

# How to Save Money In Your Small Data Center

Dale Sartor, P.E. Steve Greenberg, P.E. Lawrence Berkeley National Laboratory

DATE 08/20/2018





## **Today's Presenters**

Name	Organization
Dale Sartor, P.E.	LBNL
Steve Greenberg, P.E.	LBNL

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http://datacenterworkshop.lbl.gov/



### **Agenda**

- Why small data centers are important
- Simplest Measures
  - Information Technology (IT)
  - Cooling
  - Electrical distribution
- Still simple, a little more work
  - IT refresh and virtualization
- Break
- Higher-level investment, but very cost-effective
  - Move data center functions elsewhere
  - Implement IT and infrastructure power monitoring
  - Capital upgrades to cooling system
- Training for IT and Facility Staff
- Resources

### **Why Small Data Centers are Important**

- Definition: "Small" is less than 5,000 square feet of computer floor
- Have nearly half of the total servers
- Use 40 billion kWh/yr in the US (~\$4 billion)
- Embedded data centers often dominate the entire building's energy use even though they are a small fraction of the total floor area
- Have challenges in terms of good management:
  - Typically no one person in charge, and no one's full-time job
  - Security risks
  - Computing and supporting infrastructure energy not monitored
- Have large energy-saving opportunities, typically 20 40%. 30% savings would result in ~\$1 billion per year in savings, across US data center industry.
- Not exempt from Data Center Optimization Initiative

### **Data Center Optimization Initiative (DCOI)**

#### Specific goals for data centers:

- Promote energy optimization, efficiency, and performance
- Installing and monitoring advanced energy meters in all data centers by fiscal year 2018
- Establishing a Power Usage Effectiveness (PUE) target of 1.2 to 1.4 for new data centers and less than 1.5 for existing data centers.

#### Run by OMB and GSA

https://datacenters.cio.gov/

#### **Simplest Measures**

- Turn off unused servers
- Improve server power management
- Improve air management
- Increase temperature setpoints toward the high end of the range set by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE)
- Turn off active humidity control
- Minimize requirements for Uninterruptible Power Supplies (UPS)

#### **Turn off unused servers**

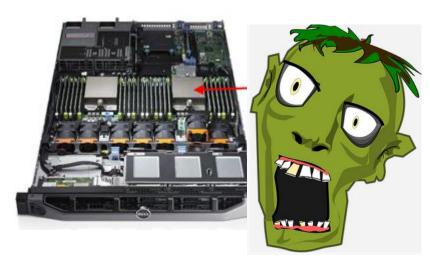
Known as "comatose" or "zombie" servers: they do no useful work,

but use

- Power
- Space
- Cooling
- Estimated 20-30% of servers are comatose
- An idle server uses
  - ~50% of full-load power (100% utilization)
  - ~75% of typical load power (25% utilization)

#### What to do:

- Establish and maintain a list of what's running on each machine
- Shut down unused servers

