U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Air Management 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

Outline

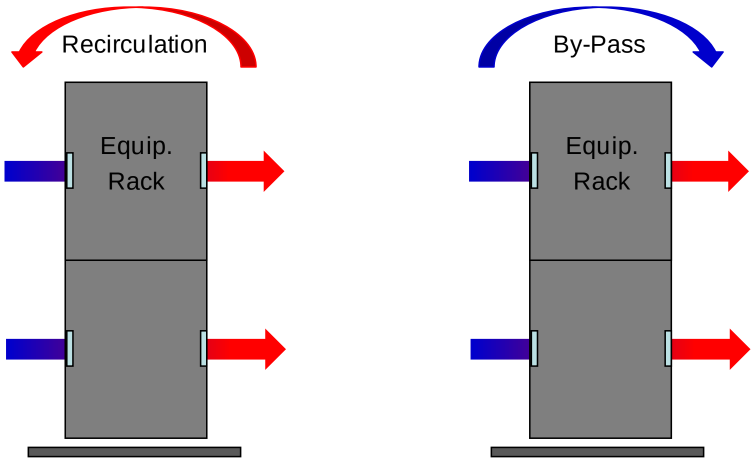
- Learn Basic Air Management "Best Practices"
- Detect Common Problems
- Correct Common Problems.

Although this webinar provides only an overview of Air Management, knowing the basics allows detecting many common problems. And, the ability to detect problems is the initial step towards correcting them.

The DCEP training program provides a more in-depth look at Air Management
http://datacenters.lbl.gov/dcep

What is Air Management?

The goal of Air Management is to minimize mixing of hot and cold air streams by minimizing air *recirculation* of hot air and minimizing *by-pass* of cold air in the data center room. Successfully implemented, both measures result in energy savings and better thermal conditions.



Air Management Goals and Results

Goals

- Raise supply air temperature
- Lower supply airflow rate
- Maintain (or improve) server conditions.

Results

- Improving chiller efficiency
- Reducing fan energy
- Ensuring server conditions
- Enhancing economizer utilization.

Importance of Air Management

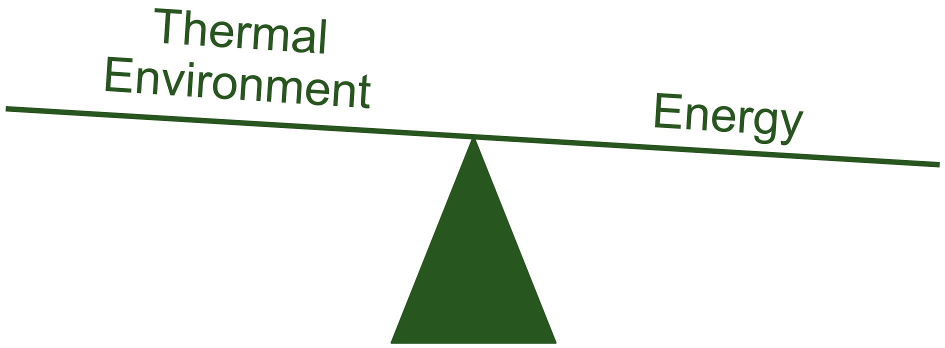
Energy Management. Air Management reduces operating costs (OPEX) by enhancing economizer utilization, improving chiller efficiency, and reducing fan energy.

Thermal Management. Adequate thermal conditions (server intake temperatures) are important for the reliability and longevity of IT equipment.

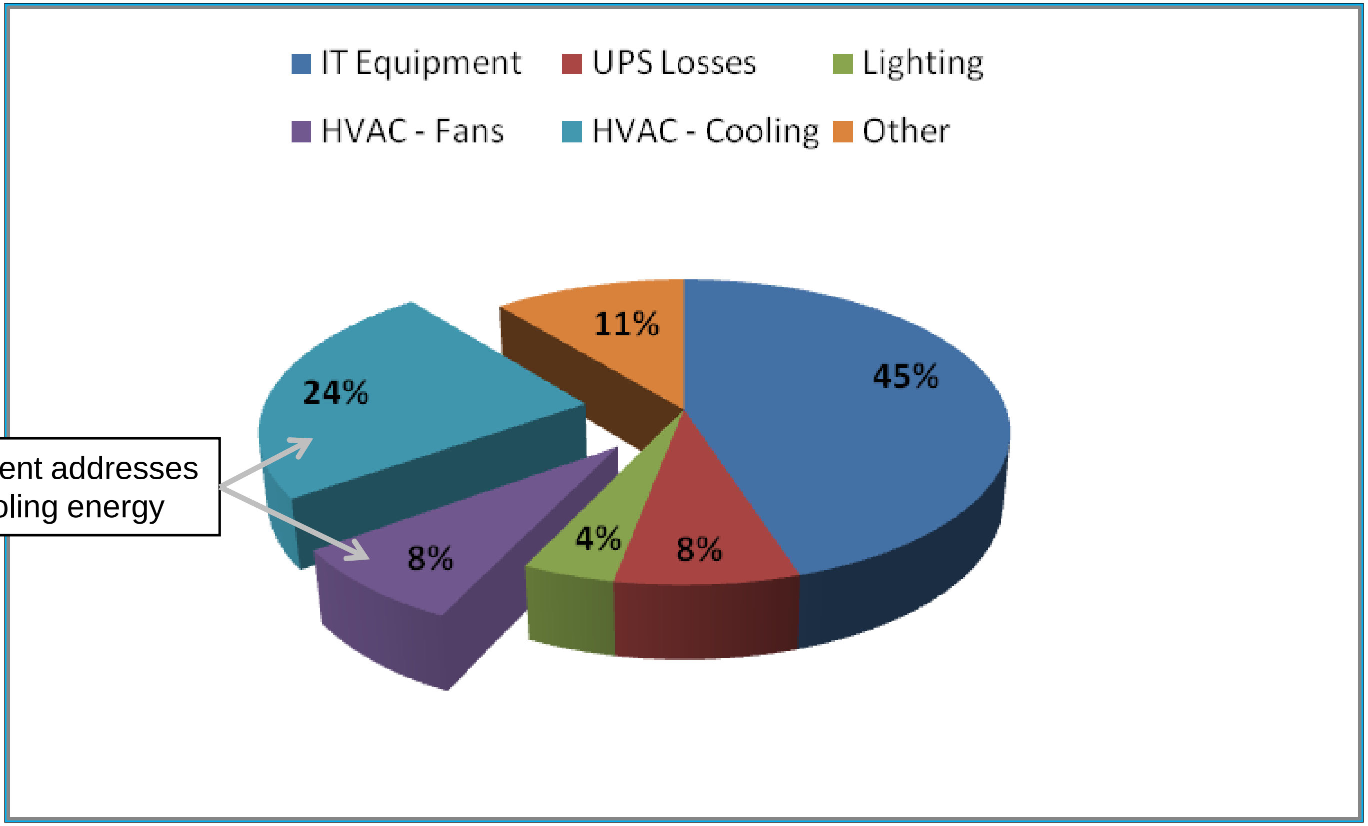
Capital Management. Air Management reduces capital investments (CAPEX) for cooling equipment, air-moving equipment, and real estate.

Energy vs. Thermal Performance

One significant difference compared to most other energy-efficiency measures is that air management may impact the thermal server environment. Energy-efficiency measures can only be considered after the conformance with the thermal specification has been demonstrated.



