U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Data Center Toolkit Webinar Series: Part 3 - Air Management

October 7, 2020

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

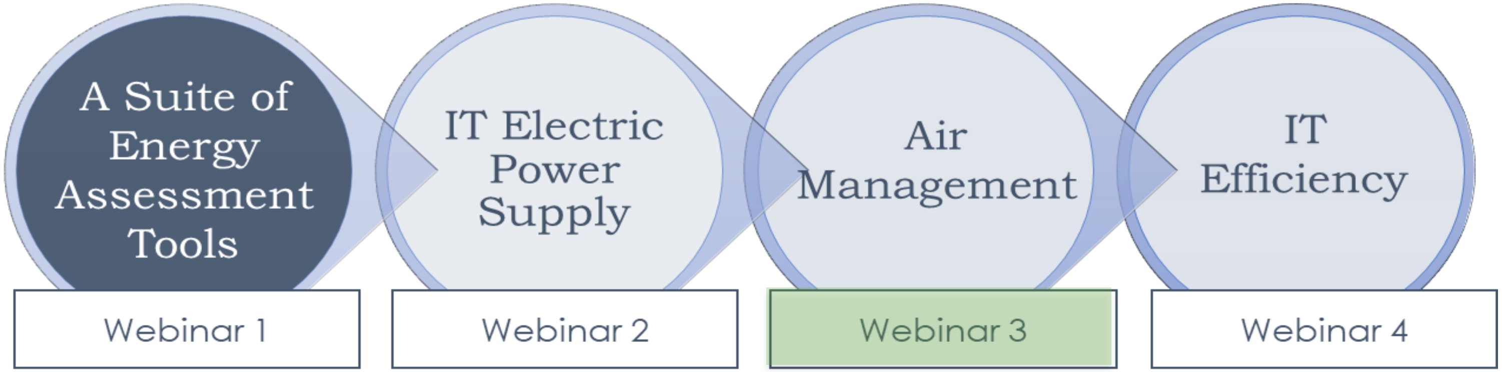
Webinar Agenda

Agenda	
I.	Introduction
II.	Air Management: Challenges and Opportunities
III.	Air Management Tool Suite and Key Metrics
IV.	Resources and Q&A

Learning Objectives

- Airflow and temperature aspects of data center operations, challenges in air management and opportunities to save energy and improve the thermal IT environment;
- Center of Expertise air management tool suite: The Air Management Tool, the Air Management Estimator and the new Air Management Lookup Tables;
- Key data requirements, calculation of two key Air Management metrics, interpretation of those metrics and tool outputs; and
- Ways in which the tool contribute to a concrete plan of action and budget and engender institutional support for retrofits and energy-efficient procurements.

Third in a Four-Webinar Series



View Recording
View Slide Deck
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Held on 9/10/20

Webinar 4: IT Efficiency
December 7 from 1:00 – 2:30 pm EDT
Link coming soon

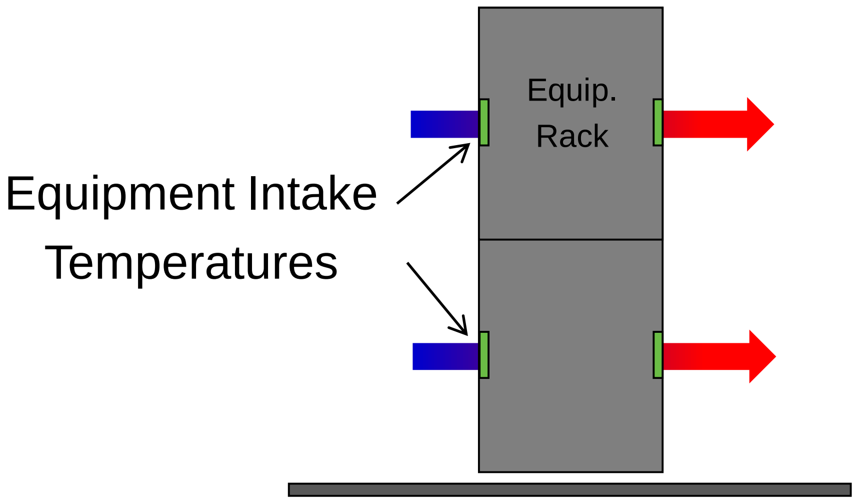
Air Management:
Challenges and Opportunities

First, What is Air Management?

- **Air management in data centers is about keeping cold and hot air from mixing**
  – Cold supply air should enter the heat-generating IT-equipment without mixing with hot air
  – Hot exhaust air from the IT-equipment should return to the air handler without mixing with cold air.
- **Managing the cold and hot air streams is important for cooling infrastructure energy management, IT equipment thermal management, and capital management.**

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.



Temperature Measurements

It is not necessary to collect data for every IT rack. Measuring every other or third rack is generally adequate. The racks at the end of the equipment rows should be included.

Three probes per measured IT rack is recommended. These probes should be placed at three elevations ("knee, hip, and head") directly on the perforated front door to the rack.

For more guidance, please follow the link below.

https://datacenters.lbl.gov/resources/datacenter-air-management-tool-data-collection-guide

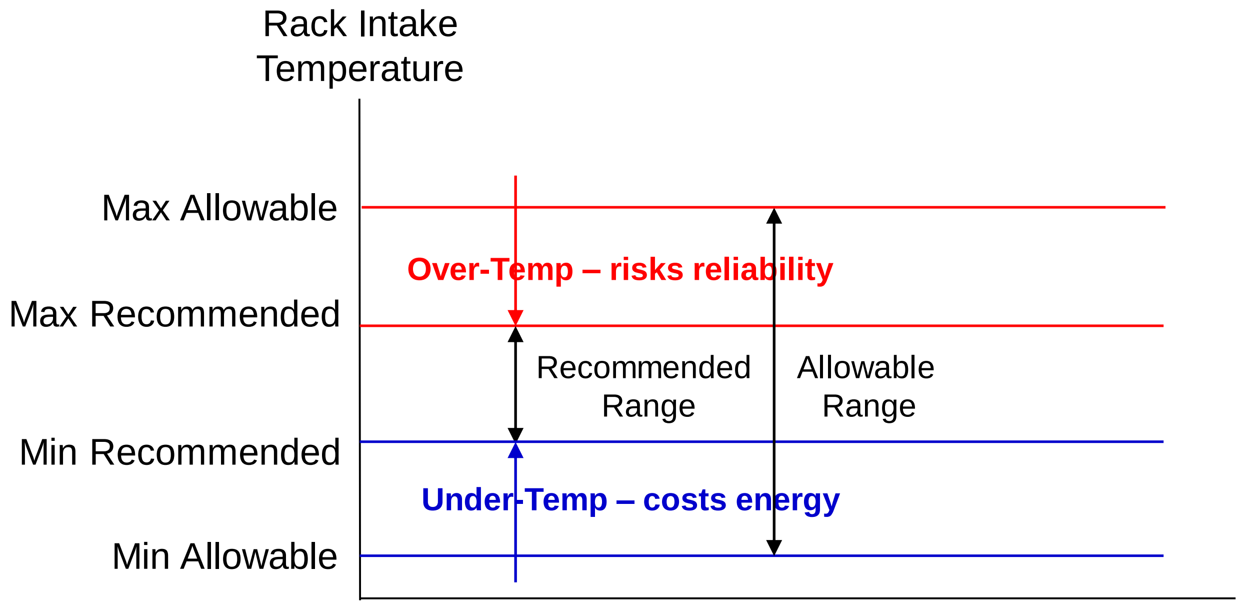
Key Nomenclature

Recommended range (statement of reliability):

Preferred facility operation; most values should be within this range.

Allowable range (statement of functionality):

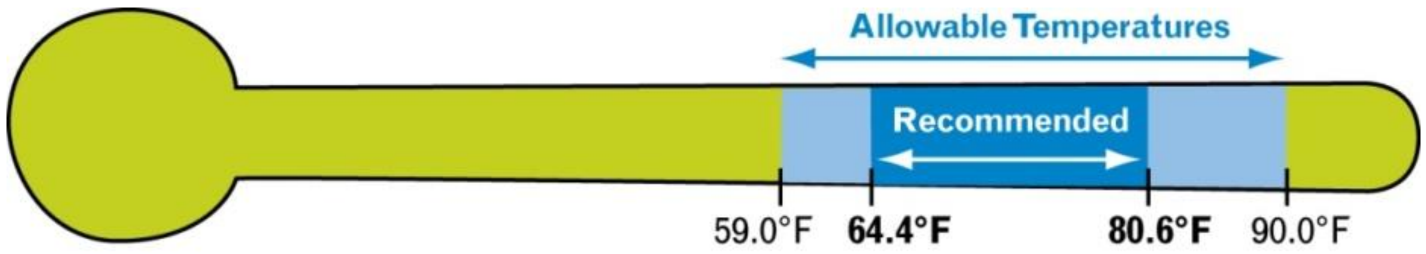
Robustness of equipment; no values should be outside this range.



ASHRAE Environmental Guidelines

- Default recommended range = 64.4 - 80.6F
- Provides guidance for operating above the default upper limit

- Default allowable range = 59.0 – 89.6F (Class A1)
- Six classes with allowable ranges up to 113.0F



Opportunity: Data Center Energy Efficiency

Adopting the ASHRAE or NEBS environmental criteria provides opportunities for reduced cooling energy use.

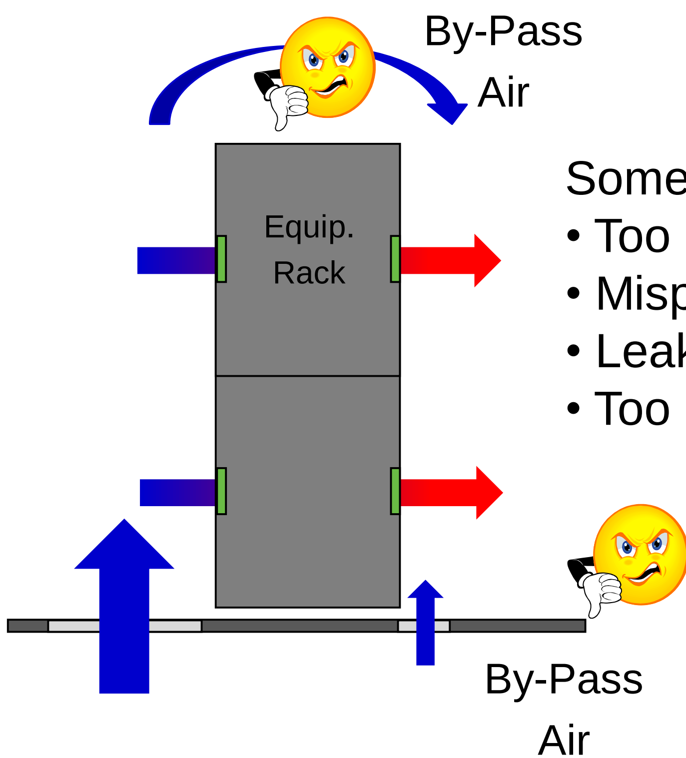
With proper air management, the supply temperature can often be raised well above 65°F (18°C) without negatively affecting the thermal IT environment.

