



How Hot Can You Go? Raising Operating Temperatures in Data Centers

Wednesday, May 17

11:15 AM – 12:30 PM



Panelists

- Dave Breland, Intuit
- John Dumler, Digital Realty
- Dale Sartor, Lawrence Berkeley National Laboratory
- John Clinger, ICF, Moderator

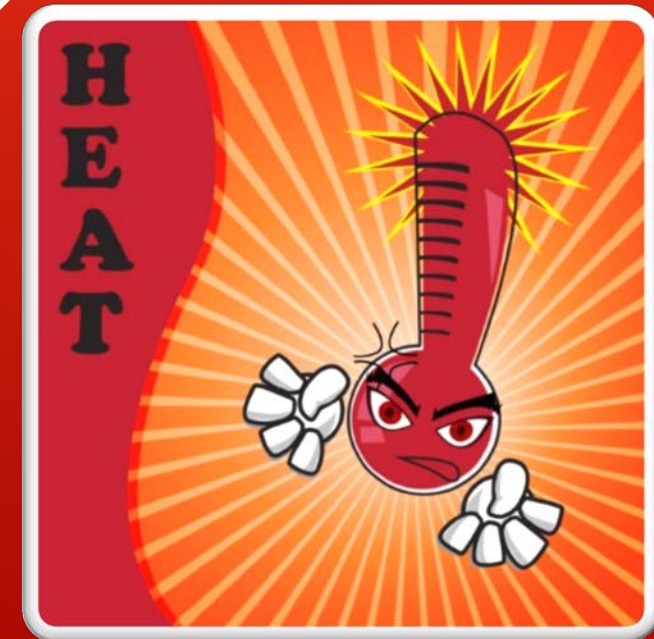
Dave Breland

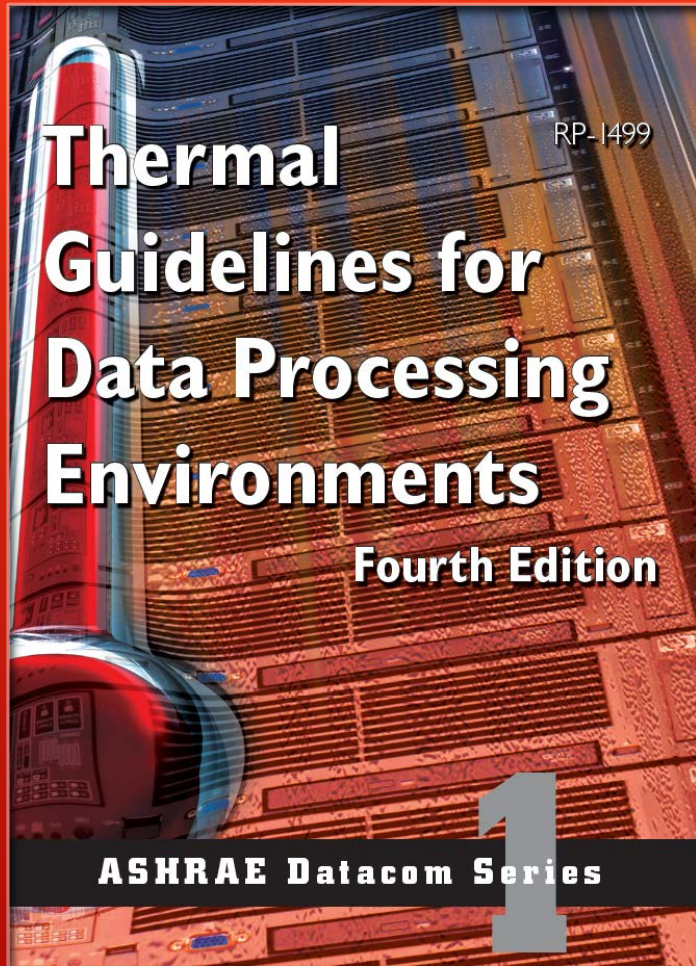
Intuit



HOW HOT CAN I GO?

Intuit's Journey in Quincy Washington





FIRST- I NEEDED A GUIDE

ASHRAE Datacom Series formerly TC9.9

These environmental envelopes pertain
to air entering the IT equipment

Conditions at SEA LEVEL

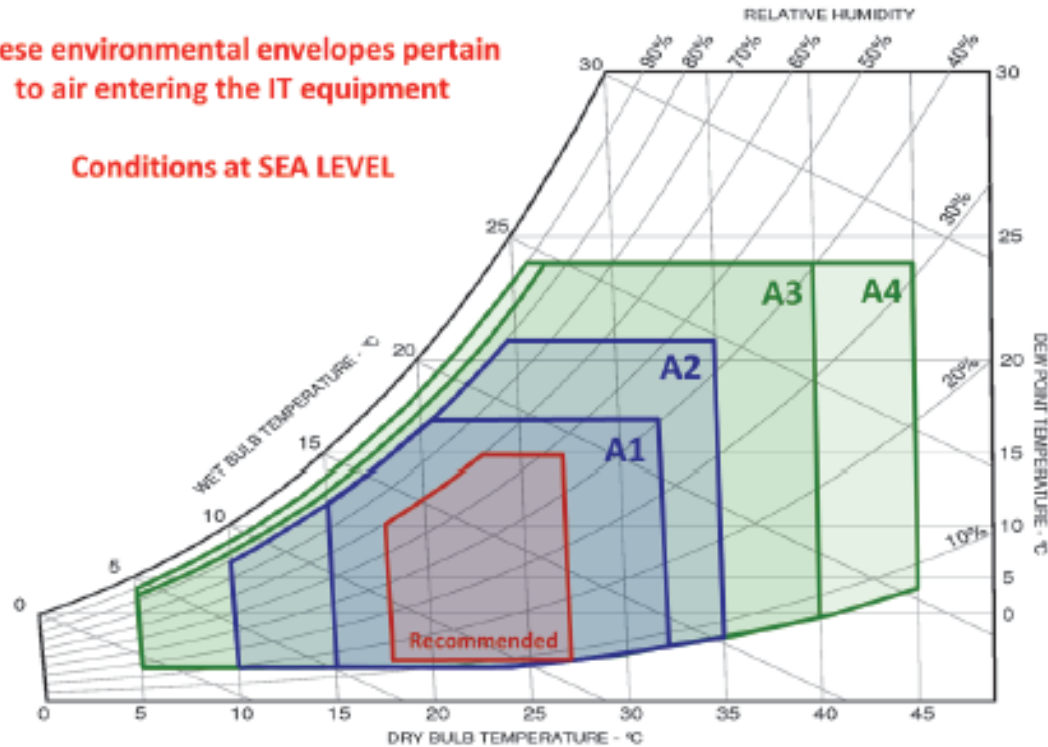


Figure 2.3 2015 recommended and allowable envelopes for ASHRAE Classes A1, A2, A3, and A4.

INSIDE ASHRAE'S DATACOM GUIDE

2.2.1 Environmental Class Definitions for Air-Cooled Equipment

Compliance with a particular environmental class requires full operation of the equipment over the entire allowable environmental range, based on nonfailure conditions.

Class A1: Typically a data center with tightly controlled environmental parameters (dew point, temperature, and RH) and mission-critical operations; types of products typically designed for this environment are enterprise servers and storage products.

Table B.1 2015 Thermal Guidelines—I-P Version (SI Version in Table 2.1)

Class ^a	Equipment Environment Specifications for Air Cooling						
	Product Operation ^{b,c}					Product Power Off ^{c,d}	
	Dry-Bulb Temperature ^{e,g} , °F	Humidity Range ^{h,i,k,l} Noncondensing	Maximum Dew Point, ^k °F	Maximum Elevation ^{e,j,m} , ft	Maximum Rate of Change ^f , °F/h	Dry-Bulb Temperature, °F	Relative Humidity, ^k %
Recommended (Suitable for all four classes; explore data center metrics in this book for conditions outside this range.)							
A1 to A4	64.4 to 80.6	15.8°F DP to 59°F DP and 60% rh					
Allowable							
A1	59 to 89.6	10.4°F DP and 8% rh to 62.6°F DP and 80% rh	62.6	10,000	9/36	41 to 113	8 to 80
A2	50 to 95	10.4°F DP and 8% rh to 69.8°F DP and 80% rh	69.8	10,000	9/36	41 to 113	8 to 80
A3	41 to 104	10.4°F DP and 8% rh to 75.2°F DP and 85% rh	75.2	10,000	9/36	41 to 113	8 to 80
A4	41 to 113	10.4°F DP and 8% rh to 75.2°F DP and 90% rh	75.2	10,000	9/36	41 to 113	8 to 80
B	41 to 95	8% to 82.4°F DP and 80% rh	82.4	10,000	N/A	41 to 113	8 to 80
C	41 to 104	8% to 82.4°F DP and 80% rh	82.4	10,000	N/A	41 to 113	8 to 80

* For potentially greater energy savings, refer to the section "Detailed Flowchart for the Use and Application of the ASHRAE Data Center Classes" in Appendix C for the process needed to account for multiple server metrics that impact overall TCO.

IN ENGLISH

Recommended vs.
Allowable



HOW DO I KNOW?

Is there some way for me to know for sure?

PowerEdge R620



Technical Guide



Dell states 10°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C.

ASHRAE Guidelines are well within Dell Requirements

Table 33. Environmental specifications

Fresh Air: temperature, humidity, altitude de-rating

Continuous operation	10°C to 35°C (50°F to 95°F) at 10% to 80% relative humidity with 26°C (78.8°F) maximum dew point (maximum wet bulb temperature). De-rate maximum allowable dry bulb temperature at 1°C per 300m above 950m (1°F per 547 ft above 3117 ft).
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PowerEdge R820



Technical Guide



Dell states 10°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C.

ASHRAE Guidelines are well within Dell Requirements

Table 27. Environmental specifications

Fresh Air: temperature, humidity, altitude de-rating

Continuous operation	10°C to 35°C (50°F to 95°F) at 10% to 80% relative humidity with 26°C (78.8°F) maximum dew point (maximum wet bulb temperature). De-rate maximum allowable dry bulb temperature at 1°C per 300m above 950m (1°F per 547 ft above 3117 ft).
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HP ProLiant DL170e G6 Server - Overview

Product description



The DL170e G6 is optimized for efficiency, density and flexibility and can be serviced individually without impacting the operation of other server nodes sharing the same chassis. The DL2000 consists of up to 4 independent DL170e G6 servers in the 2U HP ProLiant e2000 G6 Chassis. The servers share power supplies and fans, providing greater power and cooling efficiencies.

HP states 10°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C.

ASHRAE Guidelines are well within HP Requirements

Environmental specifications

Item	Description
Thermal output (maximum operating)	392 W/hr
System inlet temperature, operating	50° to 95° F (10° to 35° C) at sea level with an altitude derating of 1.8°F per every 1000 ft (1.0°C per every 305 m) above sea level to a maximum of 10,000 ft (3050 m), no direct sustained sunlight. Maximum rate of change is 18°F/hr (10°C/hr). The upper limit may be limited by the type and number of options installed. System performance may be reduced if operating with a fan fault or above 86°F (30°C).

HP states 10°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C.

ASHRAE Guidelines are well within HP Requirements

System Inlet Temperature Operating

50° to 95° F (10° to 35° C) at sea level with an altitude derating of 1.8°F per every 1000 ft (1.0°C per every 305 m) above sea level to a maximum of 10,000 ft (3050 m), no direct sustained sunlight. Maximum rate of change is 18°F/hr (10°C/hr). The upper limit may be limited by the type and number of options installed.

System performance may be reduced if operating with a fan fault or above 86°F (30°C).

HP ProLiant DL2000 server technologies



Cisco states 0°C – 40°C while the ASHRAE Guideline allows 15°C – 32°C.
ASHRAE Guidelines are well within Cisco Requirements

Cisco Nexus 9396PX



Environmental Specifications

Environment		Specification
Temperature	Ambient operating temperature	32 to 104° F (0 to 40° C)
	Ambient nonoperating	-40 to 158° F (-40 to 70° C)
Relative humidity	Ambient (noncondensing)	5 to 95%
Altitude	Operating	0 to 13,123 feet (0 to 4,000 meters)

Cisco Nexus 7000 18-Slot Switch

[Compare Models](#)
[View 3D Model](#)



Cisco states 0°C – 40°C while the ASHRAE Guideline allows 15°C – 32°C.
ASHRAE Guidelines are well within Cisco Requirements

Climatic Environment

Table 10 summarizes the climatic environment for the Cisco Nexus 7000 4-, 9-, 10-, and 18-Slot chassis.

Table 10. Climatic Environment

Item	Description			
	Cisco Nexus 7000 4-Slot Chassis	Cisco Nexus 7000 9-Slot Chassis	Cisco Nexus 7000 10-Slot Chassis	Cisco Nexus 7000 18-Slot Chassis
Temperature	<ul style="list-style-type: none">Operating: 32 to 104°F (0 to 40°C)Short term: 23 to 131°F (-5 to 55°C)*Nonoperating: -40 to 158°F (-40 to 70°C)* <p>Note:</p> <ul style="list-style-type: none">Chassis external thermal requirements are defined in the GR-63-CORE Network Equipment Building Standards (NEBS) specification published by Telcordia Technologies in Section 4.1.2, Operating Temperature and Humidity Criteria.Short term refers to a period of not more than 96 consecutive hours and a total of not more than 15 days in 1 year (a total of 360 hours in any given year, but no more than 15 occurrences during that 1-year period). <p>* 131°F (55°C) and 25% relative humidity for equipment shelves that fill less than half the frame (length)</p>			
Humidity	<ul style="list-style-type: none">Relative humidity (nonoperating): 5 to 95%, noncondensingRelative humidity (operating): 5 to 90%, noncondensing <p>Note: An ambient relative humidity between 45 and 50% is suggested to reduce corrosive problems, to provide an operating time buffer in the event of failures, and to reduce interference from static discharges.</p>			

NetApp Disk Shelves and Storage Media Technical Specifications

NetApp states 0°C – 40°C while the ASHRAE Guideline allows 15°C – 32°C.

ASHRAE Guidelines are well within NetApp Requirements



Environmental Specifications

Environment		Specification
Temperature	Ambient operating temperature	32 to 104°F (0 to 40°C)
	Ambient nonoperating	-40 to 158°F (-40 to 70°C)
Relative humidity	Ambient (noncondensing)	5 to 95%
Altitude	Operating	0 to 13,123 feet (0 to 4,000 meters)

Apple states 0°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C.

ASHRAE Guidelines are well within Apple Requirements

Electrical and operating requirements

- Line voltage: 100–240V AC
- Frequency: 50Hz to 60Hz, single phase
- Maximum continuous power: 450W
- Operating temperature: 50° to 95° F (10° to 35° C)
- Relative humidity: 5% to 95% noncondensing
- Maximum altitude: 16,400 feet (5000 meters)
- Typical acoustical performance, sound pressure level (operator position): 12 dBA at idle



Pure Storage states 5°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C.
ASHRAE Guidelines are well within Pure Storage Requirements

ENVIRONMENTAL

//M10, //M20, //M50, //M70	RANGE	NOTES
Operating Temperature	5° to 35° C	Derate 1 C per 300 m above 950 m
Non-operating Temperature	0° to 60° C	
Operating Humidity	10 – 80%	Non-condensing
Non-operating Humidity	5 – 95%	At a maximum temperature of 33° C. Non-condensing, web bulb 33° C.



