The webinar will start momentarily....

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Webinar: Thermal Guidelines and Temperature Measurements in Data Centers

May 13, 2021

FEMP Federal Energy Management Program

Webinar Logistics

- This webinar is being recorded. The Q&A section will not be made publically available.
- Your phone will be muted throughout the webinar.
- Enter any questions in the Question Box throughout the webinar.
- Instructions to take the quiz will be provided at the end of webinar.
- Slides will be sent out afterwards to those who attend the entire webinar.

Today's Speakers

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CENTER OF EXPERTISE
FOR ENERGY EFFICIENCY IN DATA CENTERS

Webinar Agenda

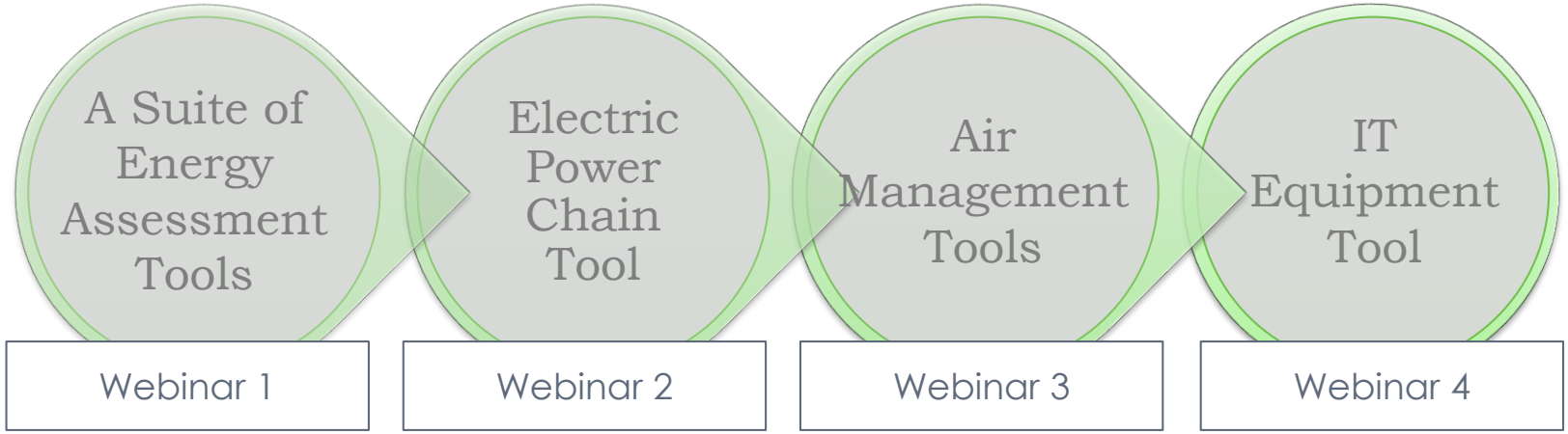
Agenda	
I.	Introduction
II.	Context of Thermal Management in Data Centers
III.	Thermal Guidelines and Temperature Measurements
IV.	Resources and Q&A

Learning Objectives

- Explore **generalized thermal best practices** for data centers.
- Convey the **importance of accurate temperature measurements** at the IT equipment.
- Identify ways to **limit sensor hardware and labor costs** to avoid foregoing temperature measurements all together due to cost concerns.
- Illustrate **accurate low-density temperature sensor configurations** on the IT equipment racks..

Previous Four-Part Webinar Series

This training series introduced a broad toolkit for identifying energy-saving opportunities in data centers.



https://www.wbdg.org/continuing-education/femp-courses/fempodw049

Slides from Webinars 2, 3, and 4 at
datacenters.lbl.gov/resources/energy-efficiency-toolkit-series
datacenters.lbl.gov/resources/energy-efficiency-toolkit-series-air
datacenters.lbl.gov/resources/energy-efficiency-toolkit-series-it

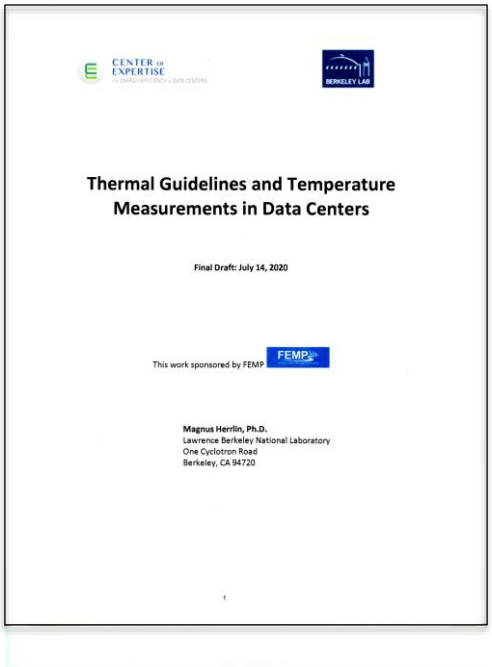
DOE Tool Suite

- Data Center Profiler (“DC Pro”), online
- PUE Estimator, online
- Air Management Tool, Excel
- Air Management Estimator, Excel
- Electrical Power Chain Tool, Excel
- IT Equipment Tool, Excel.

http://datacenters.lbl.gov/tools

Master Document

The bulk of this slide presentation is a summary of the 2020 document “Thermal Guidelines and Temperature Measurements in Data Centers”. It can be found at datacenters.lbl.gov/resources/thermal-guidelines-and-temperature



Context of Thermal Guidelines and Thermal Management in Data Centers

Guidelines Help Comply w/ Federal Requirements

Implementing thermal management in data centers will help agencies comply with several federal requirements:

i) Energy Policy Act of 2005 (EPAct)
ii) Energy Independence and Security Act of 2007 (EISA)
iii) Energy Act of 2020
iv) Executive Order 13990
v) The Data Center Optimization Initiative/FITARA

Implementing thermal management also furthers such FEMP initiatives as the ESPC/UESC program, the 50001 Ready program, and the Energy Efficient Product Procurement Program.

Why Are Thermal Guidelines Important?

Standardized temperature and humidity ranges enable:

- IT equipment manufacturers to design their equipment to ensure proper operation and reliability
- Data center designers and operators to know when they're providing the proper temperature and humidity ranges of cooling air.

