U.S. DEPARTMENT of ENERGY | Federal Energy Management Program

The Next Frontier: Growing Data Centers

T04-S03, August 5th, 2025

FEMP Summer CAMP (Courses Aligned with Mission Priorities)

Dr. Vijay Gadepally

Senior Staff, Massachusetts Institute of Technology (MIT) Lincoln Laboratory

Agenda

- Session Learning Objectives
- Data Center Components and AI (Dr. Gadepally)
- Data Center Drivers and Challenges (Mr. Kirk Phillips)
- Data Center Key Metrics (Mr. Kendall Kam)
- Deploying Liquid Cooled Systems and Optimizing Energy Savings (Mr. David Martinez)
- Q&A

Session Learning Outcomes

1. Identify the key drivers behind the growing demand for data centers, including AI, cloud computing and real-time analytics
2. Recognize the energy and infrastructure challenges associated with operating data centers
3. Evaluate innovative energy solutions and strategic partnerships to support data center growth in federal facilities
4. Identify appropriate financing and procurement pathways to meet increased power and computational demands

How do we find suitable locations for a data center?

How do we measure data center efficiency?

What are the techniques to improve efficiency?

Data Center Components

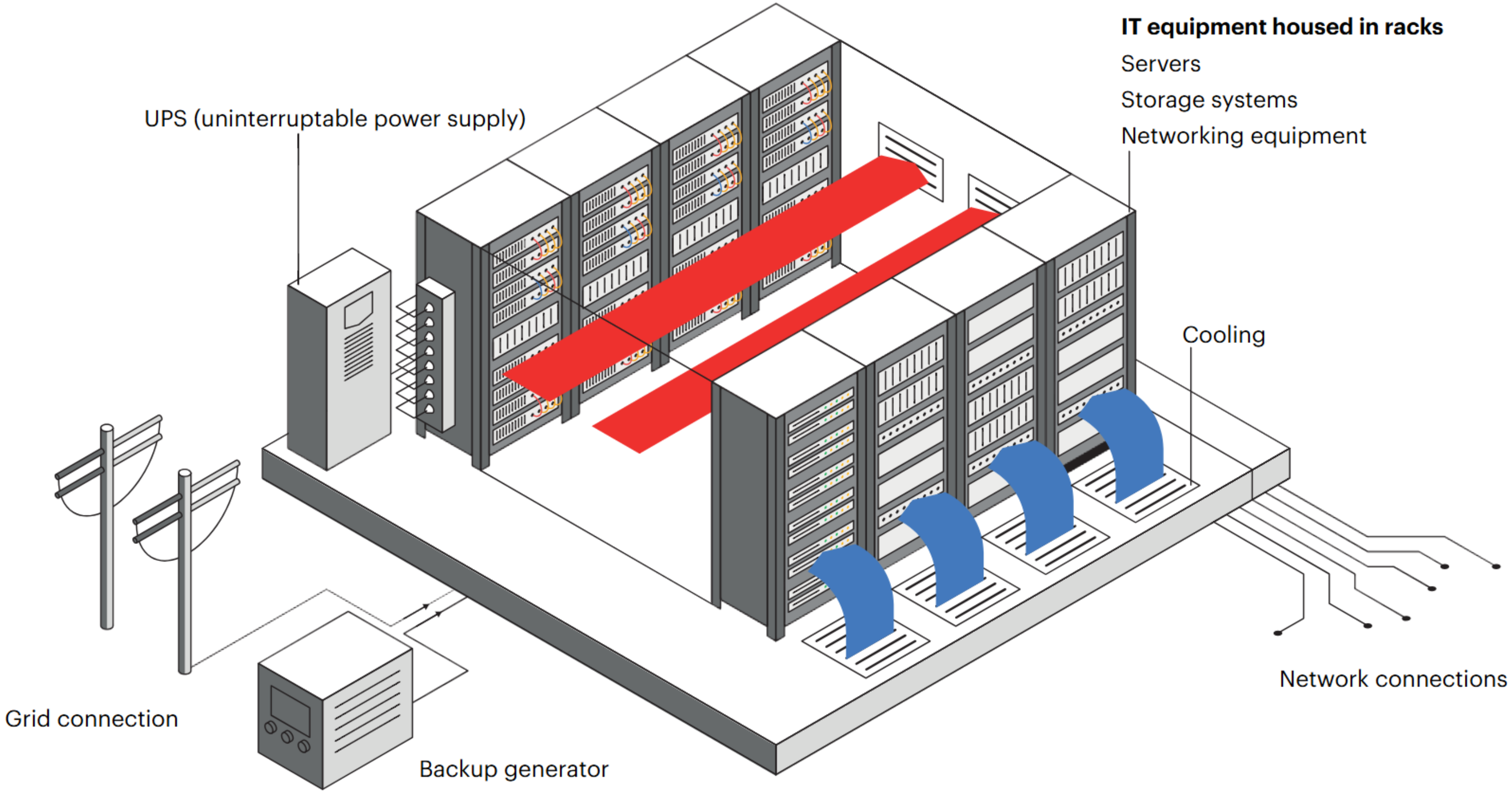


Image Source: IEA (2025), *Energy and AI*, IEA, Paris https://www.iea.org/reports/energy-and-ai, Licence: CC BY 4.0

Data Centers and Artificial Intelligence

Energy and power availability is going to be a bottleneck for U.S. AI dominance.

"AI power demands estimated to grow at [Compound Annual Growth Rate] between 25-33%"

Schneider Electric (October 2023)

"…power required for sustaining AI's rise is doubling roughly every 100 days"

World Economic Forum (April 2024)

"A single ChatGPT conversation uses a bottle of water"

Forbes (March 2024)

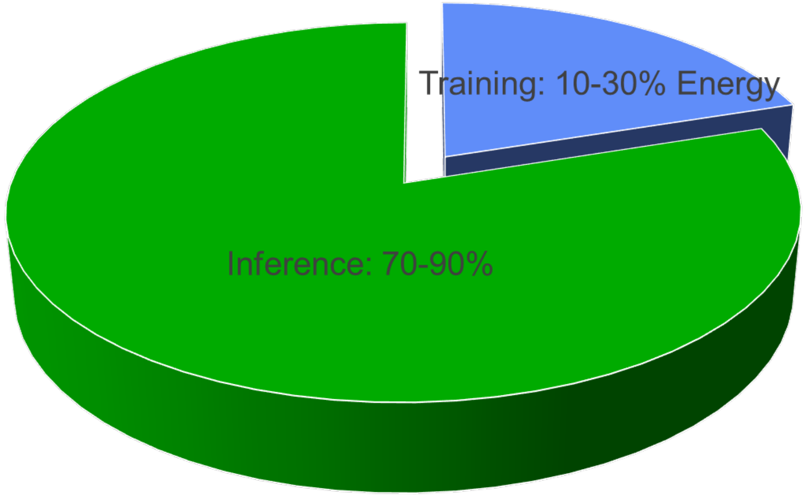
"Generating an image uses as much energy as charging your phone"

MIT Technology Review (December 2023)

"AI uses as much energy as a small country"

Vox (May 2024)

Typical GenAI training energy expenditure cost parity with O(200M) inferences



90% Inference: https://aws.amazon.com/blogs/aws/amazon-ec2-update-inf1-instances-with-aws-inferentia-chips-for-high-performance-cost-effective-inferencing/