Although OSHA does not have a particular regulation or standard that covers high-temperature environments, the General Duty Clause, Section 5(a)(1) of the Occupational Safety and Health Act of 1970 (OSHA 2012b), requires each employer to “furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm.” OSHA has interpreted this rule such that employers shall provide means and methods that will reduce the likelihood of worker heat stress. These means or methods may include issuing personal protective equipment (PPE), minimizing exposure through frequent breaks, frequent hydration, and developing a heat stress program. There are various manufacturers that produce PPE for hot working environments.

Table E.1 Permissible Heat Exposure Threshold Limit Value (TLV) (ACGIH 1992)

Work/Rest Regimen	Work Load ¹		
	Light	Moderate	Heavy
Continuous work	30.0°C (86°F)	26.7°C (80°F)	25.0°C (77°F)
75% work, 25% rest, each hour	30.6°C (87°F)	28.0°C (82°F)	25.9°C (78°F)
50% work, 50% rest, each hour	31.4°C (89°F)	29.4°C (85°F)	27.9°C (82°F)
25% work, 75% rest, each hour	32.2°C (90°F)	31.1°C (88°F)	30.0°C (86°F)

1. Values are in °C and °F (wet-bulb globe temperature [WBGT]).

Appendix E

OSHA and Personnel Working in High Air Temperatures



INTUIT'S JOURNEY IN QUINCY WASHINGTON

THEN

- Original Design 72°F top of Rack
- CWS Temp 47°F
- Economizer Start OAWBT 45°F with a CWST of <47.5°F.
- Economizer Stop 48.5°F CWST
- Averaged 48% of year on economizer at current load

NOW

- Current Control 78.5°F top of Rack
Warn 80°F Alarm
- CWS Temp 61°F
- Economizer Start OAWBT 58°F with a CWST of <61.5°F.
- Economizer Stop 64°F CWST
- Now average 65% on water side economizer

The screenshot displays the 'Chilled Water Plant Setup-Lead' interface. At the top, it shows 'Main' and 'Econ Run Time (Since Aug 1)' as 4,088.2 hours. The title 'Chilled Water Plant Setup-Lead' is prominently displayed. On the right, 'OA Drybulb' is 54.3 deg F and 'OA Wetbulb' is 44.2 deg F, with the 'intuit' logo. Below this, there are sections for 'GLOBAL CLG TOWER SP's' (15.5, 0.3, 12.0), 'ALL ROOMS' staging parameters (bypass flow, stage up/down, precool basins), and 'CHILLER STAGING PARAMETERS'. The main area contains a table for Chiller 1 and Chiller 2, with columns for Desired Rank, Operating Rank, Chiller Alarm, PCHWP Alarm, CWP Alarm, Tower Alarm, and Econ On/Off. Chiller 1 is set to Rank 3, Operating Rank 3.0, and is currently Off. Chiller 2 is set to Rank 1, Operating Rank 1.0, and is currently Off. At the bottom, 'ECON AVAILABLE?' is set to 'True' and 'OPERATOR: YOUR CMD TO GO FOR ECONOMIZER' is also set to 'True'.

	DESIRED RANK	OPERATING RANK	CHILLER ALARM?	PCHWP ALARM?	CWP ALARM?	TOWER ALARM?	ECON ON?
CHILLER 1	3	3.0	Off	#1	False	False	Normal
CHILLER 2	1	1.0	Off	#2	False	False	Normal

Main

Chiller Room 1

intuit.

OA Drybulb OA Wetbulb

53.7 deg F 44.0 deg F

Econ Run Time
(Since Aug 1)

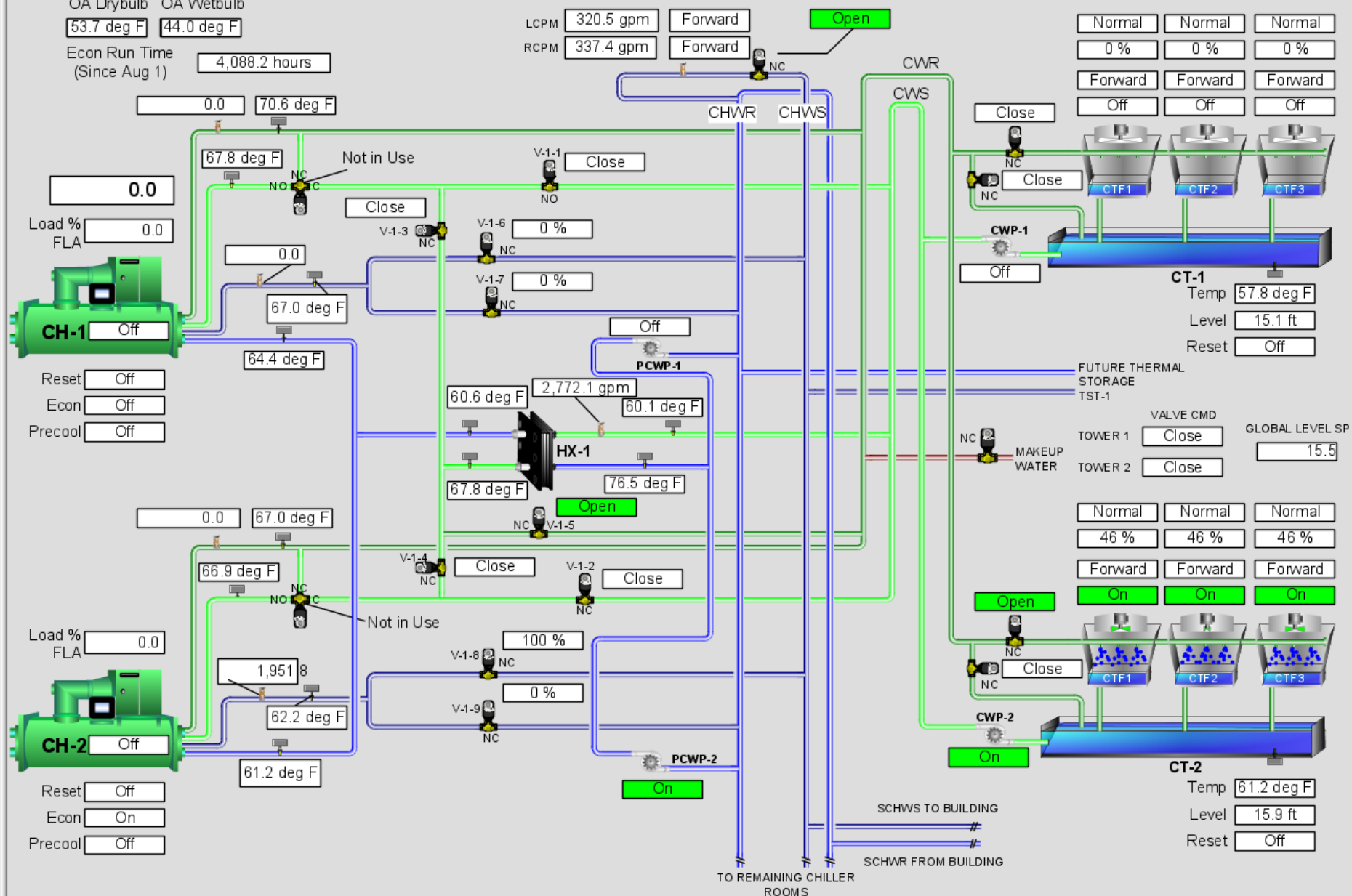
4,088.2 hours

LCPM 320.5 gpm Forward
RCPM 337.4 gpm Forward

Open

Normal	Normal	Normal
0 %	0 %	0 %
Forward	Forward	Forward
Off	Off	Off

One of Our
Cooling
Plants






- ▶ Balance data halls using Purkey instruments and Tileflow Software, to ensure cold aisle temps $\leq 78.5^{\circ}\text{f.}$ at top of rack.
- ▶ Raised CWST to get all of the CRAH control valves at their mid range.
- ▶ Operators monitor weather patterns and redundant cooling tower storage to extend economizer hours when possible.
- ▶ My biggest bang is staying on my economizer as long as possible.
- ▶ With my water side economizer, it's as far as I can go. Most later version data centers around me are using 100% outside air or probably half have gone to the Munters Evaporative Cooling units.

SO THIS IS HOW WE HAVE DETERMINED
HOW HOT WE CAN GO

John Dumler

Digital Realty



How Hot Can You Go?

Raising ITE Operating Temperatures in Data Centers

05/16/17

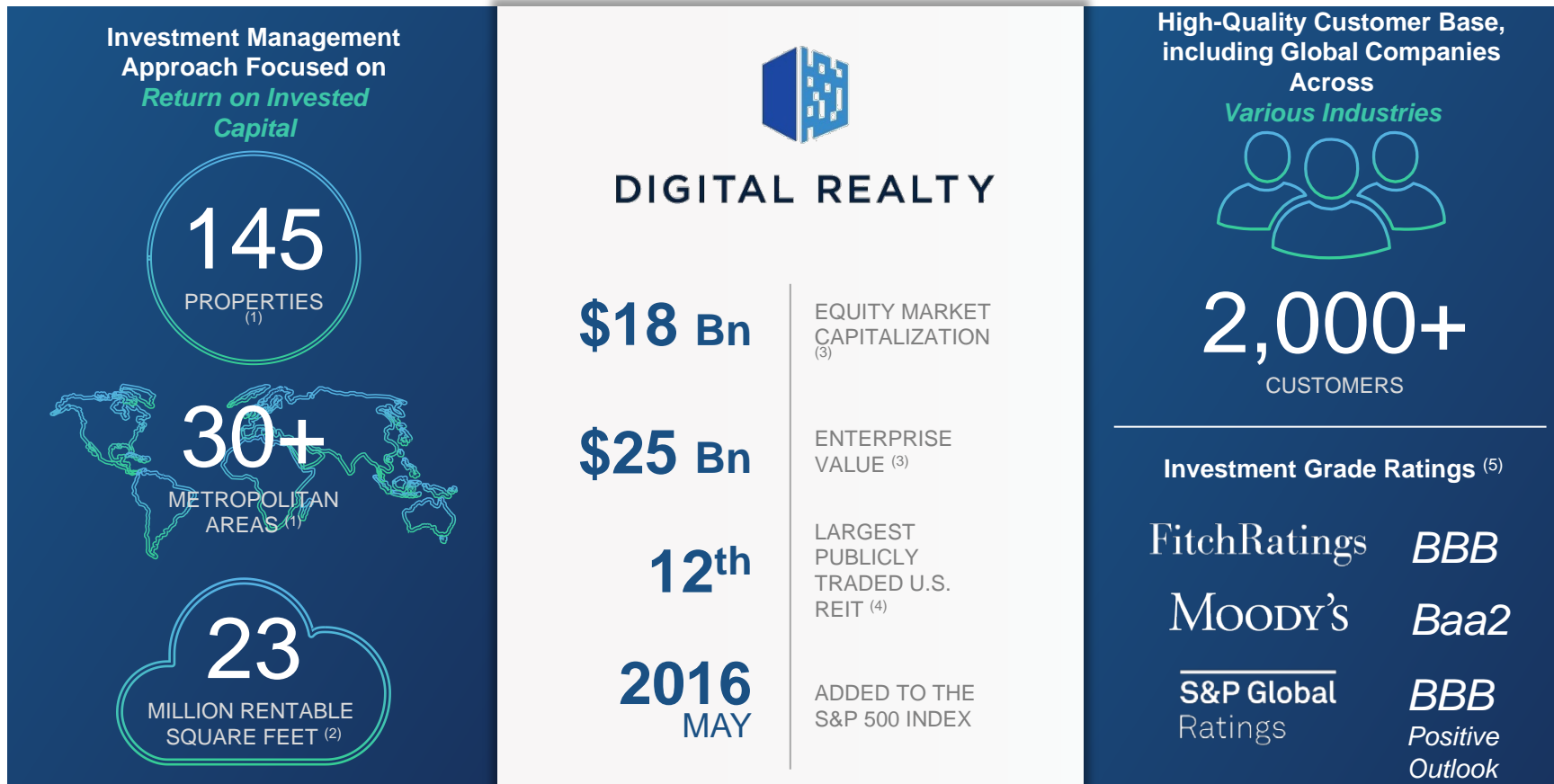


DIGITAL REALTY

1. Digital Realty Company Overview
2. Better Buildings Commitment
3. How Hot Can You Go?
 - A. Simple Colo Case Study

Digital Realty at a Glance (NYSE: DLR)

Leading Global Data Center REIT



1) As of December 31, 2016. Includes investments in fourteen properties held in unconsolidated joint ventures.

2) As of December 31, 2016. Includes 2.0 million square feet of active development and 1.1 million square feet held for future development.











3) As of February 24, 2017, based on the closing stock price of \$107.83. Includes Digital Realty's pro rata share of unconsolidated joint venture debt.

4) U.S. REITs within the RMZ. Source: companies' financials based on latest public filings. Based on equity market capitalization as of February 23, 2017.

5) These credit ratings may not reflect the potential impact of risks relating to the structure or trading of the Company's securities and are provided solely for informational purposes. Credit ratings are not recommendations to buy, sell or hold any security, and may be revised or withdrawn at any time by the issuing organization in its sole discretion. The Company does not undertake any obligation to maintain the ratings or to advise of any change in ratings. Each agency's rating should be evaluated independently of any other agency's rating. An explanation of the significance of the ratings may be obtained from each of the rating agencies.