“Typical” Data Center Power Allocation

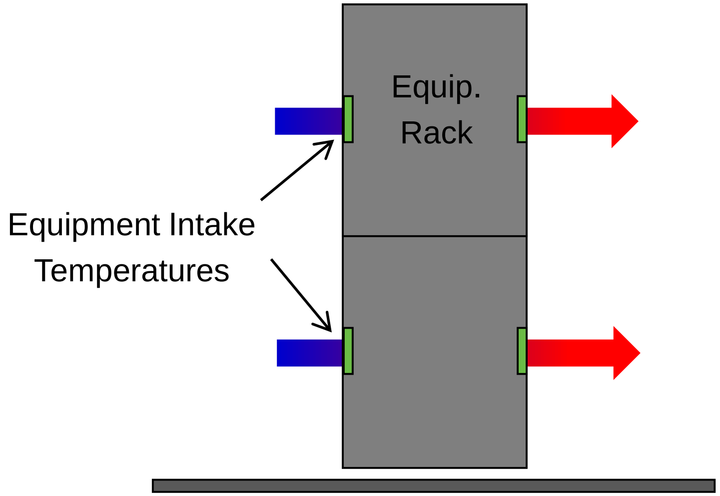


Air Management addresses fan and cooling energy

Source: LBNL Data Center Characterization Project, 2002

Equipment Intake Conditions

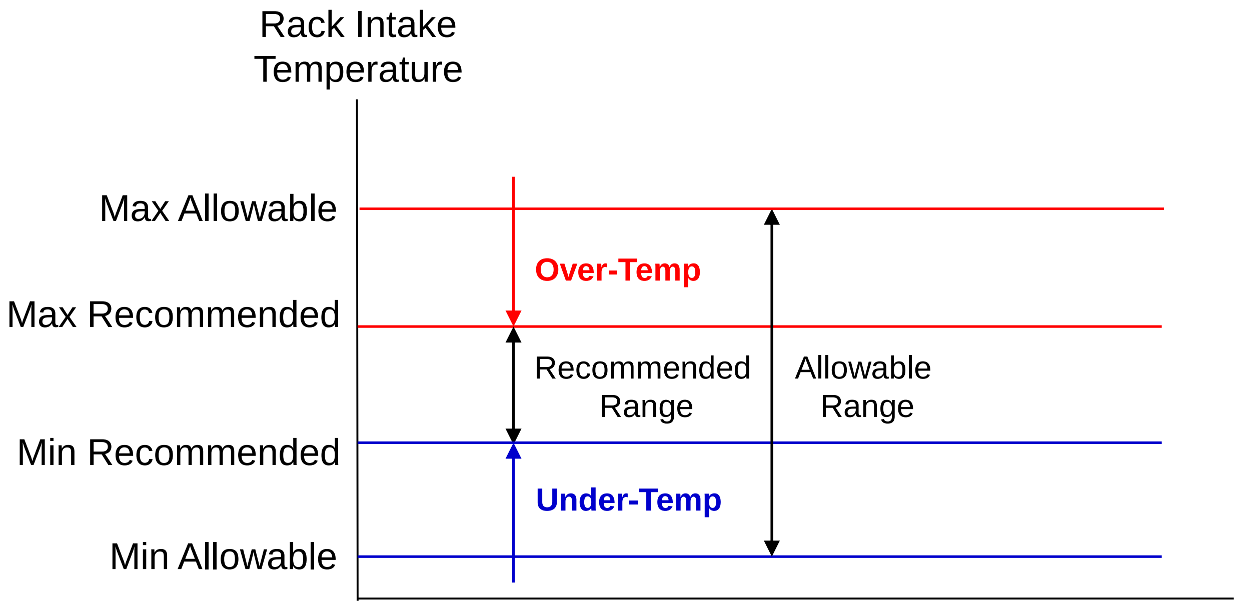
Air-cooled electronic equipment depends exclusively on the *intake* air temperature for effective cooling. Today, most environmental specifications refer to the intake conditions.



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.



Environmental Specifications (°F)

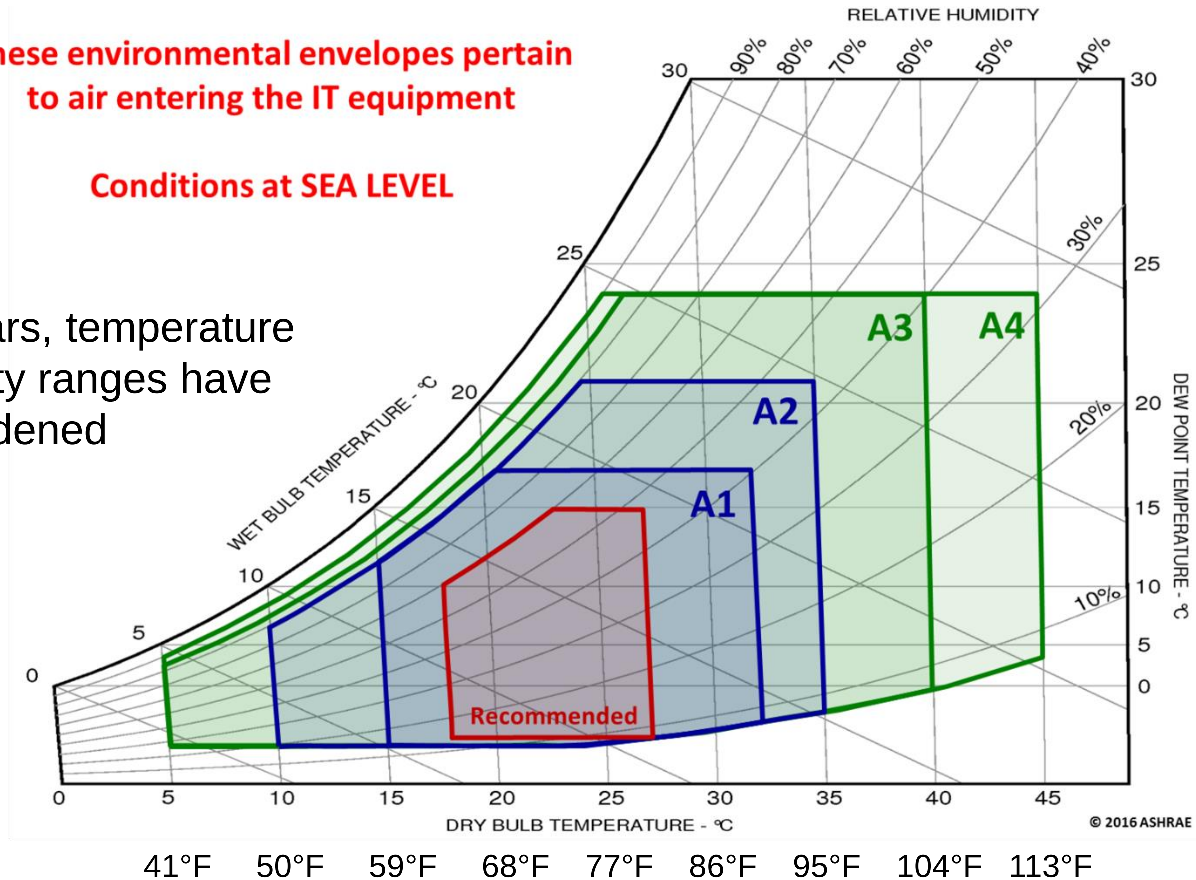
Air intake temperatures (and humidity) for IT equipment within a data center are specified by ASHRAE and Telcordia NEBS. Compliance can be demonstrated with the Rack Cooling Index (RCI).

(@ 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 (RH)		
Data Centers Class A1	16°F DP to 59°F DP and 60% RH	10°F DP and 8% RH to 63°F DP and 80% RH
Telecom NEBS	≤55% (practice)	5 – 85%

ASHRAE Reference: ASHRAE (2015); NEBS References: Telcordia (2012 and 2001)
(ASHRAE Class A1 temperatures are rounded to degree F from degree C)

ASHRAE 2015 Specifications (°C)

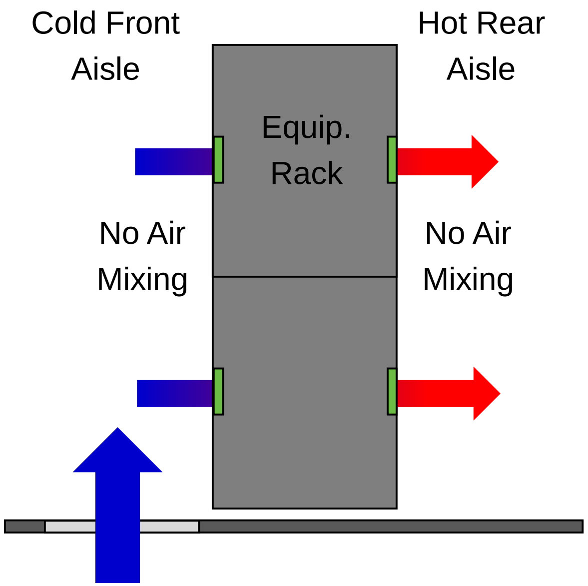
Over the years, temperature and humidity ranges have widened



