U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Air Management Resource Webinar

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FEMP Federal Energy Management Program

Before We Begin

- Please, do NOT put the call on hold
- All lines have been muted, to be unmuted or to ask a question, please go to your meeting controls panel and raise your hand
- To submit questions through the chat box, click the chat button and type in the dialogue box at the bottom right. Please, select if you want your comment to go to the entire group or Elena Meehan to prompt a question to the presenter.
- Slides will be posted at datacenterworkshop.lbl.gov

Introduction

FEMP and the Center of Expertise for Energy Efficiency in Data Centers (CoE) assists federal agencies and other organizations implement data center energy efficiency projects by supplying technical support, tools, best practices, analyses, and the introduction of technologies.

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DC Overview

Center of Expertise for Energy Efficiency in Data Centers (CoE)

- **Assists federal agencies and other organizations implement data center energy efficiency projects**
  - Training (webinars, on-demand, live workshops (Data Center Energy Practitioner (DCEP) Program)
  - Technical support
  - Tools (Profiler Tools)
  - Best practices
  - Analyses (Guidance for Small Data Centers)
  - Introduction of technologies

datacenters.lbl.gov

Outline

- Provide an overview of Air Management: Best practices and detecting/correcting problems (30 min)
- Describe resources available at the Center of Expertise and how to tie them together (30 min).

Air Management (AM) Goal and Results

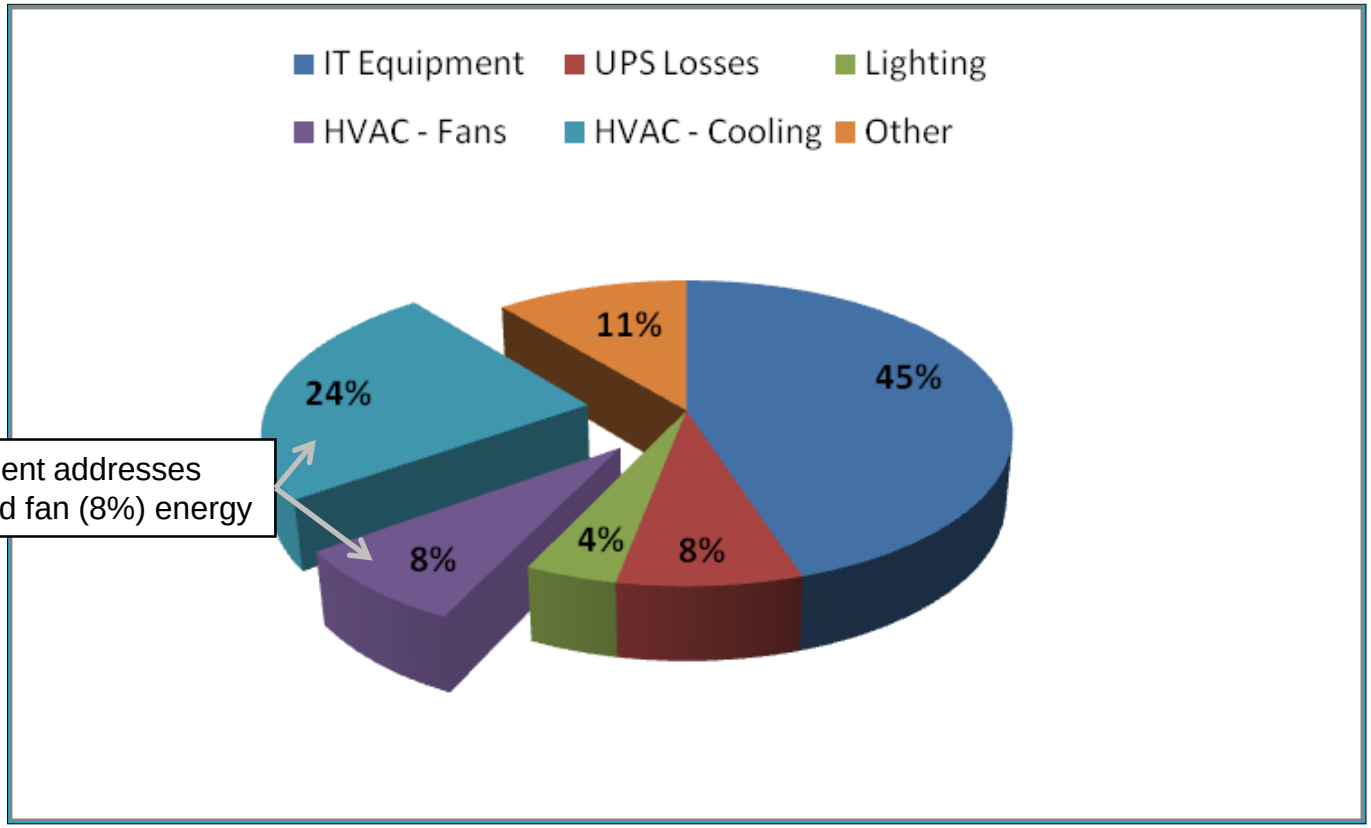
Goal (What is Air Management anyway?)

- Supply the IT equipment with the desired air temperature with minimum fan and cooling energy by limiting the mixing of cold and hot air in the data center.

Results

- Improving chiller efficiency and reducing fan energy
- Enhancing economizer utilization
- Increasing reliability and longevity of the IT equipment
- Reducing capital investments and regaining lost capacity.

Typical Data Center Power Allocation

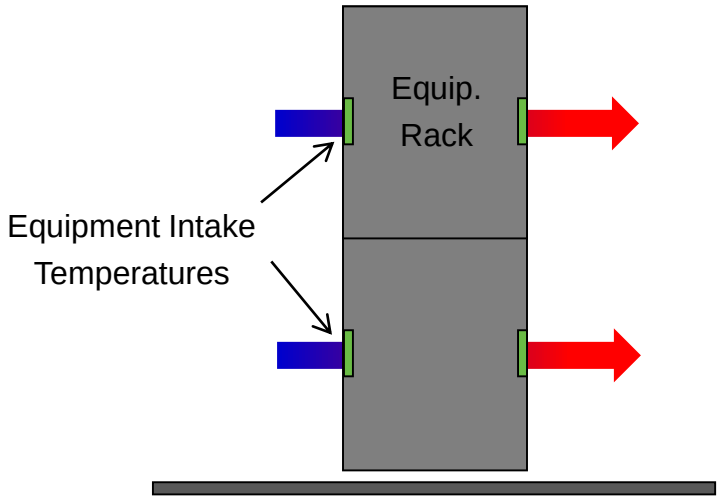


Air Management addresses cooling (24%) and fan (8%) energy

Source: LBNL Data Center Characterization Project, 2002

Equipment Intake Conditions

Air-cooled IT gear depends on the *intake* temperature for effective cooling. Today, most environmental guidelines refer to the intake conditions.