High-Quality, Diversified Customer Base

TOP 20 CUSTOMERS

Customer Rank		Locations	% of ABR ⁽¹⁾	Customer Rank		Locations	% of ABR ⁽¹⁾
1		23	7.8%	11	Fortune 50 Software Company	6	1.4%
2	 CenturyLink™	49	5.7%	12	 SUNGARD® AVAILABILITY SERVICES™	9	1.4%
3	 EQUINIX	20	3.4%	13	TATA COMMUNICATIONS	17	1.4%
4	 ORACLE®	10	2.6%	14	 NTT Communications	14	1.3%
5	 at&t	44	2.5%	15	 rackspace®	4	1.2%
6	facebook	9	2.2%	16	 Hewlett Packard Enterprise	5	1.2%
7	LinkedIn	4	2.1%	17	amazon	14	1.1%
8	JPMORGAN CHASE & CO.	16	1.9%	18	U B E R	4	1.1%
9	Morgan Stanley	9	1.5%	19	ebay	2	1.1%
10	 verizon	53	1.4%	20	NaviSite®	4	1.1%
Total Annualized Base Rent							43.4%

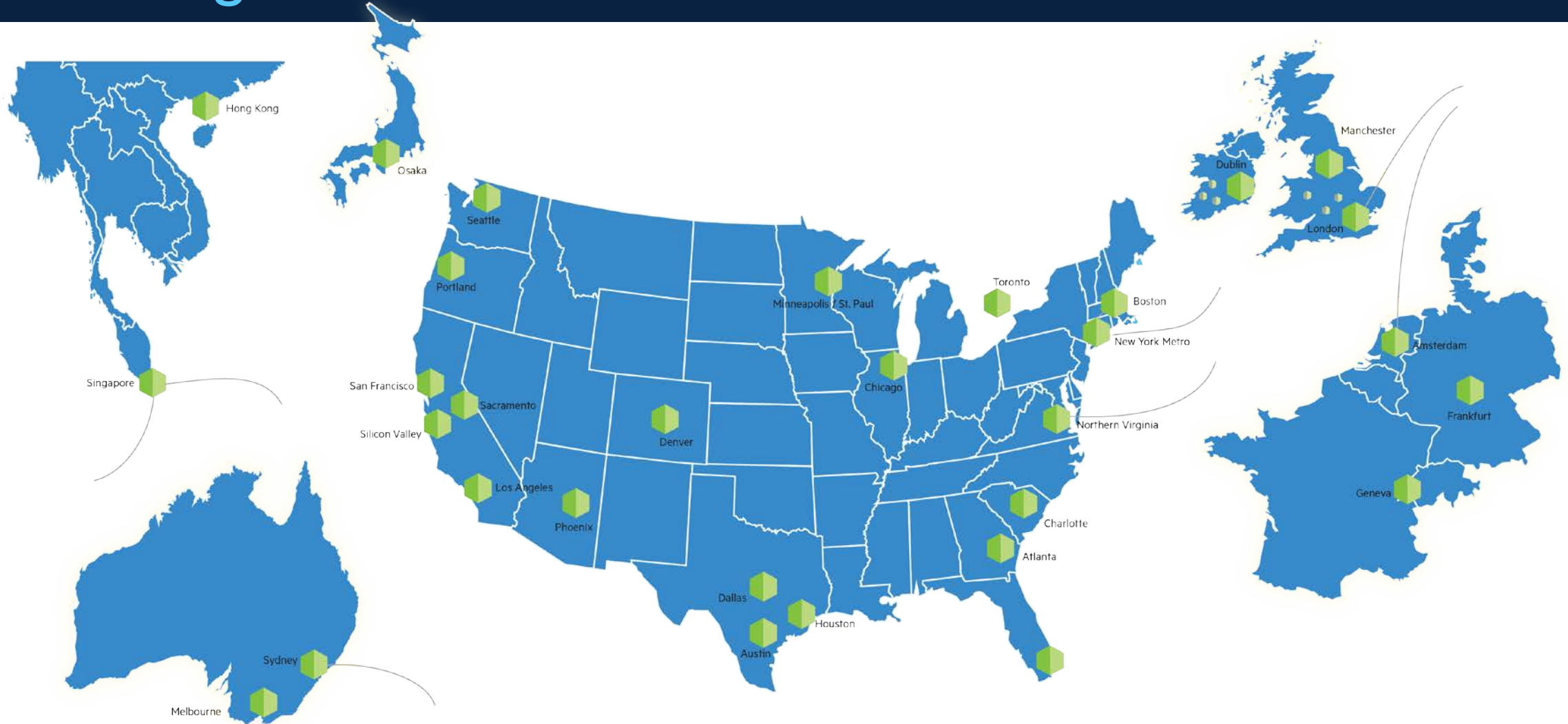
Note: As of December 31, 2016. Represents consolidated portfolio plus our managed portfolio of unconsolidated joint ventures based on our ownership percentage.

Our direct tenants may be the entities named in this table above or their subsidiaries or affiliates.

1) Calculation based on annualized base rents (monthly contractual cash base rent before abatements under existing leases as of December 31, 2016 multiplied by 12).

Unmatched Global Scale

Providing Customer Solutions in 30+ Metro Areas



Industry Leading Sustainability Track Record and Commitment to Energy Efficiency

Management and organizational commitment to sustainability

- Full time REIT-sustainability expertise in-house
- Senior executive with sustainability management responsibility
- Integrated cross-functional teams



Track record of sustainable project investment

- Successfully allocated \$493 million of proceeds from data center industry's first green bond
- Signed long term contract to purchase 100% renewable energy for US colocation business



Industry-leading clean energy solutions

- 600 gigawatt-hours of renewable power sourced globally
- #6 in EPA Green Power Partnership Tech and Telecom sector for renewable energy



Award-winning data center designs with third party certification

- 50+ green building certifications globally
- 5 new certifications in 2016 including Green Mark Platinum rating for 3 Loyang Way, Singapore



Thought leadership and innovation in energy efficiency

- US DoE Better Building's Challenge for data centers participant; 20% energy savings by 2024
- The Green Grid board-level and technical committee ship



Better Buildings Challenge Update

- How is Digital involved?
 - Digital has publicly committed to reduce our non-IT energy intensity, within a 20MW sub-portfolio of properties, by 20% over 10 years.
 - ~25% Cumulative Progress (vs. 2013 baseline)
 - Air Management Improvements
 - Controls enhancements
 - CRAH/C EC fan upgrades
 - Operational efficiencies
 - EPA Energy Star Certifications

PROGRESS



Goal
Achieved

How Hot Can You Go?

WHY RAISE TEMPERATURES?

Raising Temps because....

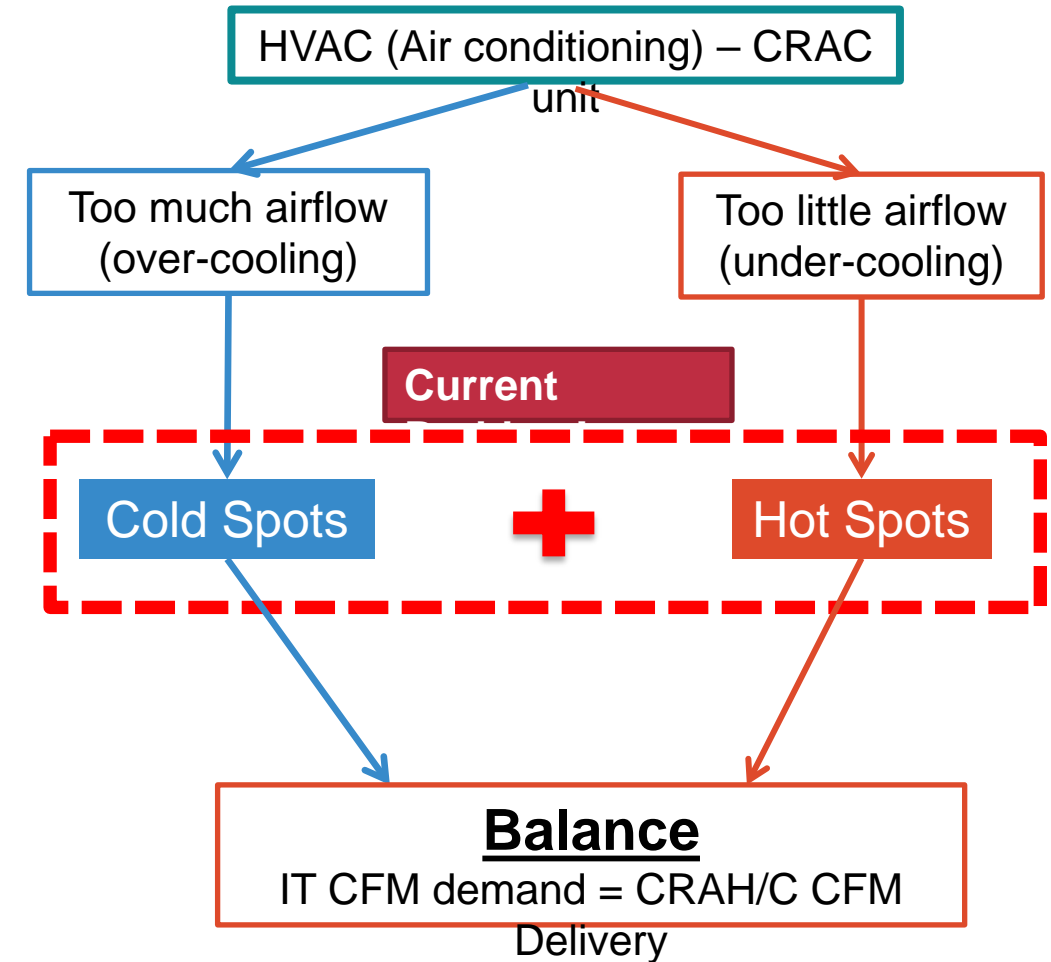
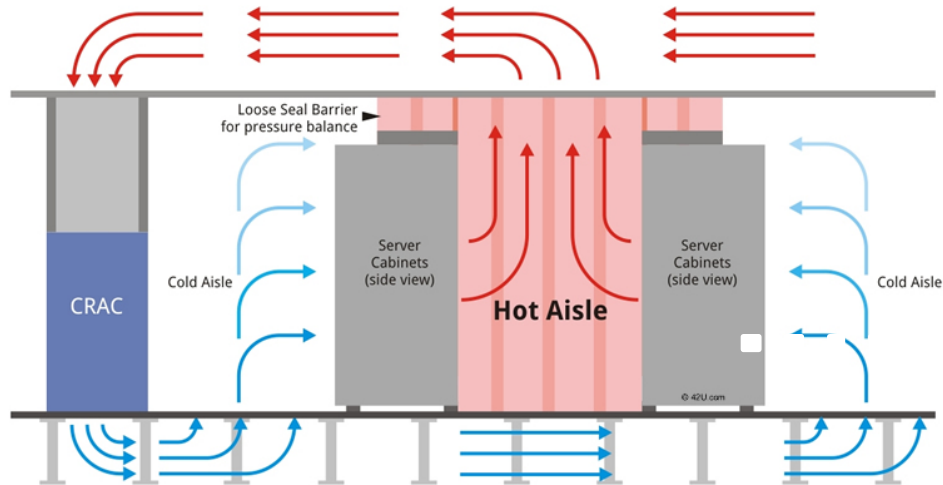
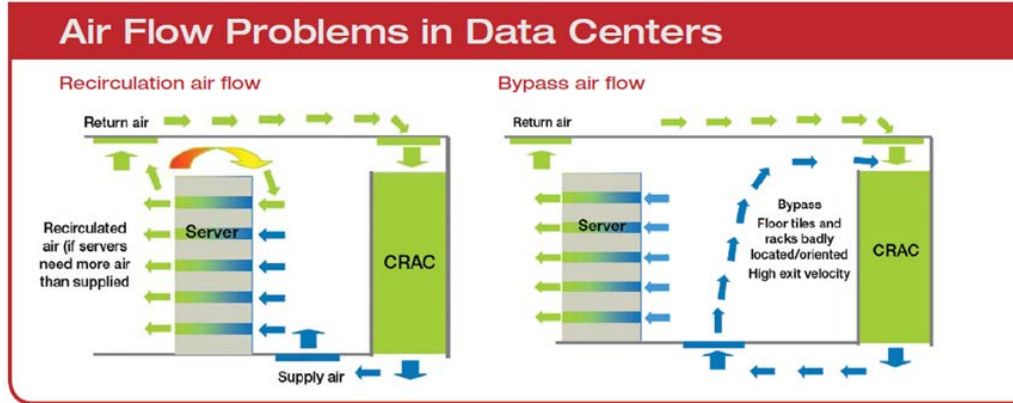
- A vendor told me it was required by code
- I'll save energy by just doing it
- I heard it was a good idea at a conference
- My competition is doing it
- I think I can get good PR miles out of it
- My boss told me to

Raising Temps because....

- ENERGY SAVINGS
 - Lower fan/pump energy
 - More Economizer Hours
 - Better efficiency performance on HVAC
- Couple w/ Containment for improved reliability (X FACTOR)
 - ASHRAE Thermal Guidelines
 - Reduce hardware failures

David Quirk P.E. – VP, DLB Associates

Why is air management important: Big Picture



Simple Colo Example - Identifying Issues & Baselining

“Seeing” Air Management Issue



FLIR ONE ~ \$250

Simple Colo Example - Opportunity

Real-World Findings:

Existing Annual Energy Costs for fans on 9th Floor from CRAC's

16 units x 4.1HP x 3 motors/unit
= 12.3HP/unit x 16 units
= 196HP

196HP x 0.746kW/HP
= 146kW

146kW x 8760hrs/year
= 1,278,969kWh/year

1,278,969kWh/year x \$0.08/kwh

= ~\$102,000/year in energy costs from fans only.

IT airflow demand ~600kW x 130CFM/kW = 78,000 CFM

Actual Airflow = 15,000CFM x 16 units = 240,000 CFM

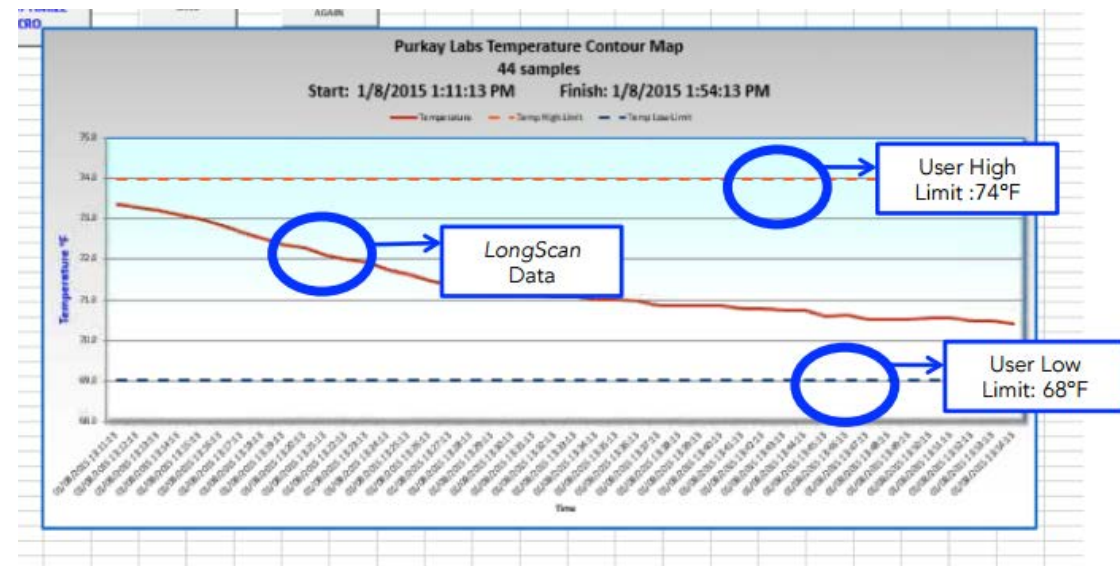
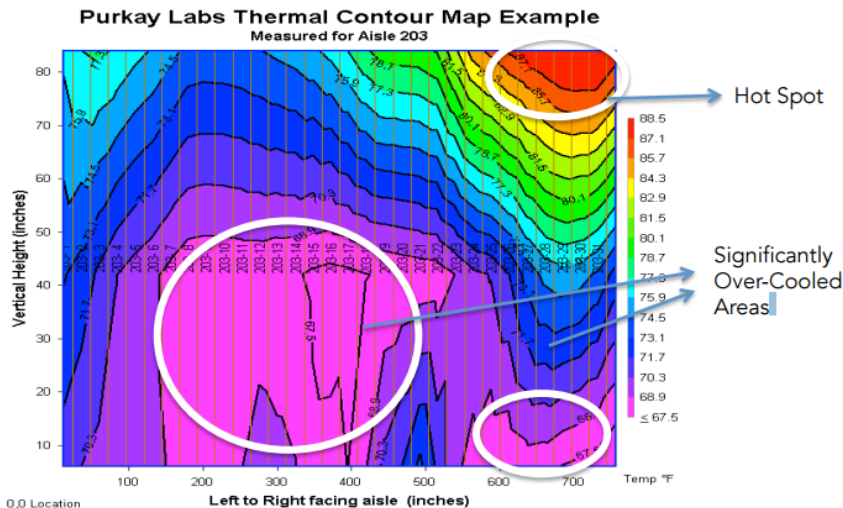
-> 3x airflow , @ 0.3" W.C.