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

Design for Separation of Cold and Hot Air

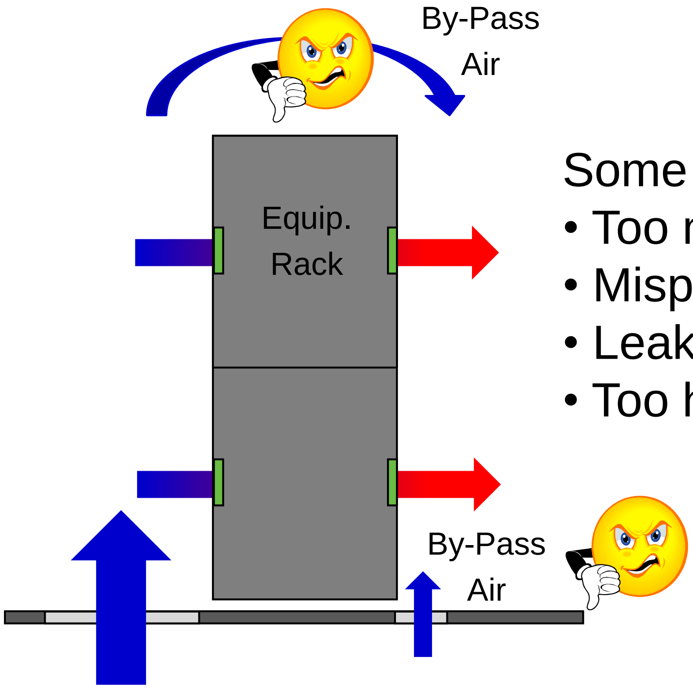
The preferred strategy is to supply cold air as close to the equipment intakes as possible without prior mixing with ambient air and return hot exhaust air without prior mixing with ambient air, i.e., *once-through* cooling.



An optimal server "class" moves air from the cold front aisle to the rear hot aisle, conserving hot and cold aisles.

Key Challenge #1: By-Pass Air

By-pass air does not participate in cooling the gear and should be minimized. At the room level, net by-pass air will always happen when the supply airflow is higher than the IT equipment airflow. At the rack level, however, leakage pathways may be the sole cause.

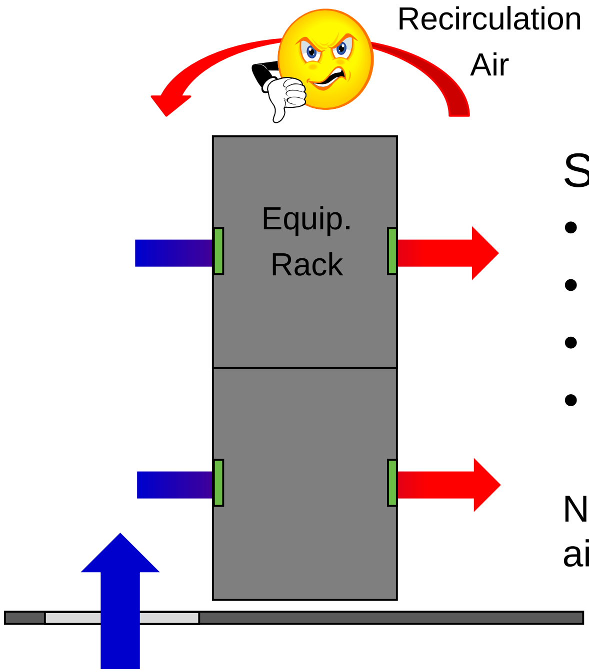


Some common causes:

- 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 will always happen when the supply airflow is lower than the IT equipment airflow. At the rack level, however, leakage pathways may be the sole cause.



Some common causes:

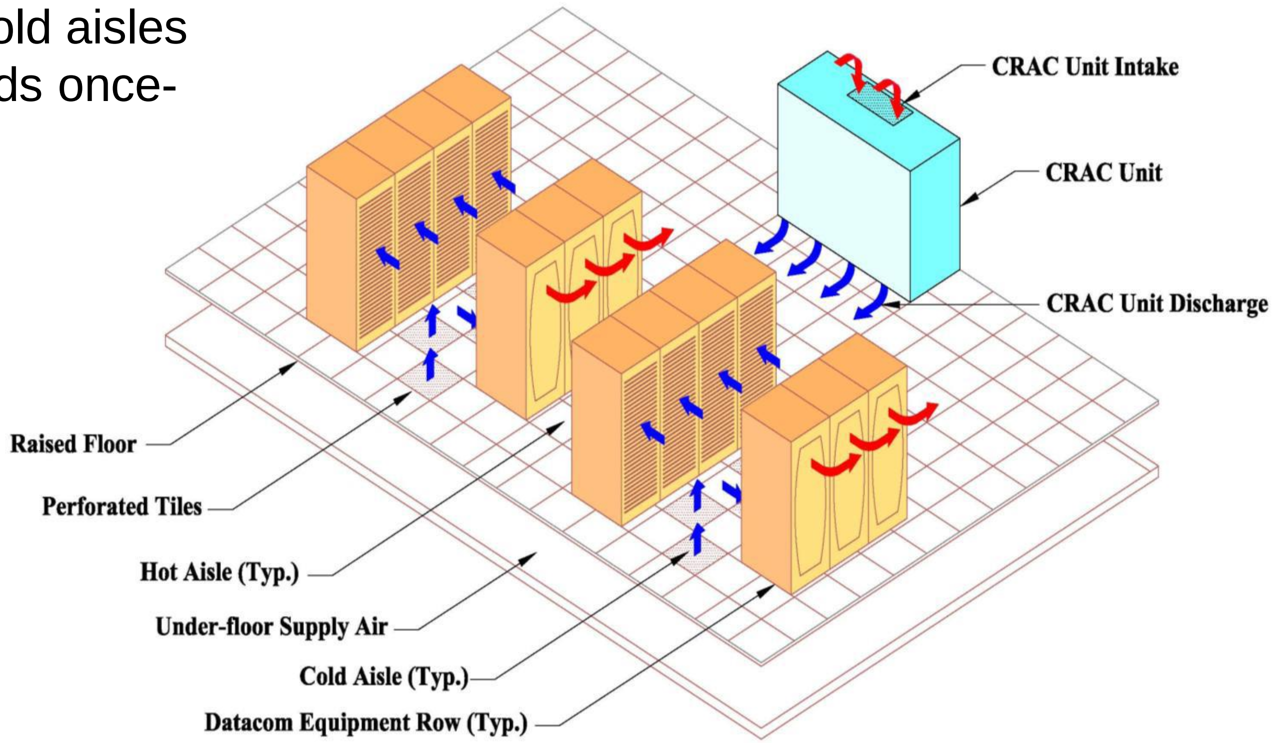
- Too little supply airflow
- Lack of blanking panels
- Gaps between racks
- Short equipment rows.

Note that by-pass air and recirculation air often coexist.

Hot and Cold Aisles

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

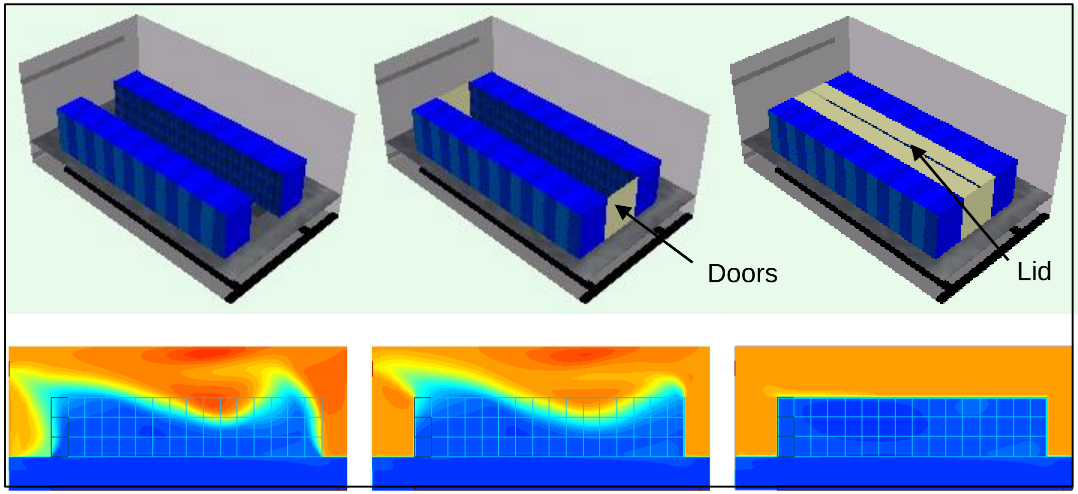
Cold air is supplied into the cold front aisles, the servers move the air from the front to the rear, and the hot exhaust air is returned to the air handler from the hot rear aisles.