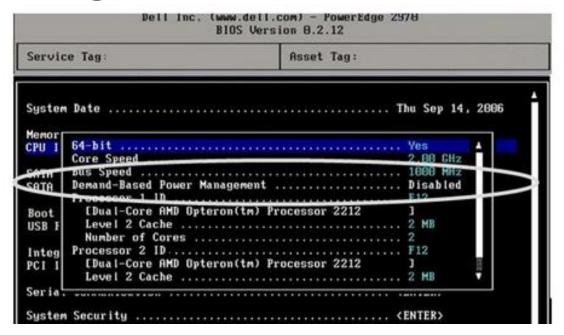


#### Improve server power management

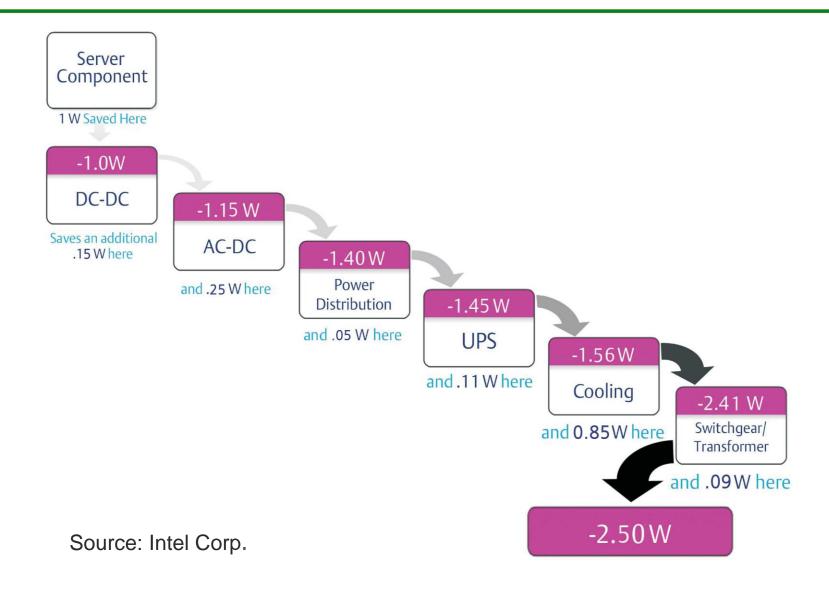
- Most servers are shipped with power management turned on
- Most servers in use have power management turned off

#### What to do:

- Check power management settings and enable
  - Processor
  - OS (Operating System)/hypervisor
  - BIOS (Basic Input/ Output System)

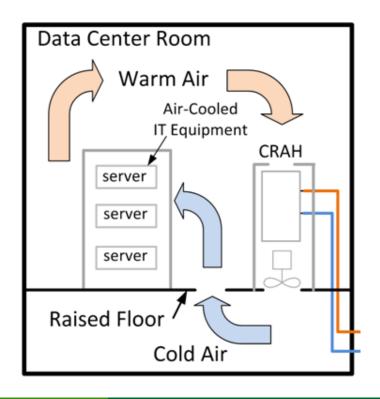


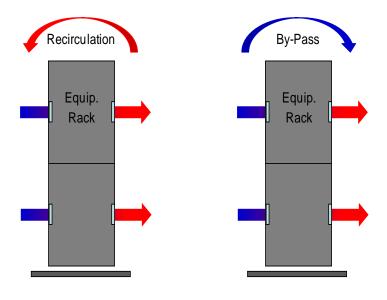
#### **Actual Saving of One Watt Saved at the IT Equipment**



#### Improve air management

- Cool supply air ideally gets from cooling equipment to the Information Technology (IT) inlet without mixing with hot discharge air
- Hot discharge air ideally returns from the IT exhaust to the cooling equipment without mixing with the cool supply air





Note: CRAH (Computer Room Air Handler) is the cooling equipment

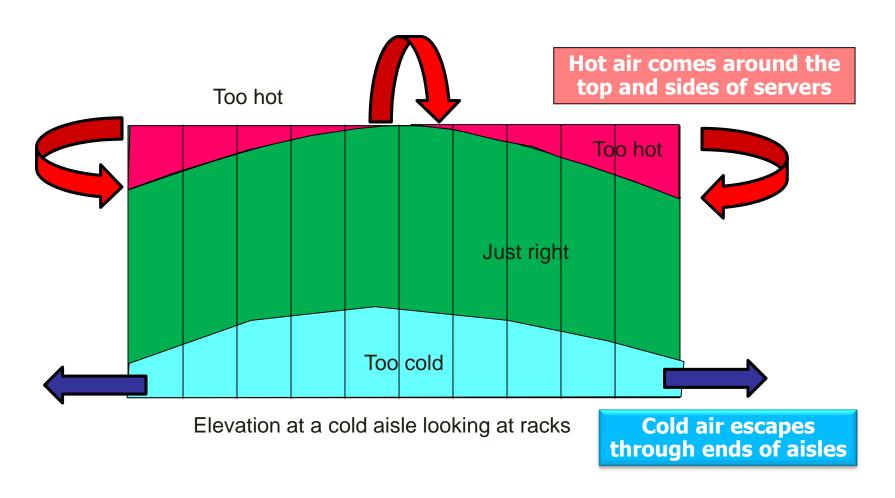
## Reduce By-Pass and Recirculation Air

Bypass Air / Short-Circuiting Recirculation Leakage

Wastes fan energy as well as cooling energy and capacity

Increases inlet temperature to servers

#### **Typical Temperature Profile 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.

#### Improve air management, con't

#### What to do:

- Clear the desired air path (e.g. abandoned and cluttered cables)
- Block the undesirable air paths
  - Within and between racks
  - Cable and conduit cutouts from under floor and into ceiling plenum
  - Rack tops and row ends