This is only for
one floor

How Do We
Quickly Identify
And Address Air
Management
Issues and make

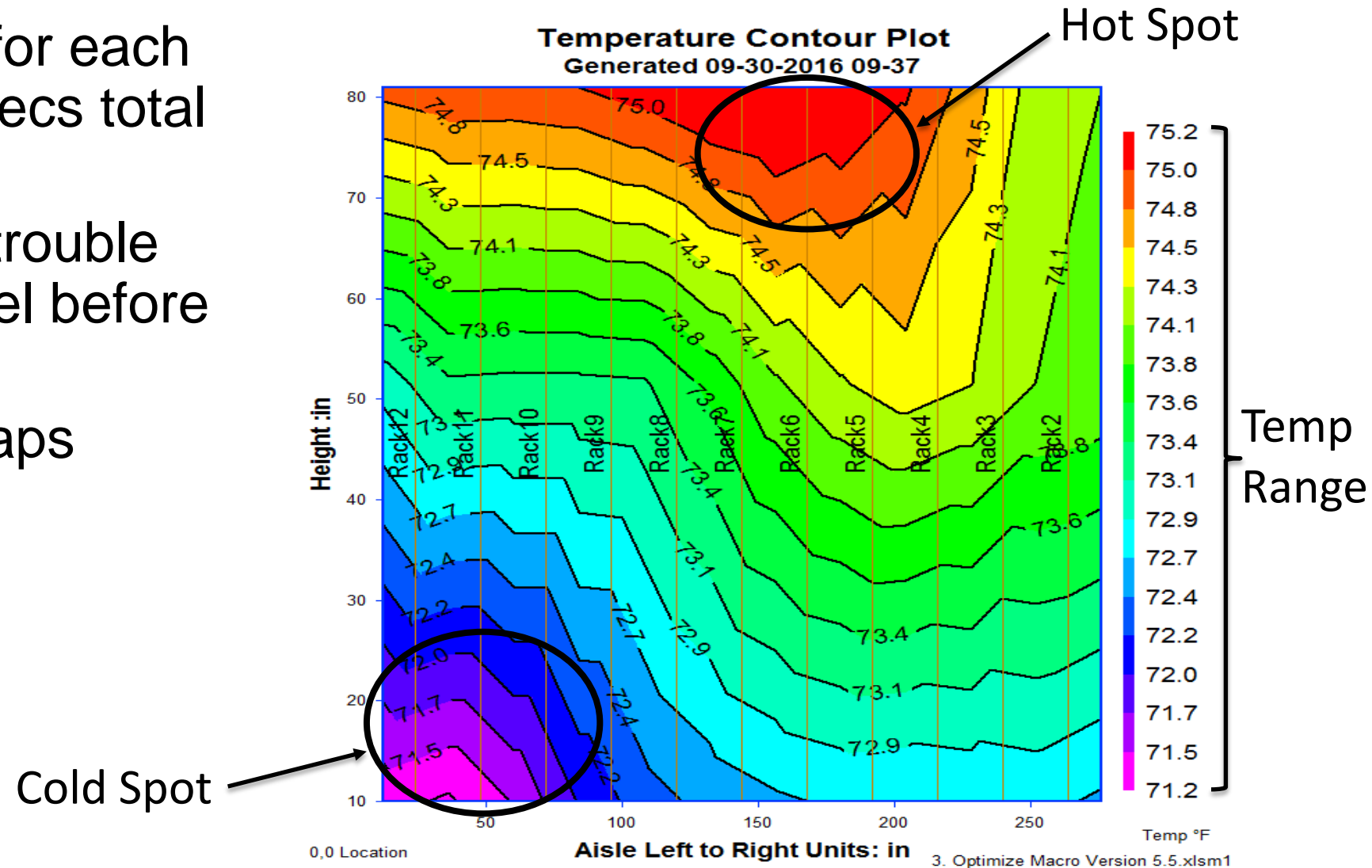
Audit Tool: Audit-Buddy

- Collects data on temperature and humidity on a rack level
 - Plots graphs and produces tables for quick visual analysis by operators
 - Spread out sensors help identify under and over-compensated spots on a rack level
 - Comes in both °F and °C for facilities using metric
- Investigate customer feedback/complaints conveniently
 - Provide accurate data to customers to prevent mistrust
 - Easily identify and rectify complaints



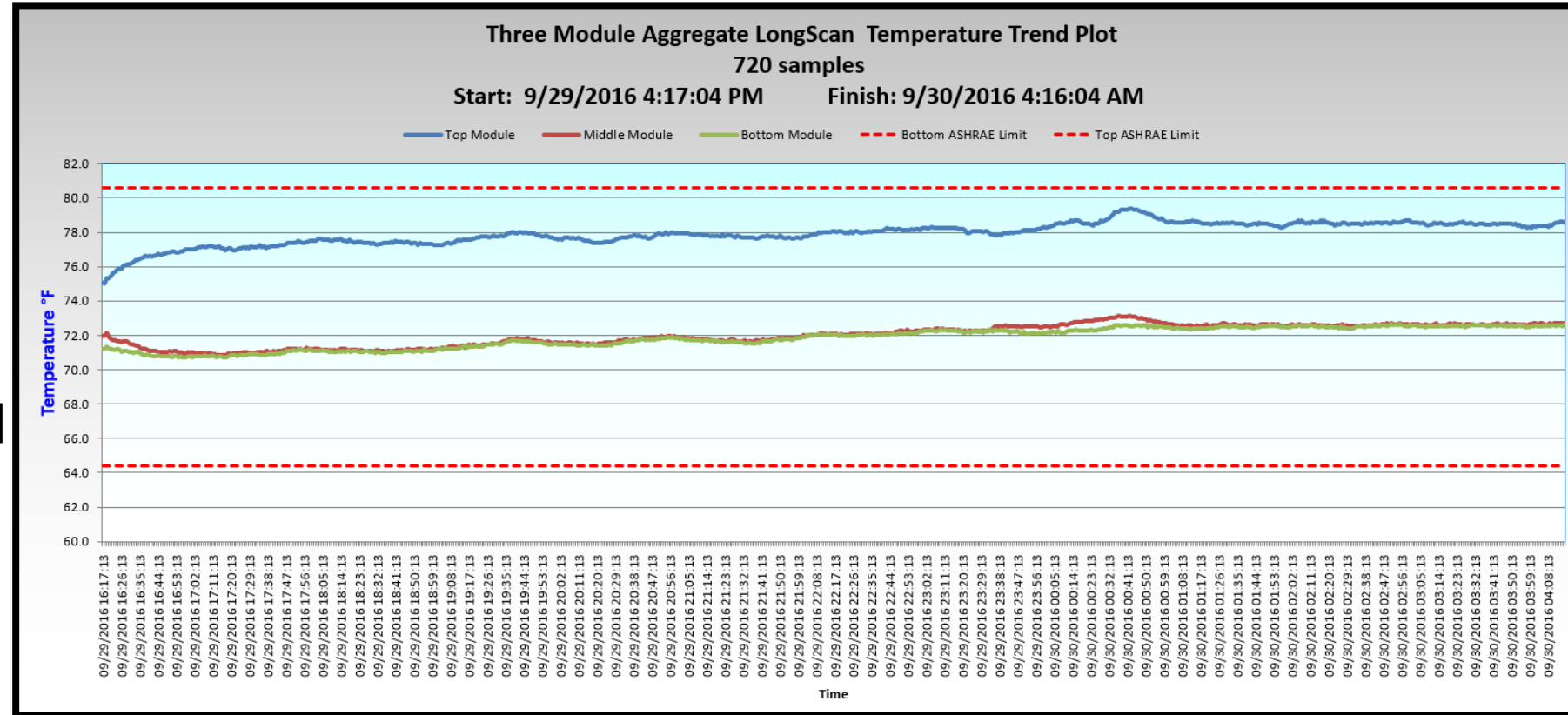
Audit-Buddy Scan Modes: QuickScan

- 20 secs active scan for each rack in an aisle (40 secs total per rack)
- Quick way to detect trouble spots on an aisle level before deep analysis
- Produces contour maps
 - Temperature
 - Humidity
 - Dew Point
 - Delta-T

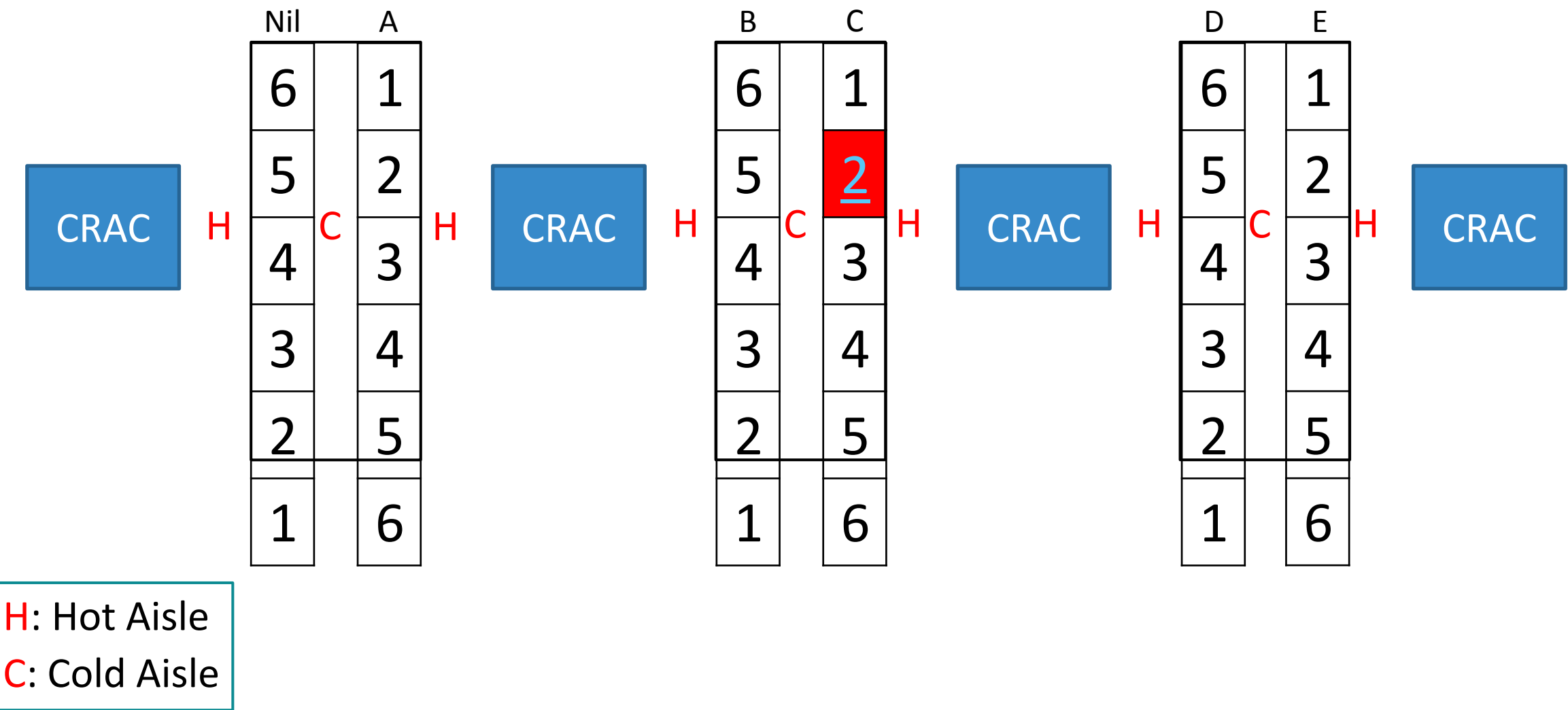


Audit-Buddy Scan Modes: LongScan

- Deeper analysis on a rack level
- Last up to 1 hour to 7 days
- Samples every minute
- Generate time-trend vs temperature graph
- To track temperature trends on problematic racks with respect to time



Scan Modes: Real-World Findings - Level 9 floor plan

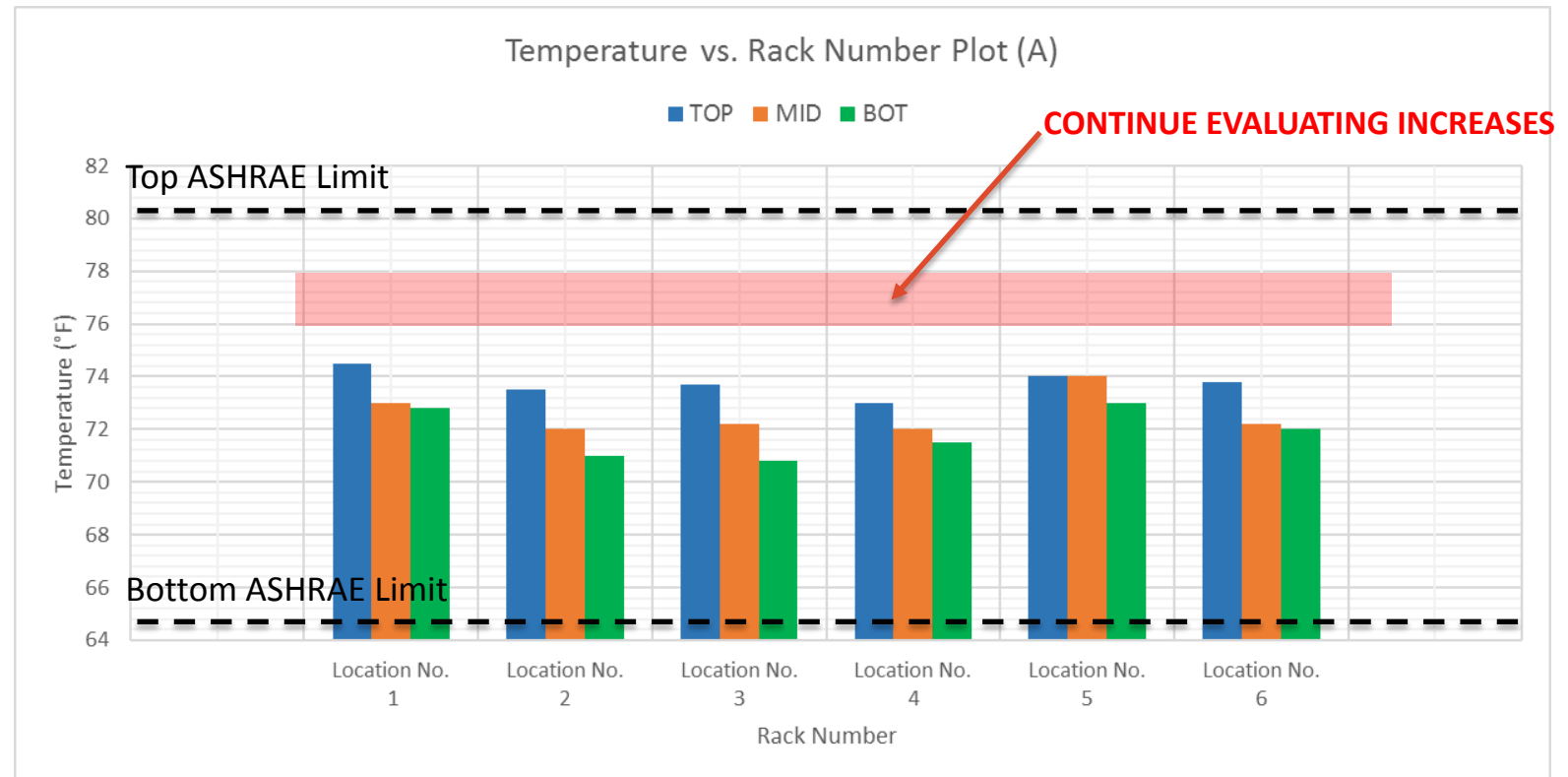


Simple Colo Example - Findings & Actions

- Large span of cold isle temps, most at or below 68°F. Why? **WE MUST GO HOTTER**
- A few isolated hot spots. (*site controlling to worst case*)
- Step #1: Fixed Air Management issues:
 - Cold isle doors pre-existing
 - Added numerous blanking panels (many pre-existing)
 - Added dampers on perforated tiles to help balance airflow
 - Sanity check with balometer hood (CFM vs IT load – 800+CFM/tile)
- 0.3" W.C. - Modified CRAC fan controls to modulate fans to 70% minimum on low/no call for cooling.
- Identified CRAC in area of influence with sustained no-load and turned off.
 - Minimal temperature change (small drop – less warm air mixing with cool air under floor)
 - Saved \$6,400/yr
- Level Set
- Start Increasing CRAC Return Air Set point – 1°F every full day.