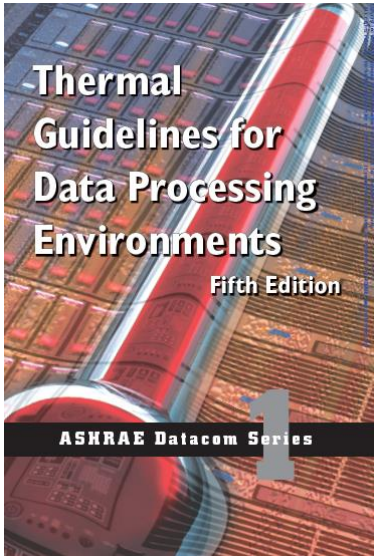
Evolution of Thermal Guidelines

Published by industry organizations in cooperation with equipment manufacturers and operators to create consensus guidelines

- ASHRAE for data centers
  - Thermal Guidelines for Data Processing Environments
    - 5th Edition, 2021 (current)
- NEBS for telecommunication facilities
  - Thermal Management in Telecommunications Central Offices
    - 1st Edition, 2001
  - Requirements: Physical Protection
    - 4th Edition, 2012

Key Thermal Guidelines

- Provide guidance on temperature and humidity for IT equipment and IT equipment spaces.
- Provide standardized test conditions for IT gear.
- Provide standardized operating IT environments.

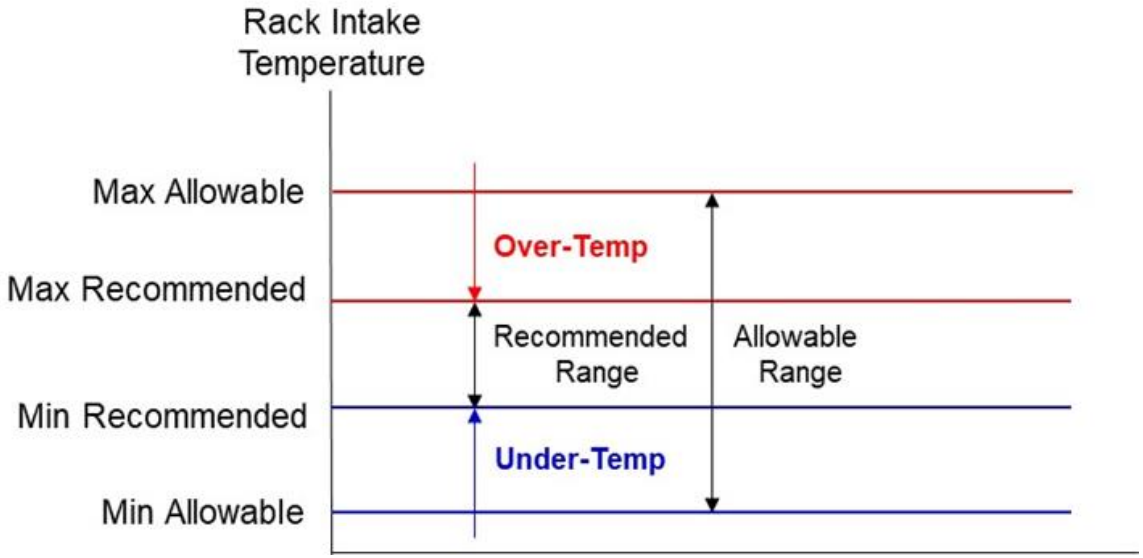


ASHRAE
Thermal Guidelines
www.ashrae.com

NEBS
GR-3028 and GR-63
https://telecom-info.njdepot.ericsson.net/site-cgi/ido/docs2.pl?ID=&page=home

Recommended and Allowable Ranges

- Recommended rack intake air temperature
  - Statement of reliability; preferred facility operation
- Allowable rack intake air temperature
  - Statement of functionality; no temps outside this range
- Recommended range always fully within the Allowable range



Comparison Between ASHRAE and NEBS Guidelines

Comparison between ASHRAE and NEBS.

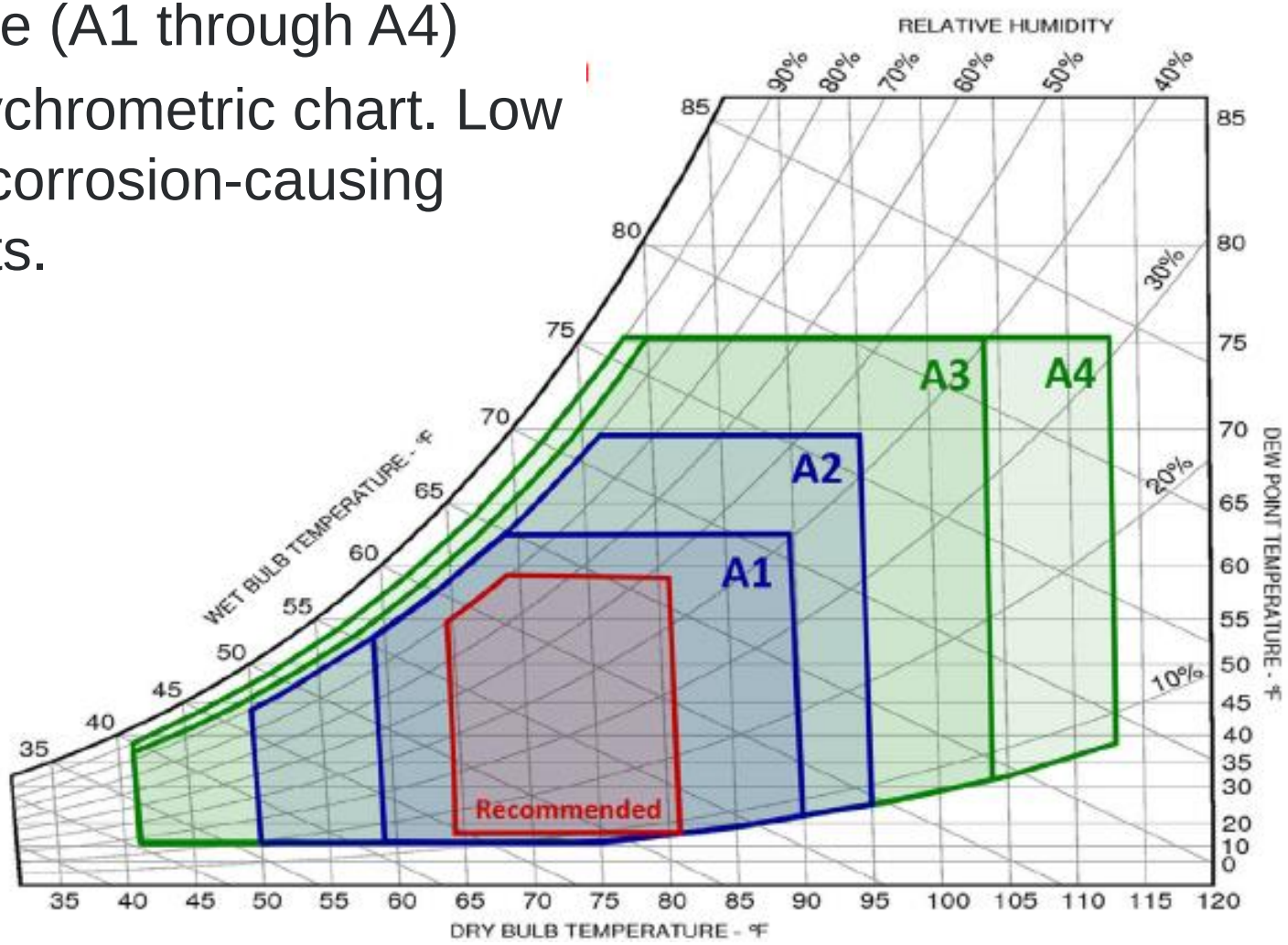
(@ Equipment Intake)	Recommended (Facility)	Allowable (Equipment)
Temperature		
Data Centers Class A1	65° – 80°F	59° – 90°F
Telecom NEBS	65° – 80°F	41° – 104°F
Humidity	**16°F to 59°F DP and 70% or 50% RH (corrosion dependent)**	
Data Centers Class A1		10°F DP and 8% RH to 63°F DP and 80% RH
Telecom NEBS	≤55% (practice)	5 – 85%