Data Center Drivers and Challenges

Mr. Kirk Phillips

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Kirk A. Phillips

Director, Air Force Office of Energy Assurance

Accelerating Energy Assurance

Innovation Principles

- Mission focused
- Leverage all acquisition tools
- Combine funding for comprehensive solutions
- Long-term planning with short-term goals
- Teaming for success

Key Strategies

- Execute utility-scale projects that address several challenges
- Drive mutually-beneficial industry partnerships for third-party financing and maximum value from use of available land
- Pilot and adopt innovative technologies that can provide powerful pathways to energy resilience

*"We view all our efforts through the lens of **resilience**."*

– Air Force Office of Energy Assurance (AF OEA)

Policy and Strategy Driving DAF Data Center Development

Executive Orders

- Removing Barriers to American Leadership in Artificial Intelligence (**EO 14179**)
- Declaring a National Energy Emergency (**EO 14156**)
- Unleashing American Energy (**EO 14154**)

Statute

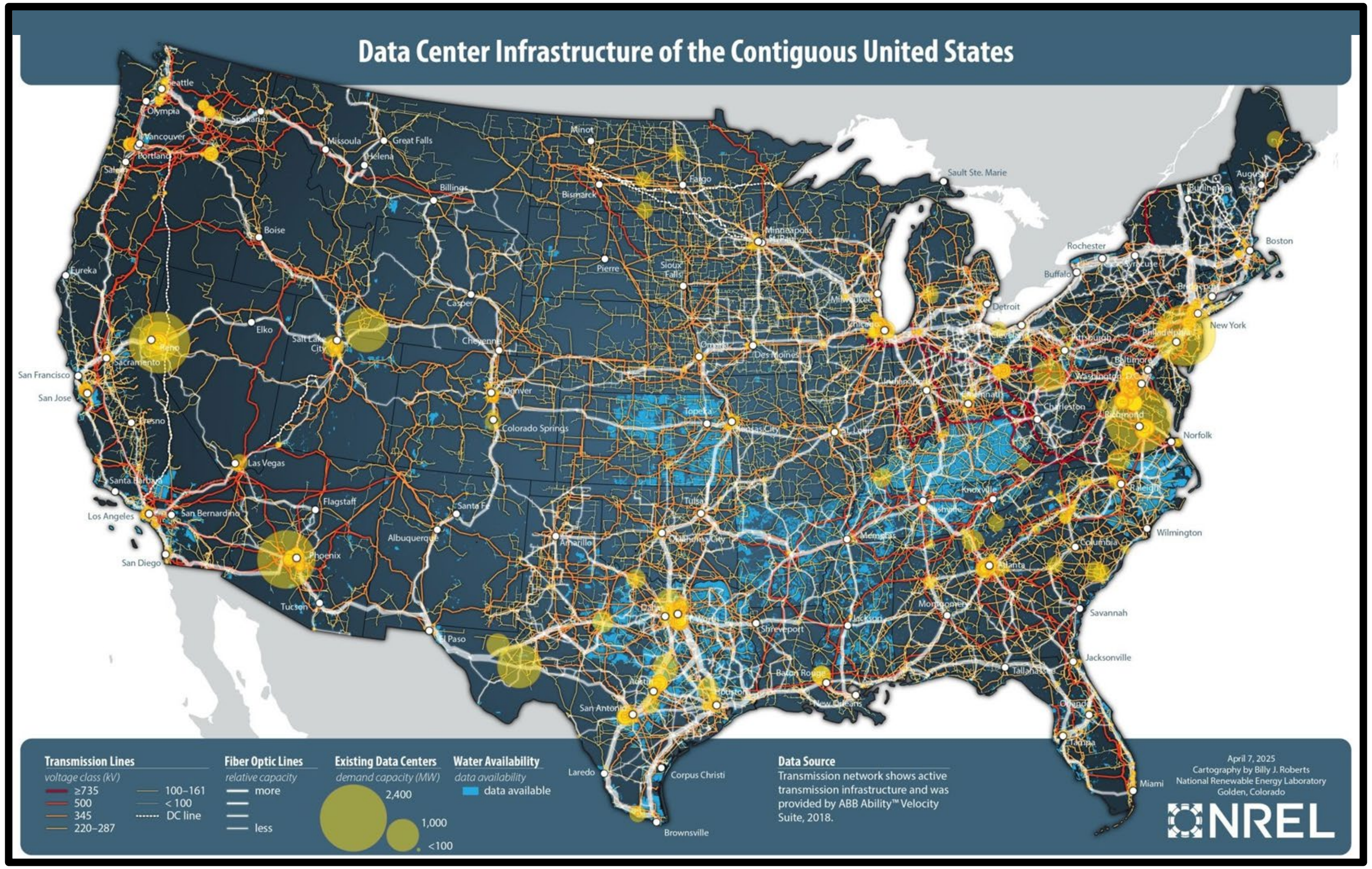
- **10 U.S.C. § 2920:** Mandates energy resilience and security measures on military installations

Value Proposition

DAF	Industry
• Share mutual energy resilience needs (e.g., on-site generation, access to fiber) • Optimize land to “highest and best use” • Rent / in-kind consideration directed to energy resilience investments first • Mission data processing capabilities • Other Air Force infrastructure – mission and quality of life	• Reduced community consultation and roadblocks • Security with perimeter access • Alignment with national defense priorities • Utility capacity prioritization • Access to expeditious regulatory review

DAF Approach to Siting Data Centers

- **Acquisition Approach:**
  - Lease/easement
  - OTA when appropriate
- **Development considerations**
  - Acquisition expediency
  - Fast moving market
  - Utility capacity availability
  - Water availability
  - Leasing vs. owning land
  - Site access
  - Mission deconfliction
  - Term of land agreement
  - State/energy market regulatory policies



Data Center Key Metrics

Mr. Kendall Kam

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Kendall Kam

Energy Program Manager, FEMP

Allocation of Energy Use in Data Centers

Computing (60%):
Includes energy use by all equipment directly carrying out IT processes

Servers:
Equipment for processing information

Storage:
Equipment for storing information

Networking:
Equipment for moving information

Infrastructure (40%):
Includes energy use by everything that is not IT equipment

Cooling:
Facility cooling systems (including fans and pumps)

Power:
Equipment to supply, transform, and distribute power

Other:
Lights, office space, etc.

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Why Are Performance Metrics Important?

- Metrics help make sense of a vast amount of information
- Metrics make the data actionable to help with optimization
- Managing energy performance in data centers requires metrics
- Metering is needed to provide the raw data

Operational Metrics

- Here, the focus is on **operational metrics** (how one operates equipment) rather than design metrics (how one selects equipment)
- This is not an exhaustive review, but focused on a few key, easy-to-measure metrics well-anchored in the industry
- It is intended to be a **practical guide** for people working in data centers on improving efficiency without necessarily buying new equipment

Key Metrics

Selection of Key Metrics

Data center efforts to save energy may impact the IT equipment's thermal conditions. Safeguarding space temperatures to ensure IT reliability is a high priority. Also, these facilities often use a large amount of water to reduce cooling energy, and energy use translates into CO_2 release at the power plant.

The challenge is to select proper metrics.

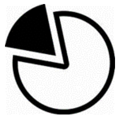
Selected Key Metrics

We have selected the following metrics from industry sources:

- Utilization (multi-dimensional)
- Power Usage Effectiveness (PUE)
- Rack Cooling Index (RCI)
- Water Usage Effectiveness (WUE)
- Carbon Usage Effectiveness (CUE)

These five metrics mesh and provide a holistic view of optimization beyond energy.