Simple Colo Example - Findings & Actions

- Raised set points of remaining area of influence CRAC return temps between 6°F-8°F
 - (Baselines 70°F-72°F)
 - Increased capacity (1-3%)
 - Systematic process
- Rack inlets raised in somewhat linear fashion (surprising)
- Inlet temps remain within SLA's, more efficient operation and reduced stranded capacity
- No operational issues to date.
- More Upgrades ongoing (targeting turning off another 3 CRAC units (of 16 total), additional containment, wireless monitoring.)



John R. Dumler, P.E. , C.E.M.

Technical Operations Manager, Energy

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jdumler@digitalrealty.com

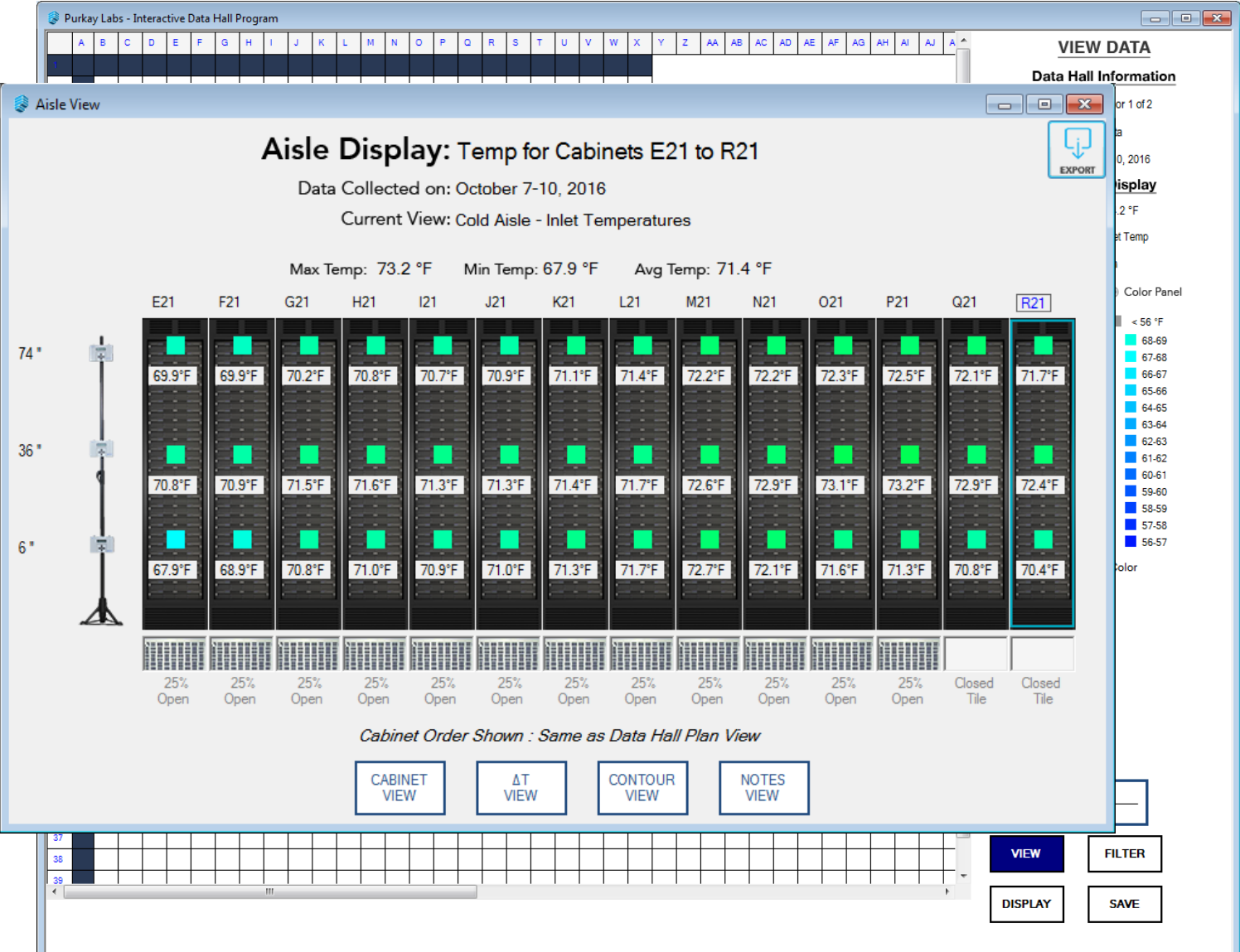
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DIGITAL REALTY

Appendix

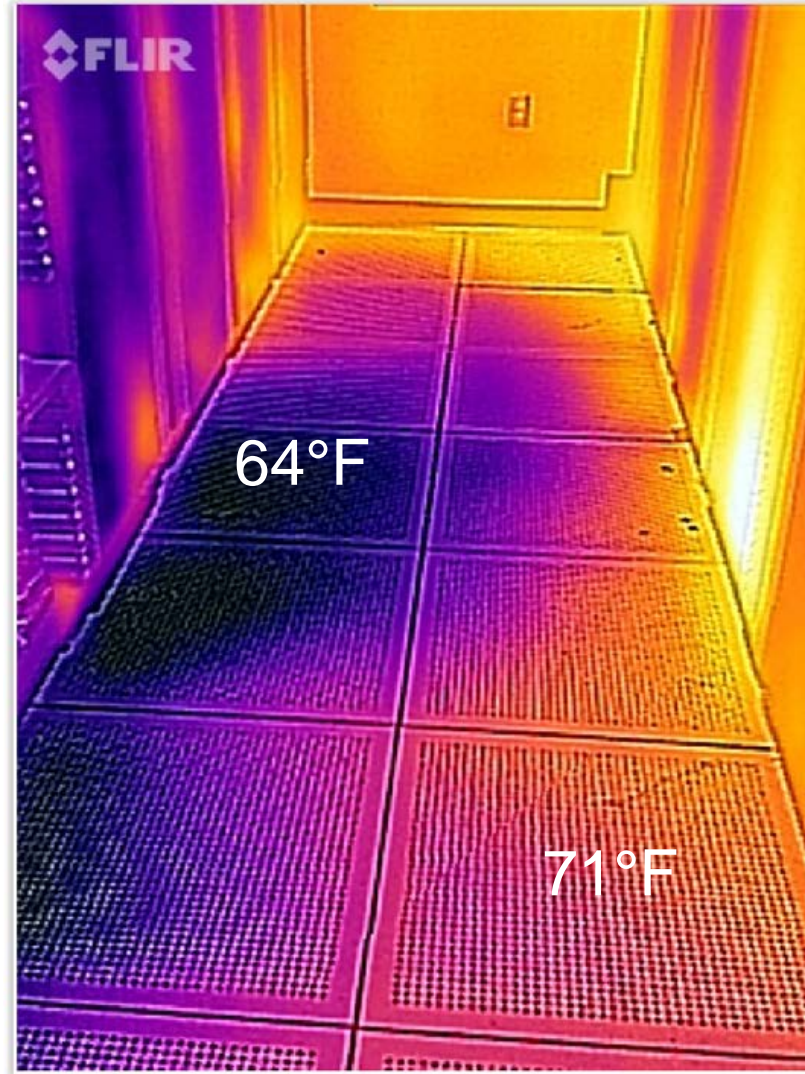
Data Hall: An Interactive Map – Aisle View



Return

Simple Colo Example - Identifying Issues & Baselining

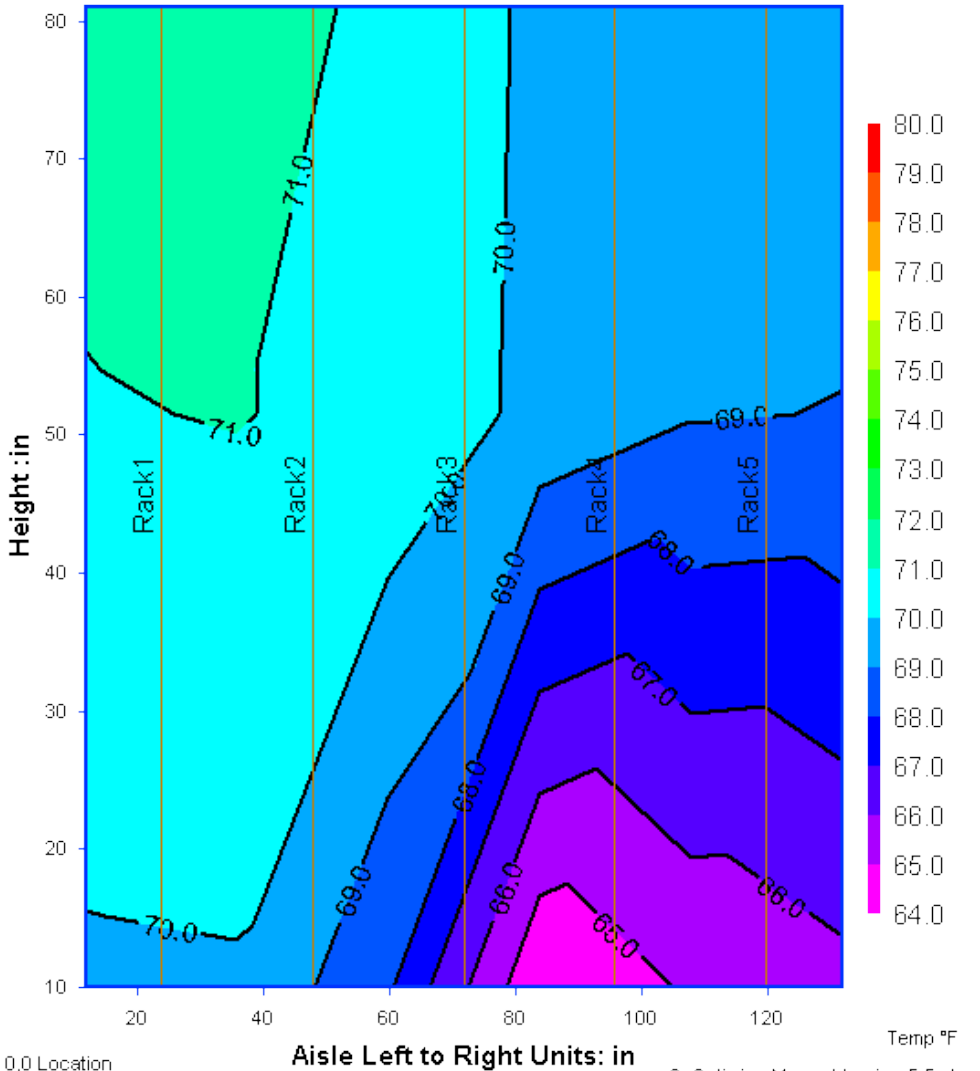
“Seeing” Air Management Issue



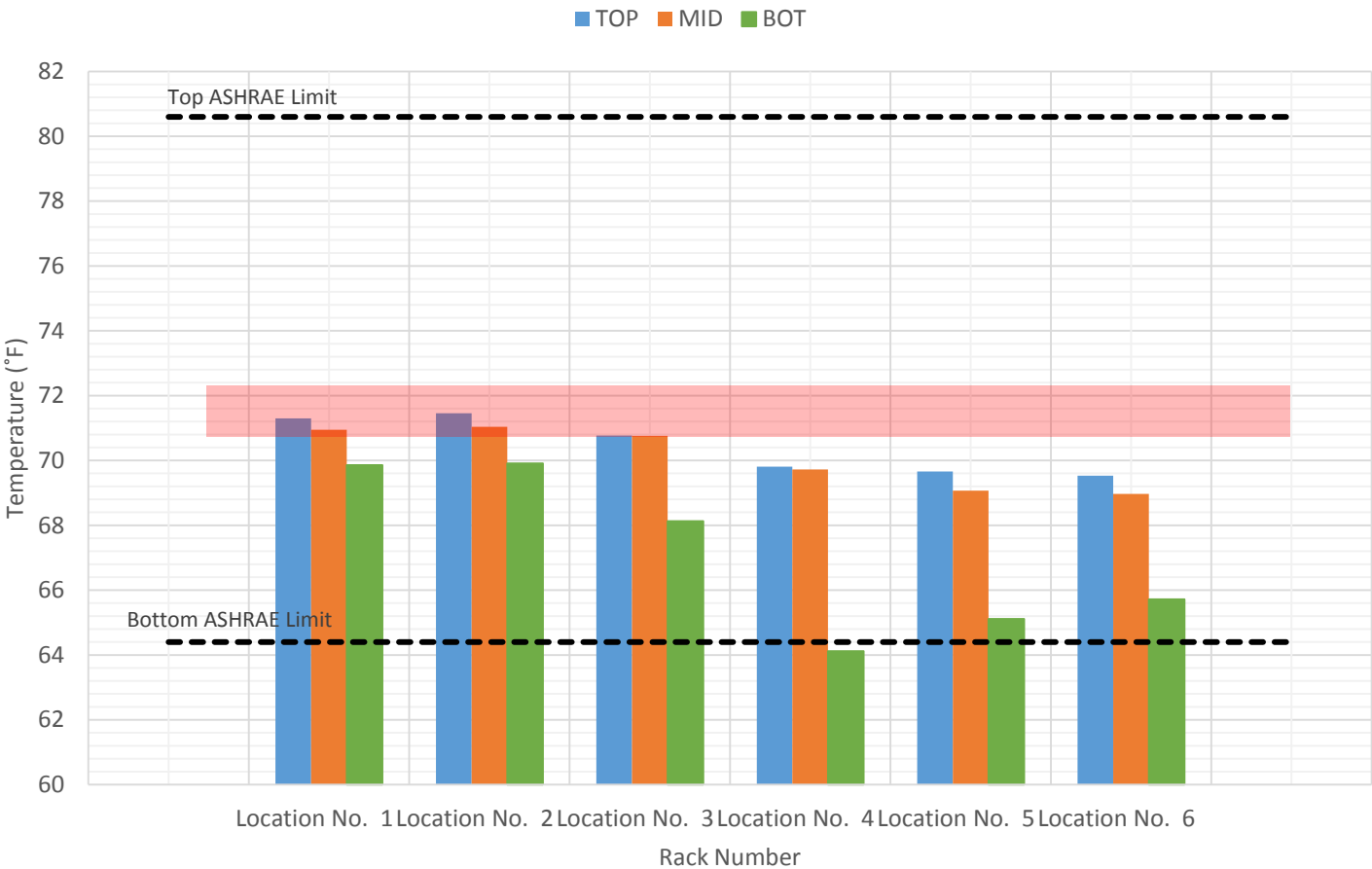
FLIR ONE ~ \$250

Nil Temperature Contour Plot

Temperature Contour Plot
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QuickScan Temperature vs. Rack Number Plot (Nil)