ASHRAE Thermal Guidelines (2021)

Recommended and

Allowable (A1 through A4)

on a psychrometric chart. Low level of corrosion-causing pollutants.

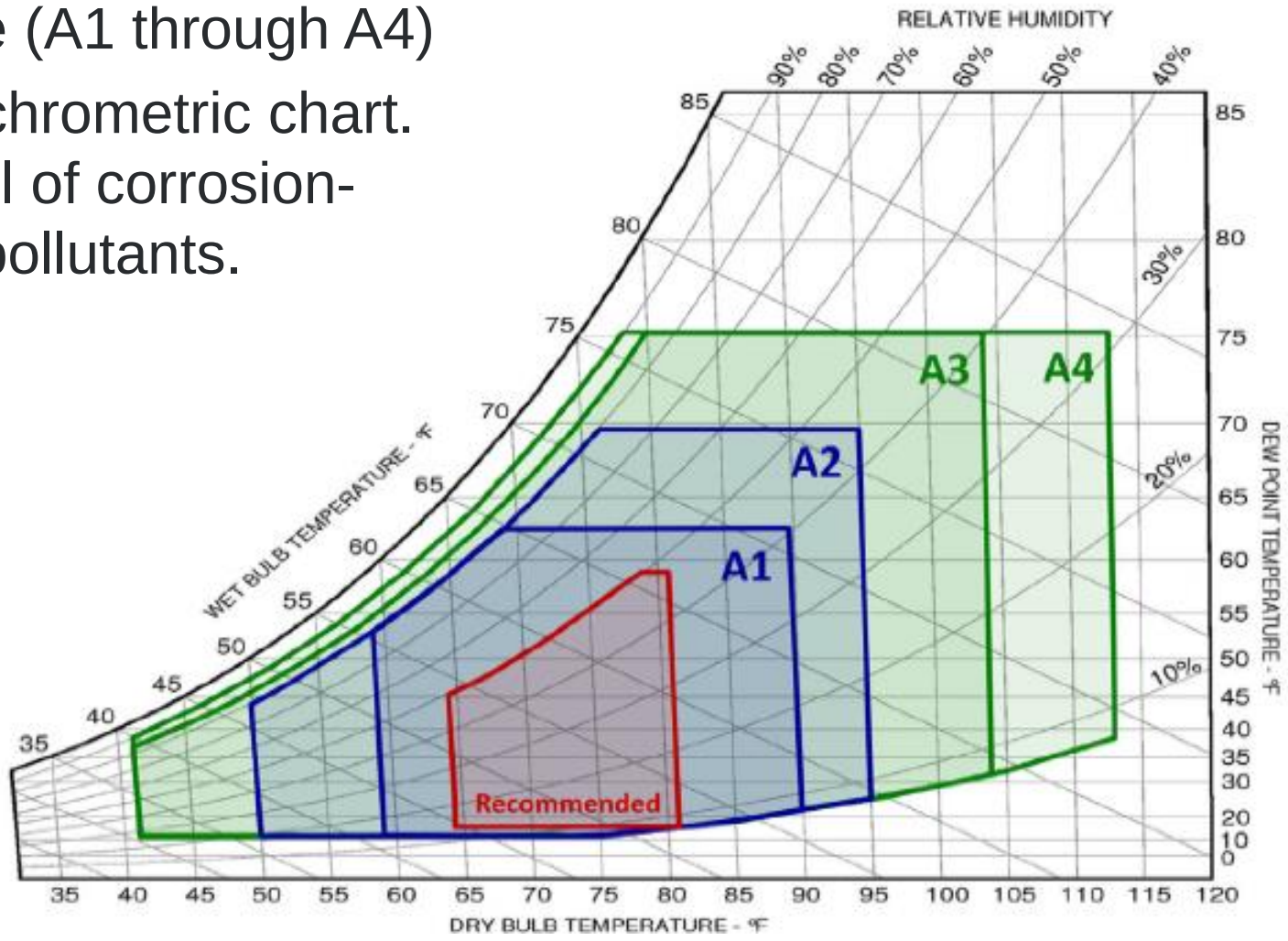


ASHRAE Thermal Guidelines (2021)

Recommended and

Allowable (A1 through A4)

on a psychrometric chart.
High level of corrosion-causing pollutants.



Generalized Thermal Best Practices In Data Centers

Best Practices = First Step

The thermal best practices provided in the Data Center Energy Practitioner (DCEP) training program* are summarized on the next two slides. Included are practices from ASHRAE, NEBS, and other industry documents.

These best-practice recommendations are a first step towards temperature management and measurements in data centers, ultimately saving infrastructure energy as well as protecting the IT equipment.

* DCEP: http://datacenters.lbl.gov/dcep

Best Practices #1

- Use environmental specifications per ASHRAE or NEBS. Select the default **Recommended** temperature range of **65°-80°F** [18°-27°C] at the IT air intakes. Warmer intake temperatures and supply air temperatures require less cooling energy.

- Select **Allowable** temperature range A2 or higher. IT equipment is often rated for wider temperatures than the A1 range. ASHRAE's **A1 Allowable** range is **59°-90°F** [15°-32°C] and **A2 Allowable** range is **50°-95°F** [10°-35°C].