Energy savings can be realized in the following areas:

- Improved chiller efficiency
- Increased economizer utilization (> min. outdoor air)
- Reduced energy for humidification/dehumidification.

Key Challenge #1: By-Pass Air

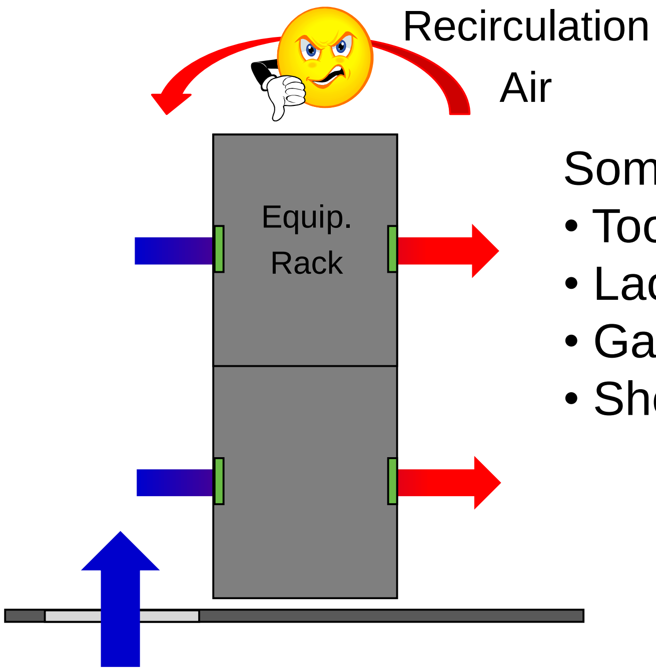
By-pass air does not participate in cooling the gear and should be minimized. At the room level, net by-pass air will always happen when the supply airflow is higher than the IT equipment airflow. At the rack level, however, leakage pathways may be the sole cause.



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

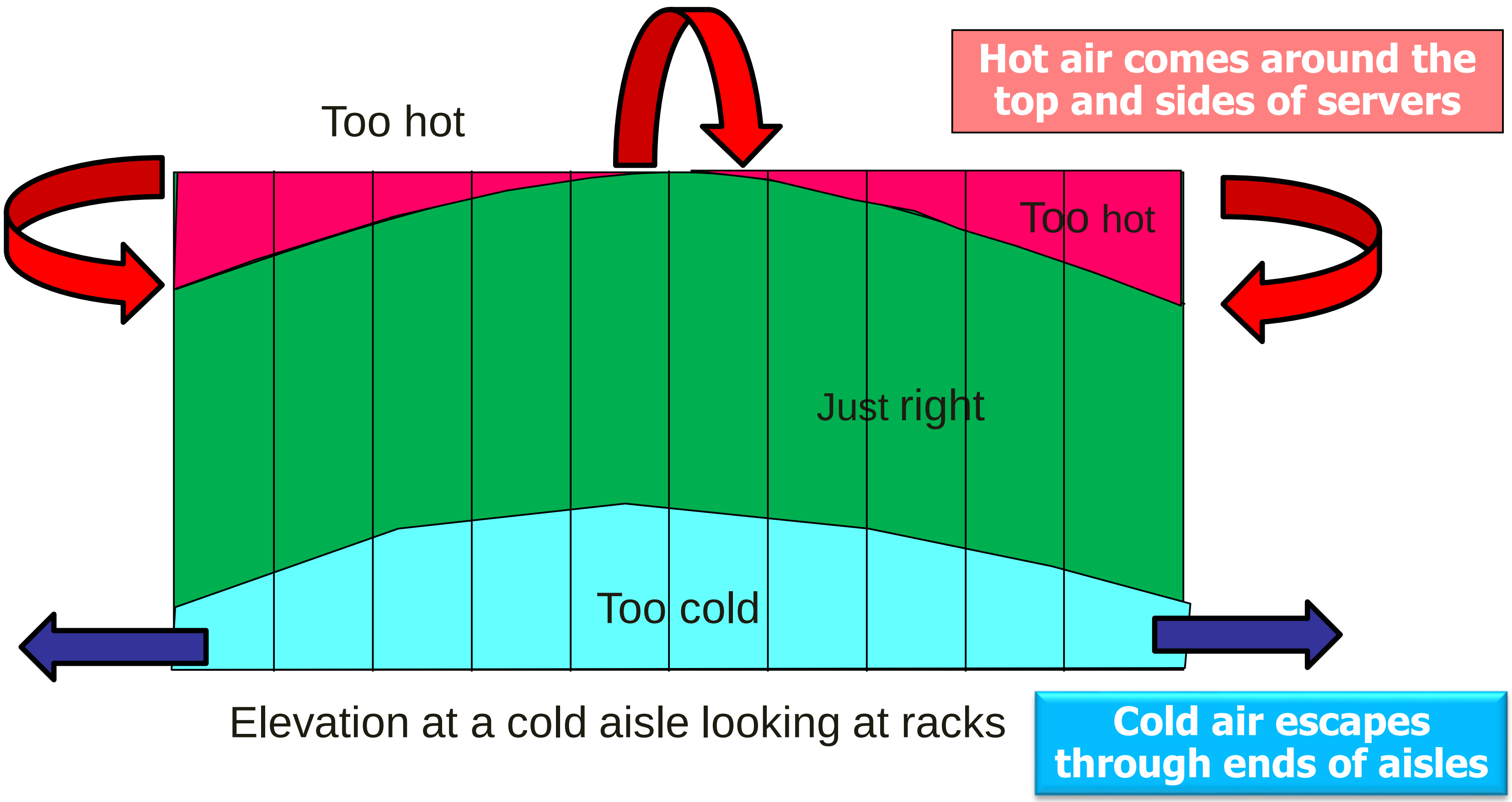
Key Challenge #2: Recirculation Air

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.

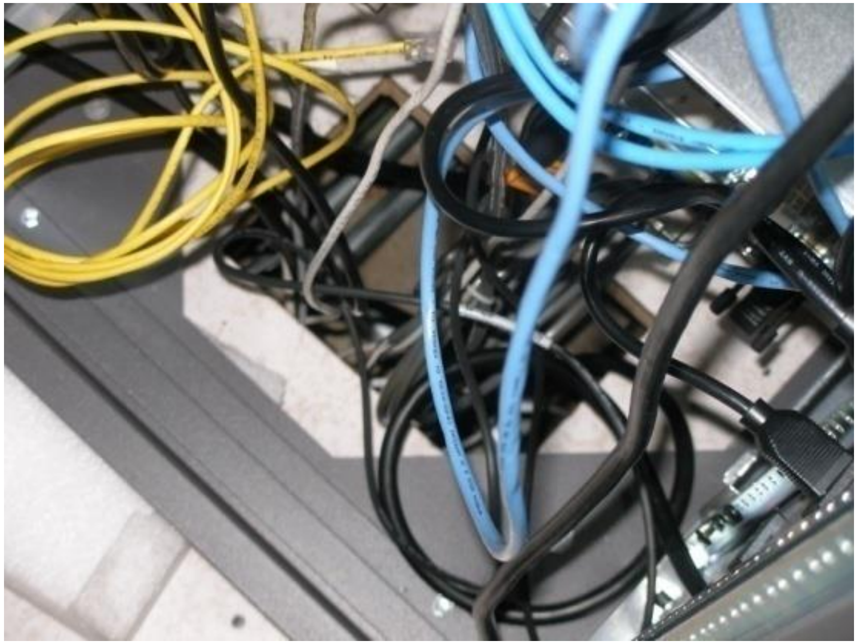
Result of By-pass and Re-circulation Airflow: Typical Temperature Profile of Intake Side of Row with Under-floor Supply



There are numerous references in ASHRAE.
See for example V. Sorell et al; “Comparison of Overhead and Underfloor Air Delivery Systems in a Data Center Environment Using CFD Modeling”; ASHRAE Symposium Paper DE-05-11-5; 2005.

Action: Maintain Raised-Floor Seals

Maintain seals of all potential leaks in the raised floor plenum



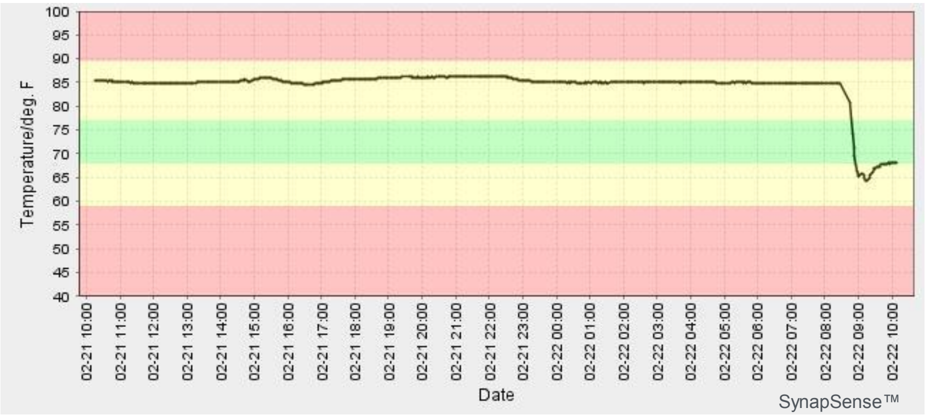
Unsealed cable penetration (inside rack)