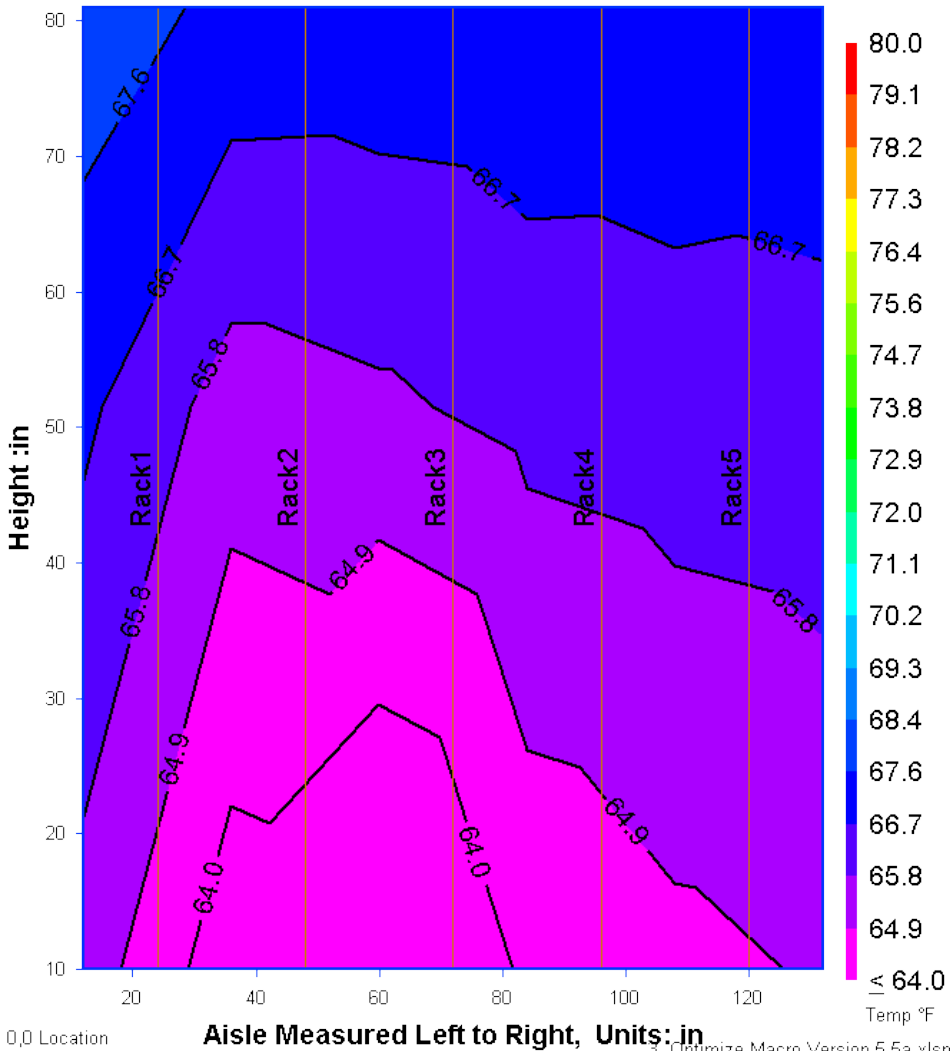


Return

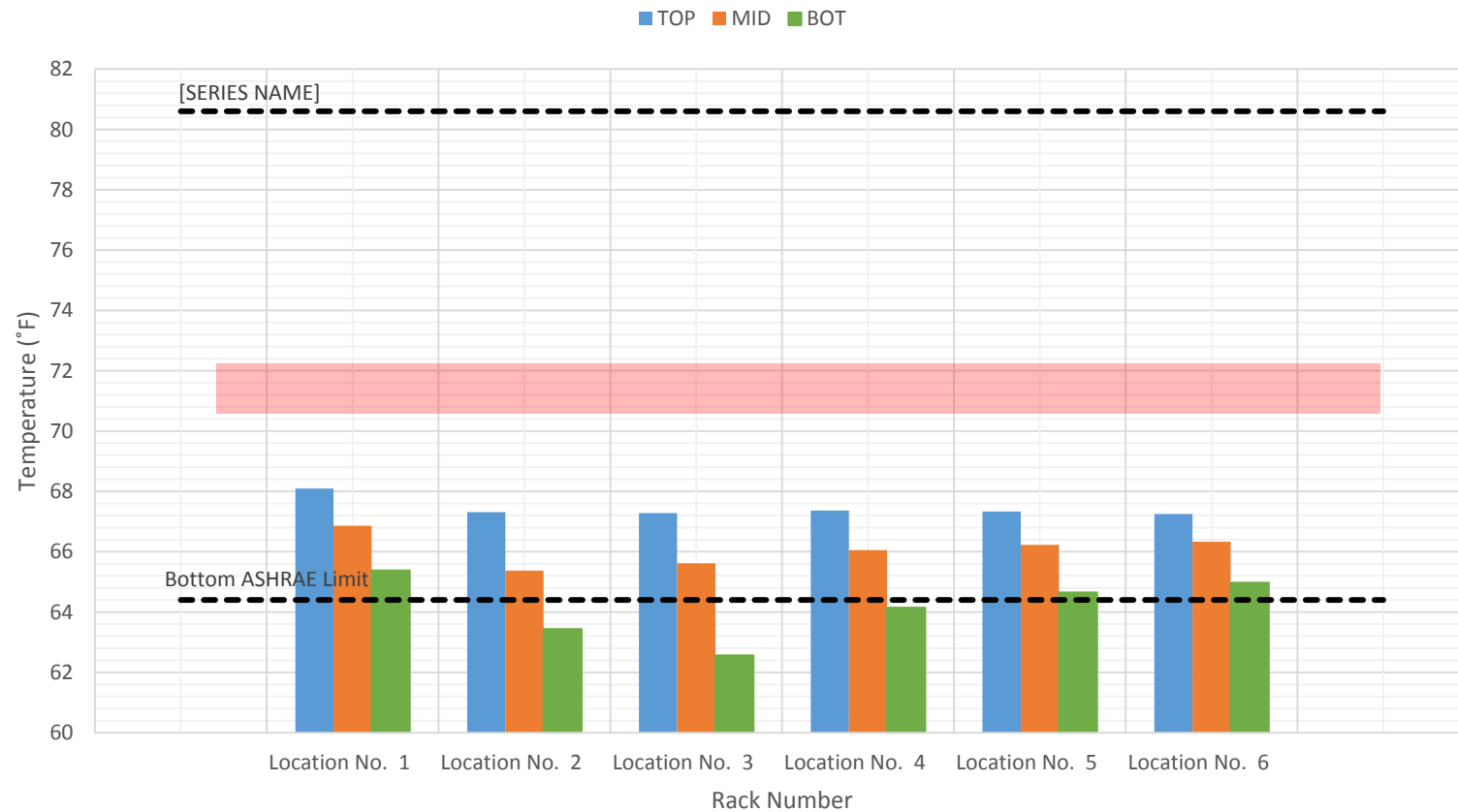
A Temperature Contour Plot

Temperature Contour Plot

Generated 10-06-2016 12-04



QuickScan Temperature vs. Rack Number Plot (A)



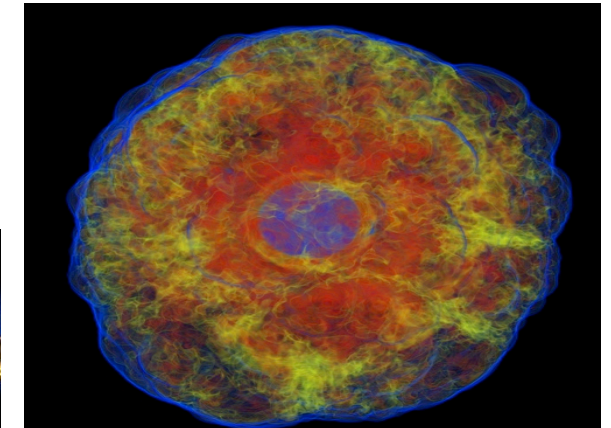
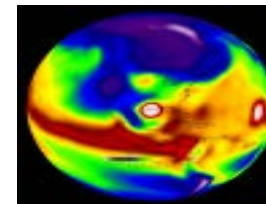
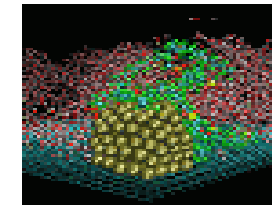
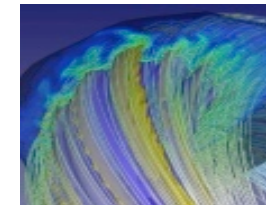
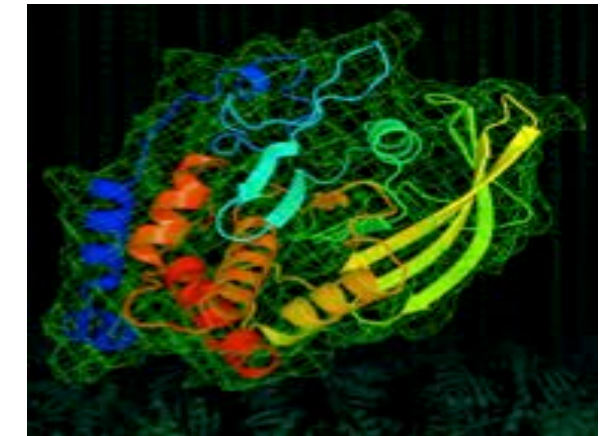
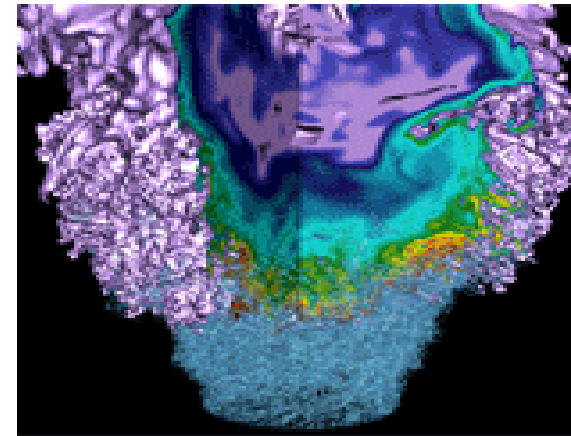
Return

Dale Sartor

Lawrence Berkeley National Laboratory

NERSC

Shyh Wang Hall



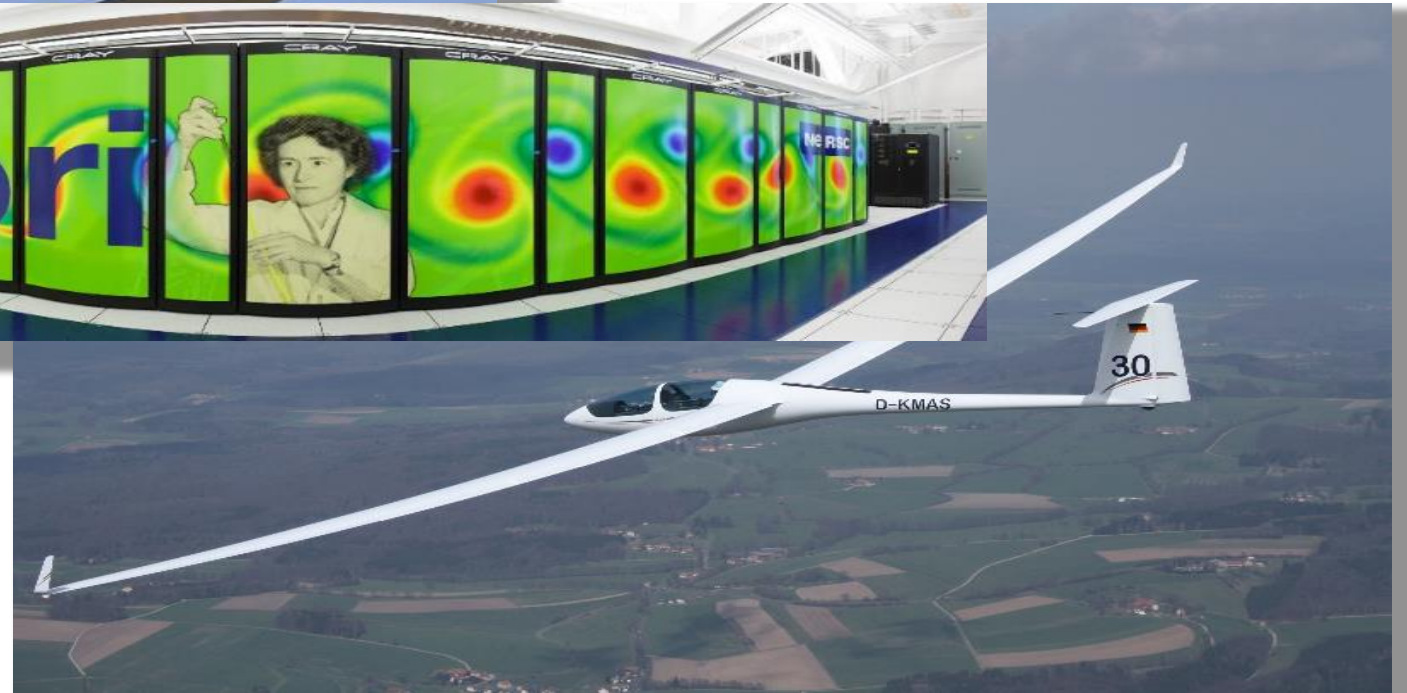
Better Buildings Summit
Washington DC
May 16, 2017
Dale Sartor, PE

What does your Energy look like?