- The maximum **Recommended** temperature can be increased **beyond 80°F** (27°C) if the user is aware of the potential drawbacks and benefits. This could be especially useful if Class A2 or higher were selected for the Allowable temperature.

- Intake temperatures above around 77ºF [25°C] for IT gear with variable-speed fans may speed up the fans and increase the energy use. The **increase in fan energy** may sometimes be larger than the reduction in cooling energy.

Best Practices #2

- **Reset supply air temperature** upward to keep the most demanding intake air temperatures as close to 80°F [27°C] as possible or whatever max Recommended temperature was selected. A **setpoint of 77°- 79°F** [25°-26°C] may be the most practical approach for the Recommended range.

- **Control** supply temperature (and airflow) based **on IT equipment intake air temperatures** and not on the CRAC or CRAH return temperature. Use wired or wireless external-to-rack temperature sensors or use IT equipment on-board sensors. All ENERGY STAR servers have the latter capability.

- **Showing compliance** with equipment intake temperature specifications is the ultimate cooling performance metric in data centers. The DOE Air Management Tools use the Rack Cooling Index (**RCI**)* for that purpose. More on this metric later…

* DOE Air Management Tool and RCI: http://datacenters.lbl.gov/tools

Importance of Accurate Temperature Measurements

Importance of Accurate Temperature Data

- Providing critical input to effective air management
- The more refined air management, the more important to have access to quality temperature data
- Saving cooling energy with higher supply temperatures
- Protecting the IT equipment from thermal events

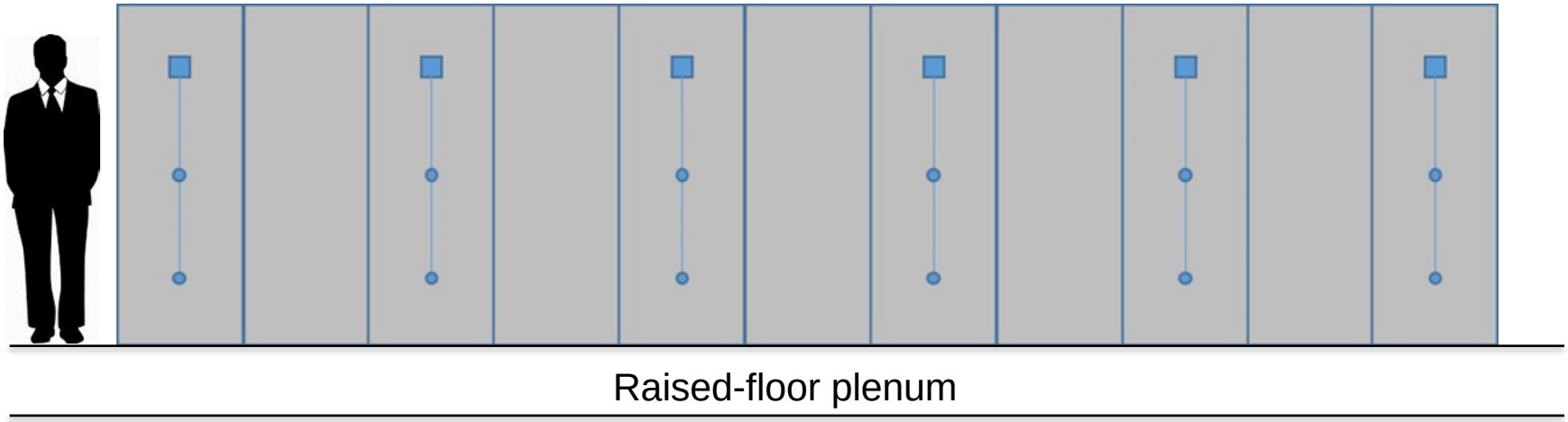
Limiting Sensor Hardware and Labor Costs

Lower Sensor Density

- Cost savings with lower sensor density could be quite significant in sensor hardware and labor costs
- A proven reduced-count sensor scheme is needed
- Without a sensible sensor reduction, data centers may forego temperature measurements altogether

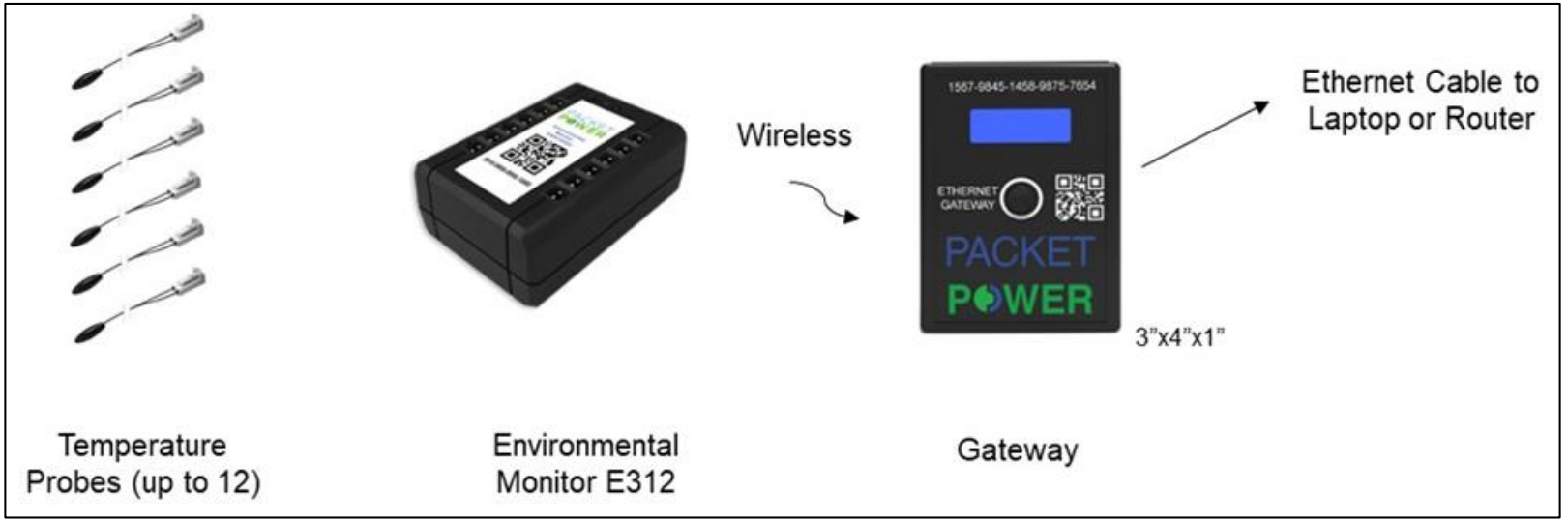
Setup of External Sensors

Common probe setup for an 11-rack lineup with three probes on every other rack (frontal view)