Graphics courtesy of DLB Associates

Enhancing Separation of Hot/Cold Air

Physical barriers can be used to enhance the separation of hot and cold air but the placement of barriers must take into account fire codes. Enclosed aisles permit high supply and—in turn—return temperatures.

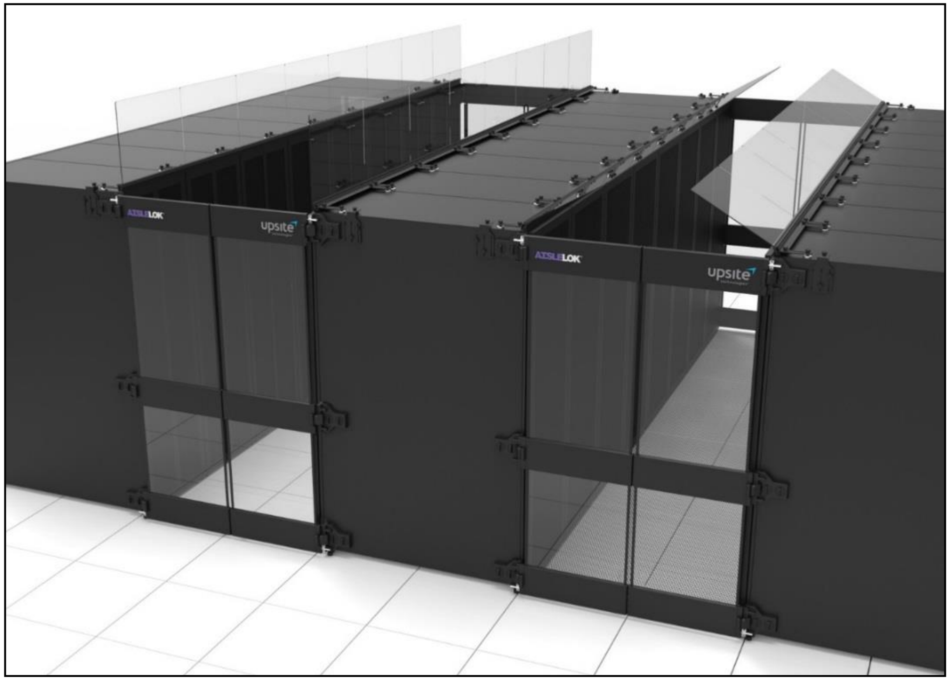


Open
Semi-enclosed cold aisle
Fully-enclosed cold aisle

Graphics courtesy of ANCIS Incorporated

“Enough” Containment

Full containment is not always necessary. Adding baffles above the racks can prevent bypass airflow and/or exhaust recirculation.



Courtesy of Upsite Technologies

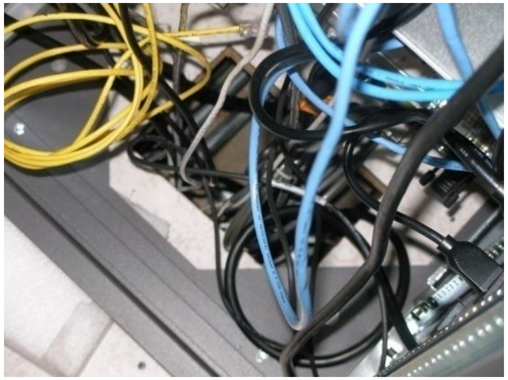
Perforated Floor Tiles/Diffusers

Perforated floor tiles (or over-head diffusers) should *only* be placed in the cold aisles and approximately match the need of the server equipment. As discussed before, too little or too much supply air may result in poor overall operating conditions. The hot aisles are supposed to be hot and perforated tiles should not be placed in those aisles.

A tile/diffuser program should be in place. Over-head diffusers should direct the air downwards (narrow spread) rather than horizontally (wide spread).

Maintain Tight Raised Floors

A large fraction of the air from the air-handler(s) is often lost through leaks in the raised floor. Such leakage often causes by-pass air that does not contribute to cooling the electronic equipment. A rigorous program should be in place to maintain the raised floor.



Unsealed cable penetration in floor under equipment rack

Picture courtesy of ANCIS Incorporated

Grommet

Picture courtesy of Upsite Technologies

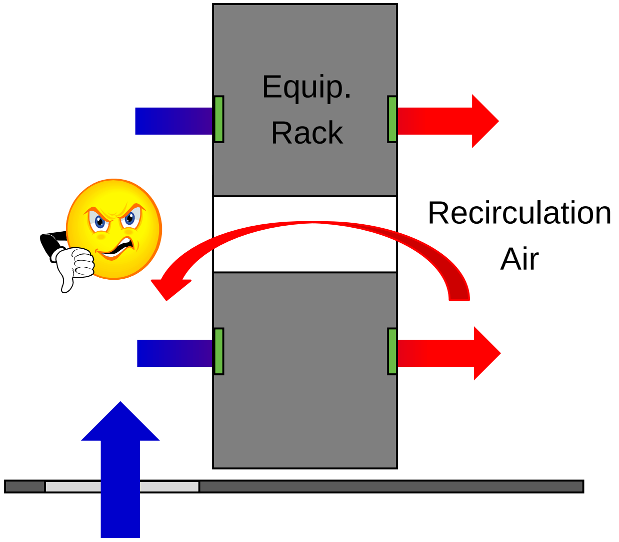
Cable Congestion

Cable congestion in raised-floor plenums can sharply reduce the total airflow as well as degrade the airflow distribution through the perforated floor tiles. No cable trays should be placed below the perforated tiles. It is generally quite obvious when there is too much “stuff.”

Pictures courtesy of ANCIS Incorporated

Managing Blanking Panels

Managing blanking panels and unbroken equipment lineups is especially important in hot and cold aisle environments. *Any* opening between the aisles will degrade the separation of hot and cold air. A rigorous program should be in place to maintain the panels.



Two Blanking Panels
Courtesy of Upsite Technologies

Air Balancing

When changes are made to the electronic equipment inventory, the air-distribution system needs eventually be rebalanced. A system out of balance results in a degraded thermal equipment environment and often higher airflow rates and energy costs to combat hot spots. Relatively high pressure drops at the *diffuser level* improve the chances for a successful balancing.

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 accomplished by 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 frequency drives (VFDs) should be used for fans. The power input to a fan is proportional to the cube (ideal situation) of the speed of the device.
  - A decrease of 10% in fan speed results in a 27% decrease in energy consumption
  - A decrease of 20% in fan speed results in a 49% decrease in energy consumption.
- Turning off constant air volume (CAV) fans only results in a linear relationship between airflow and energy consumption. Also, turned-off units without backdraft dampers will serve as pathways for by-pass air.