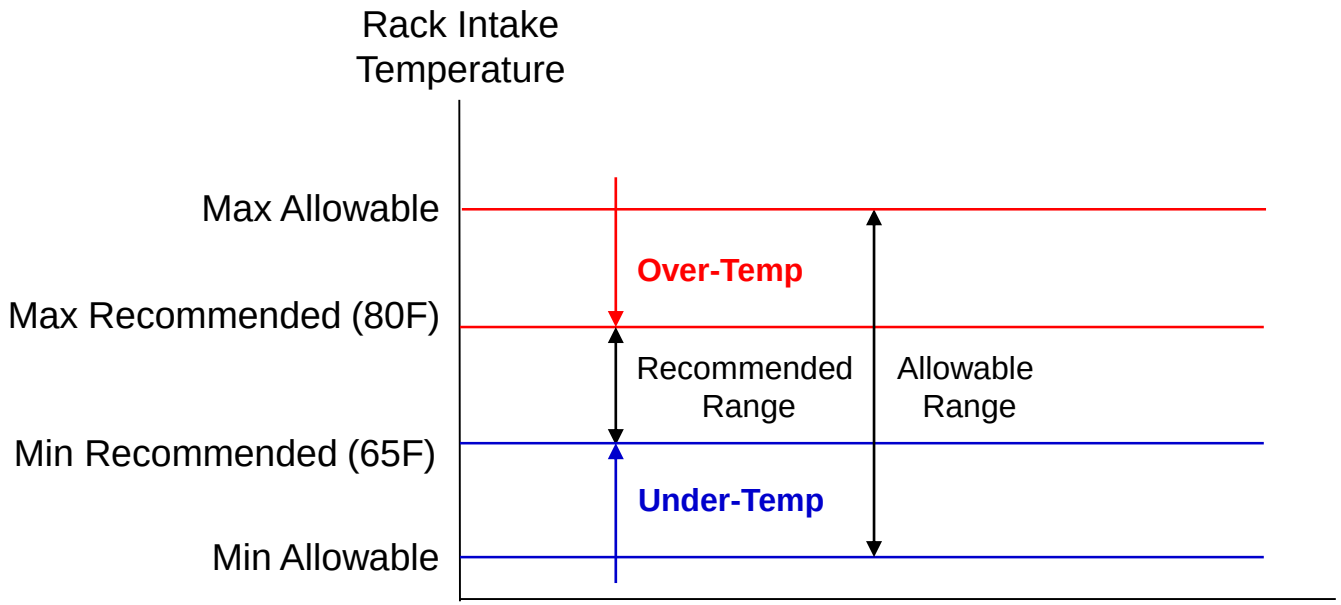


Side view of equipment rack

Recommended and Allowable Temperatures

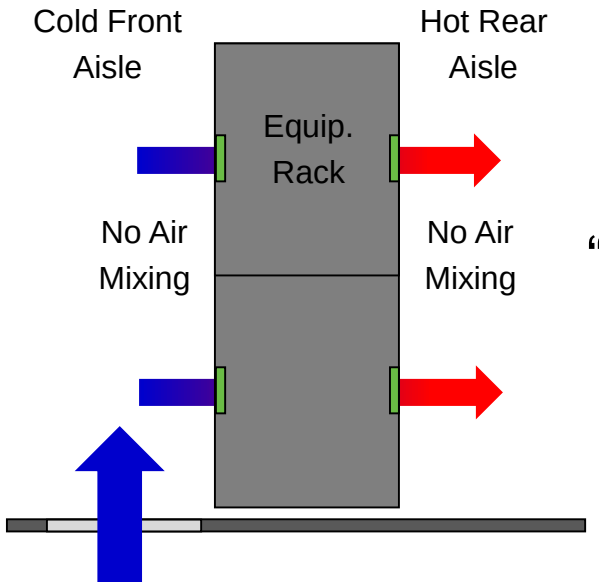
Recommended range (statement of reliability): Preferred facility operation; most values should be within this range.

Allowable range (statement of functionality): Robustness of equipment; no values should be outside this range.



Design for Separation of Cold and Hot Air

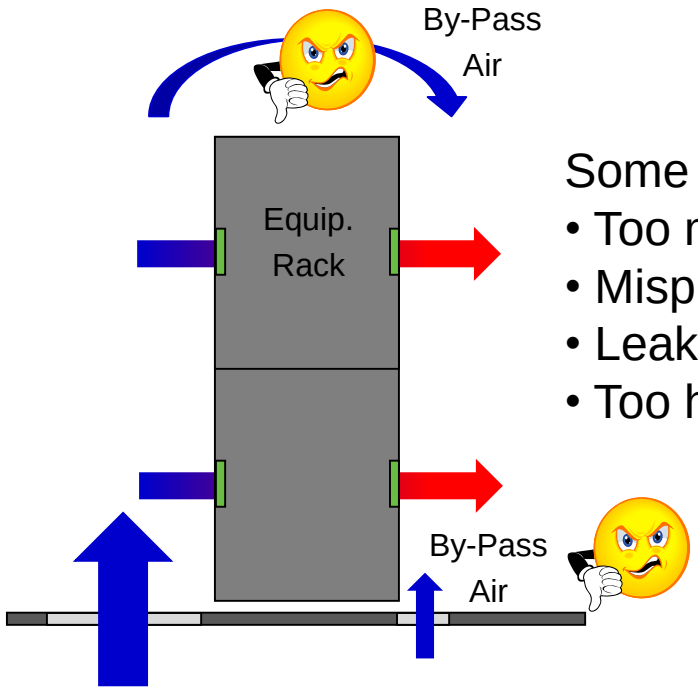
The preferred strategy is to supply cold air as close to the intakes as possible without mixing with ambient air and return hot exhaust air without mixing with ambient air.



"Once-through cooling"

Key Challenge #1: By-Pass Air

By-pass air does not participate in cooling the gear and should be minimized. Net by-pass air happens when the total supply airflow > total IT equipment airflow.

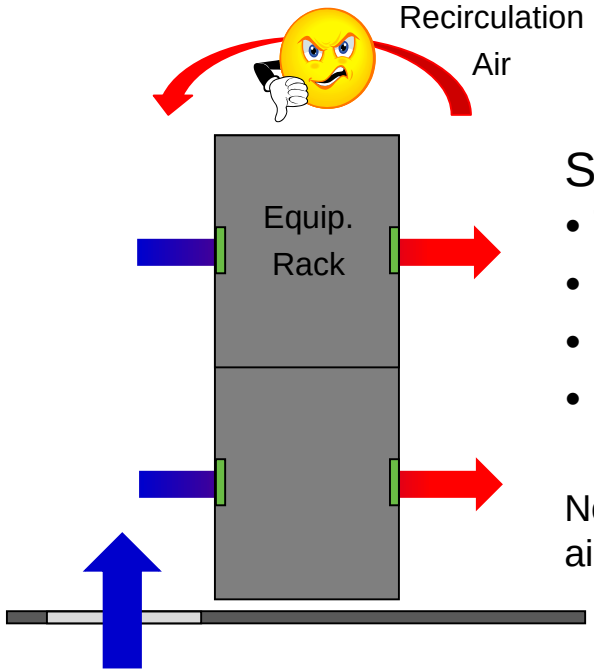


Some common causes:

- Too much supply airflow
- Misplaced perforated tiles
- Leaky cable penetrations
- Too high tile exit velocity.

Key Challenge #2: Recirculation Air

Recirculation air often causes hotspots and should be minimized. At the room level, net recirculation air happens when the total supply airflow < total IT equipment airflow.