External Sensors

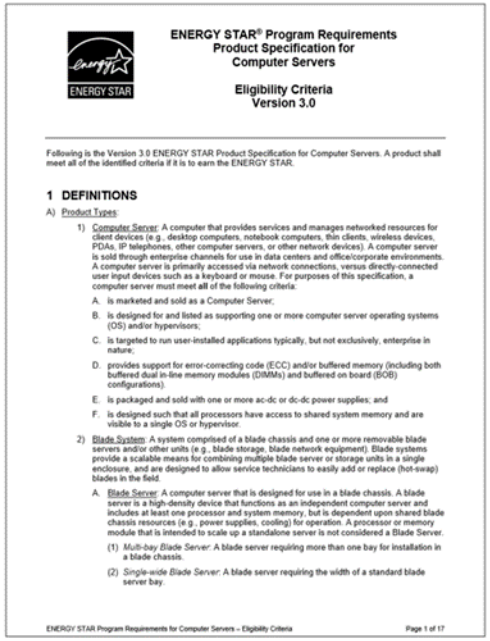
- Stationary (permanent external sensors)
- Portable (temporary external sensors) – example below. Evaluated at LBNL: https://datacenters.lbl.gov/resources/demonstration-portable-air-management



www.packetpower.com

Network Exchange With IT On-board Sensors

- Network with built-in (on-board) sensors
- Requirement for ENERGY STAR servers.



ENERGY STAR® Program Requirements
Product Specification for
Computer Servers

Eligibility Criteria
Version 3.0

Following is the Version 3.0 ENERGY STAR Product Specification for Computer Servers. A product shall meet all of the identified criteria if it is to earn the ENERGY STAR.

1 DEFINITIONS

A) Product Types:

1) Computer Server: A computer that provides services and manages networked resources for client devices (e.g., desktop computers, notebook computers, thin clients, wireless devices, PDAs, IP telephones, other computer servers, or other network devices). A computer server is sold through enterprise channels for use in data centers and office/corporate environments. A computer server is primarily accessed via network connections, versus directly-connected user input devices such as a keyboard or mouse. For purposes of this specification, a computer server must meet **all** of the following criteria:

A. is marketed and sold as a Computer Server;

B. is designed for and listed as supporting one or more computer server operating systems (OS) and/or hypervisors;

C. is targeted to run user-installed applications typically, but not exclusively, enterprise in nature;

D. provides support for error-correcting code (ECC) and/or buffered memory (including both buffered dual in-line memory modules (DIMMs) and buffered on board (BOB) configurations).

E. is packaged and sold with one or more ac-dc or dc-dc power supplies; and

F. is designed such that all processors have access to shared system memory and are visible to a single OS or hypervisor.

2) Blade System: A system comprised of a blade chassis and one or more removable blade servers and/or other units (e.g., blade storage, blade network equipment). Blade systems provide a scalable means for combining multiple blade server or storage units in a single enclosure, and are designed to allow service technicians to easily add or replace (hot-swap) blades in the field.

A. Blade Server: A computer server that is designed for use in a blade chassis. A blade server is a high-density device that functions as an independent computer server and includes at least one processor and system memory, but is dependent upon shared blade chassis resources (e.g., power supplies, cooling) for operation. A processor or memory module that is intended to scale up a standalone server is not considered a Blade Server.

(1) *Multi-bay Blade Server:* A blade server requiring more than one bay for installation in a blade chassis.

(2) *Single-wide Blade Server:* A blade server requiring the width of a standard blade server bay.

ENERGY STAR Program Requirements for Computer Servers – Eligibility Criteria Page 1 of 17

The ENERGY STAR Specification document
https://www.energystar.gov/products/spec/enterprise_servers_specification_version_3_0_pdf

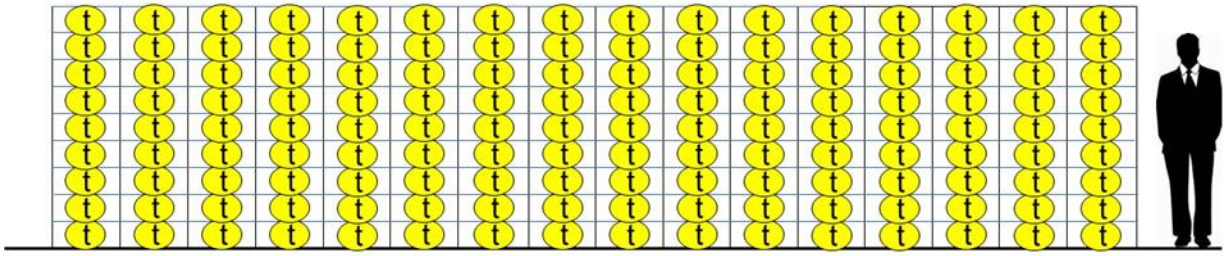
Accurate Low-Density Temperature Probe Configurations

How to Reduce the Sensor Count

- Number of sensors
- Placement of the sensors
  - IT intake (primary)
  - Vertically
  - Horizontally

Reference Placement Scheme

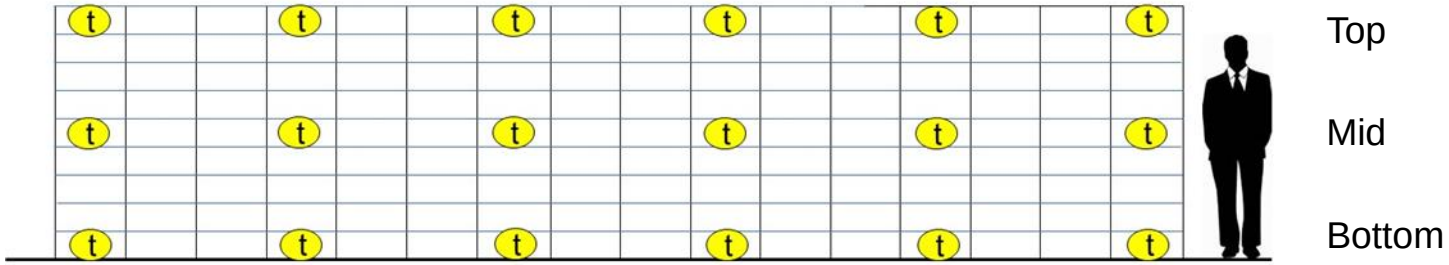
- Reference scheme
  - All IT equipment air intakes measured
  - Most accurate placement scheme
  - Internal recirculation in rack could give poor values
  - … but, costly (hardware and labor).