Benefits of Performance Metrics

- Show Conformance
- (Real-Time) Monitoring
    - Trending
    - Reporting
    - Benchmarking
- Show Performance
- Design Specification
- Product Development

Metrics in the DOE Air Management Tools

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

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

Determining the Compliance and the RCI

The thermal specifications become truly useful when there is an objective way of determining the compliance; the Rack Cooling Index (RCI) compresses the intake temps 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

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

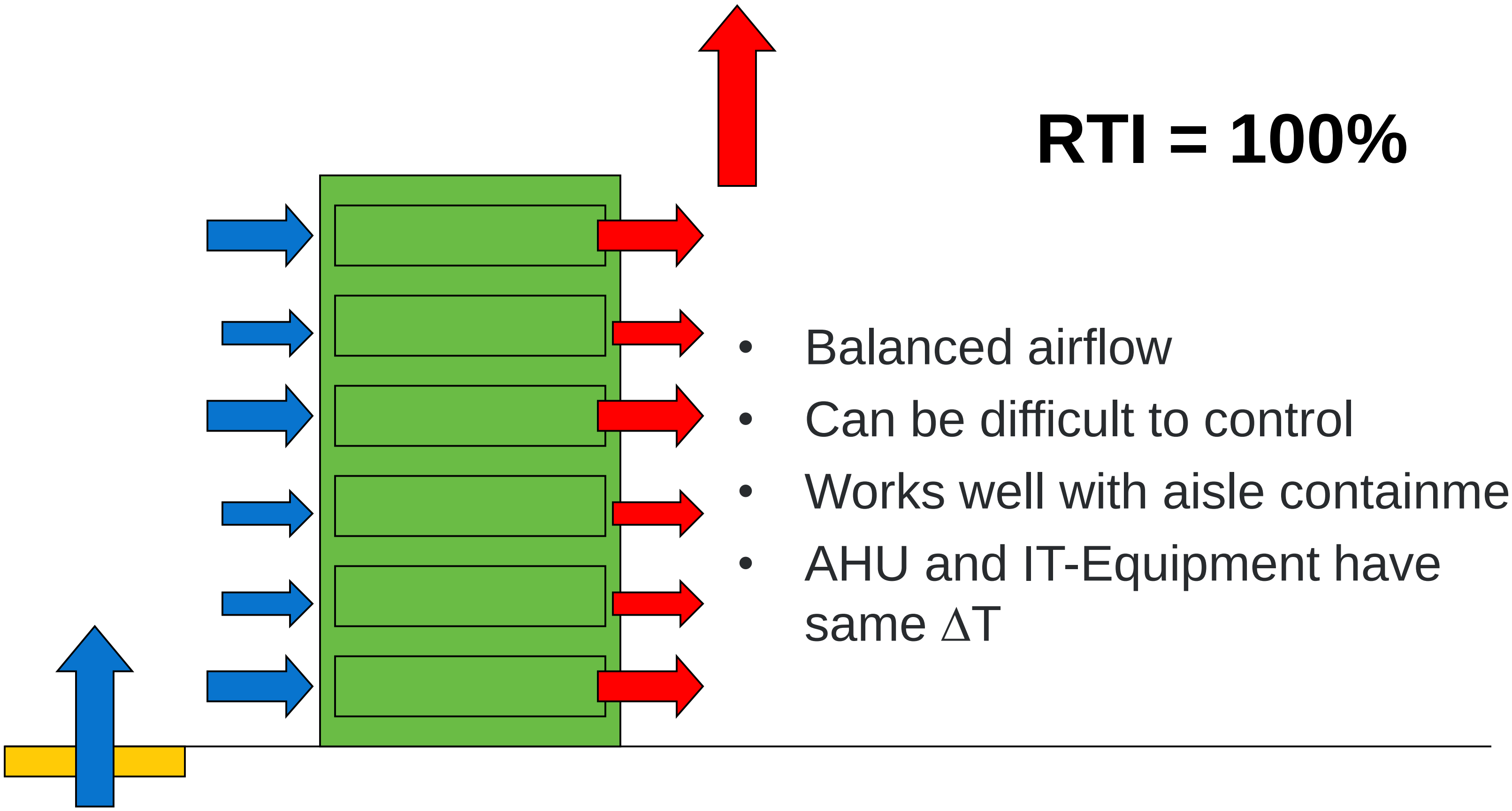
Airflow Requirements and the RTI

- Typically, more air is delivered by the cooling system than is drawn into the electronic 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
- Evaluate the airflow from the computer room air conditioners compared to the need of the electronic equipment (RTI metric)
- RTI is a measure of net by-pass or net recirculation air. It is the ratio of total equipment airflow to total air-handler airflow.

Interpretation:

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

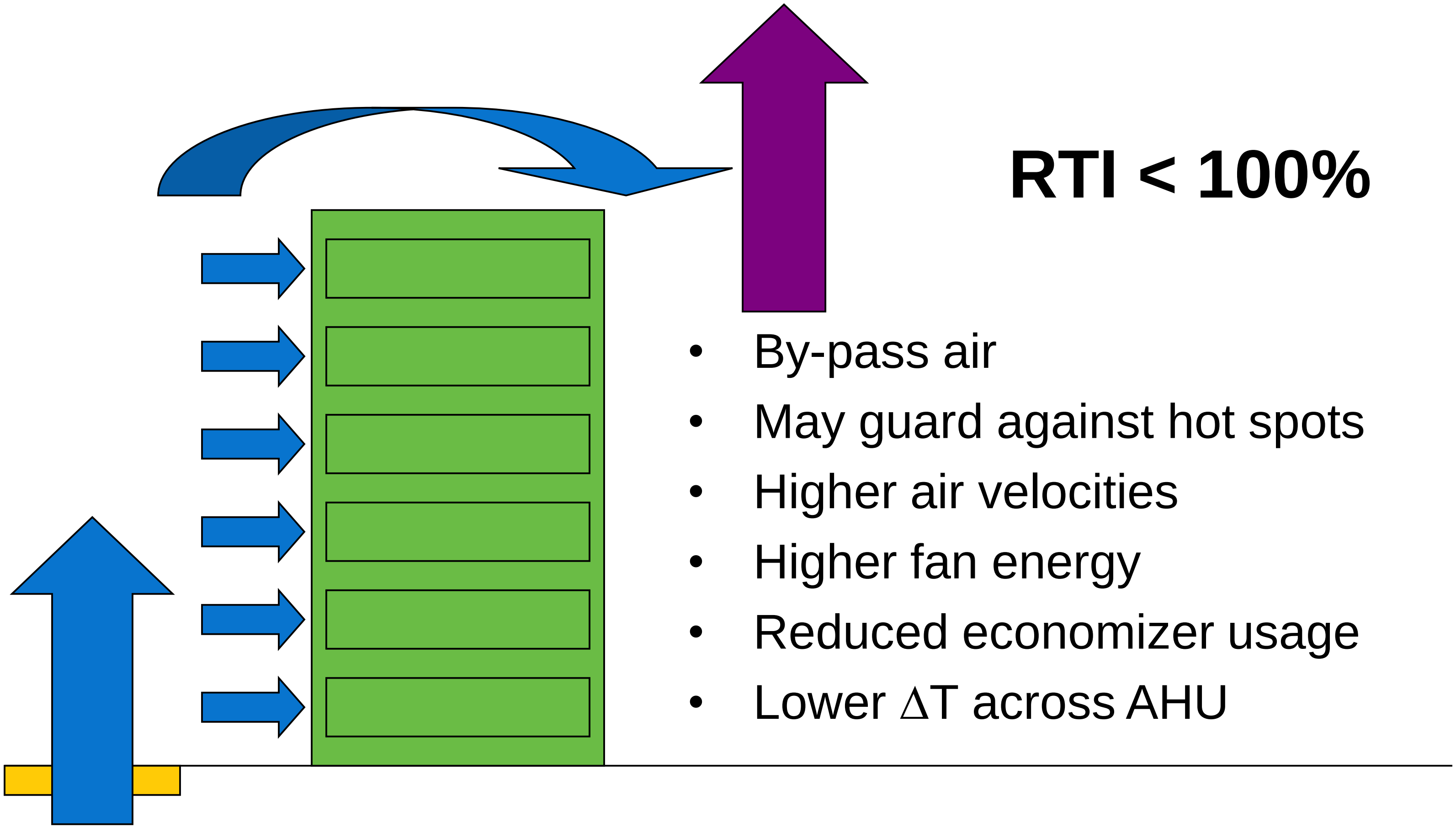
HVAC Airflow Equal To IT Airflow



RTI = 100%

- Balanced airflow
- Can be difficult to control
- Works well with aisle containment
- AHU and IT-Equipment have same ΔT