Some common causes:

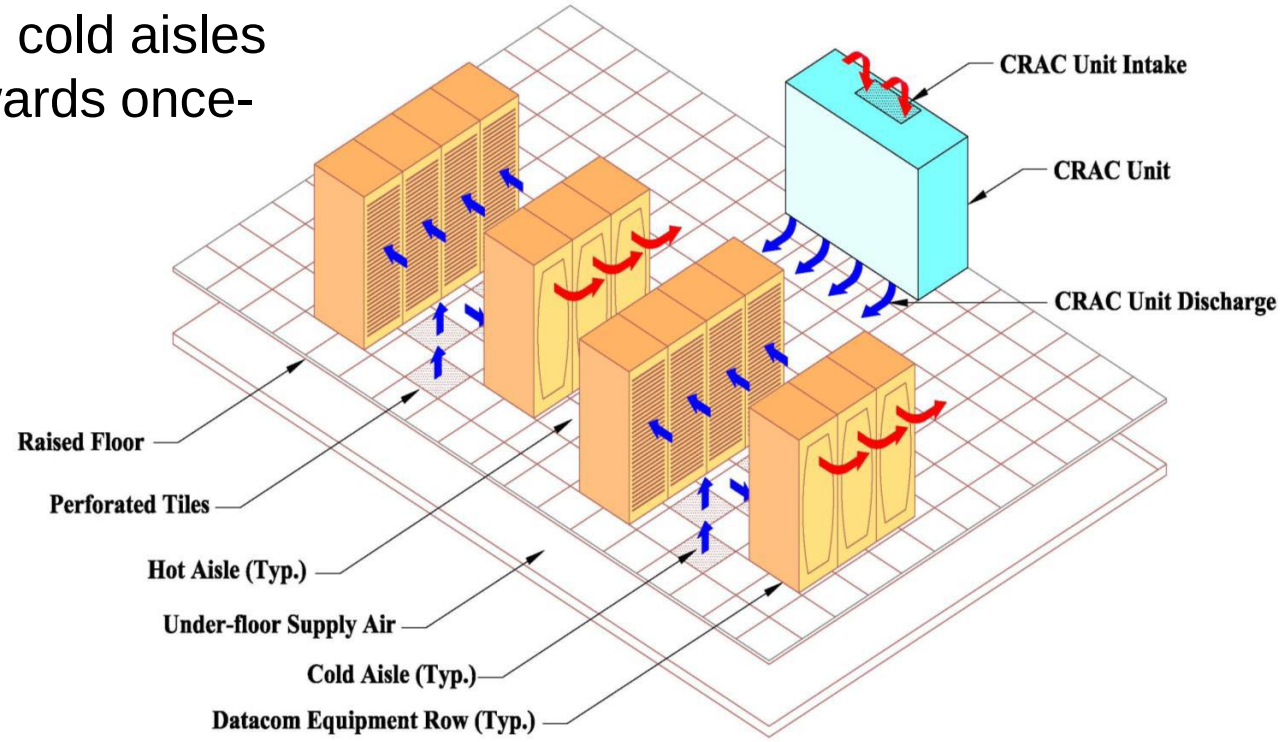
- Too little supply airflow
- Lack of blanking panels
- Gaps between racks
- Short equipment rows.

Note that by-pass air and recirculation air often coexist in a data center.

Hot and Cold Aisles

Arranging the space in alternating hot and cold aisles is the first step towards once-through cooling.

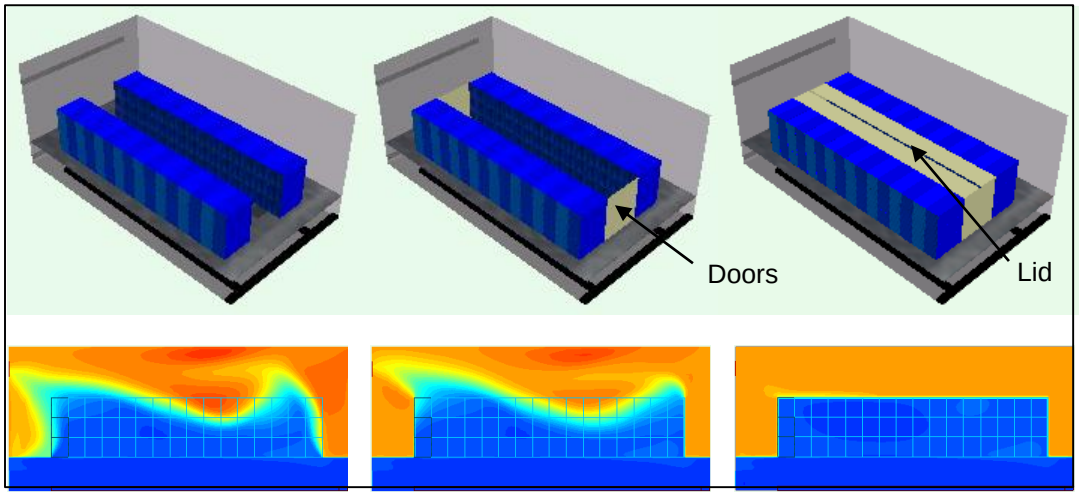
Cold air is supplied into the cold front aisles, the servers move the air from the front to the rear, and the hot exhaust air is returned to the air handler from the hot rear aisles.



Graphics courtesy of DLB Associates

Enhancing Separation of Hot/Cold Air

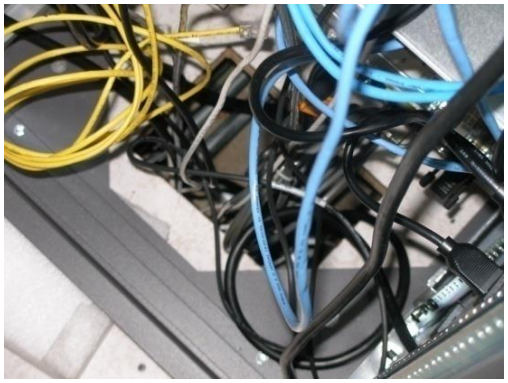
Physical barriers can enhance the separation of hot and cold air (watch fire codes). Enclosed aisles permit higher supply and—in turn—return temperatures.



Graphics courtesy of ANCIS Incorporated

Maintain Tight Raised Floors

A large fraction of the air from the air-handlers is often lost through leaks in the raised floor. Such leakage often causes detrimental by-pass air.



Unsealed cable penetration in floor under equipment rack

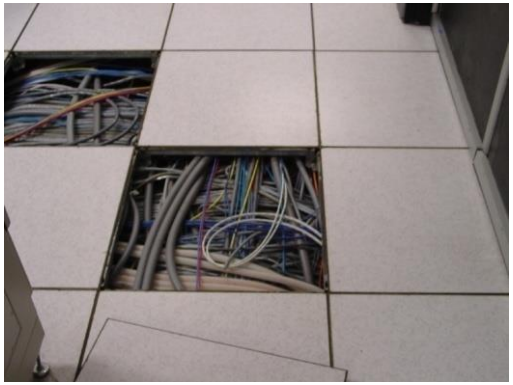
Picture courtesy of ANCIS Incorporated

Grommet

Picture courtesy of Upsite Technologies

Cable Congestion

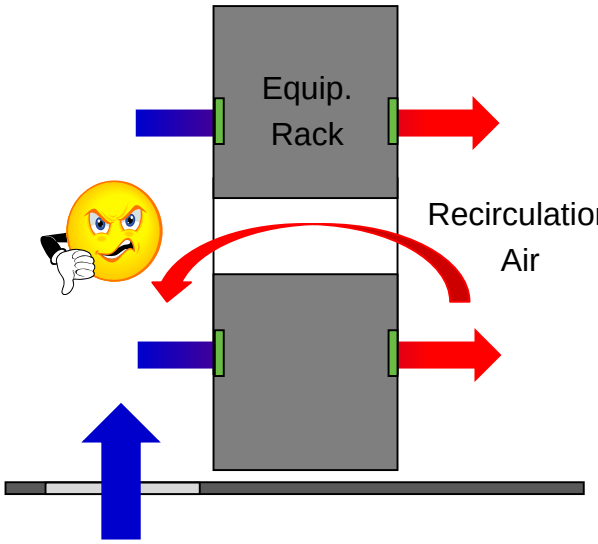
Cable congestion in raised-floor plenums can sharply reduce the total airflow as well as degrade the airflow distribution through the perforated tiles.