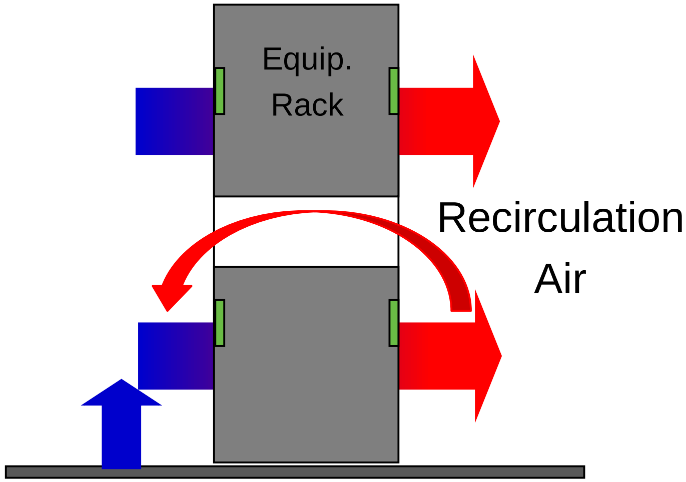
Sealed cable penetration

Action: Manage Blanking Panels

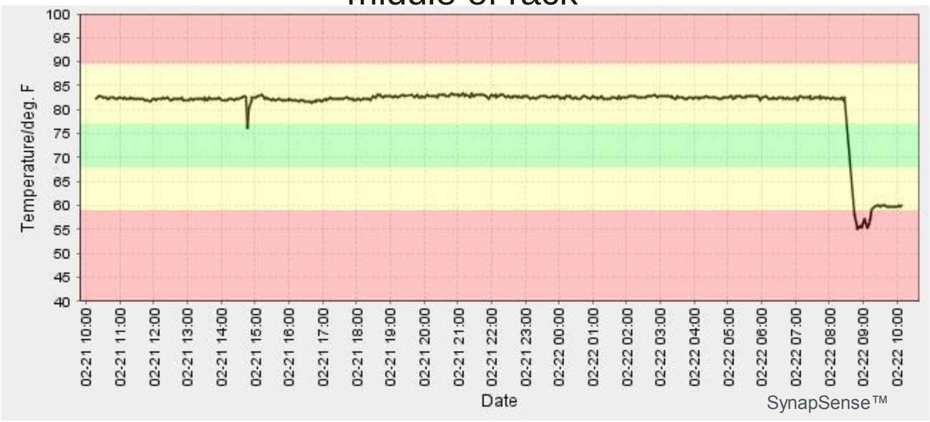
- Any opening will degrade the separation of hot and cold air
- Maintain blanking panels
  - One 12" blanking panel reduced temperature ~20°F