HVAC Airflow Higher Than IT Airflow



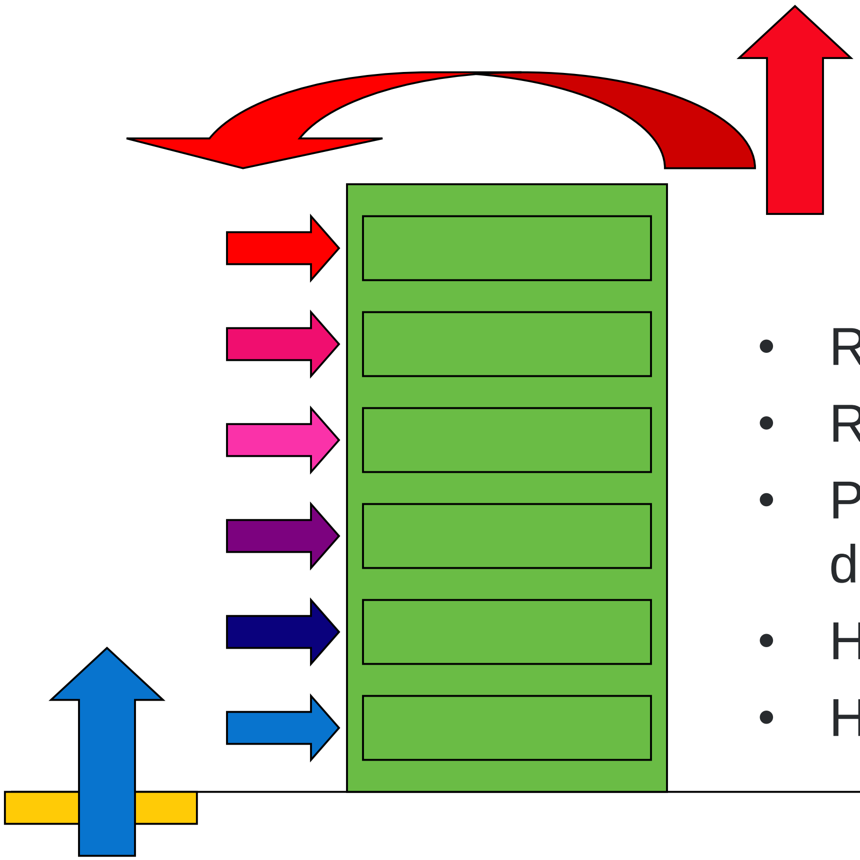
RTI < 100%

- By-pass air
- May guard against hot spots
- Higher air velocities
- Higher fan energy
- Reduced economizer usage
- Lower ΔT across AHU

By-Pass Air: Energy and Thermal Implications

More supply airflow is required as the by-pass air is *in addition to* the server airflow requirements. Although by-pass air increases the operational costs (higher fan operating costs), it may safeguard against elevated thermal conditions. Reducing the by-pass air may also help regain stranded cooling and airflow capacity.

HVAC Airflow Less Than IT Airflow



RTI > 100%

- Recirculation air
- Risk for hot spots
- Possible equipment failure or degradation
- Higher hot aisle temperature
- Higher ΔT across AHU

Recirculation: Energy/Thermal Implications

Recirculation air leads to less control of the equipment intake conditions; the implications may be reduced reliability and longevity. Local “hot spots” may lead to a perceived need to increase the *overall* supply airflow (higher fan energy) or reduce the supply temperature (lower chiller efficiency and less opportunity for air-side and water-side economization).

Liquid Cooling Solutions

There is a number of liquid cooling solutions that shorten or even eliminate the air path, including the following:

- Modular in-row cooling units placed directly in the server rack lineups. They allow higher supply temperatures, which could reduce energy usage
- Modular cooling units placed over the cold aisles or over the server lineups can be used with traditional raised-floor systems for high-density loads
- Rear-door heat exchangers often neutralize the hot exhaust air to near ambient conditions. These exchangers could reduce the cooling equipment footprint.

Air-Management Controls

- Air-management controls:
  - Temperature (IT equipment intake/exhaust, supply/return)
  - Humidity
  - Airflow.
- Use centralized controls rather than distributed; limit AHU infighting (temperature and humidity)
- Calibrate the sensors (implement calibration program)
- Commission the controls thoroughly.

Temperature/Airflow Controls

- 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)
  - At 77°F [25°C] two-speed/variable-speed server fans may speed up.
- Retrofit air handlers with variable frequency drives (VFD)
- 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.

Data Gathering

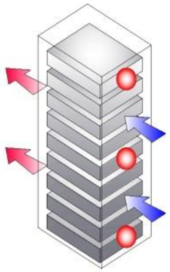
Examples of Data Sources

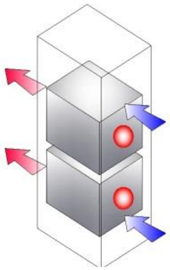
- Real-Time Data
- Measurements
- IT-Manufacturers On-Line Calculation Tools
- IT-Manufacturers Thermal Reports
- Nameplate Data

Temperature Measurements

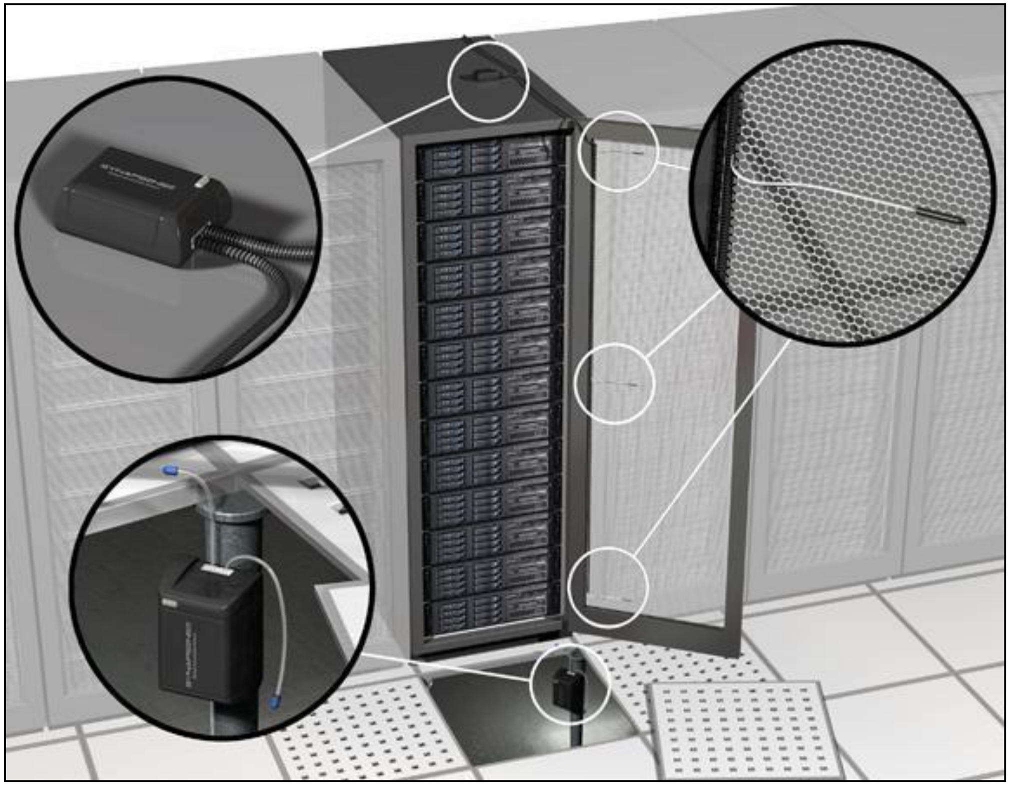
- Critical temperature readings:
  - AHU Supply/Return: Determine ΔT_{AHU} to calculate RTI
  - Rack Intake: To calculate RCI
  - Rack Intake/Exhaust: Determine $\Delta T_{Equip.}$ to calculate RTI.

- At the racks, the quantity and location of the measurement points depend on the content of the rack. It is important that the measurement points coincide and are flush with the equipment intake openings.