Pictures courtesy of ANCIS Incorporated

Managing Blanking Panels

Managing blanking panels and unbroken equipment lineups is especially important in hot and cold aisle environments.



Two Blanking Panels
Courtesy of Upsite Technologies

How to Realize Energy Savings

This is a two-step process:

1. Physically arrange the space to promote separation of hot and cold air. This can be done with a number of measures per above. These measures by themselves do not save energy but rather enable savings.

2. To realize the savings at least one of two additional things must happen: Increase in supply air temperature (higher chiller efficiency and economizer utilization) and/or decrease in supply airflow rate (lower fan operating costs and fan heat).

Variable Speed Fans

- Variable speed drives (VSDs) should be used for fans. Power input to a fan is proportional to nearly the cube of the speed of the device.
    - A reduction of 20% in fan speed results in almost a 50% reduction in energy.
- Turning off constant air volume fans only results in a linear relationship between airflow and energy. Also, turned-off units without backdraft dampers will serve as pathways for by-pass air.

Metrics in the DOE Air Management Tools

Two high-level air management metrics are used in the DOE Air Management Tools (described later):

- Rack Cooling Index (RCI)
- Return Temperature Index (RTI).

Thermal Compliance and the RCI Metric

Thermal guidelines become useful when there is a way of determining compliance; the Rack Cooling Index (RCI) compresses the intake temperatures into RCI_{HI} and RCI_{LO}.

- RCI_{HI} = 100% No over-temperatures (< max. rec.)
- RCI_{LO} = 100% No under-temperatures (> min. rec.)
- Both = 100% Absolute compliance.

In other words, RCI is a measure of how effectively the equipment is cooled within an intake temperature specification.

Interpretation:

Poor	Good	"Ideal"
<90%	>95%	100%

Herrlin, M. K. 2005. *Rack Cooling Effectiveness in Data Centers and Telecom Central Offices: The Rack Cooling Index (RCI)*. ASHRAE Transactions, Volume 111, Part 2. http://www.ancis.us/publications.html

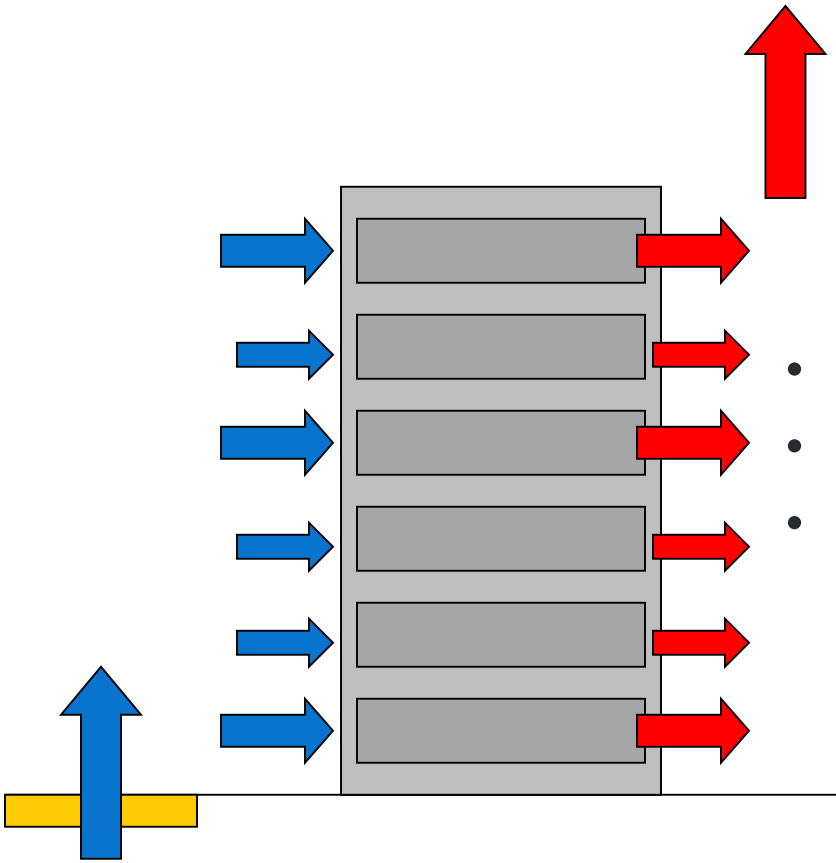
Airflow Requirements and the RTI Metric

- Typically, more air is delivered by the cooling system than is drawn into the IT equipment due to net by-pass air
- Poor air management is the driver for over-provisioning the airflow; hotspots often dictate the need for extra air
- RTI is a measure of net by-pass or net recirculation air. It is the ratio of total IT equipment airflow to total air-handler airflow.

Interpretation:

Net By-Pass	Balanced Airflow	Net Re-circulation
<100%	100%	>100%

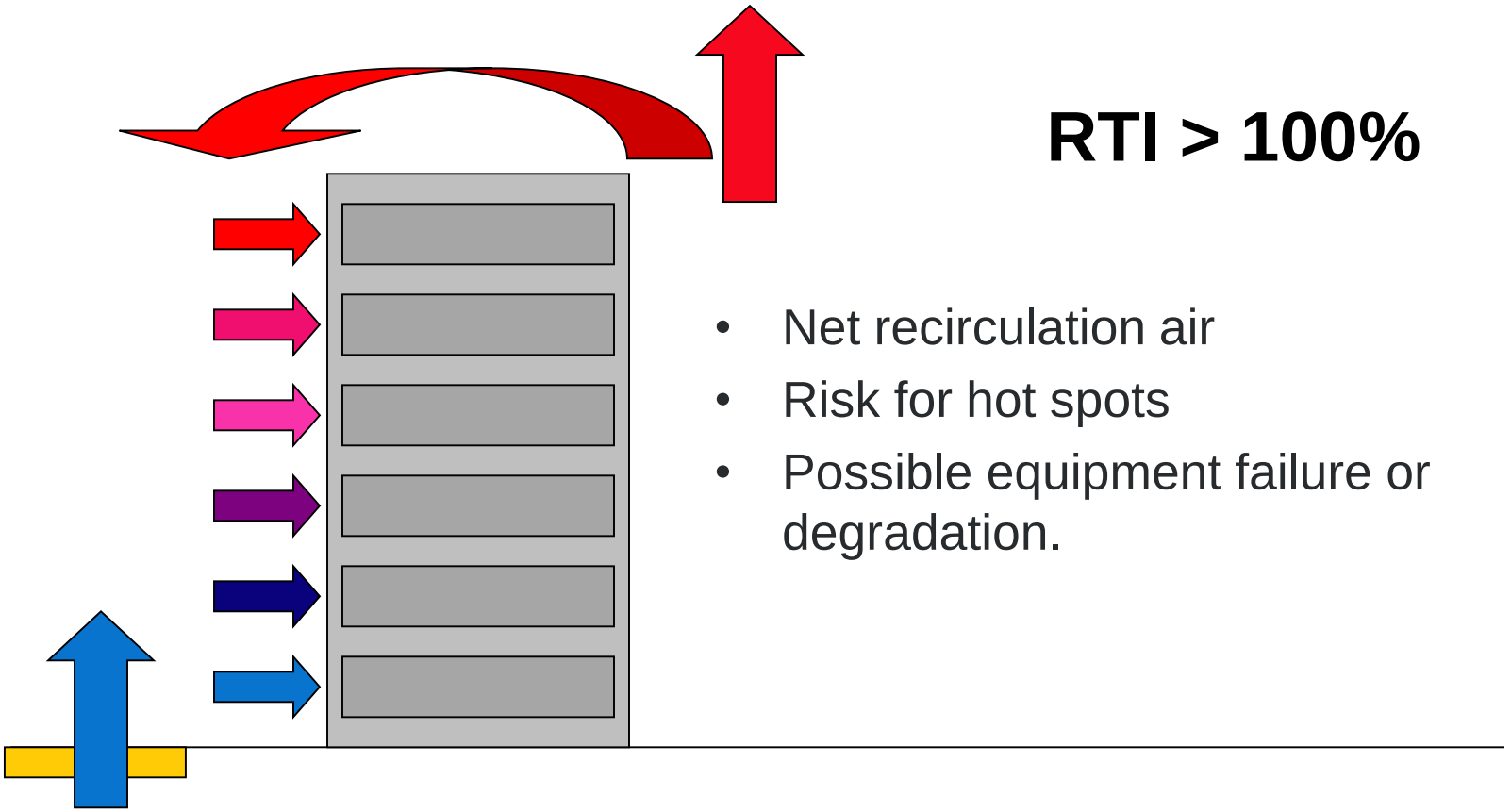
HVAC Airflow Equal To IT Airflow



RTI = 100%

- Balanced airflow
- Can be difficult to control
- Works well with aisle containment.

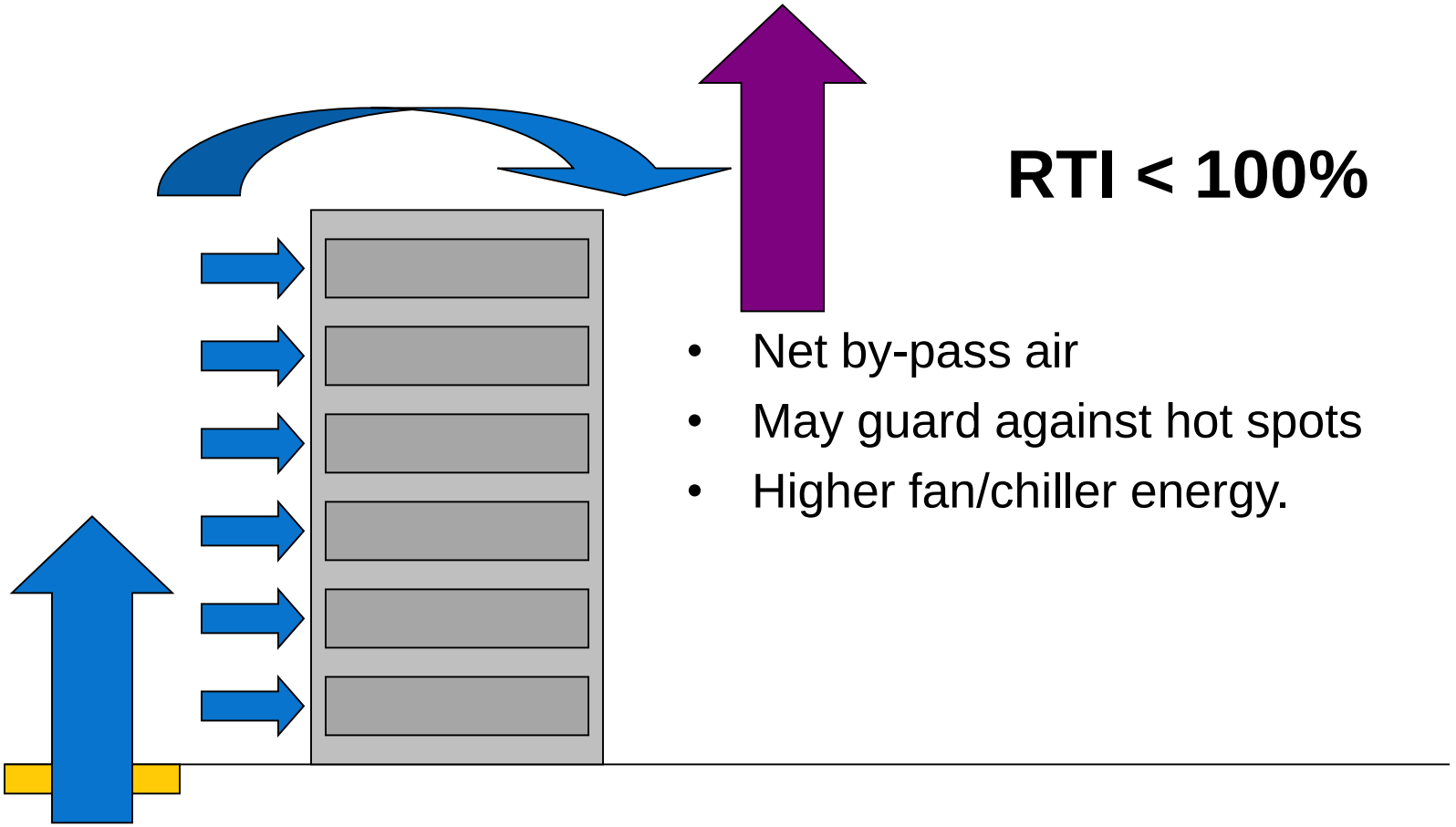
HVAC Airflow Less Than IT Airflow



RTI > 100%

- Net recirculation air
- Risk for hot spots
- Possible equipment failure or degradation.

HVAC Airflow Higher Than IT Airflow



RTI < 100%

- Net by-pass air
- May guard against hot spots
- Higher fan/chiller energy.

Temperature Measurements

Temperature Readings

At the racks, the quantity and location of the temperature probes depend on the content of the rack – strictly speaking. But, from a practical perspective, the configuration shown below to the left is recommended on every other or third rack in the equipment row.

Temperature/Airflow Controls (Guidelines)

- Use environmental specifications per ASHRAE or NEBS
  - Target intake temperatures between 65°F [18°C] and 80°F [27°C]
  - Select appropriate allowable range (depends on application)
  - Above 77°F [25°C] two-speed/variable-speed server fans may speed up.
- Retrofit air handlers with variable speed drives (VSD)
- Provide rack intake temperature data to air handlers
  - Use wired or wireless external temperature sensors
  - Network data exchange with server on-board temperature sensors.
- Control supply airflow and temperature on rack temperature
  - More/less supply airflow
  - Higher/lower supply temperature
  - Combination should be based on economics.
- Use metrics to track system performance.

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Center of Expertise (CoE) Resources

CoE has developed a number of resources for analyzing and improving air management in data centers, which collectively form a coherent approach to air management.

We will now discuss those resources and tie them together to empower data center decisions.

- DCEP certificate training
- Webinars
- Software tools
- Tool demonstrations
- R&D
- The bigger picture.

DCEP Certificate Training

The Data Center Energy Practitioner (DCEP) program provides up to three days of classroom training and two exams on energy assessments of data centers. Successful participants receive certificates.