Overview of Key Metrics



- **Utilization (multi-dimensional)**
  - The act of using something in an effective way

- **PUE (infrastructure energy)**
  - Globally harmonized metric for expressing the energy use of data center infrastructure

- **RCI (temperature compliance - bridging energy and IT reliability)**
  - Considers the number of intake temps outside the recommended range and by how much

- **WUE (water adds another dimension to energy efficiency efforts)**
  - The ratio between the annual water usage and IT equipment energy

- **CUE (carbon adds yet another dimension to energy efficiency efforts)**
  - The ratio between the annual carbon emissions and IT equipment energy

FEMP's Data Center Program

FEMP's data center program assists federal agencies and other organizations with optimizing the design and operation of energy and water systems in data centers.

Assistance	Tools	Key Resources	Training
• Project and technical assistance from the Center of Expertise, including identifying and evaluating energy conservation measures (ECMs), M&V plan review, and project design review • Support agencies in meeting Data Center Optimization Initiative requirements from the Office of Management and Budget (OMB)	• Data Center Profiler (DC Pro) Tools (x2) • Air Management Tools (x3) • IT Equipment Tool • Electrical Power Chain Tool • Energy Assessment Worksheets • The Energy Assessment Process Manual	• Better Buildings Data Center Challenge and Accelerator • Small Data Centers, Big Energy Savings: An Introduction for Owners and Operators • Data Center Master List of Energy Efficiency Actions	• Data Center Energy Practitioner (DCEP) Trainings • Better Buildings Webinar Series • Nine on-demand FEMP data center trainings • Center of Expertise Webinars

Deploying Liquid Cooled Systems and Optimizing Energy Savings

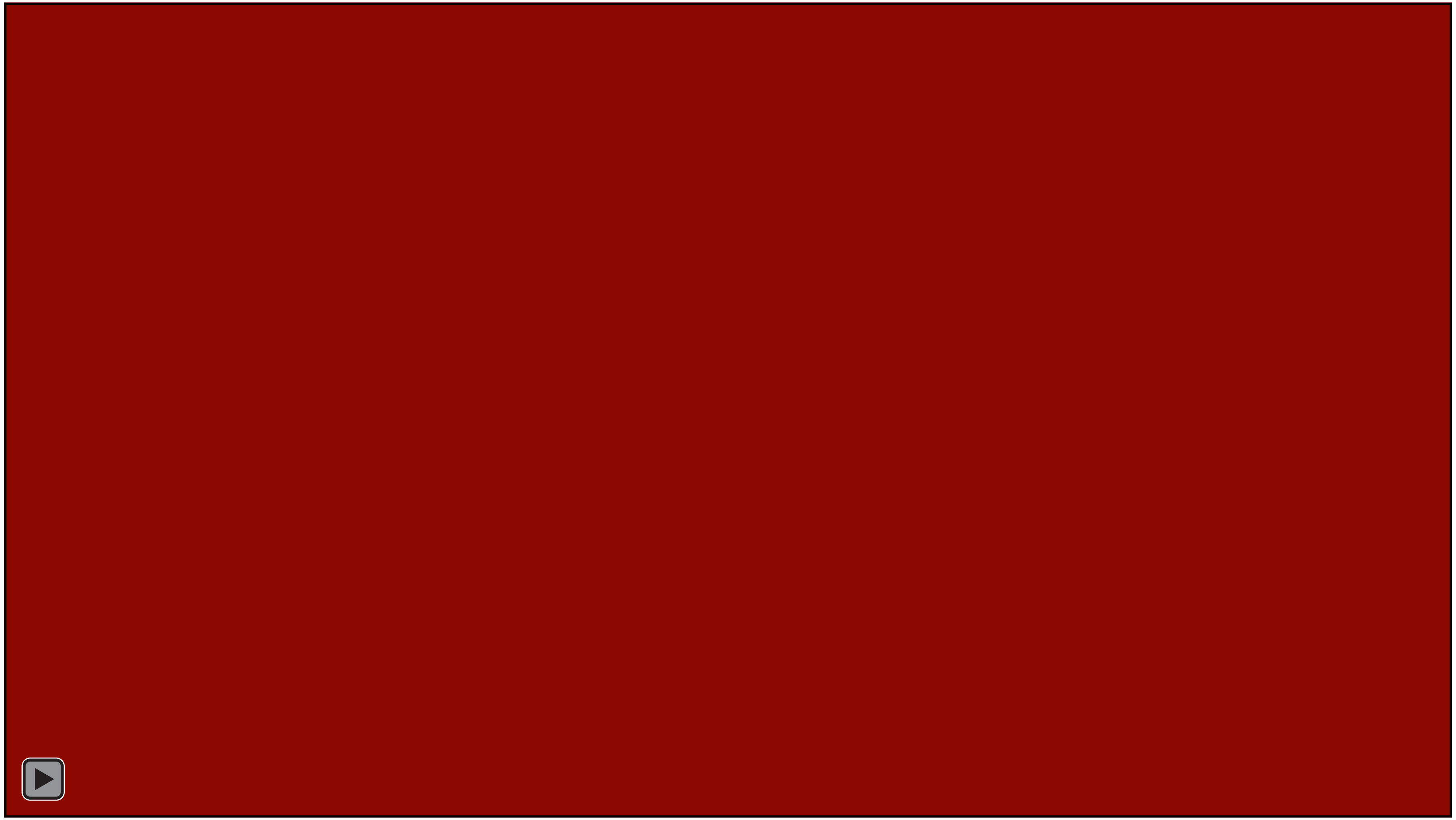
Mr. David Martinez

FEMP Summer CAMP (Courses Aligned with Mission Priorities)