Cooling Systems

Compute Systems



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The New Home for NERSC



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- **Formerly, the Computation Research and Theory Facility (CRT)**
- **142,000 square feet total**
- **IT load will dominate building**
- **4 large AHUs for air-cooled loads**
- **4 cooling towers with a heat exchanger for water-cooled loads**
- **Water-cooled supercomputers**
- **Air and water side economizers**
- **Air-side heat recovery for heating offices**
- **IT loads cooled without compressors**

NERSC hosts Cori (#5 Top 500, Nov 2016)



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File Systems and Air Cooled Computers



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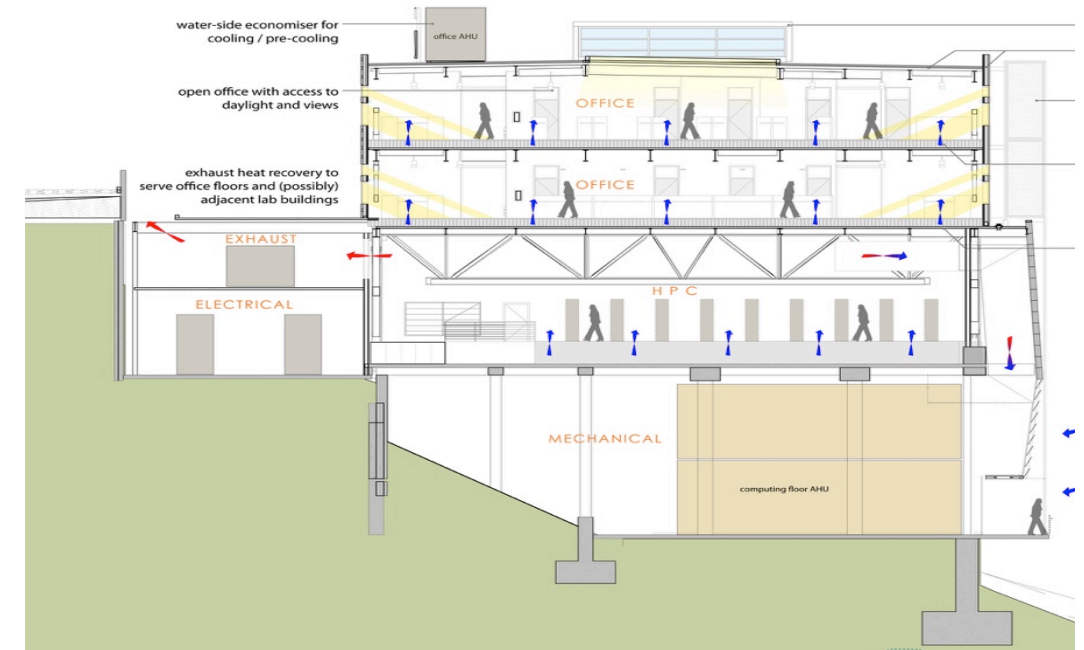
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Air System Design Approach



- Annual PUE less than 1.1
- Air-Side Economizer
- Direct Evaporative Cooling for Humidification/Pre-cooling
- Low Pressure-Drop Design

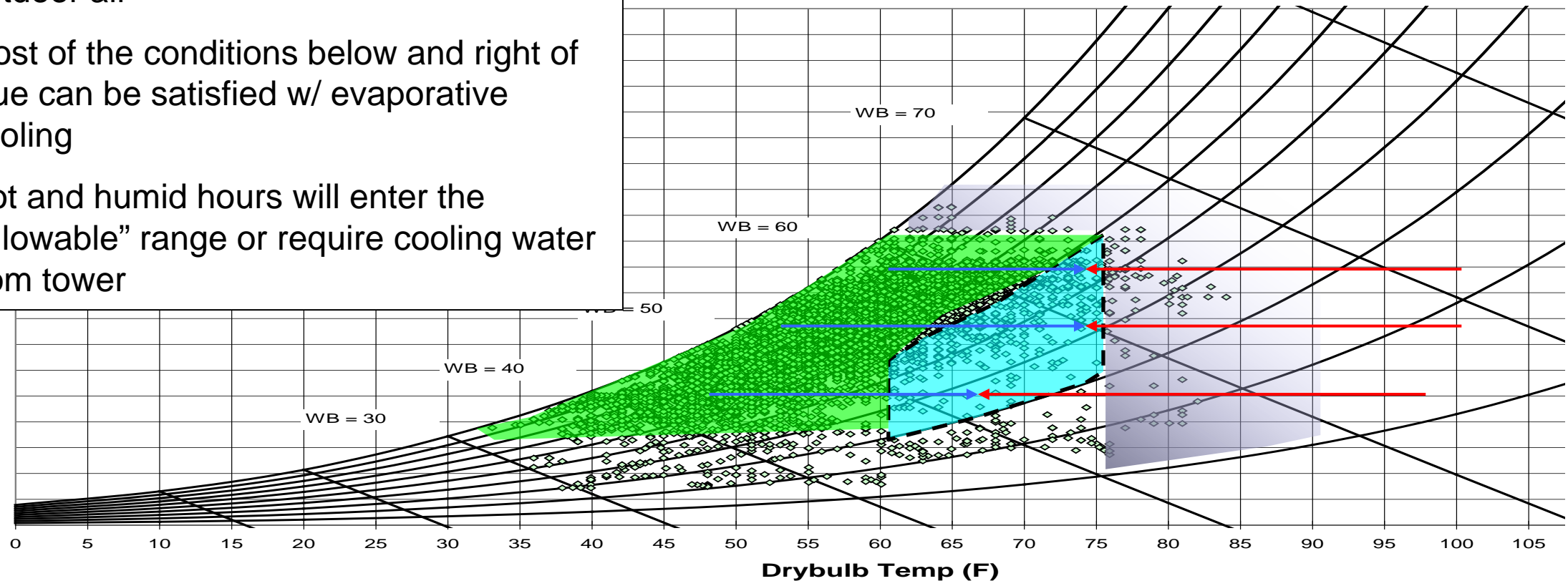


Free Cooling – Outside Air Based Design



1. Blue = recommended supply
2. Green can become blue mixing return and outdoor air
3. Most of the conditions below and right of blue can be satisfied w/ evaporative cooling
4. Hot and humid hours will enter the “allowable” range or require cooling water from tower

Annual Psychrometric Chart of Oakland, CA
(relative humidity lines are stepped by 10%,
wetbulb lines by 10 degrees F)



Free Cooling – Water Based Design



- **CRT Performance**
- **Annual PUE less than 1.1**
- **Closed-loop treated cooling water from cooling towers**
- **Headers, valves and caps for modularity and flexibility**



1st Phase 20k Sq Ft Computer floor



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Seismically isolated from building



12.5 MW power (40 MW max)



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10 MW liquid cooling (20 MW max)



6 MW of liquid cooled systems installed



2 MW Air Cooling (17 MW max)

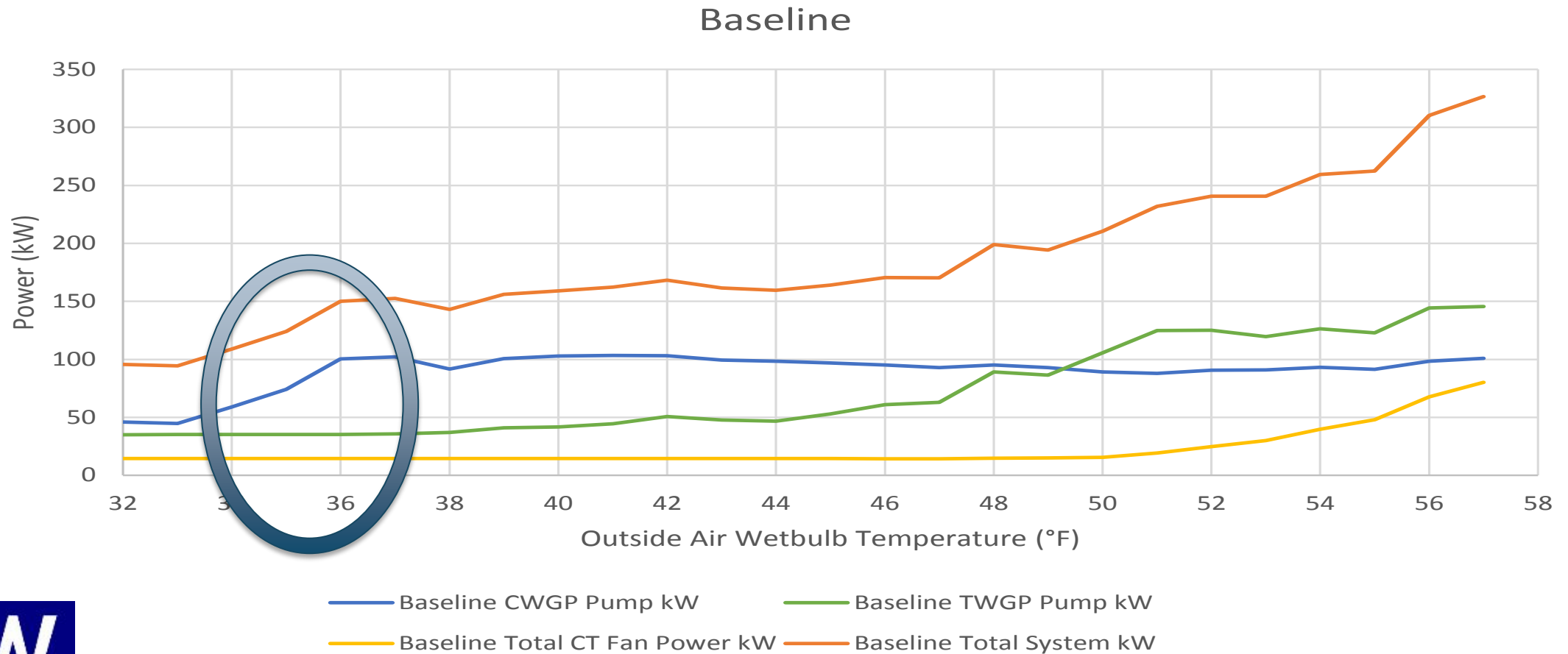


100 % Outside air capable

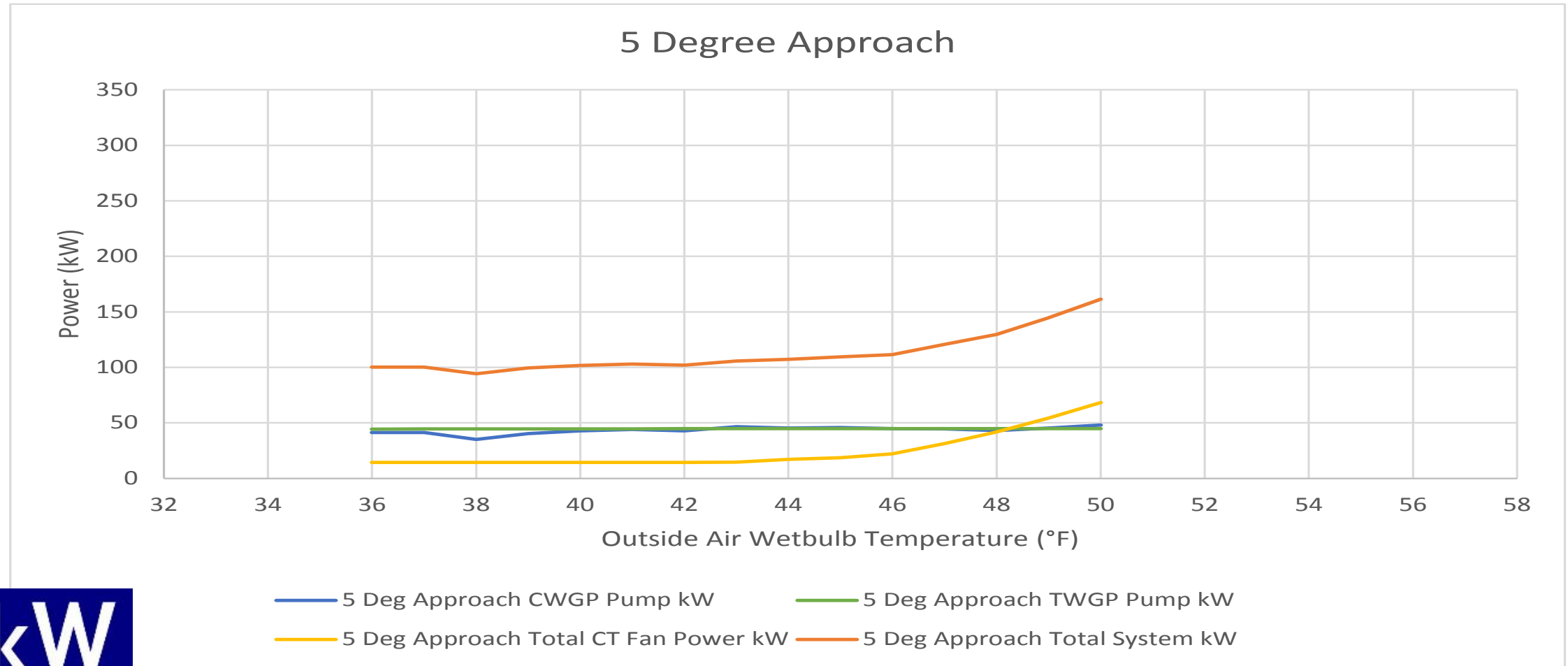


- **Performance**
- **Opportunities for improvement/optimization**
- **Lessons learned**

Liquid Cooling Performance Baseline



Liquid Cooling Performance Balanced



Data Center ASHRAE Design



Baseline Conditions

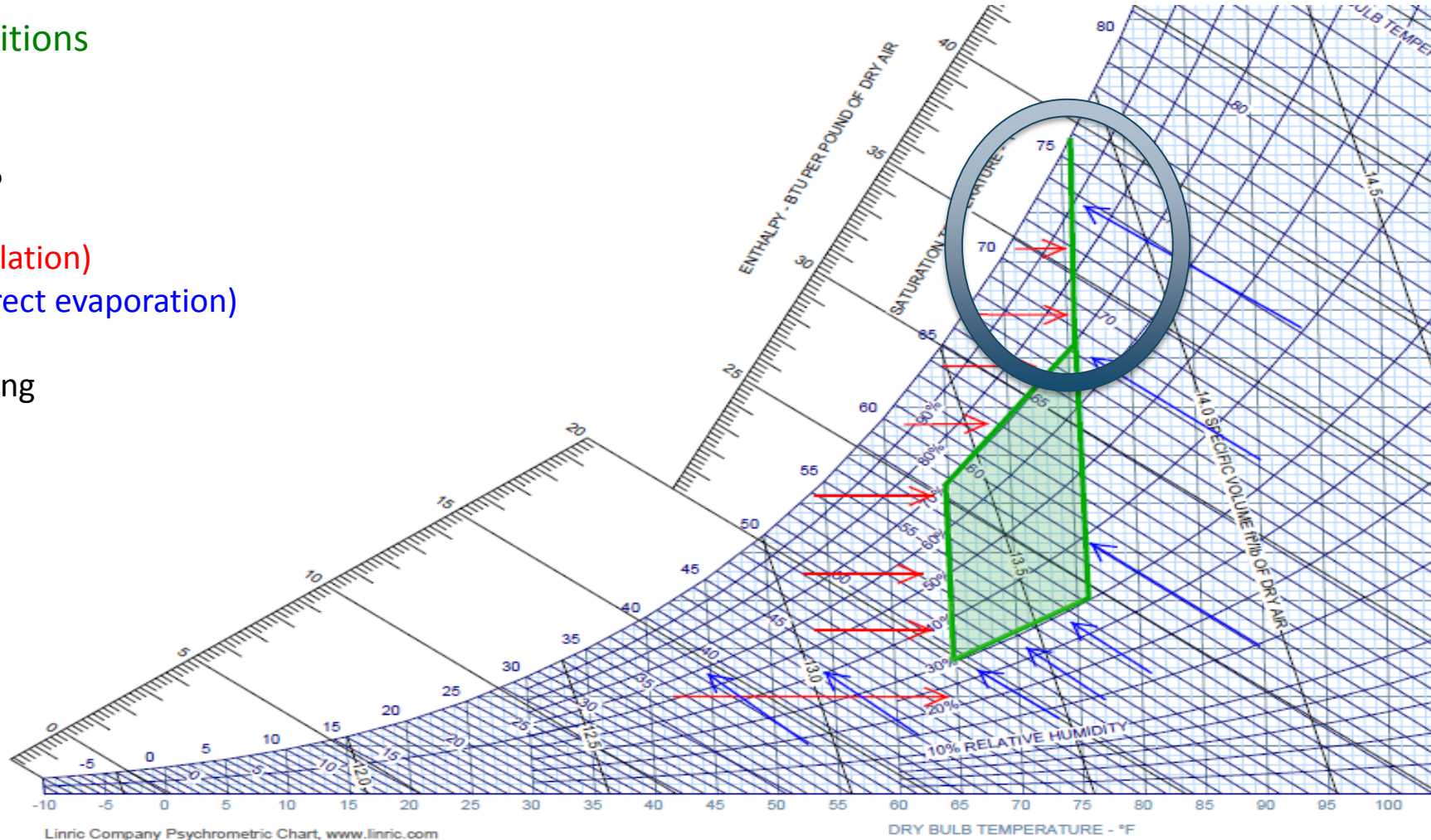
65F < SAT < 75F

30% < RH < 70%

Heating (recirculation)