top of rack



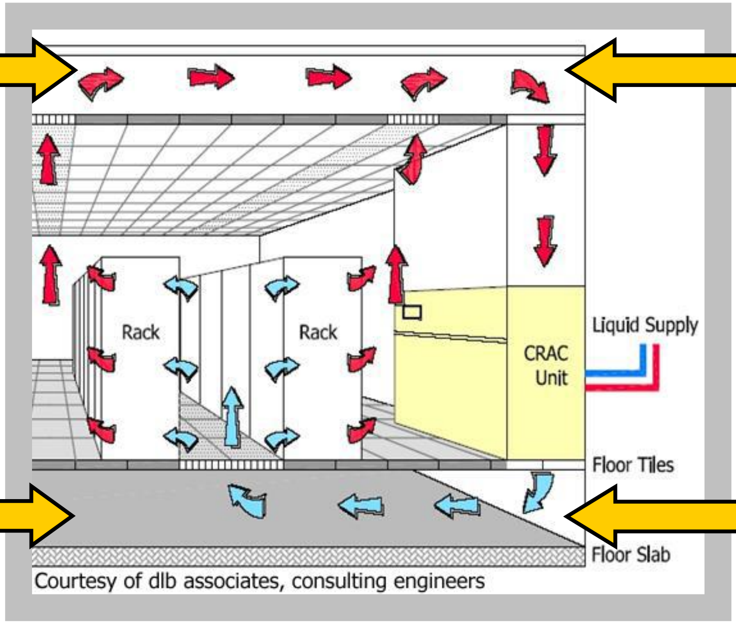


middle of rack

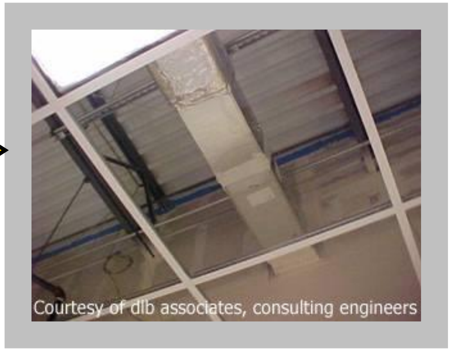


Action: Reduce Airflow Restrictions & Congestion

Congested Floor & Ceiling Cavities

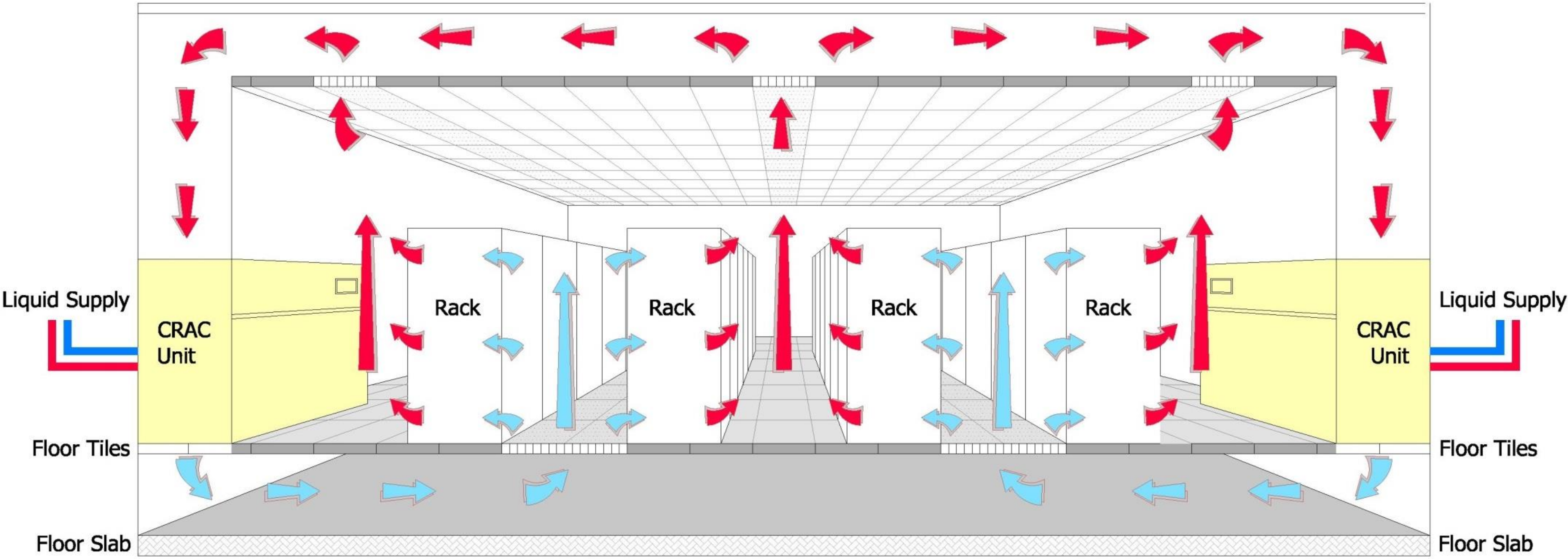


Consider the Impact that Congestion Has on the Airflow Patterns



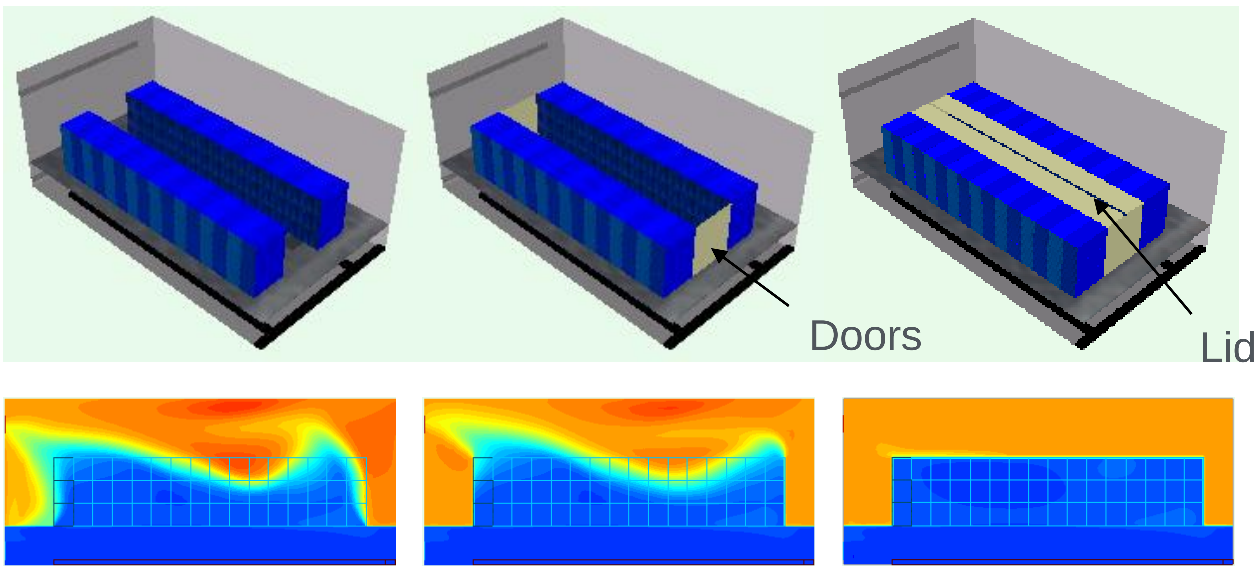
Empty Floor & Ceiling Cavities

Option: Air Distribution Return-Air Plenum



Enhanced Isolation Options

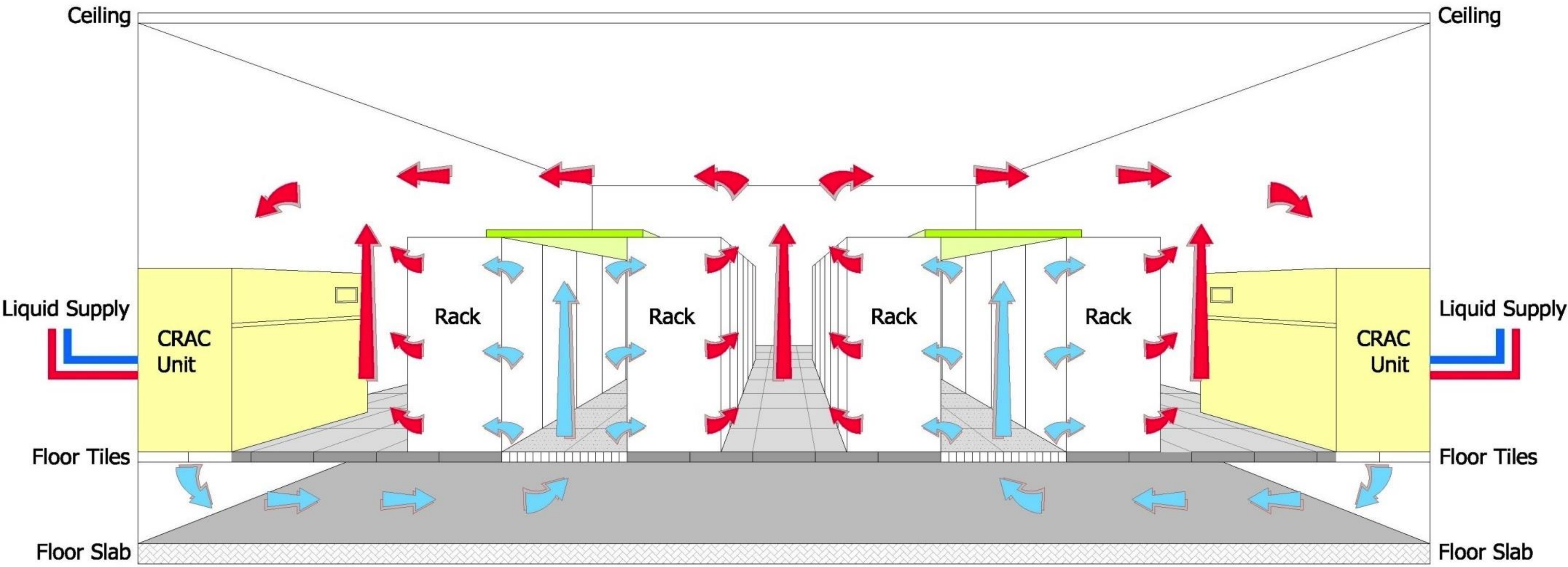
- Physical barriers enhance separate hot and cold airflow
- Barrier placement must comply with fire codes
- Curtains, doors, or lids have been used successfully



Open | **Semi-enclosed cold aisle** | **Enclosed cold aisle**

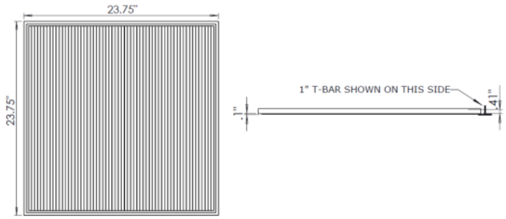
Action: Add Air Curtains for Hot/Cold Isolation

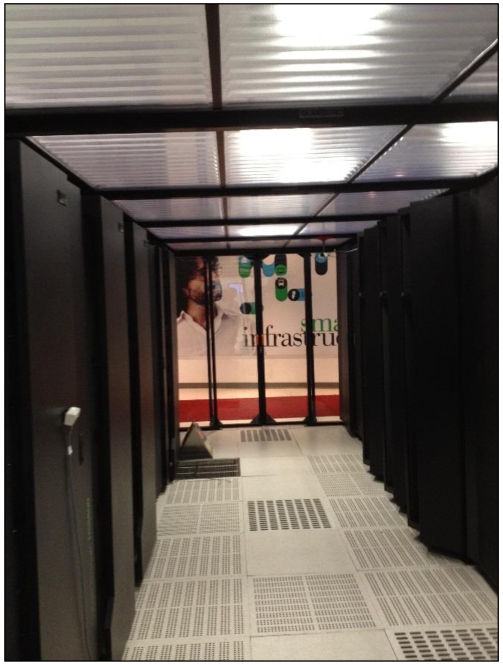
Opportunity: Cold Aisle Containment Example



LBNL's Cold Aisle Containment study achieved fan energy savings of ~75%

Options: Hot or Cold Aisle Containment





Subzero Cold-Aisle Containment

APC Hot-Aisle Containment (with in-row cooling)

Ceilume Heat Shrink Tiles

Key Air Management Metrics

Air Management Metrics

Two metrics are used in the DOE Air Management Tools:

- The Rack Cooling Index (**RCI)** is a measure of compliance with ASHRAE/NEBS temperature specifications. This metric is not a simple ratio. RCI is ≤ 100%.

- The Return Temperature Index (**RTI)** is a measure of net by-pass or net recirculation air in the data center. It is the ratio of total IT equipment airflow to total air-handler airflow.

Air Management Metrics: RCI

Thermal specifications become useful when there is an objective way of determining the operating compliance. The Rack Cooling Index (RCI) is such a metric. It provides a measure of compliance with any air intake temperature specification, e.g., ASHRAE.

No Over-Temperatures

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

Air Management Metrics: RTI

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 generally the driver for over-provisioning the airflow. 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%

Nearly all data centers have by-pass AND re-circulation.

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

Air Management Tool Suite

Air Management Tool Suite

Air management is about keeping cold and hot air from mixing – key to cooling efficiency and IT thermal management.

We will look at three tools for analyzing air management, from the most detailed to the quickest.

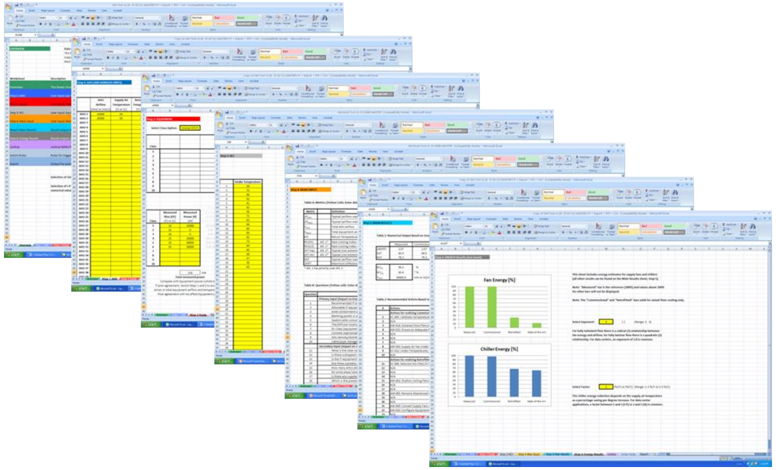
- The Air Management Tool (Excel)
- The Air Management Estimator (Excel)
- The Air Management Lookup Tables.

http://datacenters.lbl.gov/Tools

The Excel Air Management Tool

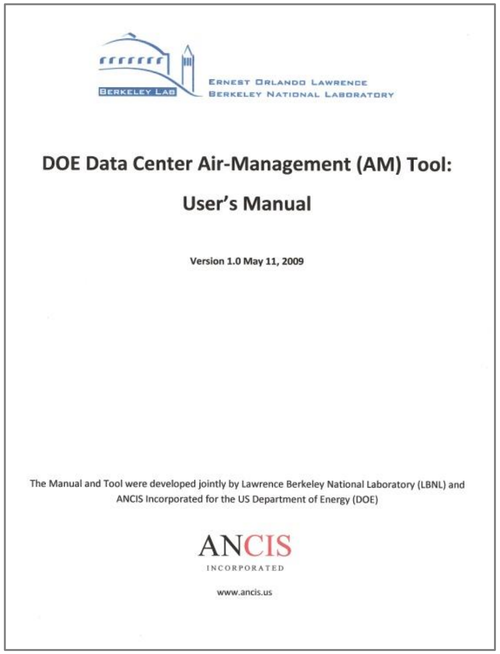
The Excel-based AM Tool was developed to fast-track energy savings in data centers. It provides:

- Potential for reducing supply airflow
- Potential for increasing supply air temp
- Measure conformance with ASHRAE Thermal Guidelines
- Estimates of energy and energy cost reduction for fans/chillers
- Air management recommendations



http://datacenters.lbl.gov/Tools

Tool Documentation


BERKELEY LAB

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

DOE Data Center Air-Management (AM) Tool:

User's Manual

Version 1.0 May 11, 2009

The Manual and Tool were developed jointly by Lawrence Berkeley National Laboratory (LBNL) and ANCIS Incorporated for the US Department of Energy (DOE)

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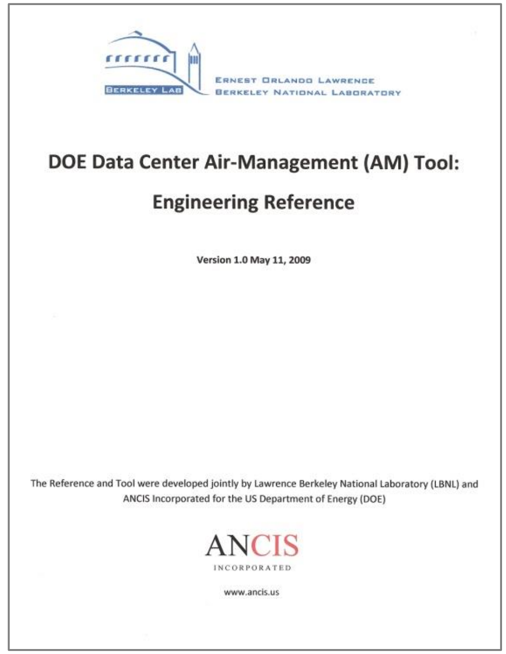
www.ancis.us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DOE Data Center Air-Management (AM) Tool:

Engineering Reference

Version 1.0 May 11, 2009

The Reference and Tool were developed jointly by Lawrence Berkeley National Laboratory (LBNL) and ANCIS Incorporated for the US Department of Energy (DOE)