David Martinez

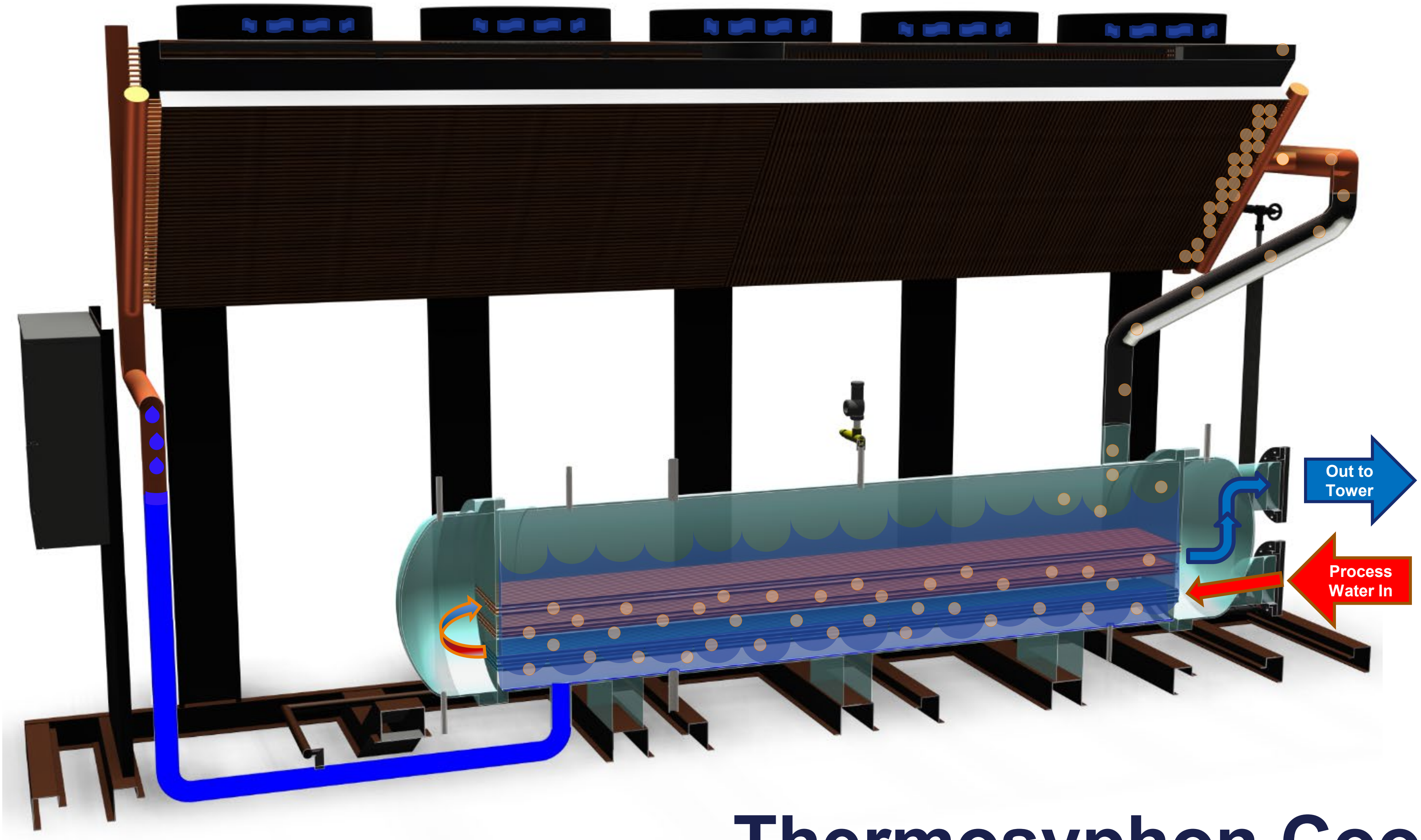
Engineering Program and Project Lead, Sandia National Labs

725 East Airflow



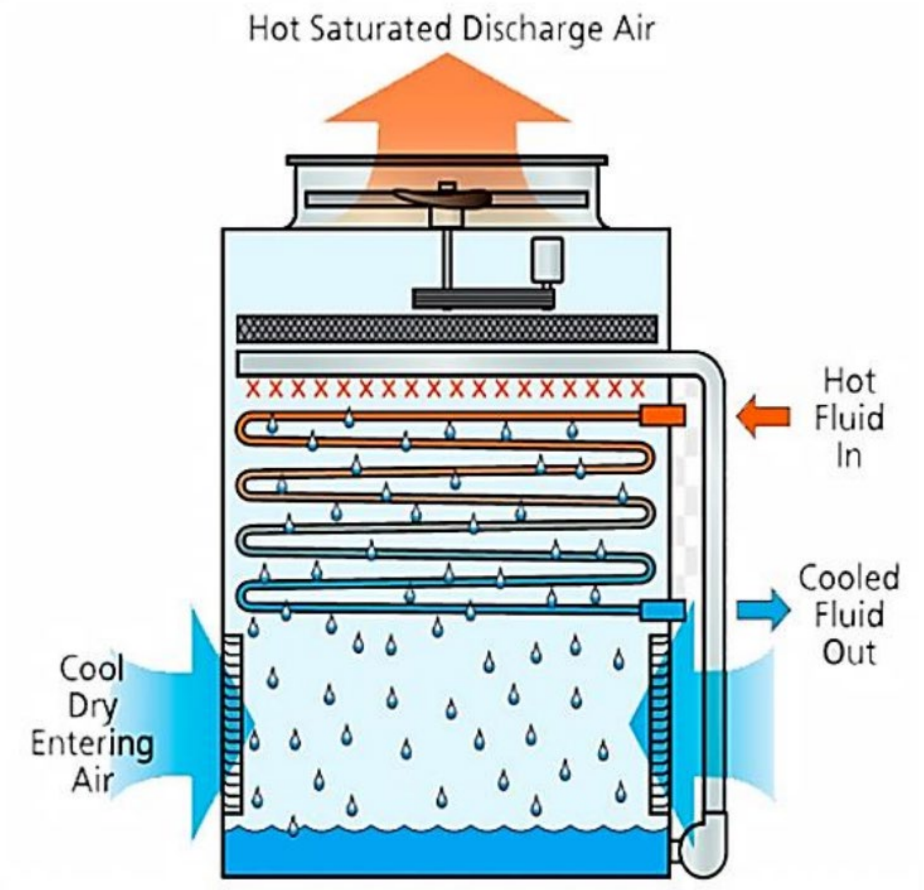
Thermosyphon

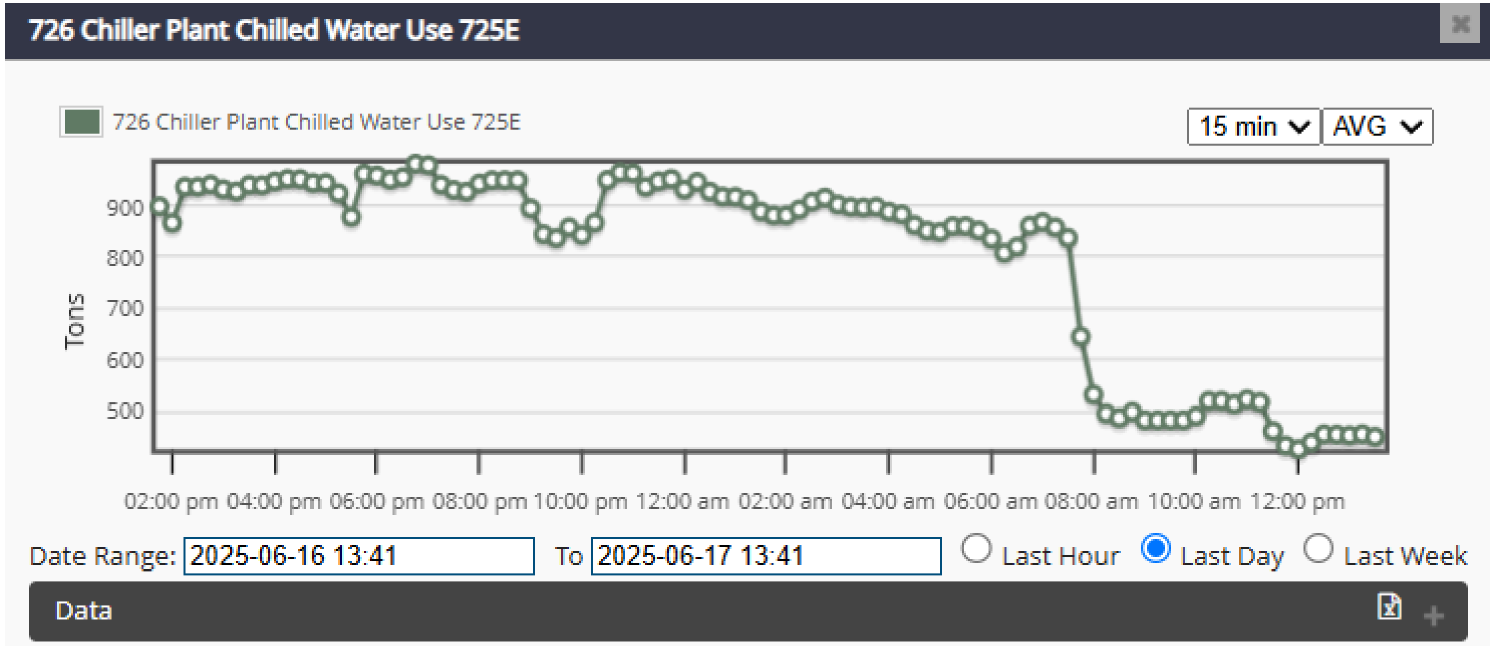
- 4 thermosyphons (~1.3 MW ea.)
- 4 degrees differential air temperature
- 9 (approx.) months of the year expected operations
- 9 (approx.) million gallons of water saved annually