Humidifying (direct evaporation)

NO Dehumidifying



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Allowing Lower Relative Humidity



Reduce Minimum Supply Air Temperature and Humidity

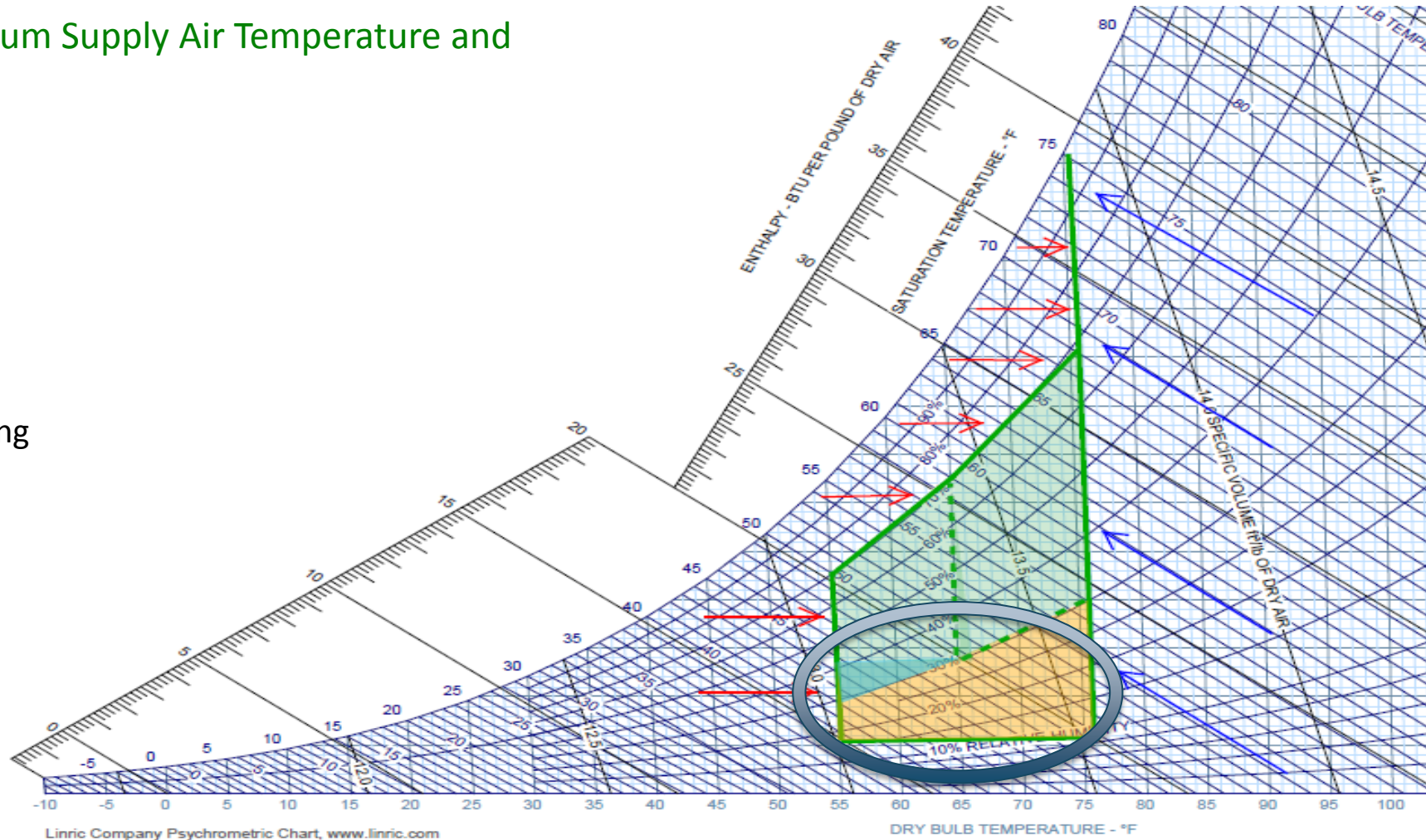
Min SAT = 55F

Min DP = 10F

Heating

Humidifying

NO Dehumidifying



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Electricity and Water Savings



		Energy Savings (kWh)		Water Savings	Cost Savings	PUE Reduction
	Measure Title	Estimated	Verified	Gallons	\$	
Controls						
1	Optimize Cooling Tower Fan and Pump Controls	-	360,000	100,000	\$ 20,880	0.007
2	Optimize Closed Loop Pump Control	240,000	-	110,000	\$ 13,920	0.005
3	Optimize AHU SAT and Flow Control	300,000	-	-	\$ 17,400	0.006
4	Reset Cooling Water Supply Temperature	600,000	-	220,000	\$ 34,800	-
5	Install Firmware to Enable ESS Mode for UPSs	190,000	-	65,000	\$ 11,020	0.004
Physical Projects					\$ -	
6	Cold Aisle Partial Containment	100,000	-	-	\$ 5,800	0.002
Total		1,400,000	400,000	500,000	\$ 100,000	0.025



IT kWh 48,200,000 *Extrapolated based on typical operation*
 Total Non-IT kWh 3,200,000 *Does not include CRAY fans*
 PUE 1.07
 Estimated Post-Case PUE 1.04
 Savings as a Fraction of Cooling System kWh 56%

Rough Savings Estimates					
		Energy Savings (kWh)		Water Savings	PUE
	Measure Title	Estimated	Verified	Gallons	Reduction
<u>Controls</u>	-				
1	Optimize Cooling Tower Fan and Pump Controls	-	360,000	100,000	0.007
2	Optimize Closed Loop Pump Control	240,000	-	110,000	0.005
3	Optimize AHU SAT and Flow Control	300,000	-	-	0.006
4	Reset Cooling Water Supply Temperature	600,000	-	220,000	(0.001)
5	Install Firmware to Enable ESS Mode for UPSs	190,000	-	65,000	0.004
<u>Physical Projects</u>					
6	Cold Aisle Partial Containment	100,000	-	-	0.002
	Total	1,400,000	400,000	500,000	0.024

Cost of electricity	\$	
	0.058	/kwh
Non IT load savings	1,190,000	kWh
Average mechanical kW savings	136	kW
Total cooling system energy	3,200,000	kWh
Total system power	365	kW
IT Load	5500	kW
IT kWh	48,200,000	kWh
Baseline PUE	1.07	
PUE after implemented measures	1.04	

Measure Breakdown

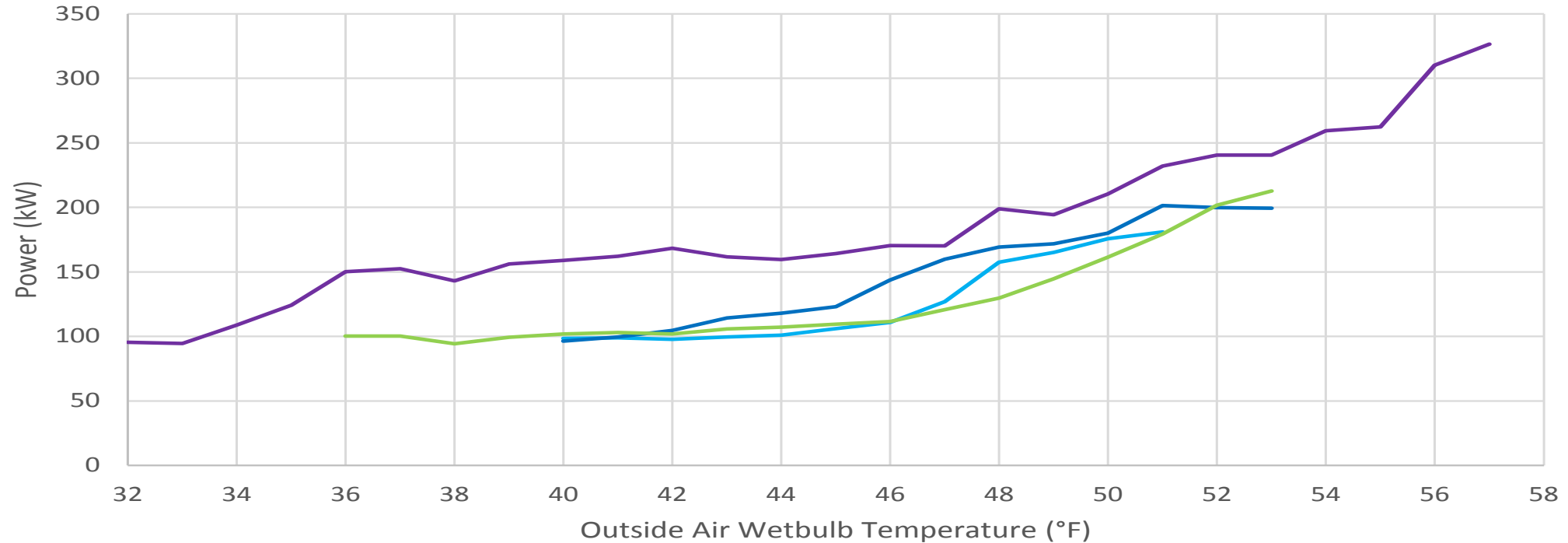


- **Cooling tower supply temperature reset based on wetbulb temperature**
- **Reduce minimum tower water pump speed based on minimum cooling tower flow**
- **Install booster pump to serve RTUs, lowering differential pressure in main cooling water loop**
- **Replace closed loop bypass valves with flow limiters**
- **Adjust closed loop differential pressure reset**
- **Reduce AHU supply air temperature as outside air temperature drops, and control fan speed based on max cold aisle temperature**
- **Turn off redundant cooling tower pump to improve pump efficiency**
- **Enable variable speed fan control on CRAY units and optimize cooling water temperature**
- **Expand cold aisle temperature/RH envelop based on ASHRAE 2015 guidelines**
- **Install firmware to enable ESS Mode (eco mode) for UPSs**

Cooling System Optimization



Total Power Comparison



— Baseline Total System kW — Reduced Min Speed Total System kW
— 4 Deg Approach Total System kW — 5 Deg Approach Total System kW

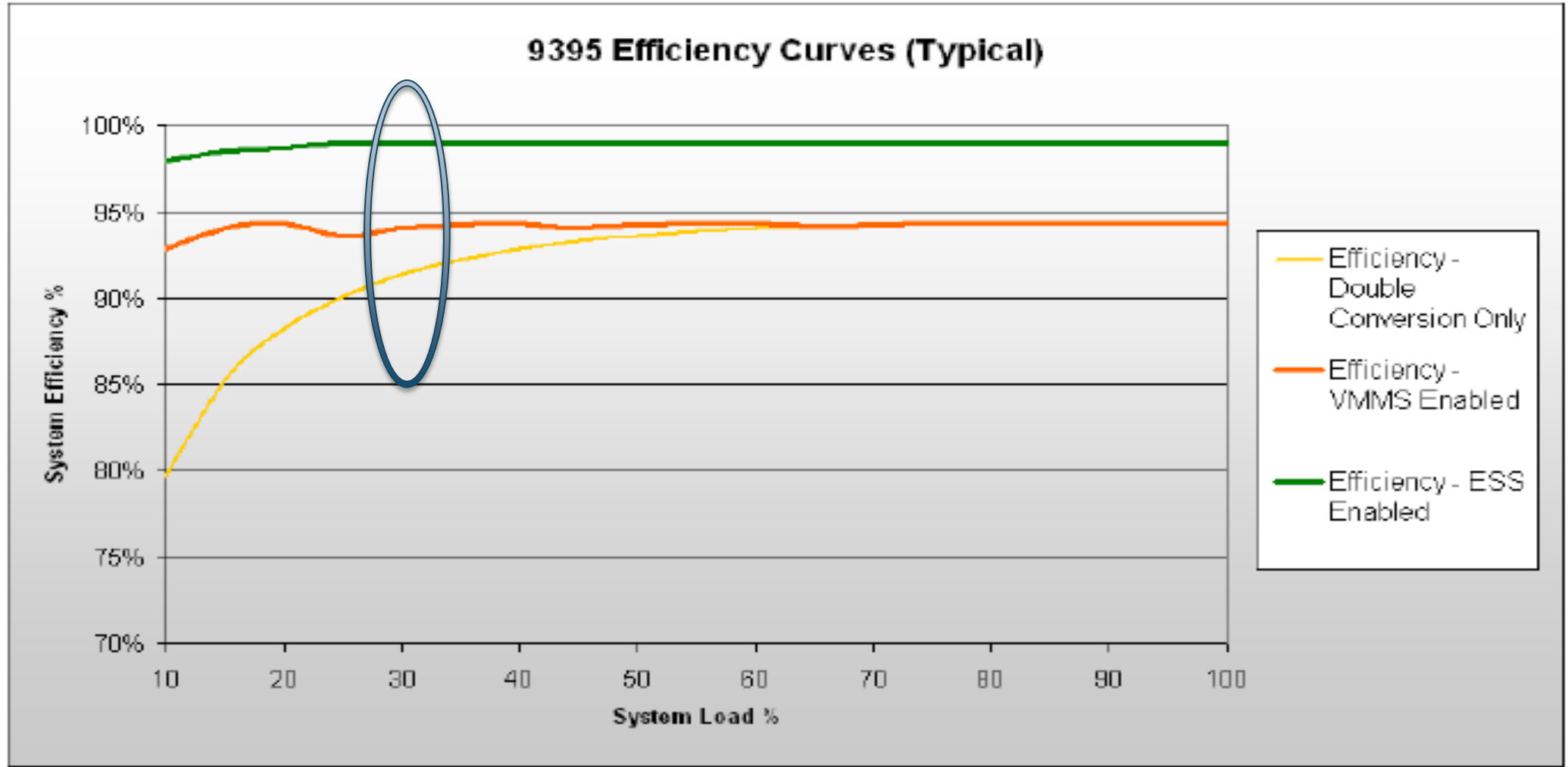


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Skip the Double Conversion Losses



Our Approach



1. Identify opportunities
2. Identify critical control boundaries
3. Try it out!
4. Verify using trend data
5. Repeat until optimized

All parties work closely throughout the project



Takeaways



- Involve full team from measure development through implementation
- Start with client priorities and question everything
- Incremental, iterative progress can be most effective
- Don't underestimate interconnectivity of systems
- A sub 1.1 PUE data center can still be improved!



The source of cool air and cool views ...



Questions?



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