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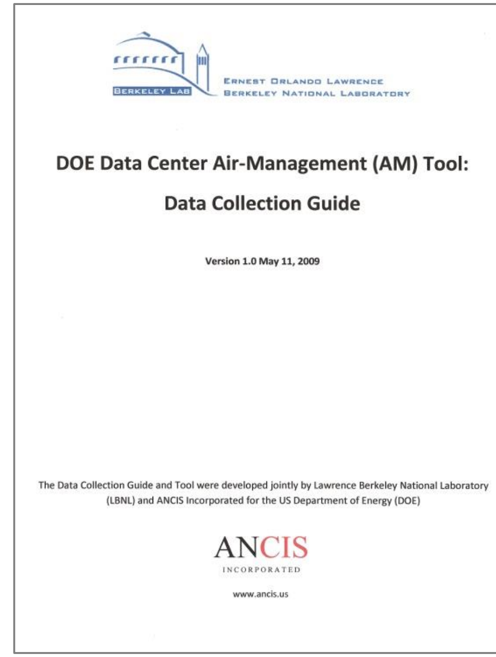
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DOE Data Center Air-Management (AM) Tool:

Data Collection Guide

Version 1.0 May 11, 2009

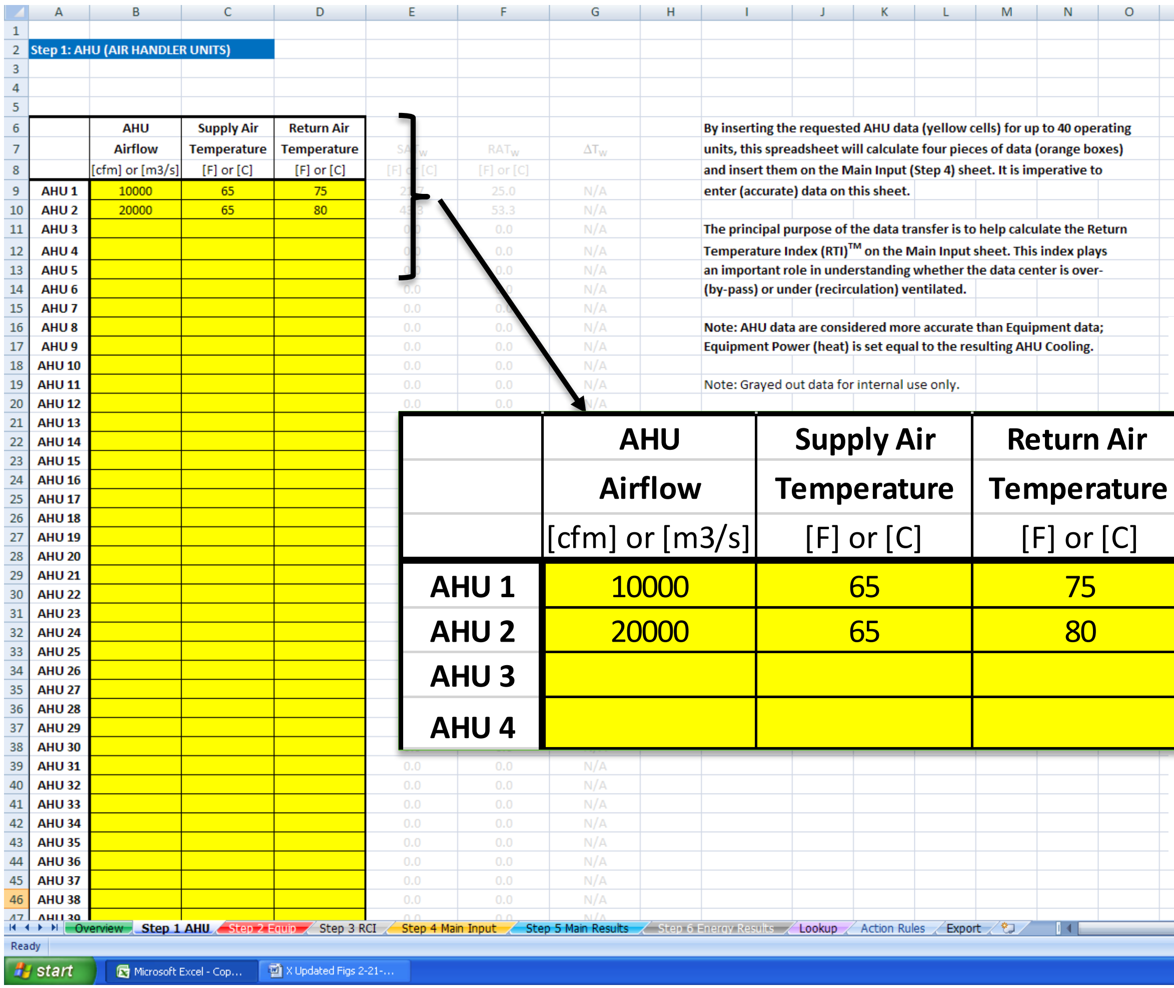
The Data Collection Guide and Tool were developed jointly by Lawrence Berkeley National Laboratory (LBNL) and ANCIS Incorporated for the US Department of Energy (DOE)

ANCIS INCORPORATED

www.ancis.us

These documents are the official resource in using the DOE Air Management Tool

Air-Handling Units



Step 1: AHU (AIR HANDLER UNITS)

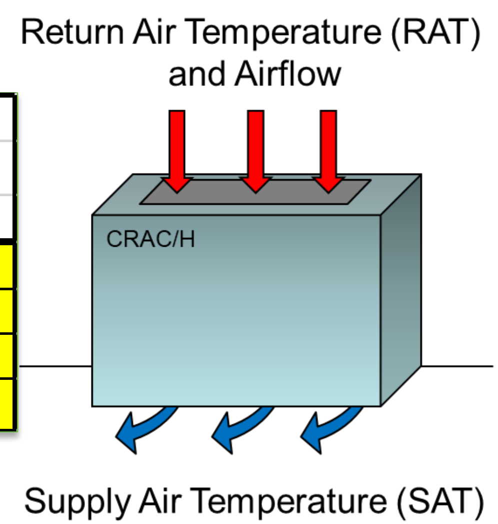
	AHU Airflow [cfm] or [m3/s]	Supply Air Temperature [F] or [C]	Return Air Temperature [F] or [C]
AHU 1	10000	65	75
AHU 2	20000	65	80
AHU 3			
AHU 4			

By inserting the requested AHU data (yellow cells) for up to 40 operating units, this spreadsheet will calculate four pieces of data (orange boxes) and insert them on the Main Input (Step 4) sheet. It is imperative to enter (accurate) data on this sheet.

The principal purpose of the data transfer is to help calculate the Return Temperature Index (RTI)™ on the Main Input sheet. This index plays an important role in understanding whether the data center is over- (by-pass) or under (recirculation) ventilated.

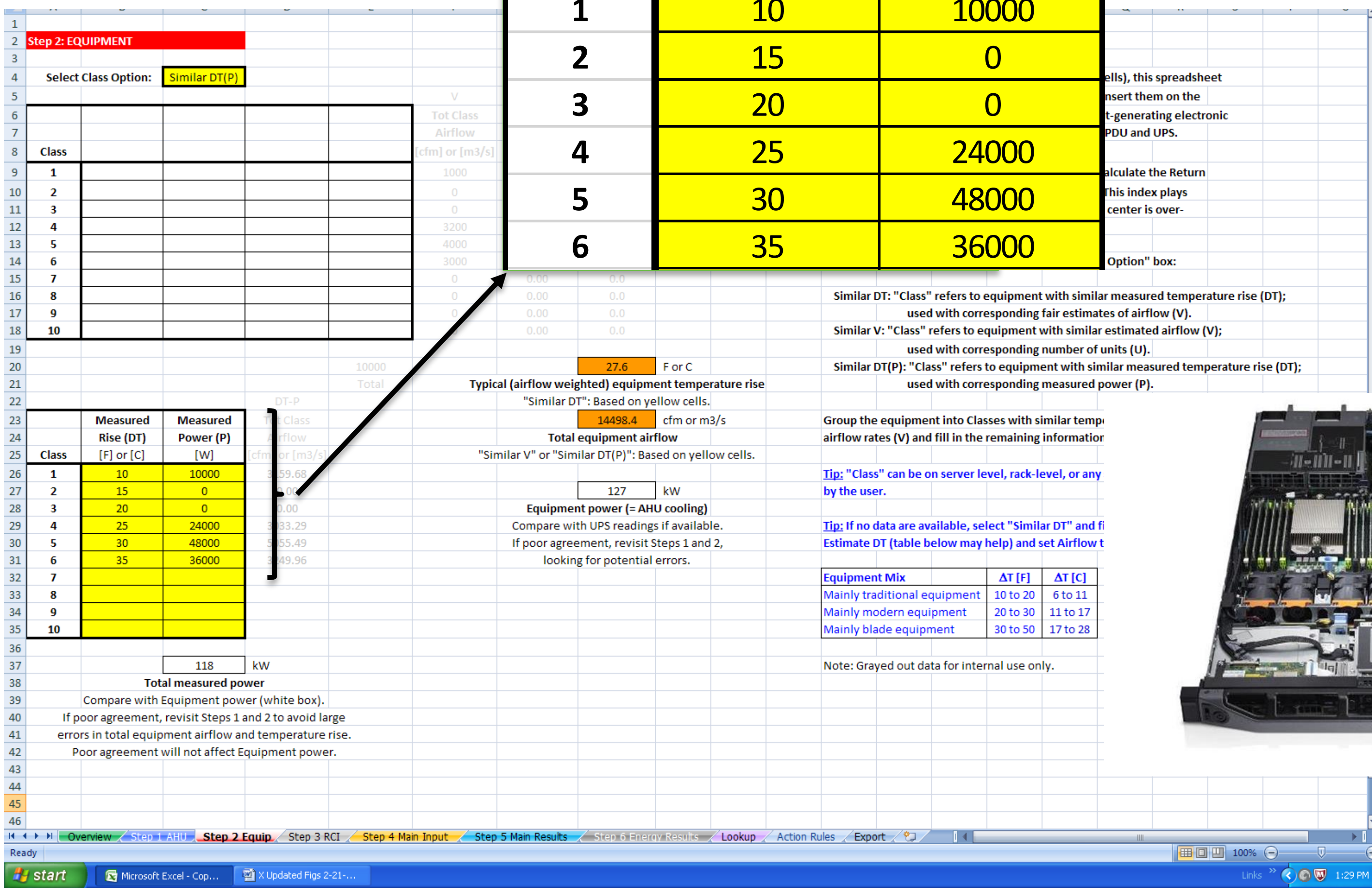
Note: AHU data are considered more accurate than Equipment data; Equipment Power (heat) is set equal to the resulting AHU Cooling.