- The Feds require DCEPs for managing their data centers
- Curriculum developed with a quasi-consensus process
- Two software tools are an integral part of the training
- Major update of curriculum in 2016, minor updates continuously
- Over 670 DCEP certificates issued to date (July 2018).

Objectives, Target Groups, and Delivery

Objectives:

- Raise the standard of energy assessors
- Greater repeatability/credibility of recommendations.

Target groups include:

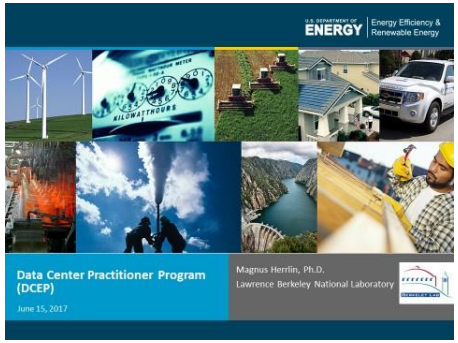
- Data center personnel (in-house experts)
- Consulting professionals (for-fee consultants).

Delivery:

- 2 Levels, Generalist and HVAC-Specialist
- IT Equipment Specialist under development
- Delivered by multiple training organizations:
  http://datacenters.lbl.gov/dcep

Webinars

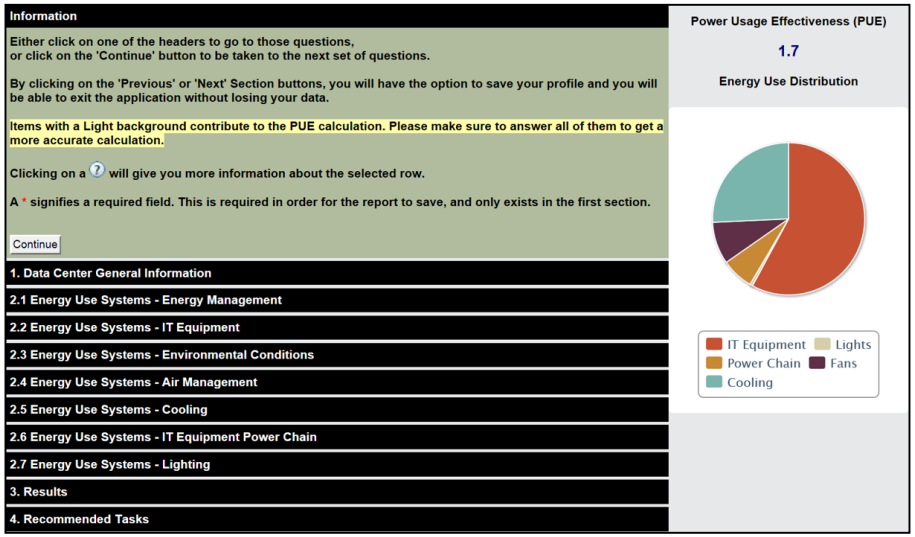
2017: DCEP Certificate Training Program



2018: Air Management Webinar

High-Level DOE DcPro Profiler

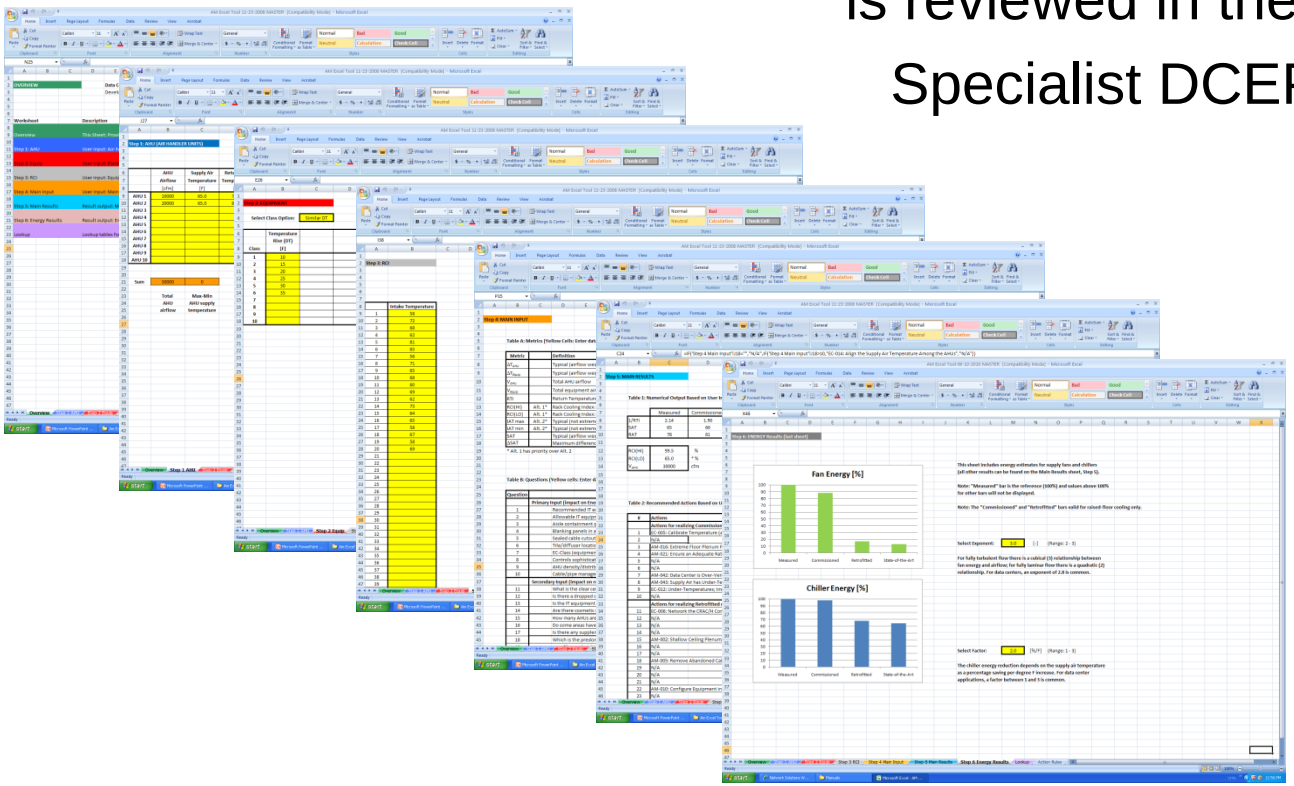
The online, high-level DcPro estimates the PUE without sub-metering. It is a scoping tool and is designed to diagnose how energy is distributed in a data center and ways to save energy.