Temperature Sensor Network



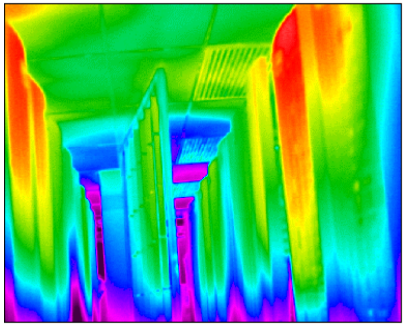
Graphics courtesy of SynapSense (Panduit)

Infrastructure Management (DCIM) Tools

- DCIM tools monitor, measure, manage and/or control data center utilization and energy consumption of all IT-related equipment (such as servers, storage, and network switches) and facility infrastructure components (such as power distribution units [PDUs] and Computer Room Air Conditioners [CRACs]). (Gartner Research)
- DCIM is primarily focused on the monitoring and management of the physical critical systems, such as cooling and power distribution equipment, the physical IT assets, and the supporting infrastructure within the datacenter. (451 Group)

Visualization of Airflow and Temperature

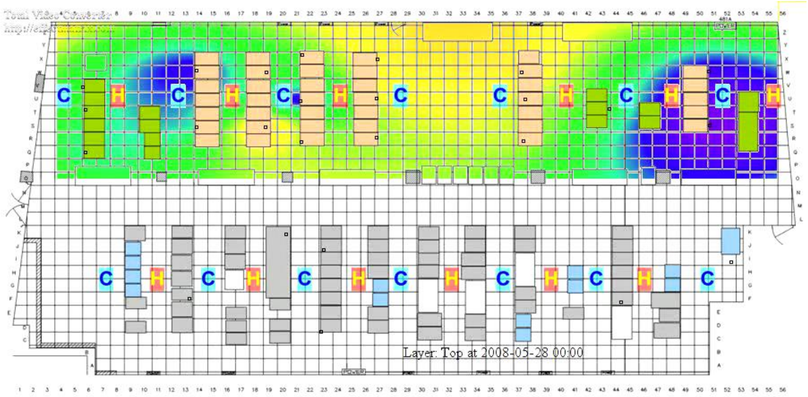
- Computational Fluid Dynamics (CFD) modeling
- Temperature sensor networks
- Infrared thermography.



Infrared

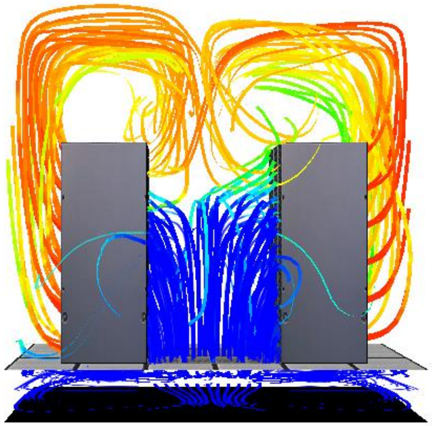
Graphics courtesy of LBNL

Sensor Network



Graphics courtesy of Synapsense

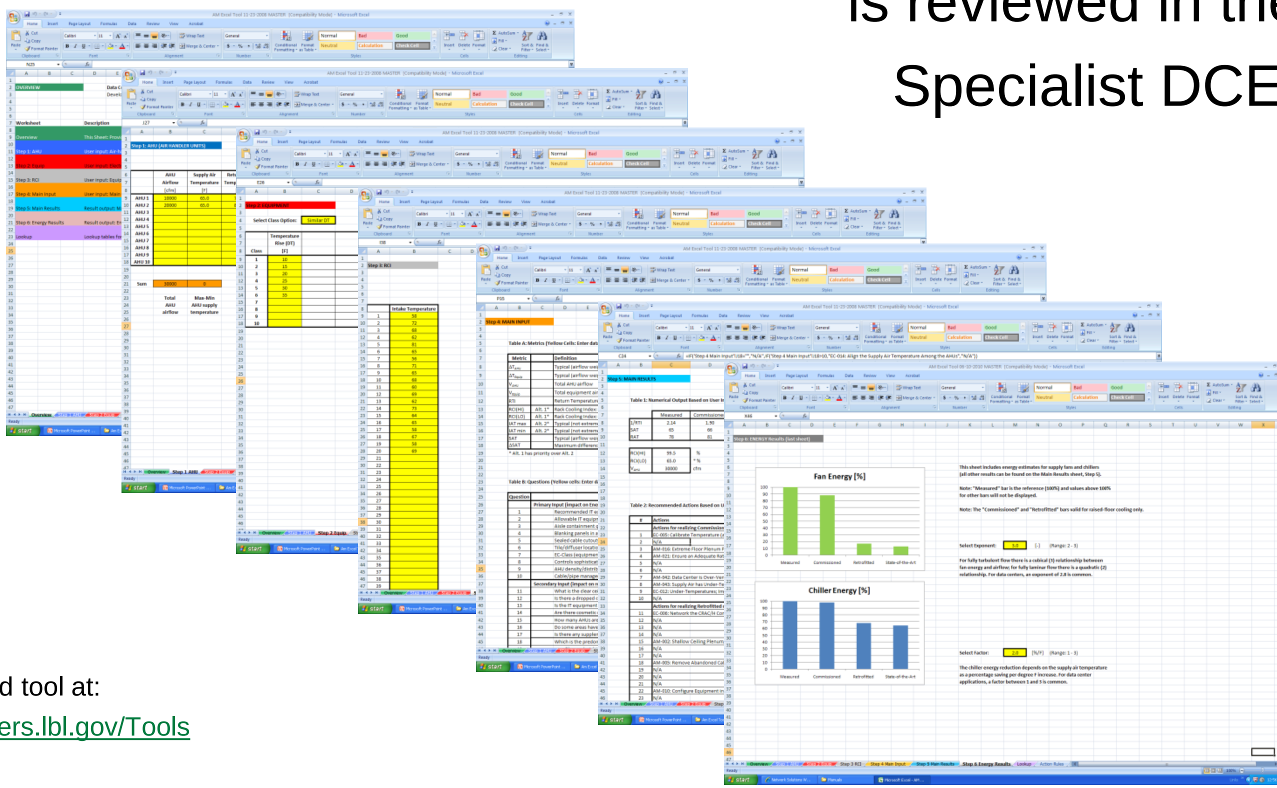
CFD



Graphics courtesy of APC

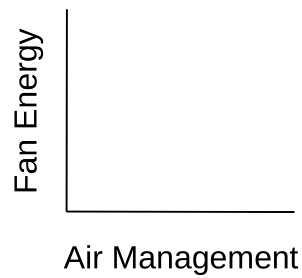
DOE Air Management Assessment Tool

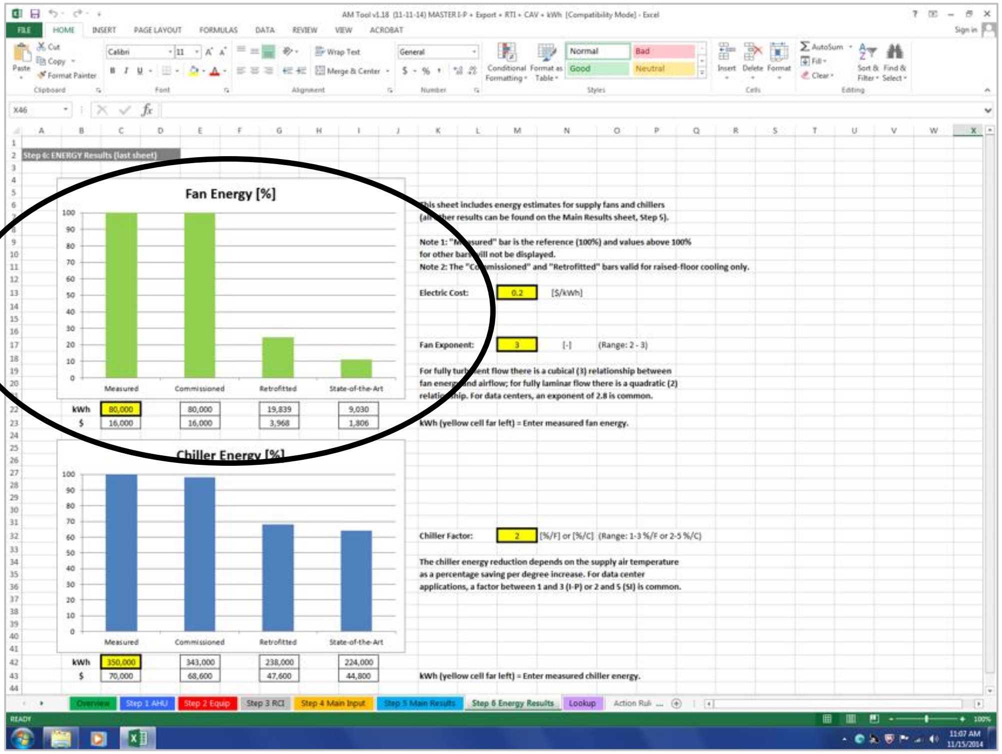
The AM-Tool developed by DOE is a free Excel tool for assessing the data center air-management status. This Tool is reviewed in the in-depth Specialist DCEP training.