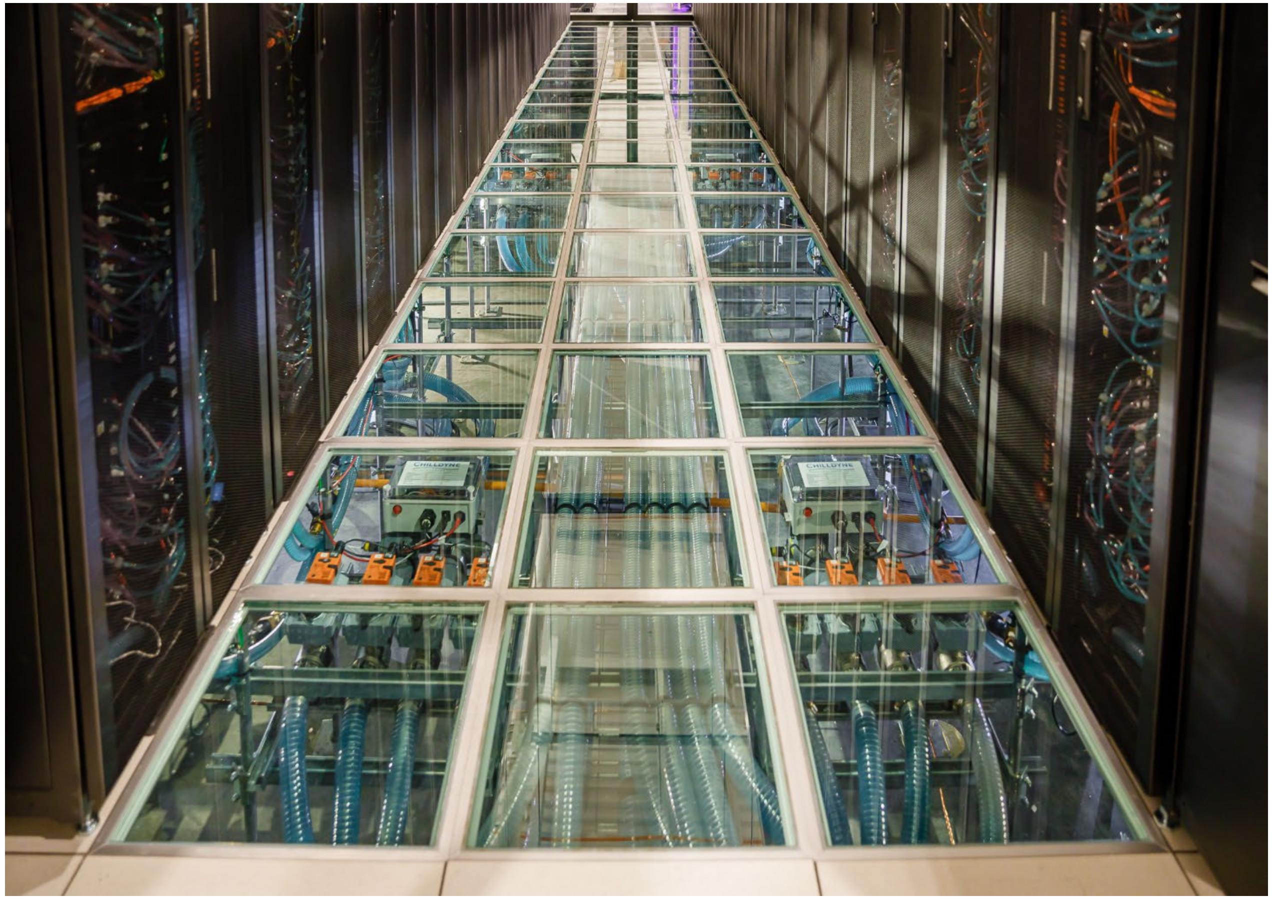
Thermosyphon Cooler

Fluid Cooler

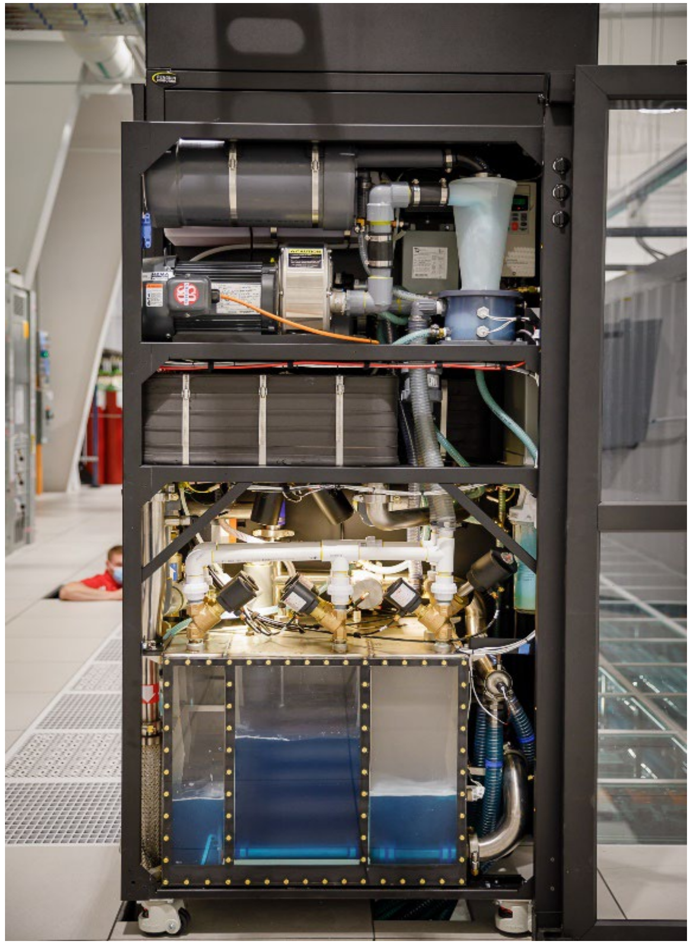




Cooling Systems

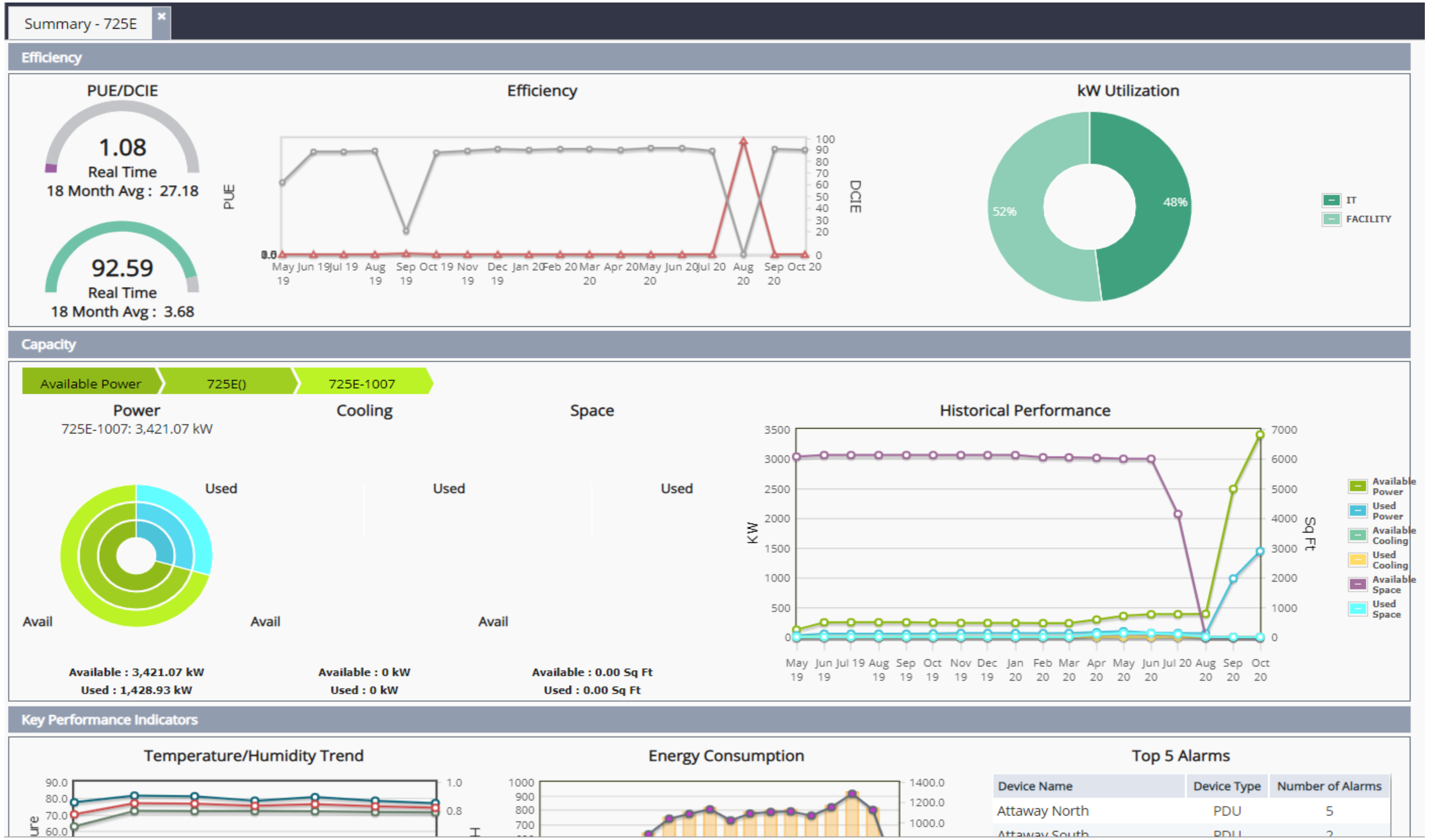