Access tool at datacenters.lbl.gov/Tools

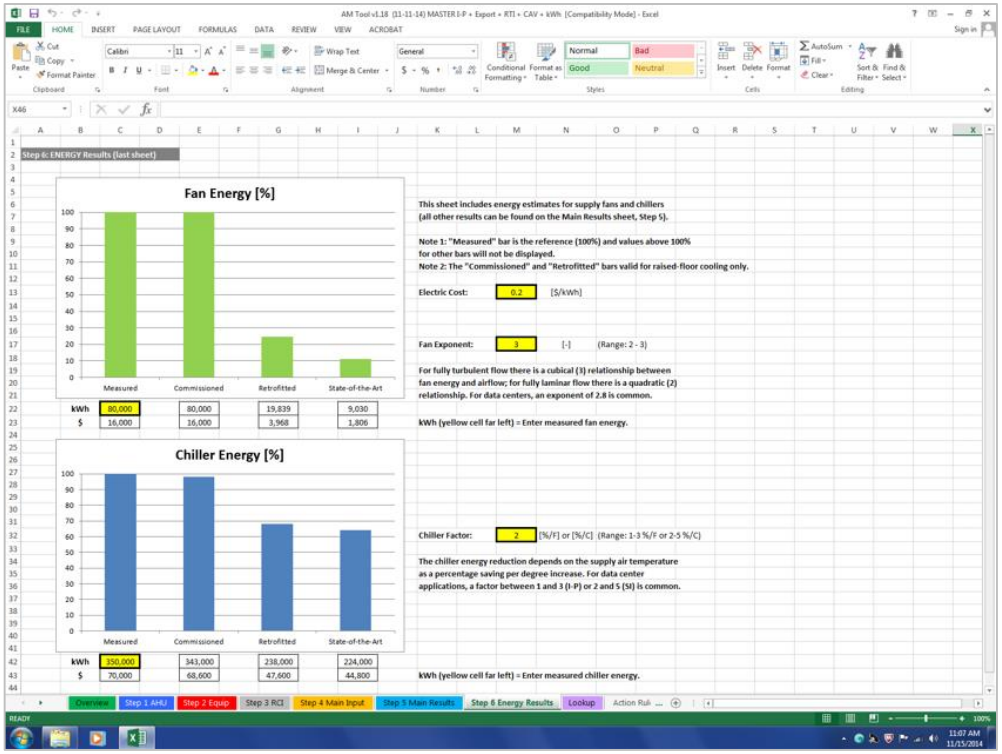
In-Depth DOE Air Management Tool

The AM-Tool developed by DOE is a free Excel tool for assessing the data center air-management status. This Tool is reviewed in the in-depth Specialist DCEP training.



Download tool at datacenters.lbl.gov/Tools

Quick Live Demo



DOE Air Management Tool: Energy Results

Download tool at datacenters.lbl.gov/Tools

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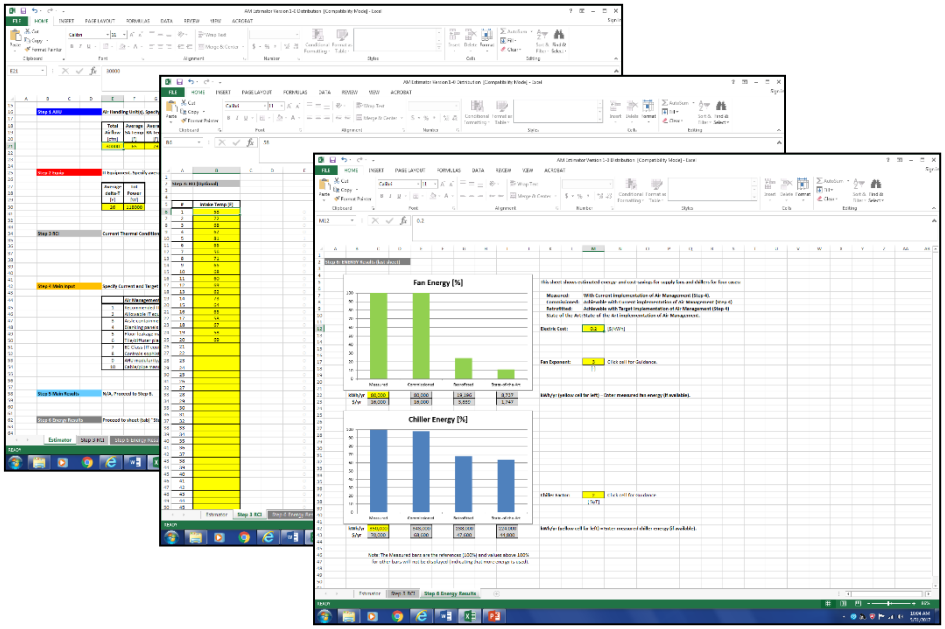
DOE Air Management Estimator

The free DOE Data Center Air Management Estimator is a simplified version of the DOE Data Center Air Management Tool, but with the same engine. The input options have been reduced in favor of increased simplicity.



Download tool at datacenters.lbl.gov/Tools

Demos: Air Management Monitoring Tools

In 2017, LBNL demonstrated two simple, portable, and inexpensive tools that can be used to measure the thermal conditions, i.e., the IT equipment intake temperatures.

Purkay Labs, Audit-Buddy:

"Tool Needs Improvements"

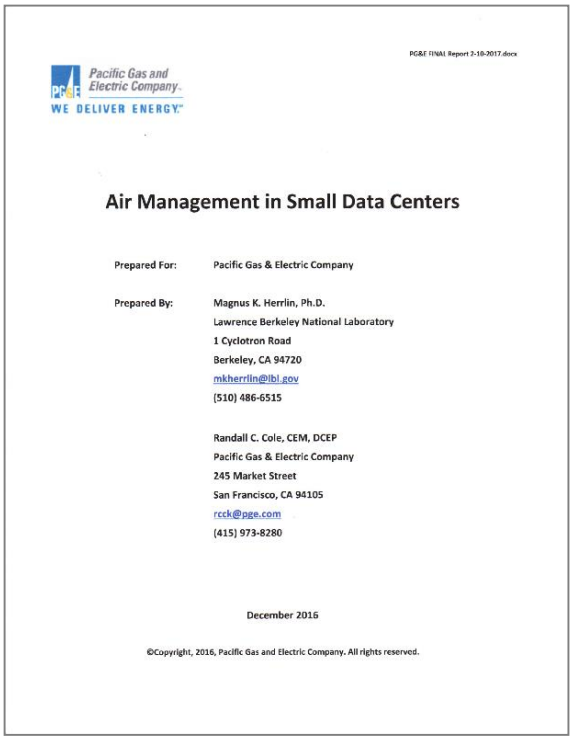
PacketPower, E302/306/312:

"Accurate and Flexible Tool"

Download report "Demonstration: Portable Air Management Measurement Tools" at datacenters.lbl.gov

R&D: Air Management "Packages"

- LBNL and PG&E have developed prescriptive "packages" of air management measures to help remove first-cost barriers.
- Methodology:
  - Define typical small data center
  - Select simulation tool
  - Define the packages
  - Determine energy savings.
- Demonstration (on-going)
  - Refine the "packages".