Note: Grayed out data for internal use only.

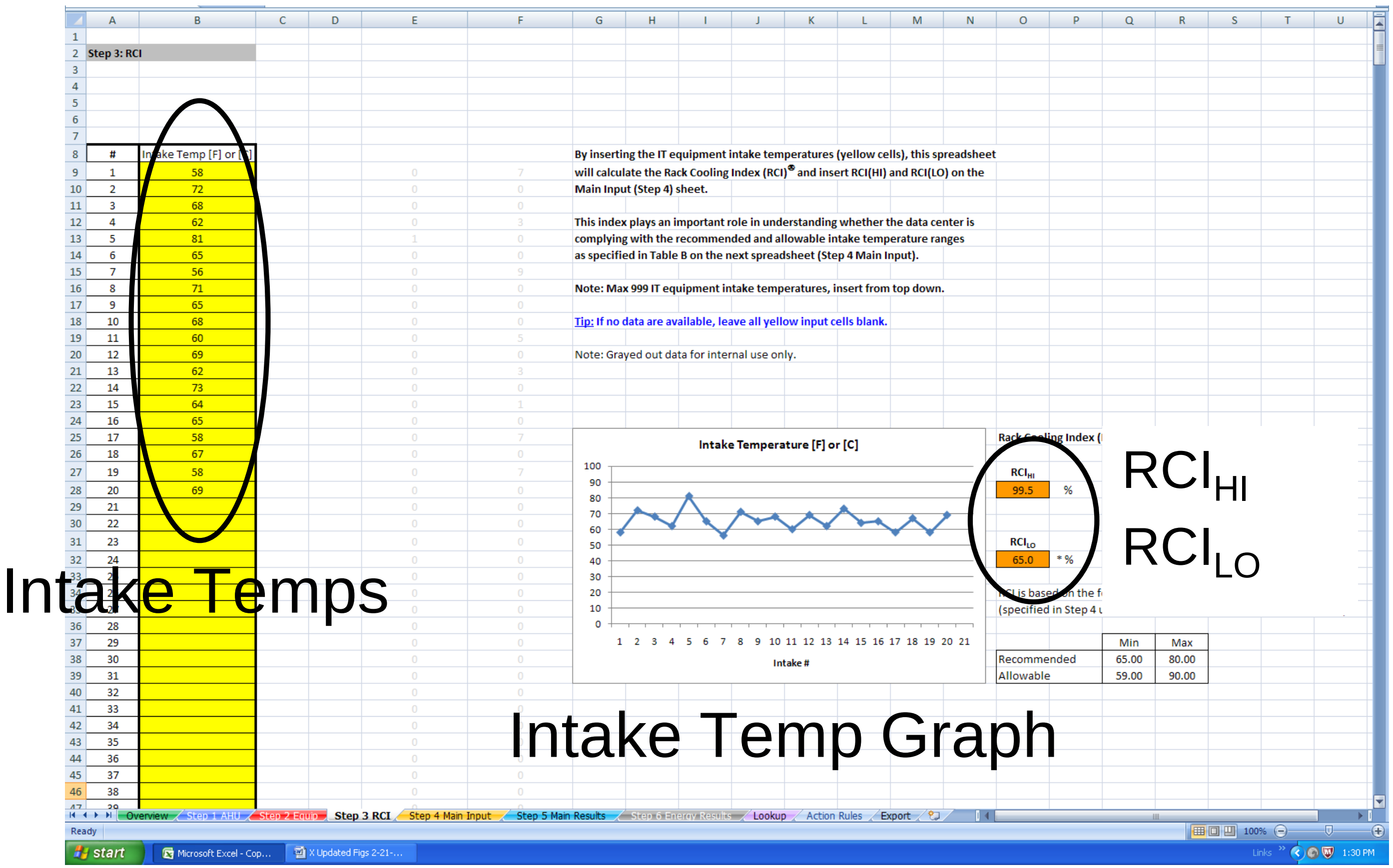


IT Equipment

Class	Measured Rise (DT) [F] or [C]	Measured Power (P) [W]
1	10	10000
2	15	0
3	20	0
4	25	24000
5	30	48000
6	35	36000



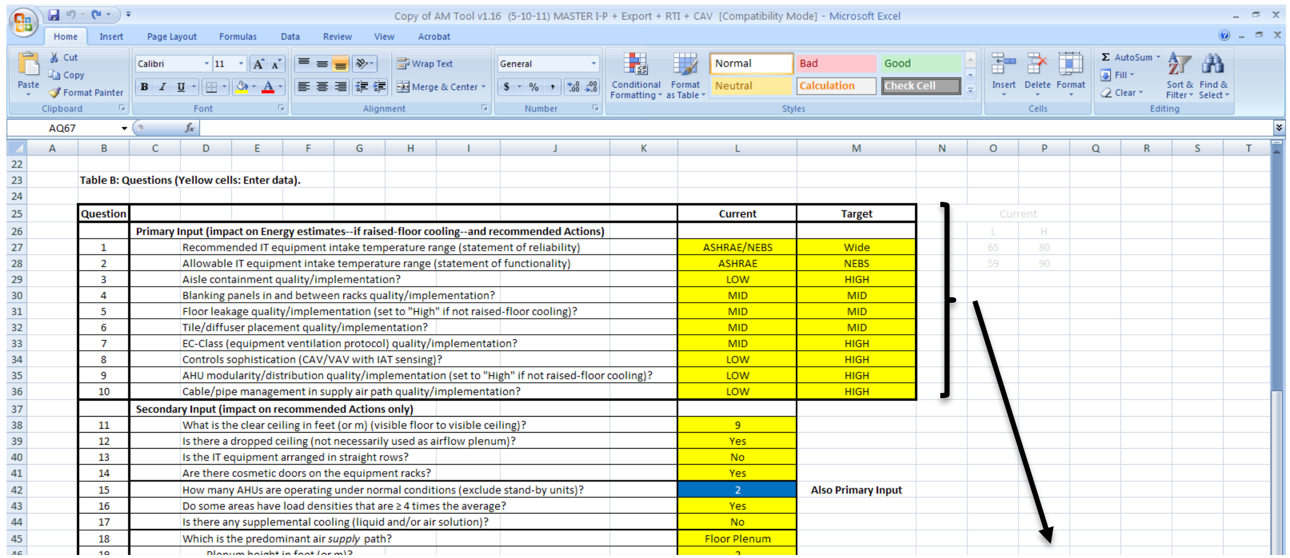
Rack Cooling Index (RCI)



Air Management Improvements

Input Data:

- Current
- Target

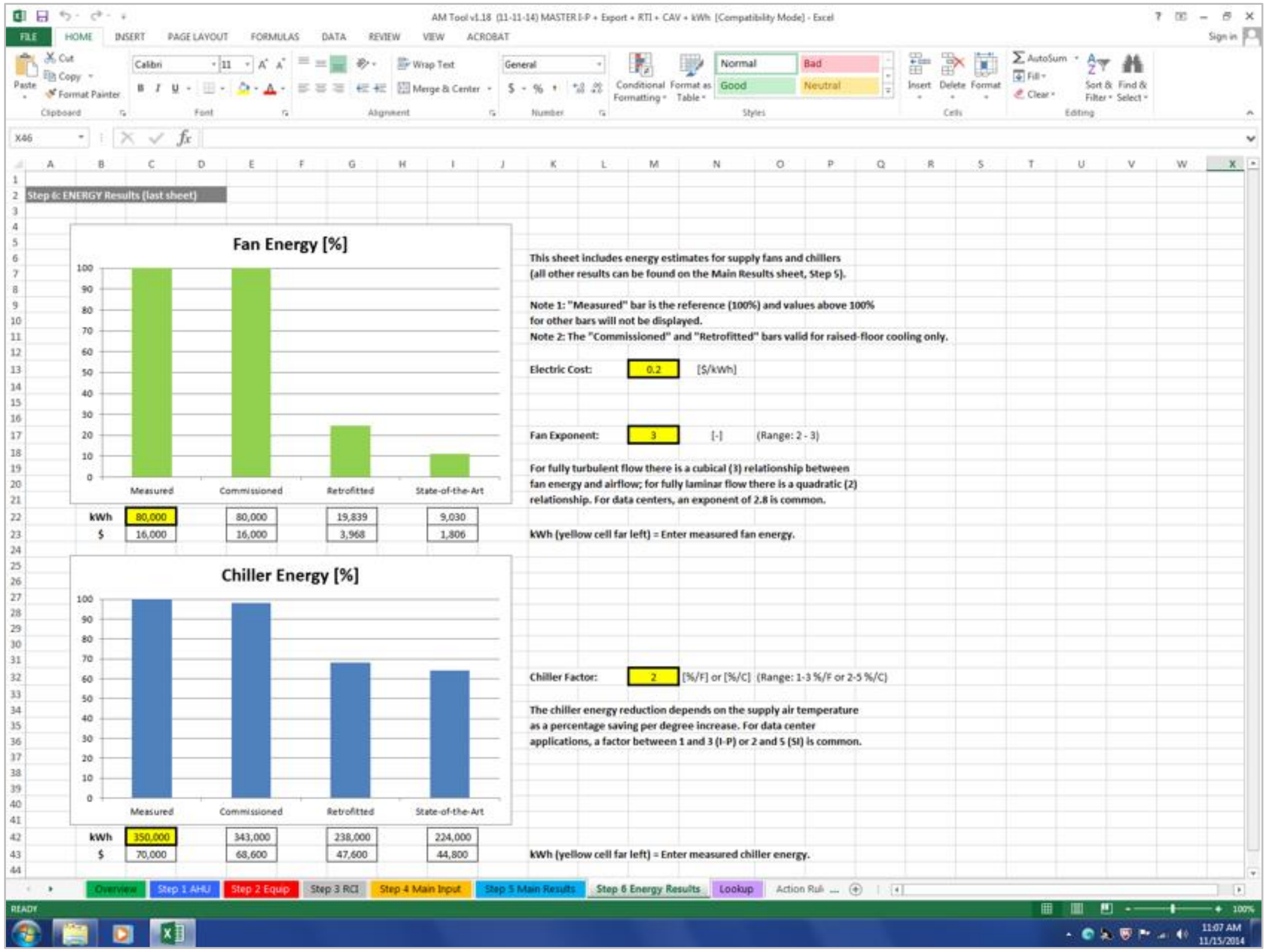


Question		Current	Target
	Primary Input (impact on Energy estimates--if raised-floor cooling--and recommended Actions)		
1	Recommended IT equipment intake temperature range (statement of reliability)	ASHRAE/NEBS	Wide
2	Allowable IT equipment intake temperature range (statement of functionality)	ASHRAE	NEBS
3	Aisle containment quality/implementation?	LOW	HIGH
4	Blanking panels in and between racks quality/implementation?	MID	MID
5	Floor leakage quality/implementation (set to "High" if not raised-floor cooling)?	MID	MID
6	Tile/diffuser placement quality/implementation?	MID	MID
7	EC-Class (equipment ventilation protocol) quality/implementation?	MID	HIGH
8	Controls sophistication (CAV/VAV with IAT sensing)?	LOW	HIGH
9	AHU modularity/distribution quality/implementation (set to "High" if not raised-floor cooling)?	LOW	HIGH
10	Cable/pipe management in supply air path quality/implementation?	LOW	HIGH