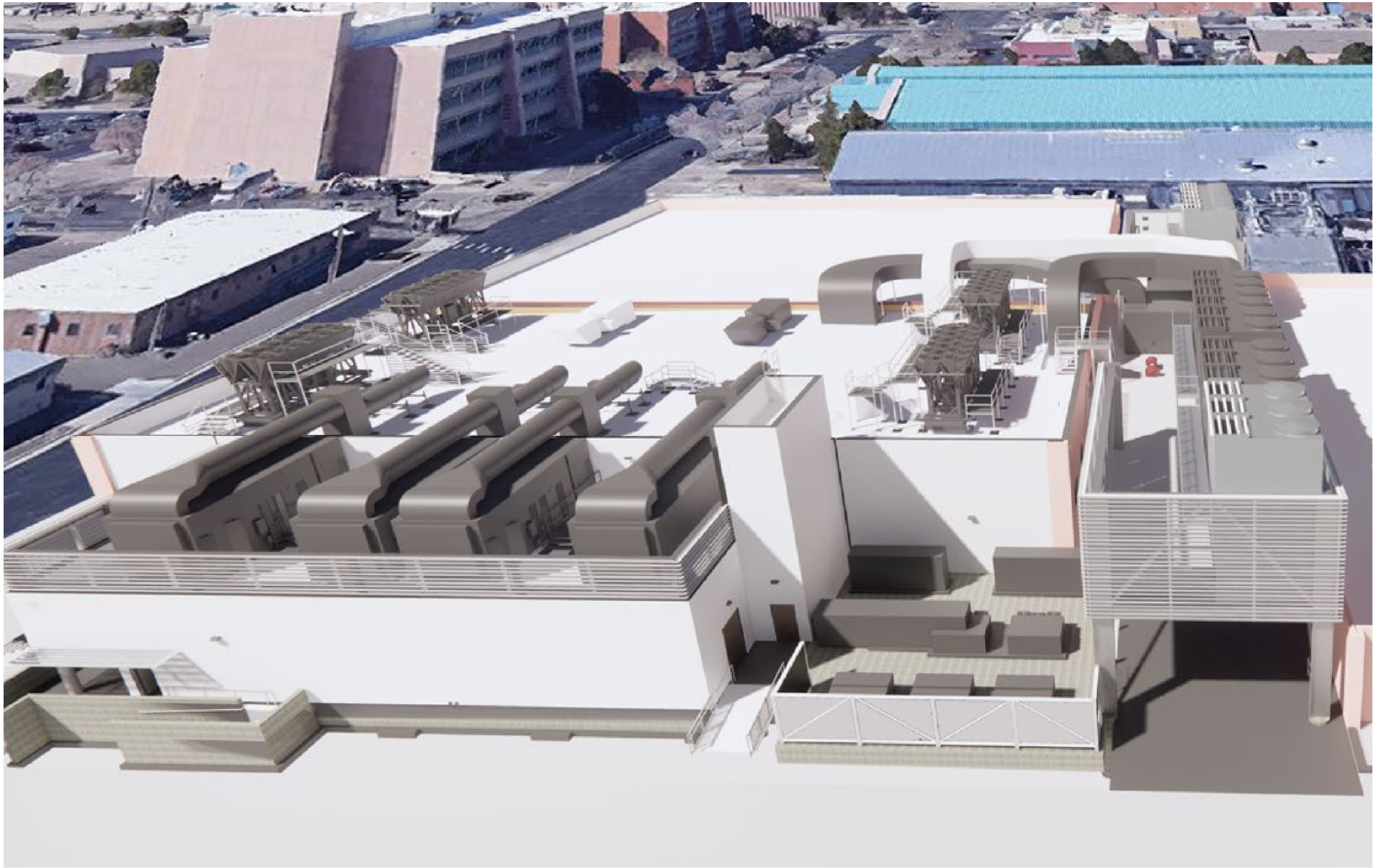
Attaway's negative pressure cooling system (70% liquid)



Cooling distribution unit (CDU)

Dashboard Real Time PUE





Questions?

