMNI system. Orange are internal OMNI systems. Green are user access points. Yellow are external systems. **Lines.** Black lines are existing data sources. Blue are work-in-progress data sources. Red are possible data paths.
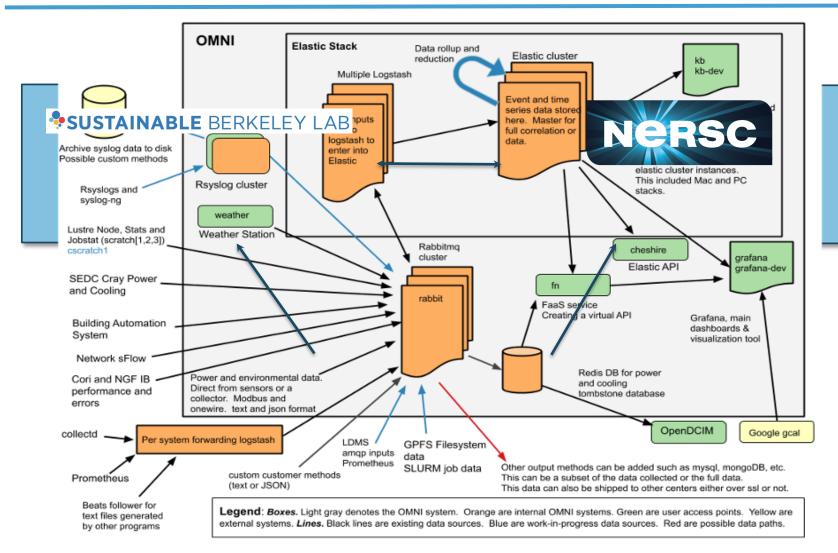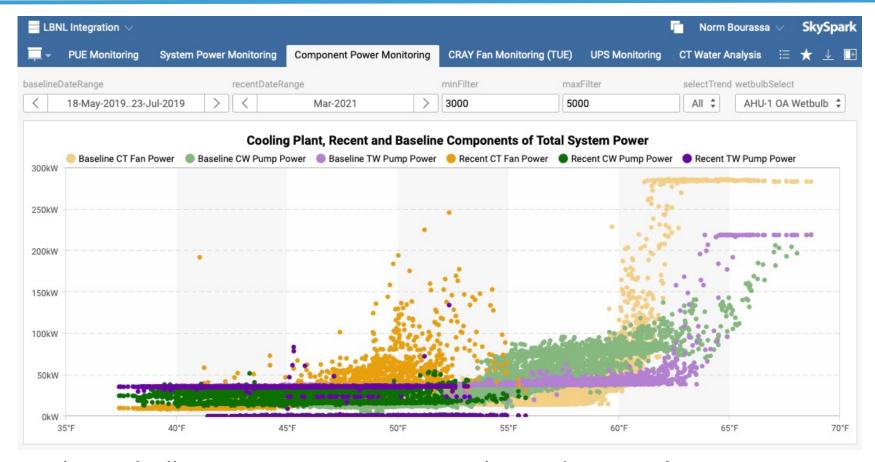
Operational Data Analytics (ODA)

- SkySpark allows us to create custom real-time data visualizations
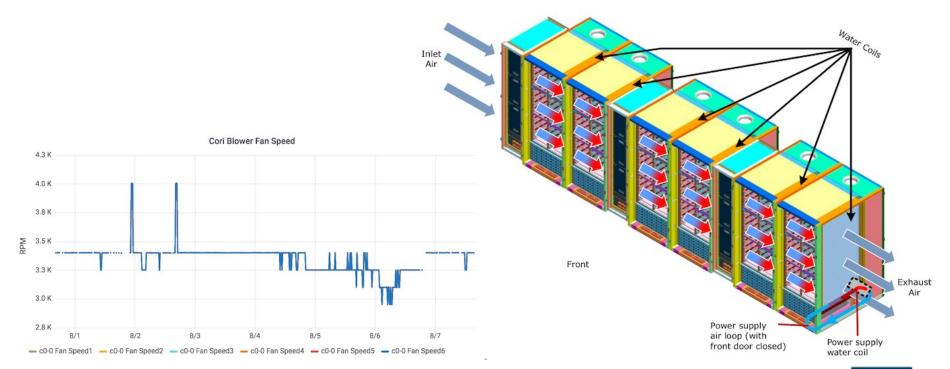- Fast tool for ongoing optimization