Download tool at:
datacenters.lbl.gov/Tools

Fan Energy

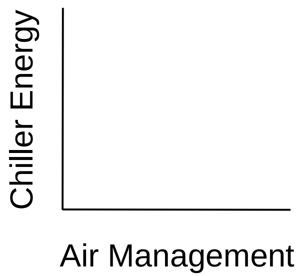


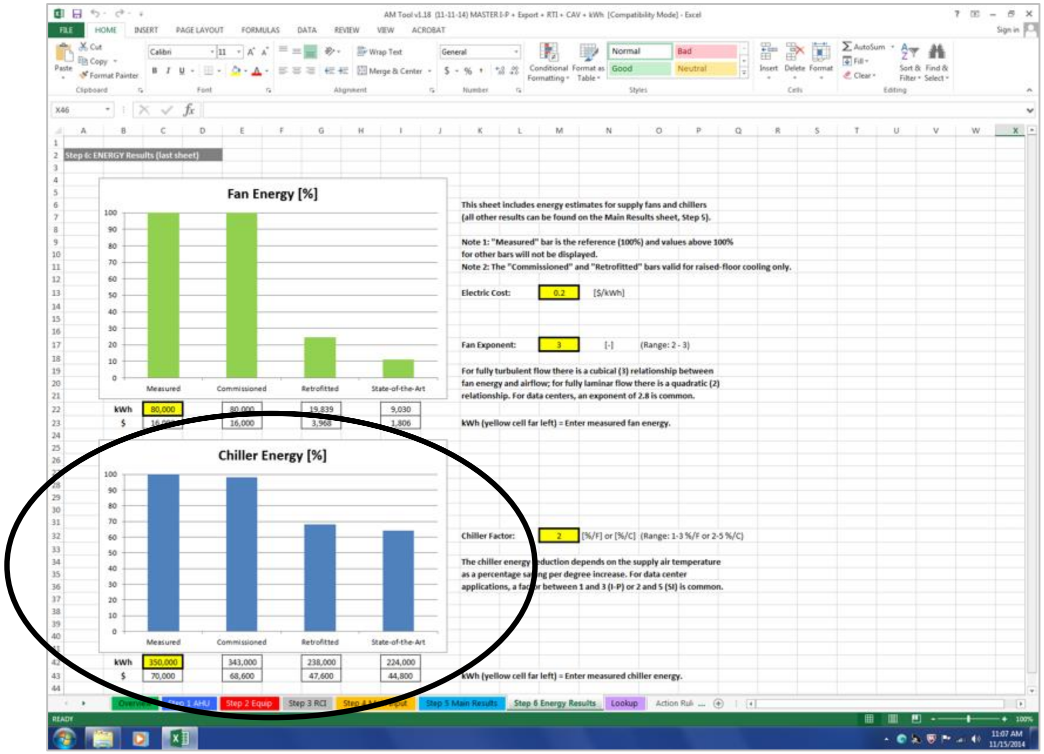


DOE Air Management Tool

Download the Data Center Air-Management Tool at http://datacenters.lbl.gov/Tools

Chiller Energy





DOE Air Management Tool

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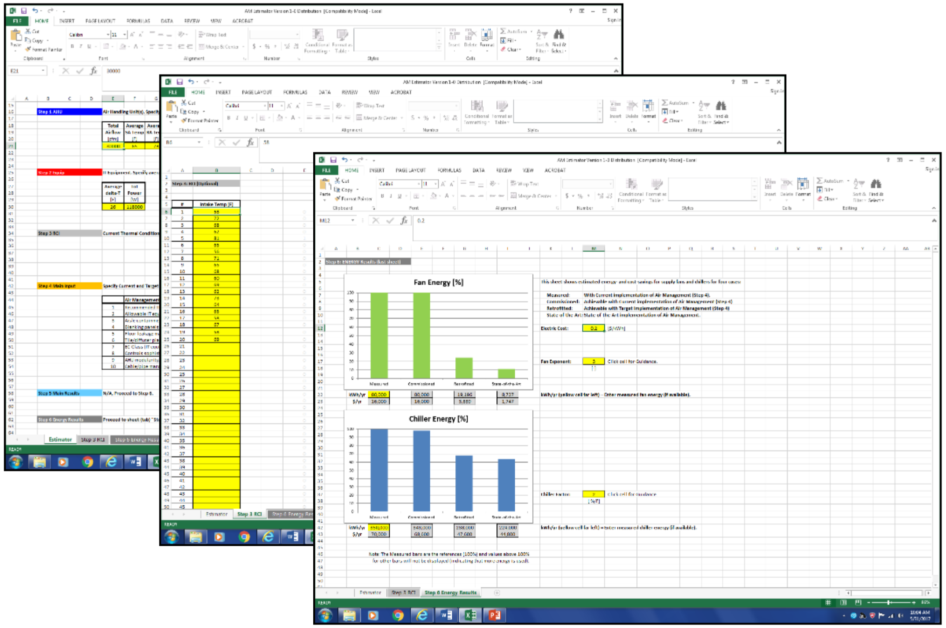
DOE Air Management Estimator

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.



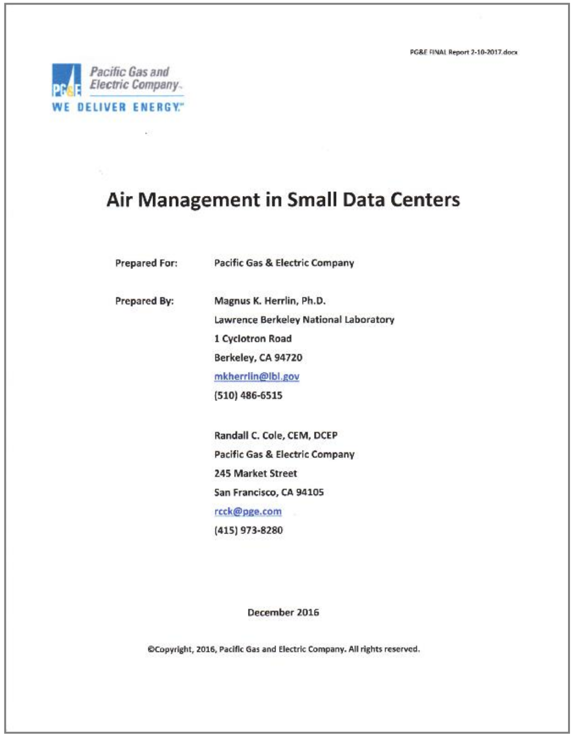
Download tool at:
datacenters.lbl.gov/Tools

Air Management "Packages"

– LBNL and PG&E developed prescriptive "packages" of air management measures through modeling. This work funded by PG&E.

– Methodology:

- Define typical small data center
- Select simulation tool
- Define the packages
- Determine energy savings.


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

Pacific Gas and Electric Company
WE DELIVER ENERGY.

Air Management in Small Data Centers

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December 2016

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Report available at:
http://datacenters.lbl.gov

Air Management Monitoring Tools

LBNL demonstrated two simple tools that can be brought in to check the thermal conditions. This work was funded by FEMP.

Purkay Labs, Audit-Buddy:

"Tool Needs Improvements"

PacketPower, E302/306/312:

"Accurate and Flexible Tool"

Download report "Demonstration: Portable Air Management Measurement Tools" (early 2018) at: http://datacenters.lbl.gov

Summary

- Understand importance of air management
- Monitor and control server intake temperatures
- Select and enforce an environmental specification
- Minimize mixing of hot and cold air (good separation)
- Enable savings by applying air management measures
- Realize savings by adjusting supply temp and/or flow (↑chiller efficiency, ↑free cooling, ↓fan energy)
- Operate near the max recommended intake temp
- RCI metric can be used to ensure thermal compliance
- Recognize the DOE Air Management software.

References and Resources

- DCEP Website
datacenters.lbl.gov/DCEP

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

- ASHRAE Datacom Series of Books
www.ashrae.com

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In order to receive your CEUs; please, go to the following link:

https://www.wbdg.org/continuing-education/femp-courses/femplw04122018

For logistical questions related to the webinar or evaluation, please email Elena Meehan: Elena.Meehan@ee.doe.gov

Questions?

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- Slides will be available at datacenterworkshop.lbl.gov

- For content-related questions after the webinar, please use the Contact Us form on the Center of Expertise website: datacenters.lbl.gov/contact