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How to obtain your CEUs:

1. Log in to https://edu.wbdg.org/ using your WBDG credentials
   - The assessment and evaluation will be made available to attendees at 8:00am ET on Monday, August 11th
   - The assessment and evaluation will close on September 22nd
2. In the list of trainings you attended, click on the Visit link by the course you wish to complete
   - If the course you're looking for is not listed, click on My Account in the top right menu
   - If you still can't find your course, contact the WBDG support team to check your eligibility
3. Complete the assessment with a score of 80% or above
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5. Complete and submit the evaluation
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Questions or issues? Contact WBDG Support at wbdg@nibs.org.

What's an IACET CEU?

A continuing education unit (CEU) from the International Association for Continuing Education and Training (IACET) equals 10 hours of learning in an approved program for licensed or certified professionals.

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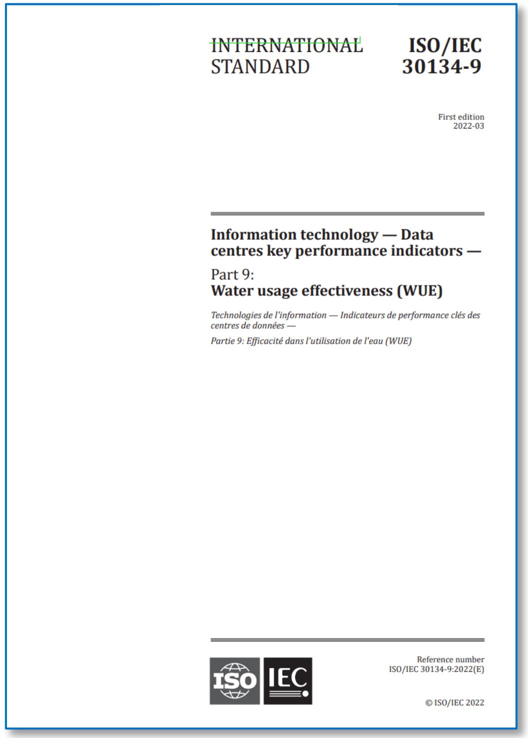
WUE – Definition

WUE is defined as the ratio between the annual water usage and the IT equipment energy.

$$WUE = \frac{\text{Annual Water Usage}}{\text{IT Equipment Energy}} \quad [L / kWh]$$

- The Annual Water Usage (the numerator) includes all water used in the operations of the data center, including humidification and cooling
- The IT Equipment Energy (the denominator) includes the load associated with all IT equipment.


INTERNATIONAL STANDARD

ISO/IEC 30134-9

First edition
2022-03

Information technology — Data centres key performance indicators —

Part 9:
Water usage effectiveness (WUE)

Technologies de l'information — Indicateurs de performance clés des centres de données —
Partie 9: Efficacité dans l'utilisation de l'eau (WUE)

Reference number
ISO/IEC 30134-9:2022(E)

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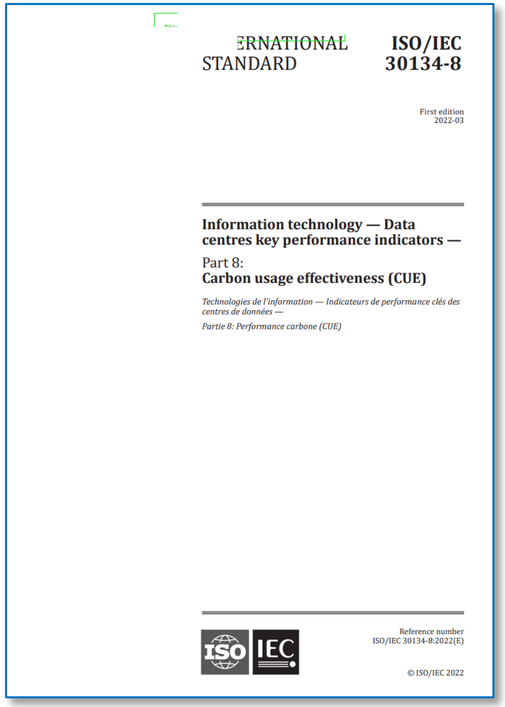
WUE: Water Usage Effectiveness (TGG, White Paper 35)
https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-9:ed-1:v1:en

CUE - Definition

CUE is the ratio between the annual carbon emissions and the IT equipment energy. For data centers that obtain electricity from the grid, CUE is defined as follows:

$$CUE = \frac{\text{Total } CO_2 \text{ Emissions}}{\text{IT Equipment Energy}} \quad [kg\ CO_2\ /\ kWh]$$

The Emissions (the numerator) are the annual CO_2 emissions from grid–based energy sources based on the Total Annual Facility Energy. CO_2 equivalent emissions include CH_4 and N_2O, which generally add only < 1% to the CO_2 numbers. The IT Equipment Energy (the denominator) consists of the load associated with all IT equipment.


ERNATIONAL STANDARD

ISO/IEC 30134-8

First edition 2022-03

Information technology — Data centres key performance indicators —

Part 8:
Carbon usage effectiveness (CUE)

Technologies de l'information — Indicateurs de performance clés des centres de données —

Partie 8: Performance carbone (CUE)

Reference number ISO/IEC 30134-8:2022(E)

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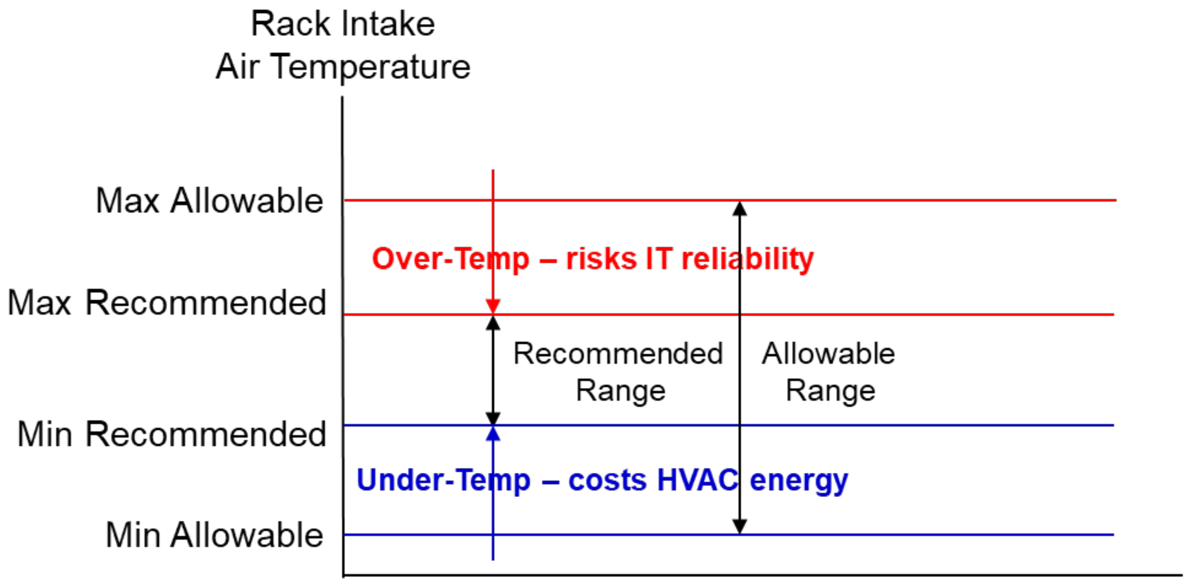
CUE: Carbon Usage Effectiveness (TGG, White Paper 32)
https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-8:ed-1:v1:en

RCI - Definition

Rack Cooling Index (RCI) (always ≤ 100%)

Poor	Good	Ideal
<90%	>95%	100%

Compliance with IT equipment intake specs is the ultimate cooling metric. RCI considers the number of intake temps outside the recommended range and by how much.