PG&E FINAL Report 2-10-2017.docx

Pacific Gas and Electric Company
WE DELIVER ENERGY

Air Management in Small Data Centers

Prepared For: Pacific Gas & Electric Company

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December 2016

Report available at:
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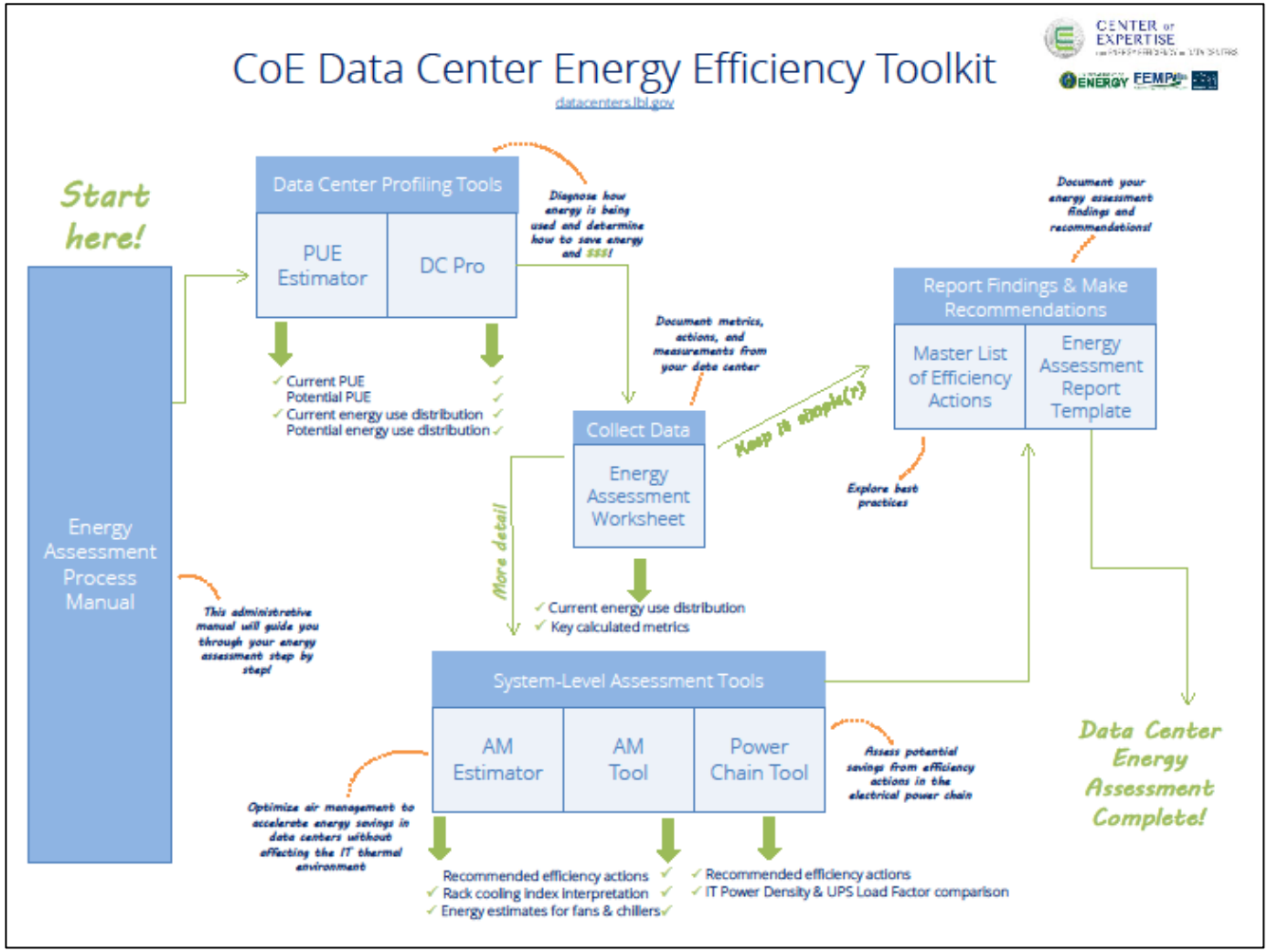
Energy Efficiency: The Bigger Picture



datacenters.lbl.gov/tools/coe-resources-toolkit

Summary

- Understand importance of air management
- Monitor and control server intake temperatures
- Ensure thermal compliance using metrics
- Enable savings with cost-effective air management measures
- Realize savings by adjusting supply temp and/or airflow
- Recognize the CoE air management resources
  - DCEP certificate training
  - Webinars
  - Software tools
  - Tool demonstrations
  - R&D
  - The bigger picture.

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References and Resources

- Center of Expertise
datacenters.lbl.gov

- DCEP Website
datacenters.lbl.gov/DCEP

- DOE Air Management Tools
datacenters.lbl.gov/Tools

Questions

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- https://www.wbdg.org/continuing-education/femp-courses/femplw09262018b

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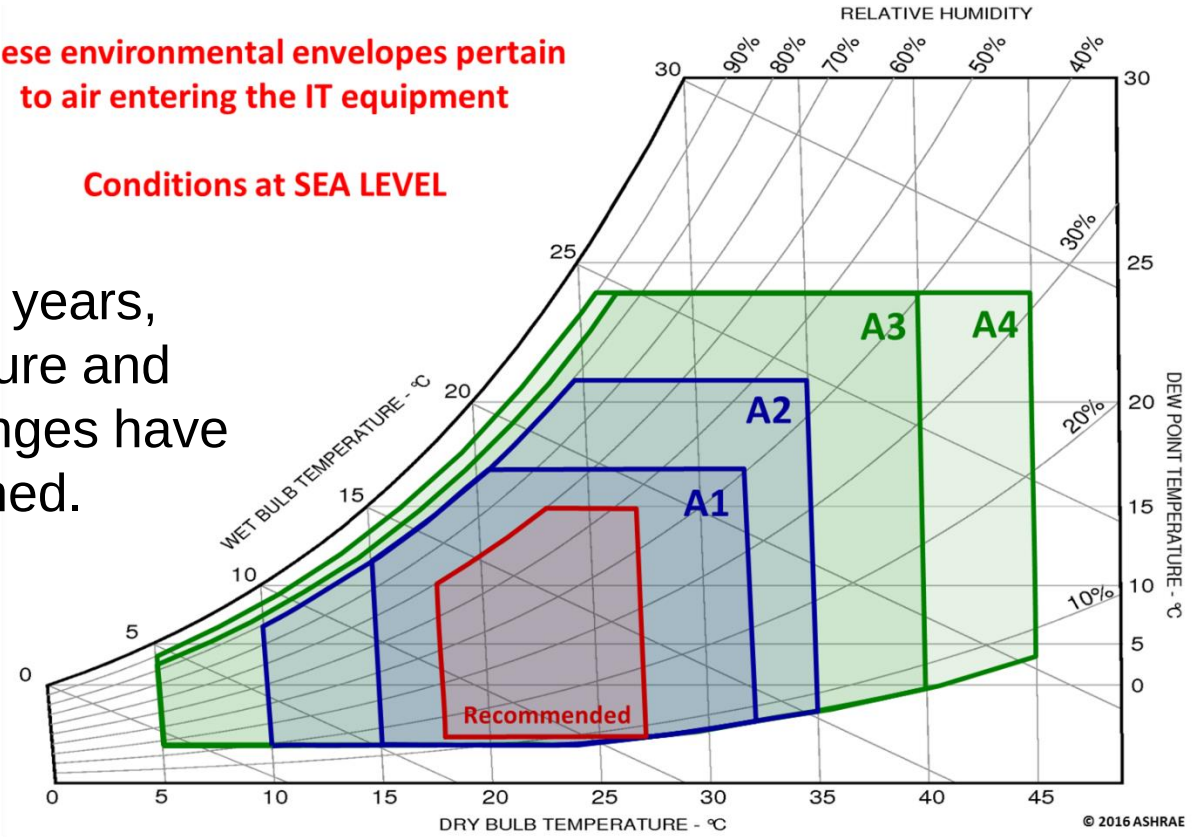
- For content-related questions after the webinar, please use the Contact Us form on the Center of Expertise website: datacenters.lbl.gov/contact
- For any of your Data Center needs, please feel free to contact FEMP/LBNL – rachel.shepherd@ee.doe.gov or mkherrlin@lbl.gov

ASHRAE 2015 Specifications (°C)

Over the years, temperature and humidity ranges have widened.



41°F 50°F 59°F 68°F 77°F 86°F 95°F 104°F 113°F

ASHRAE 2015. Special Publication, Thermal Guidelines for Data Processing Environments. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.