Results: Energy Savings

Fan Energy

Chiller Energy



Results: Takeaways

Fan Energy:

- The reduction in fan energy is often very large due to the fact that the fan energy vary with nearly the cube of the airflow. It is not uncommon to be in the 70%-80% range.
- If constant air volume (CAV) fans are used, the relationship between energy and airflow is only linear resulting in less savings.

Chiller Energy:

- The chiller-energy savings only takes into account the increase in supply air temperature. It is assumed that each °F [0.6°C] increase of the supply air temperature will result in a 1-3% savings on chiller energy.
- Additional savings are due to better utilization of air-side economizers. This depends on factors not covered in the Tool. Higher supply air temperatures may result in higher server airflows and higher costs.

The Air Management Tool – Ex 1

Say we want to understand how much energy we could save by making a number of air management changes to our equipment room and operations.

The next slide shows the changes we are planning and how they would affect the energy for supply fans and chillers.

The Air Management Tool – Ex 1 Results

Question		Current	Target
	Primary Input (impact on Energy estimates--if raised-floor cooling--and recommended Actions)		
1	Recommended IT equipment intake temperature range (statement of reliability)	ASHRAE/NEBS	Wide
2	Allowable IT equipment intake temperature range (statement of functionality)	ASHRAE	NEBS
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6	Tile/diffuser placement quality/implementation?	MID	MID
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8	Controls sophistication (CAV/VAV with IAT sensing)?	LOW	HIGH
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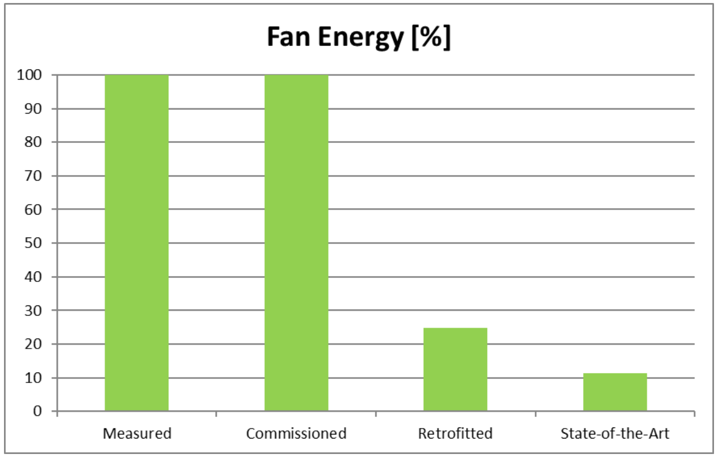
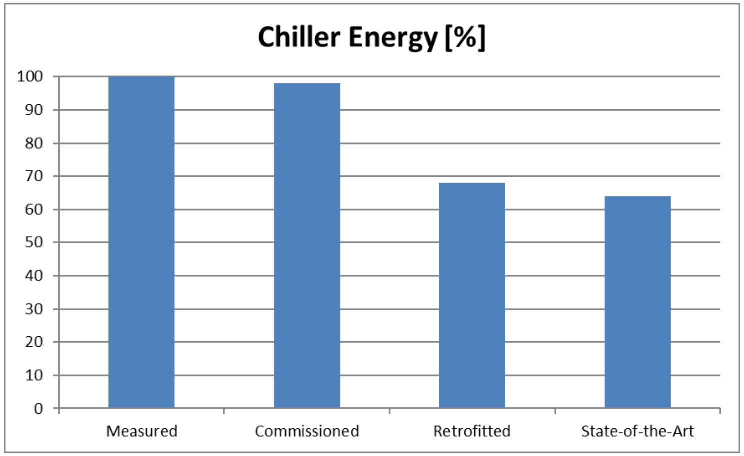
10	Cable/pipe management in supply air path quality/implementation?	LOW	HIGH





The Air Management Tool – Ex 2

We have a data center with 20 measured intake air temperatures. We operate with the ASHRAE recommended range of 65-80F and the allowable A1 range of 59-90F. What is the operating compliance with the ASHRAE Guideline?

The Air Management Tool – Ex 2 Results

#	Intake Temp [F] or [C]
1	58
2	72
3	68
4	62
5	81
6	65
7	56
8	71
9	65
10	68
11	60
12	69
13	62
14	73
15	64
16	65
17	58
18	67
19	58
20	69
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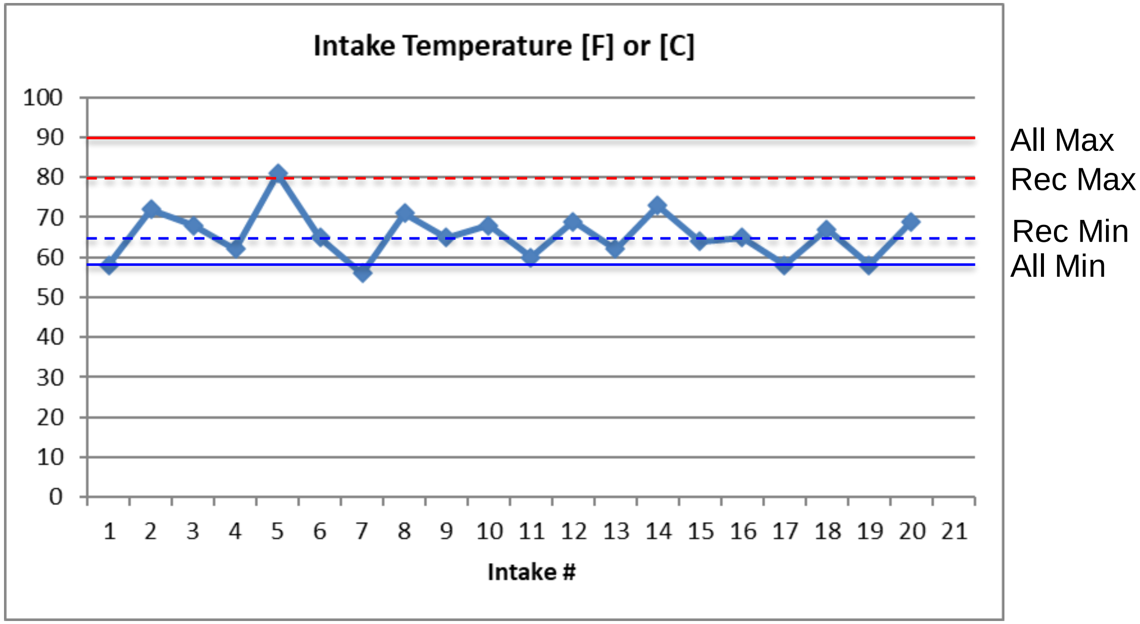


RCI_{HI}
99.5 %

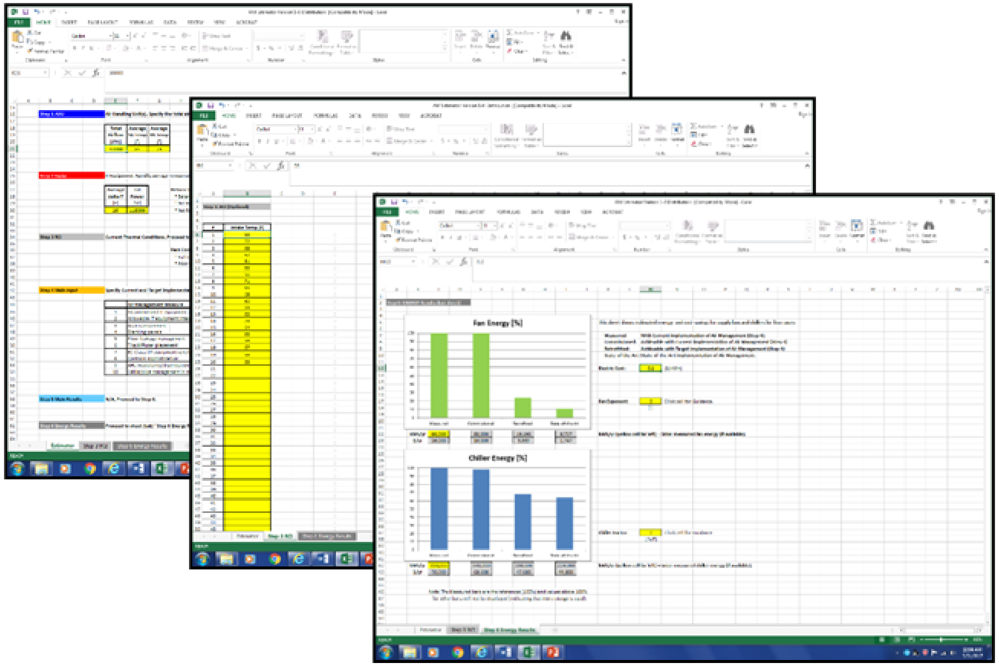
This is Excellent

RCI_{LO}
65.0 %

But this is Very Poor

The Excel Air Management Estimator

The AM Estimator is a simplified version of the Air Management Tool, using the same engine. The input has been reduced for ease of use.