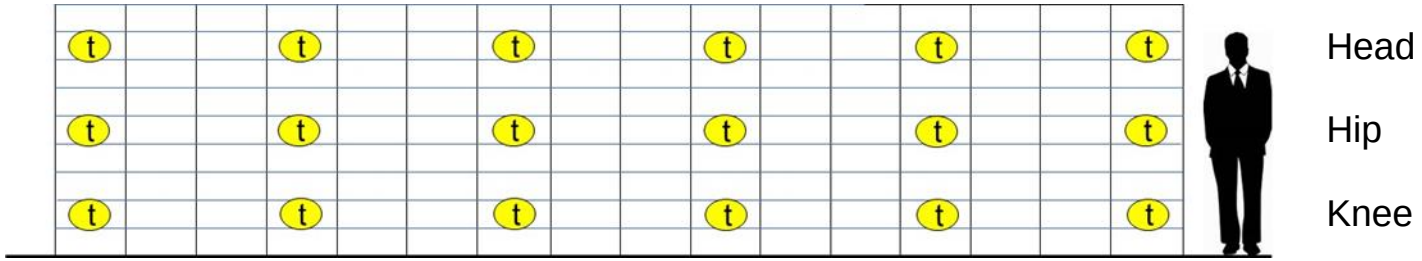
One sensor per IT equipment

Reduced Placement Schemes

- ASHRAE scheme (top picture)
- Another commonly used scheme (bottom picture)
- Difference? Slightly different vertical positioning
- Both 90% sensor count reduction (less cost and labor).



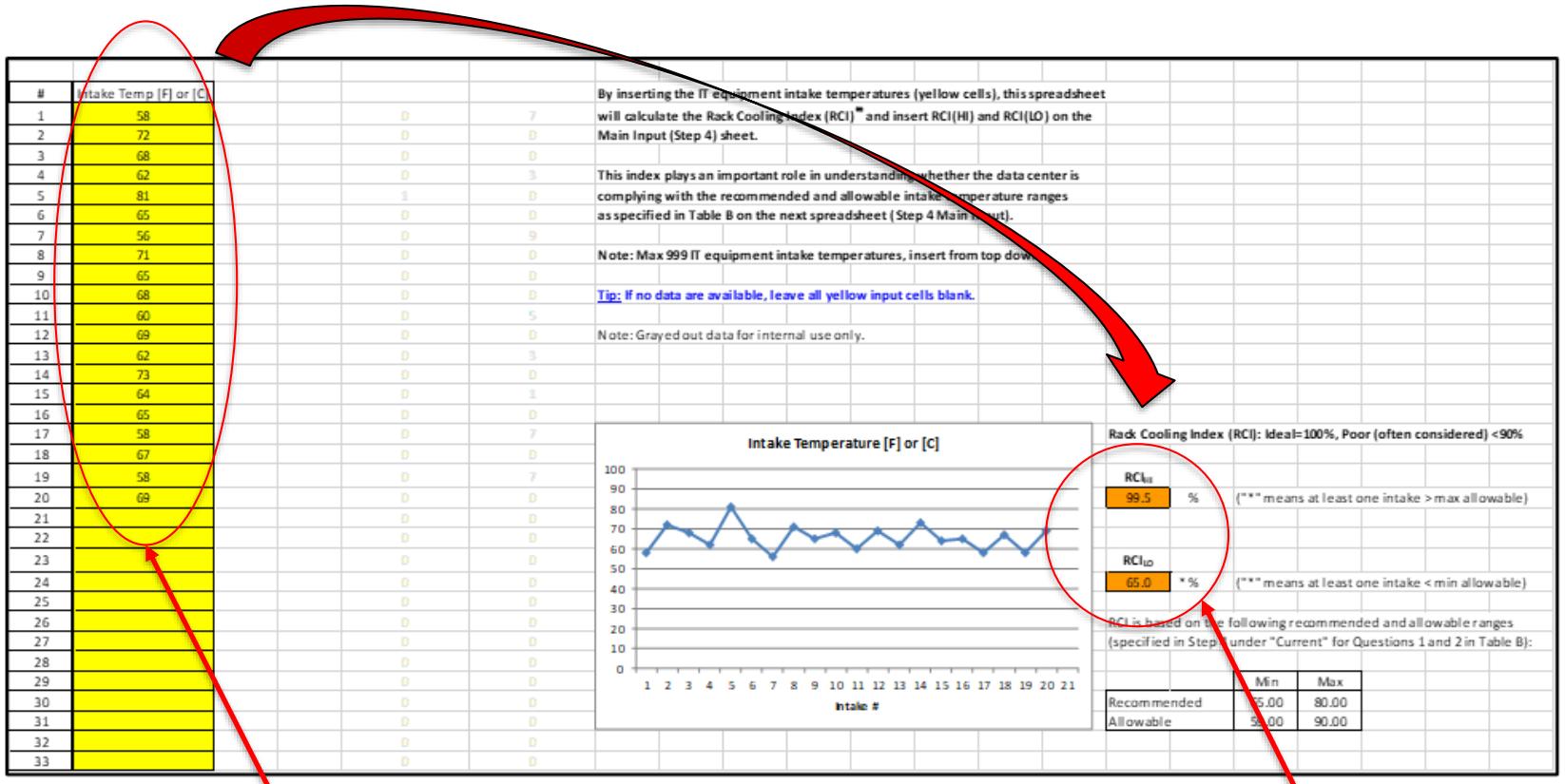
ASHRAE “Scheme 1”



Another common scheme “Scheme 2”

DOE Air Management (AM) Tool

We will use the DOE Air Management Tool to analyze how well the two reduced sensor schemes capture the overall intake air temp distribution since it has a suitable built-in metric: RCI



Input: Intake Temperatures

Output: RCI

Interpretation of RCI

- Whatever temperature ranges you choose, make sure you comply with those ranges
- The Rack Cooling Index (RCI) is a metric for showing compliance (or non-compliance)
- It takes into account not only **the number** of air intakes outside the chosen ranges but also by **how much**
- The interpretation of RCI is as follows:

Poor	Good	Ideal
<90%	>95%	100%

All temps within the Recommended range

Results

- For clarity, the focus here is on a subset of the results
- RCI is a convenient way of "scoring" the two reduced probe schemes
- Scheme 2 is overall a better choice - smaller RCI difference
- Remarkable small difference considering ~90% sensor reduction!
- Adding 2-3 sensors near the top could capture Max T even better.