RCI = 100%: Ideal, no temps above the recommended range
RCI < 90%: Poor, possibly with temps above the allowable range

Rack Cooling Effectiveness in Data Centers and Telcom Central Offices: The Rack Cooling Index (RCI). ASHRAE Transactions, Volume 111, Part 2. 2005

Utilization - Definition

Utilization is the act of using something in an effective way. More specifically for our purposes, utilization can be defined as:

Utilization = Actual performance / Max performance

For a server, for example, the actual (computational or power) utilization is often below 30%. Virtualization is key to making sure the servers are highly utilized. Low utilization not only drives energy inefficiency but it also drives inefficiencies in many other dimensions, such as data center rack/floor space.

PUE - Definition

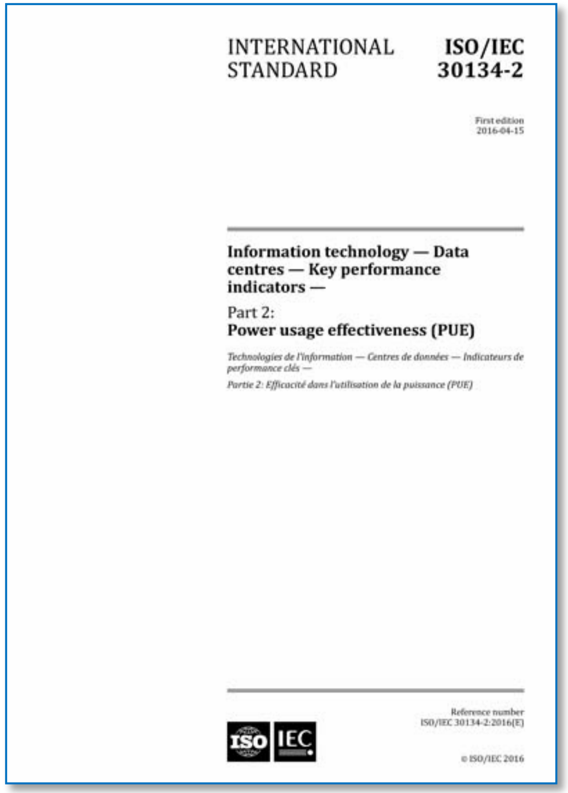
PUE = Total Annual Facility Energy / IT Equipment Energy (always >1.0)

Typical	Good	Excellent
1.7	1.4	1.2

Medium-sized enterprise data center

PUE is a globally harmonized metric for expressing the energy use of the data center infrastructure; see Standard ISO/IEC 30134. A PUE of 2 means the infrastructure uses the same energy as the IT equipment.

Standard ISO/IEC 30134-2:2016 Power Usage Effectiveness (PUE)
https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-2:ed-1:v1:en


INTERNATIONAL STANDARD

ISO/IEC 30134-2

First edition 2016-04-15

Information technology — Data centres — Key performance indicators —

Part 2: Power usage effectiveness (PUE)

Technologies de l'information — Centres de données — Indicateurs de performance clés —

Partie 2: Efficacité dans l'utilisation de la puissance (PUE)

Reference number ISO/IEC 30134-2:2016(E)

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Data Center Facts

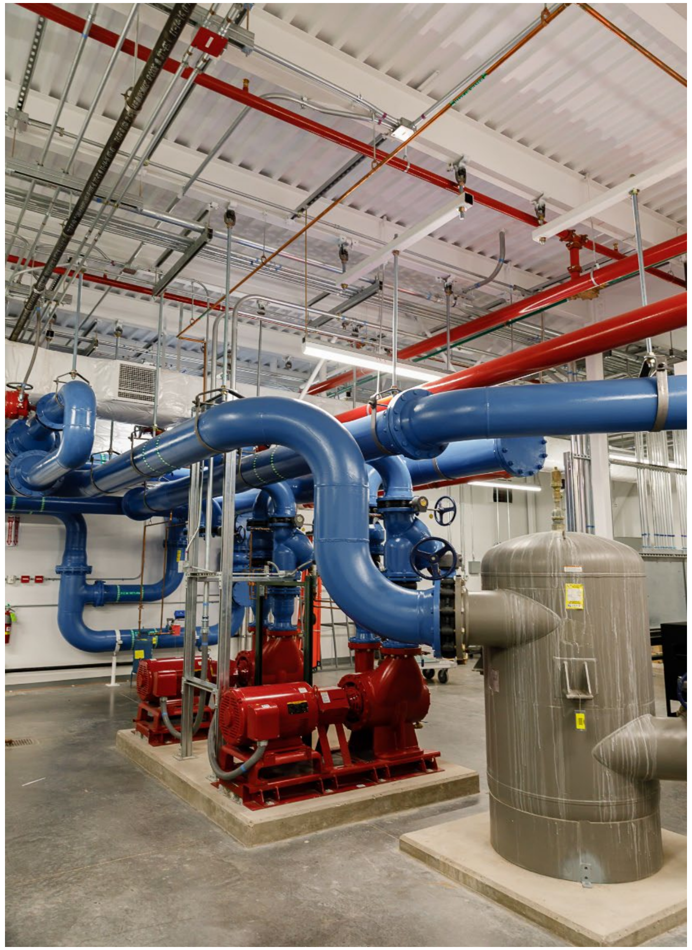
- 14,000 square feet, 3-foot raised floor
- Designed for 85% direct liquid cooled, current water temperature 76F
- Process water: Plate frame heat exchanger tied into to the 726 Mechanical System along with a path to the thermosyphons (dry bulb temp dependent)
- Process loop under the floor throughout the data center with 4-inch supply/return valves every 12 feet from center to center
- Designed for 15% air cooling at 78F supply air temperature
- Power:
  - 480 volts
  - 1.5 MW per transformer (currently at 9MW, going to 13MW next year)
  - 480-volt overhead buss system
  - 1200-amp to 800-amp buss
  - 208 available as well for auxiliary loads
- Overhead cable tray
- CommScope network
- Data Center Infrastructure Management (DCIM) System

725 HPC Data Center

725E Infrastructure

- 4 air handlers rated for 250kW of air cooling each
  - Three operating modes: outside air, evaporative cooling, or chilled water coil
  - Relief fans on return air for exhausting hot air to atmosphere
- 4 thermosyphons rated for 1300kW of liquid cooling each
  - Thermosyphons save 4 million gallons of water each per year
- 3 pumps and 2 plate frame heat exchangers to supply up to 7MW of cooling to the process water loop
- 6 switchboards and transformers rated for 1500kW each
  - 1 switchboard for infrastructure loads and 5 for IT loads

Piping



- Heat exchanger chilled water/thermosyphons
- 3 pumps for process water (pressure differential control variable frequency drives)

Process Water Loop

- Supply Water Temperature: 76F
- Pipe Size: 12 inches
- Insulation is not required
- Heat rejection accomplished by either thermosyphons or plate frame heat exchangers
- Thermosyphons operate when the outside air is more than 4°F cooler than the process water return temperature
- Plate frame heat exchangers are tied into the chilled water loop

CTS-2 Preparation