Cray XC Series - Dynamic Fan Speed Control

- **Blower Cabinets (6 High Performance Fans per)**
  - Variable from 2500 to 4000 rpm
    - <u>Dynamic</u> Fan Speed Control saves energy by sensing 5°C processor temp change (HPC load), then
    - Adjusts fan speed (entire row) up or down accordingly. Hottest processor(s) set speed on entire row
  - Command line set of a <u>Static</u> cooling coil exiting air temperature (Typ. 68 – 71°F)
    - hss.ini SMW file
    - Seasonal setting chosen for heat extract ratio of CW = 70 to 80%, balance to room air cooling

Cori Blower Fan Speed

c0-0 Fan Speed1 c0-0 Fan Speed2 c0-0 Fan Speed3 c0-0 Fan Speed4 c0-0 Fan Speed5 c0-0 Fan Speed6

Merged System & Infrastructure Data
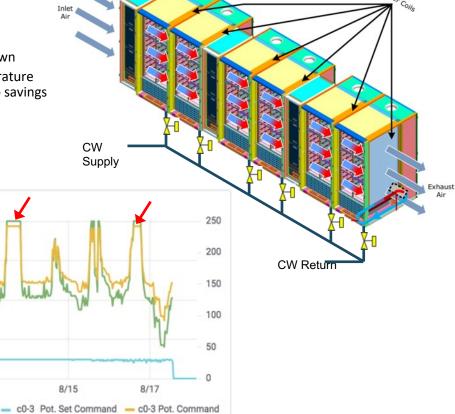
- **Out of the Box operation:** *Static cabinet air temperature setpoint*
  - Can't be set for all weather, so potential CW pumping and XC fan energy waste

- **Cooling Plant Interactive Operation:** *Variable cabinet air temperature setpoint*
  - Cooling CW Temps: Cooler cabinet air, so fan speeds turndown
  - Warmer CW Temps: Fans turn up and higher cabinet temperature setpoint reduces time at 100% open valve position, so pump savings

Water Coils

Inlet Air

CW Supply

CW Return

Exhaust Air

Cori Water Valve Position

c0-3 Position   c0-3 Pot. Set Command   c0-3 Pot. Command

- **BIG Team provided Facility Design Input**
  - Ongoing BMS Controls Review
  - Commissioning & functional testing scope and review
  - Identification of needed equipment and configuration
- **Energy Efficiency considerations in Owner's Project Requirements (OPR) during design phases**
- **Engage with equipment vendors for targeted advanced design on components & methods**

Other NERSC EE activities

- **ML based controls (in planning)**
  - CT Fans vs Pumps optimization (difficult to optimize for all seasons)
    - Cooling Water Plant COP optimization
  - AIOps (HPE)

- **Outreach and Collaboration**
  - EE HPC Working Group
    - ODA Subgroup
    - Cooling Controls Subgroup
  - DOE EERE Office
    - LBNL BTUS Division - Data Centers CoE (datacenters.lbl.gov)
    - Federal Energy Management Program

Thank You

BUILDING INFRASTRUCTURE

Ben Maxwell, SE 4557, PMP
Group Lead
(510) 486-5573 | **BHMaxwell@lbl.gov**

Brent R. Draney
Systems Integration Engineer
(510) 486-5791 | **BRDraney@lbl.gov**