		ASHRAE Allowable A1		ASHRAE Allowable A2	
Sensor Scheme	**Max T F**	**RCI_{HI} %**	**RCI_{LO} %**	**RCI_{HI} %**	**RCI_{LO} %**
Ref. Scheme Shallow	89	95.1	51.0	97.0	81.6
Scheme 2 Shallow	86	93.3	56.8	95.8	83.8
Scheme 1 Shallow ASHRAE	89	84.9	56.8	90.6	83.8
Ref. Scheme Deep	91	67.4	64.7	79.6	86.7
Scheme 2 Deep	91	65.2	65.0	78.2	86.9
Scheme 1 Deep	91	61.5	63.0	75.9	86.1

Conventional raised-floor cooling; Scheme 1 = ASHRAE; Scheme 2 = Other scheme

Summary

- We provide concise, generalized temperature best-practice recommendations based on those given in the DCEP training program

- Temperature measuring equipment is addressed including external sensors and Network Data Exchange with IT equipment on-board sensors

- Since instrumentation can become expensive, we explored reduced sensor placement schemes. The results suggest an opportunity to reduce the sensor count (and cost) without sacrificing much accuracy.

In addition, the DOE Data Center Energy Efficiency Toolkit provides the tools and a detailed process manual for organizing the thermal data center work.

Resources and Q&A

FEMP's Data Center Program

FEMP's Data Center program assists federal agencies and other organizations with optimizing the design and operation of data centers. design and operation of energy and water systems in data centers to enhance agency's mission.

Assistance

- Project and technical assistance from the Center of Expertise including identifying and evaluating ECMs, M&V plan review, and project design review.
- Support agencies in meeting OMB's Data Center Optimization Initiative requirements

Tools

- 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

Key Resources

- 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

Training

- Better Buildings webinar series
- Nine on-demand FEMP data center trainings
- Center of Expertise Webinars
- Data Center Energy Practitioner Trainings

LBNL's Center of Expertise (CoE)

Use CoE's Energy Efficiency Toolkit

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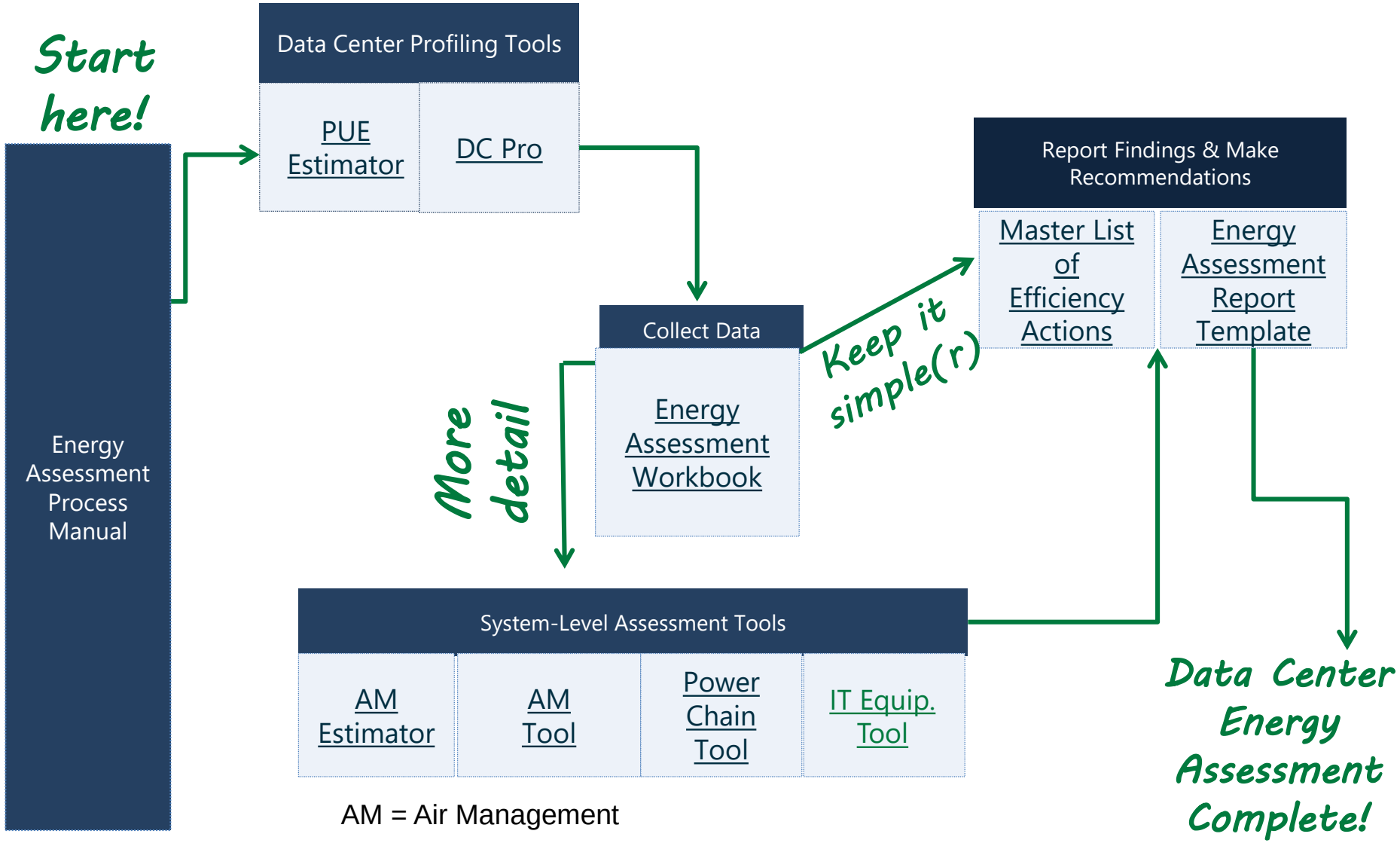
Search resources by topics of interest.

Explore the diverse activities that CoE is engaged in.