http://datacenters.lbl.gov/Tools

The Air Management Lookup Tables

This resource presents energy savings for chiller and fan equipment in a new tabular format for different air management upgrade scenarios. The tables can be used to quickly estimate the potential savings for different air management scenarios. An example:

AM Measure (AM Tool)	Reference	P1	P2 **Matched**	P3	P4 **Target**	P5
1: Recommended Range[1]	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F	65°F–80°F
2: Allowable Range[2]	N/A	N/A	N/A	N/A	N/A	N/A
3: Aisle Containment	L	L	**L**	M	**M**	H
4: Blanking Panels	L	M	**M**	M	**H**	H
5: Floor Leakage	L	M	M	M	M	H
6: Tile Placement	L	M	H	H	H	H
7: EC-Class	H	H	H	H	H	H
8: CAV/VAV (CRAC)	L (CAV)	L (CAV)	H (VAV)	L (CAV)	H (VAV)	H (VAV)
9: CRAC Modularity	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)	M (2) or H (3)
10: Cable Management	L	L	**L**	L	**M**	M

[1] The ASHRAE Recommended Range is used throughout.
[2] The ASHRAE Allowable Range does not enter the energy calculations.

http://datacenters.lbl.gov

Air Management Lookup Tables

Fan Energy

Match	Target P1	P3	P2	P4	P5
Ref. 2.51 (typical) CAV	-33%	-33%	-76%	-80%	-90%
P1 - 1.67 CAV		0%	-26%	-39%	-69%
P3 - 1.67 CAV			-26%	-39%	-69%
P2 - 1.5 VAV				-18%	-58%
P4 - 1.4 VAV					-49%
CRAC/IT Airflow	1.67 CAV	1.67 CAV	1.5 VAV	1.4 VAV	1.1 VAV

Look-Up Table with Percentage <u>Fan</u> Energy Savings and CRAC Flow/IT Airflow Ratio for Data Center with Three (3) CRAC Units

Chiller Energy

Match	Target P1	P3	P2	P4	P5
Ref - 66F	-10%	-12%	-12%	-16%	-20%
P1 - 71F		-2%	-2%	-6%	-10%
P3 - 72F			0%	-4%	-8%
P2 - 72F				-4%	-8%
P4 - 74F					-4%
SAT	71F	72F	72F	74F	76F

Look-Up Table with Percentage <u>Chiller</u> Energy Savings and Supply Air Temperature (SAT) for Data Center with Three (3) CRAC Units

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, including PUE Estimator
- Air Management Tools
- 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

Filter CoE's many resources by type and topic.

Choose from upcoming live webinars, pre-recorded trainings, and in-person Data Center Energy Practitioner (DCEP) trainings.

Search resources by topics of interest.

Explore the diverse activities that CoE is engaged in.

Follow us on Twitter @DataCenterCoE

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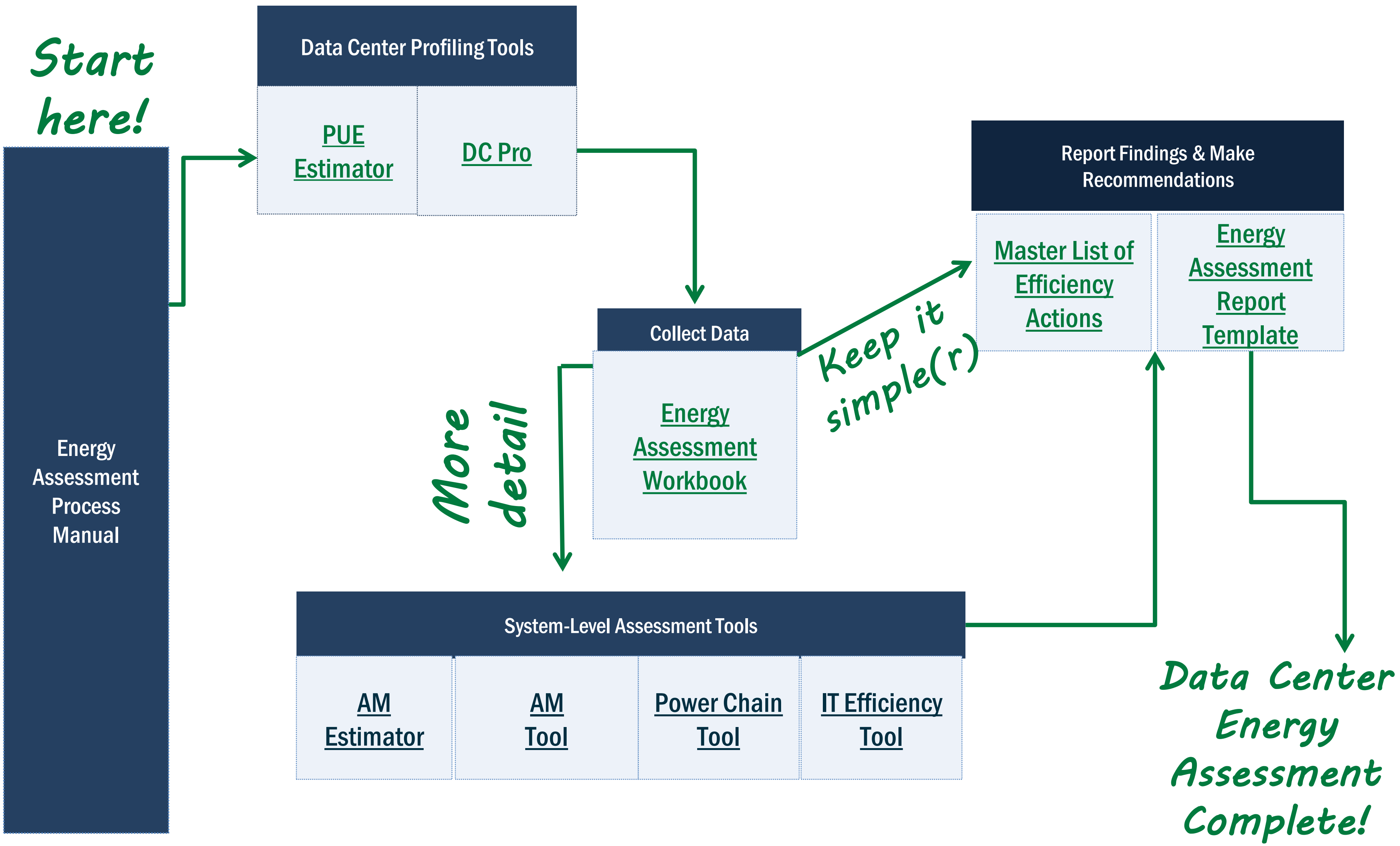
CoE Data Center Energy Efficiency Toolkit



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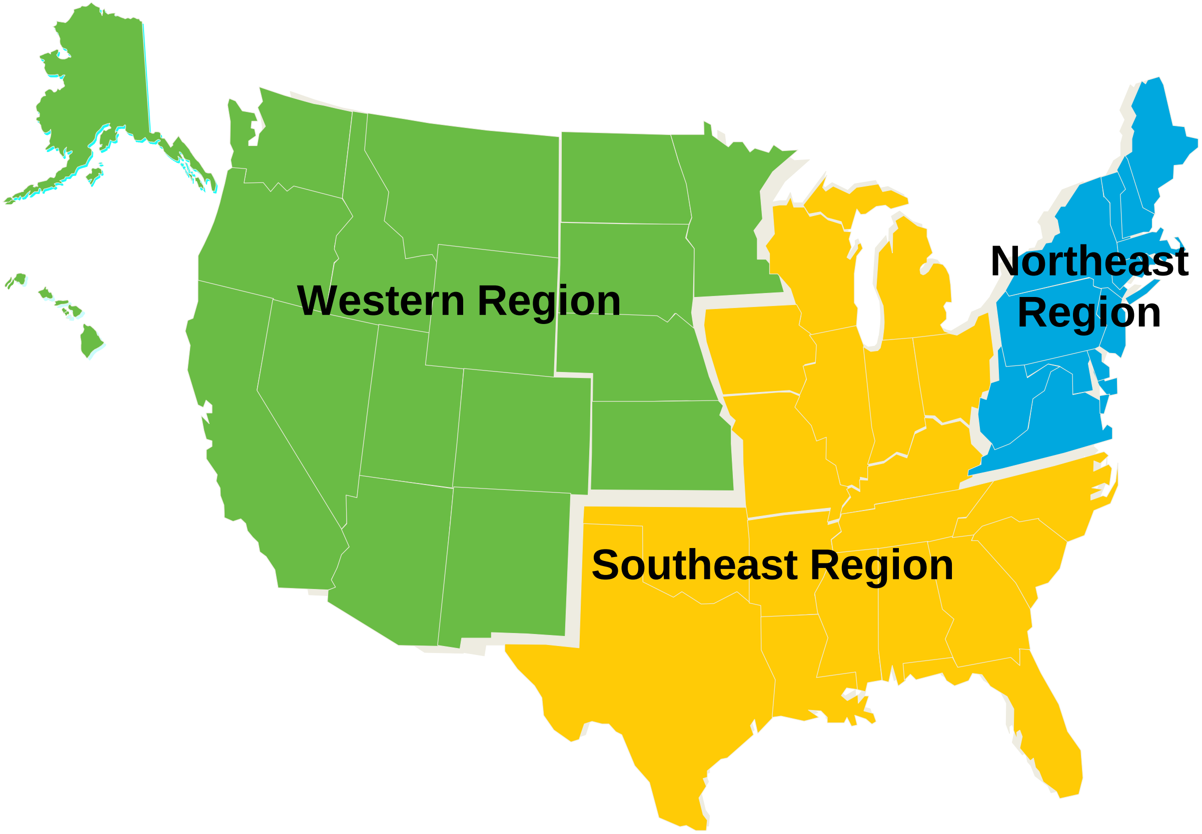

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CENTER OF EXPERTISE
FOR ENERGY EFFICIENCY IN DATA CENTERS

Questions?

IACET Credit for Webinar

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.
- Allows you to:
  - Track all of your trainings in one place.
  - Download your training certificates of completion.
- Eases the CEU-achievement process.

Visit the WBDG at www.wbdg.org to view courses and create an account

IACET Credit for Webinar

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/femplw08042020

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.