Jeff Grounds
Facilities Manager
(510) 486-7197 | **JTGrounds@lbl.gov**

Ernest Jew
Assistant Facilities Manager
EJew@lbl.gov

Eric Lucas
Electronics Fabricator/ Installer
(510) 486-7197 | **ELucas@lbl.gov**

Norman Bourassa
Energy Performance Engineer
(510) 486-502-5964 | **NJBourassa@lbl.gov**
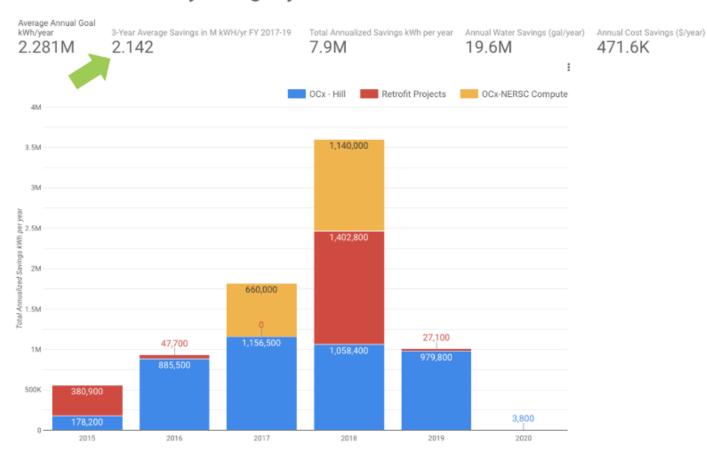
National Energy Research Scientific Computing Center

Sustainable Berkeley Lab Initiative

Maintained Efficiency Savings by Fiscal Year

Average Annual Goal kWh/year	3-Year Average Savings in M kWH/yr FY 2017-19	Total Annualized Savings kWh per year	Annual Water Savings (gal/year)	Annual Cost Savings ($/year)
2.281M	2.142	7.9M	19.6M	471.6K

Legend: OCx - Hill, Retrofit Projects, OCx-NERSC Compute

Data by year:
- 2015: OCx - Hill 178,200; Retrofit 380,900
- 2016: OCx - Hill 885,500; Retrofit 47,700
- 2017: OCx - Hill 1,156,500; Retrofit 0; OCx-NERSC Compute 660,000
- 2018: OCx - Hill 1,058,400; Retrofit 1,402,800; OCx-NERSC Compute 1,140,000
- 2019: OCx - Hill 979,800; Retrofit 27,100
- 2020: OCx - Hill 3,800

OCx = Ongoing commissioning

SBL-BIG Identified EE Measures

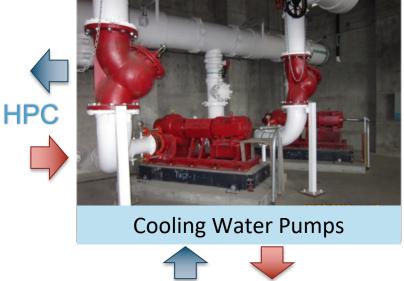|	Measure Title	Energy Savings (kWh)		Water Savings (gal)		Cost Savings	PUE
		Estimated	Verified	Estimated	Verified	$	Reduction
1	Install Firmware to Enable ESS Mode for UPSs		350,000		140,000	$20,300	0.007
2	Implement Tower Water Supply Temperature Reset and Reduced Tower Water Pump Speed		380,000		N/A	$22,040	0.008
3	Reset Cooling Water Temperature Setpoint and Enable Cray Dynamic Fan Control		275,000		110,000	$15,950	N/A
4	Install New Heat Exchanger		760,000		300,000	$44,080	0.016
5	Install Bypass Valves		35,000		10,000	$2,030	0.001
6	Reset Cray Air Temperature Setpoint	200,000		80,000		$11,600	N/A
7	Optimize Dynamic Fan Control	200,000		80,000		$11,600	N/A
8	Install Booster Pump	240,000		100,000		$13,920	0.005
9	Install Cold Aisle Temperature Sensors and Optimize AHU SAT and Flow Control	300,000		120,000		$17,400	0.006
10	Install Cray Supply Air Hoods	100,000		40,000		$5,800	0.002
	Total	1,040,000	1,800,000	420,000	560,000	164,720	0.045

Building Management System

- **B59 uses the Campus standard WebCTRL system from Automated Logic Controls (ALC)**
  - BACnet based, uses a graphical "Microblock" programming language
  - Allows owners & operators to manage and customize the building controls in-house
- **Most WebCTRL applications are for human comfort space conditioning**
  - NERSC has in-house capability to customize code to our specific HPC applications