Visit us at datacenters.lbl.gov

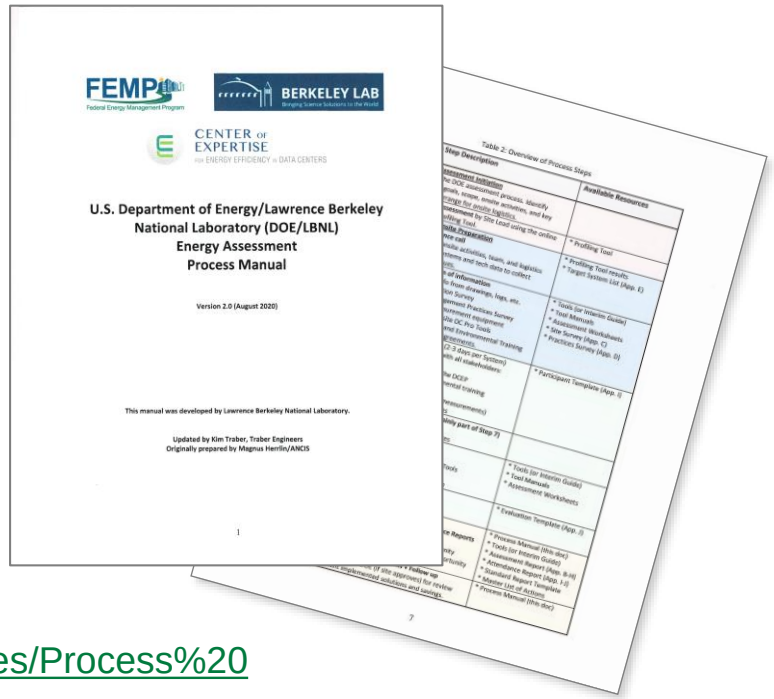
CoE Data Center Energy Efficiency Toolkit



AM = Air Management

Energy Assessment Process Manual

- The Process Manual provides administrative step-by-step instructions for conducting an energy assessment before, during, and after the onsite assessment
- Multiple appendices include useful templates for the assessments.



https://datacenters.lbl.gov/sites/default/files/Process%20Manual%20DOE%20v2_080320_0.pdf

Master List of DC Energy Efficiency Measures

- **Living encyclopedia of all data center EEMs**
  - Recognized as an essential desk reference for data center energy efficiency – top download for CoE
  - >250 energy-saving changes in components, operations or other actions
- **Several tools recommend common EEMs:**
  - DC Pro, Air Management Tool, Electric Power Chain Tool
- **The Master List contains all common EEMs, plus many others that do not appear elsewhere in the toolkit.**
- **For each EEM, the list explains the principles involved and how energy cost savings are generated, plus tips on implementation and more in-depth references.**

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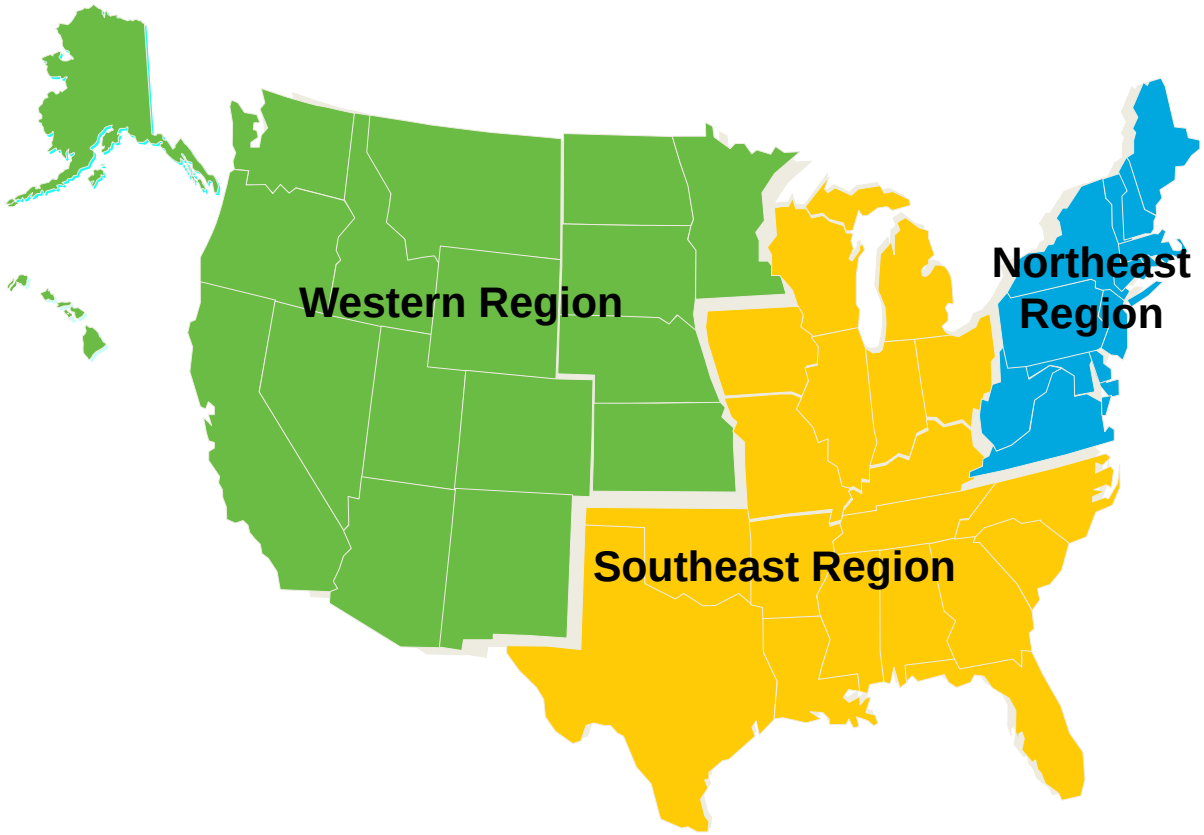

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Questions?

IACET Credit for Webinar

WBDG WHOLE BUILDING DESIGN GUIDE *a program of the* National Institute of Building Sciences

ACCREDITED IACET PROVIDER

The National Institute of Building Sciences' (NIBS) Whole Building Design Guide (WBDG) hosts the FEMP training program's learning management system (LMS).

The WBDG LMS:

- Allows for taking multiple trainings from multiple organizations through one platform.
- Houses the assessments and evaluations for all accredited courses.
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To receive IACET-Certified CEUs, attendees must:

- Attend the training in full (no exceptions).
  - If you are sharing a web connection during the training, you must send an e-mail to Elena Meehan (elena.meehan@ee.doe.gov) and indicate who was on the connection and who showed as connected (will reflect in the WebEx roster).
- Complete an assessment demonstrating knowledge of course learning objectives and an evaluation **within six weeks of the training**. A minimum of 80% correct answers are required for the assessment.

To access the webinar assessment and evaluation, visit:

https://www.wbdg.org/continuing-education/femp-courses/femplw05132021

If you have a WBDG account and enrolled previously, simply log in and click the *Continuing Education* tab on the user account page. Click *Proceed to Course* next to the course title.