Making HPC Cooling Water

HPC

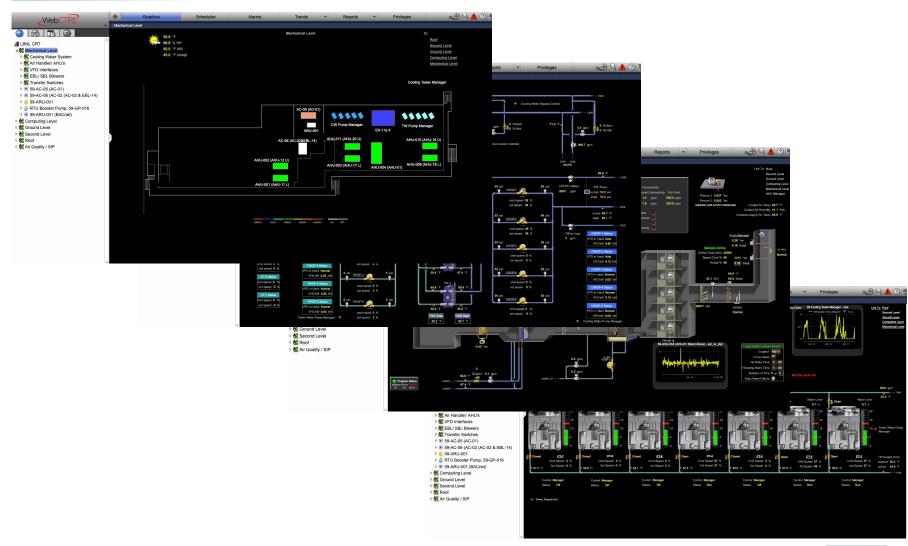Cooling Water Pumps

Cooling Towers

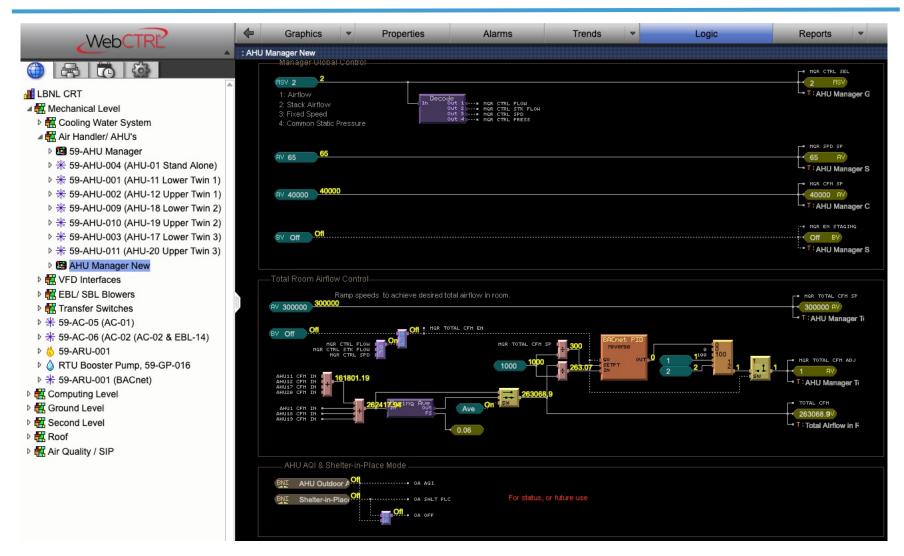Heat Exchangers

Tower Water Pumps

ALC Logic – NERSC Example

Hot Aisle Containment – Or Hot Air "Bath Tub"

- **Really is a "separation" or "chimney" system, not full containment**
  - Installed in stages from 2016 -2018
  - Panelized system better accommodates equipment churn
- **Helps drive hot air to ceiling**
  - Exhaust fans pull hot air out of the building
  - Return fans to AHUs
- **Panels located at rack front**
  - Provides cabling facilitation above rack without penetrations
- **Stayed away from drop ceiling**
  - Seismic floor connection costs
  - Fire code complications
- **Why Hot instead Cold Aisle?**
  - Many visitor tours of compute room, so human comfort a factor