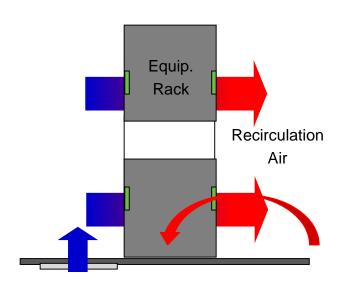
#### **Benefits:**

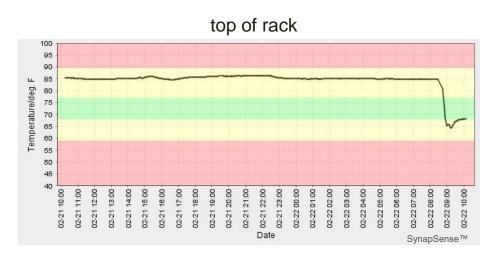
Pictures courtesy of ANCIS Incorporated

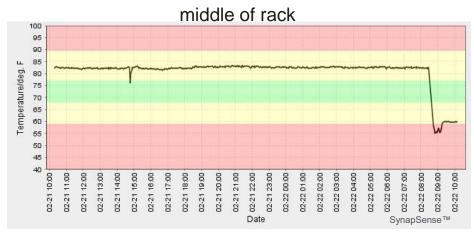
- Allows increased supply air temperature (reduced cooling energy)
- Allows reduced air flow (reduced fan energy)

#### **Air Management: Blanking Panels**

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





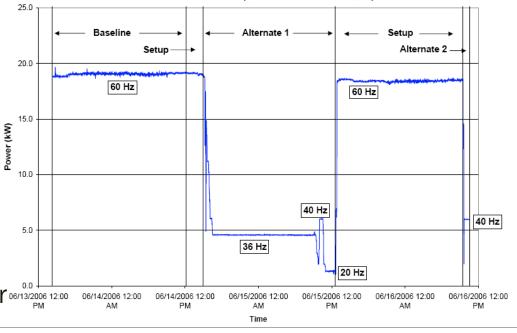


## Air Management: Fan Energy Savings

 Isolation significantly reduces bypass air, which in turn allows reduction of supply airflow

Fan speed can be reduced, and fan power is proportional to nearly the cube of the flow

• Fan energy savings of 70%–
80% is possible with variable air 06/13/2006 12:00
volume (VAV) fans



CRAH Fan Power (Sum of CRAH 23, 24, 25)

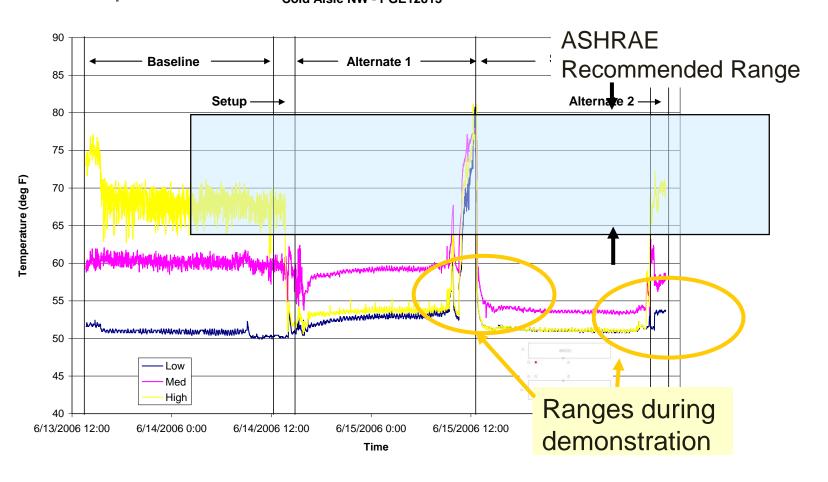
Without Enclosure

With Enclosure

Without Enclosure

## **LBNL Air Management Demonstration**

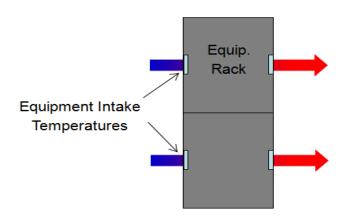
Better airflow management permits warmer supply temperatures! Cold Aisle NW - PGE12813

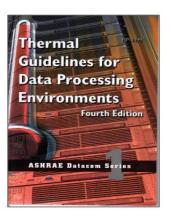


### Increase air temperature setpoints toward the high end of the **ASHRAE** range

- IT *inlet* temperature is what matters
- ASHRAE ranges:
  - Recommended range (rounded): 65 to 80° F

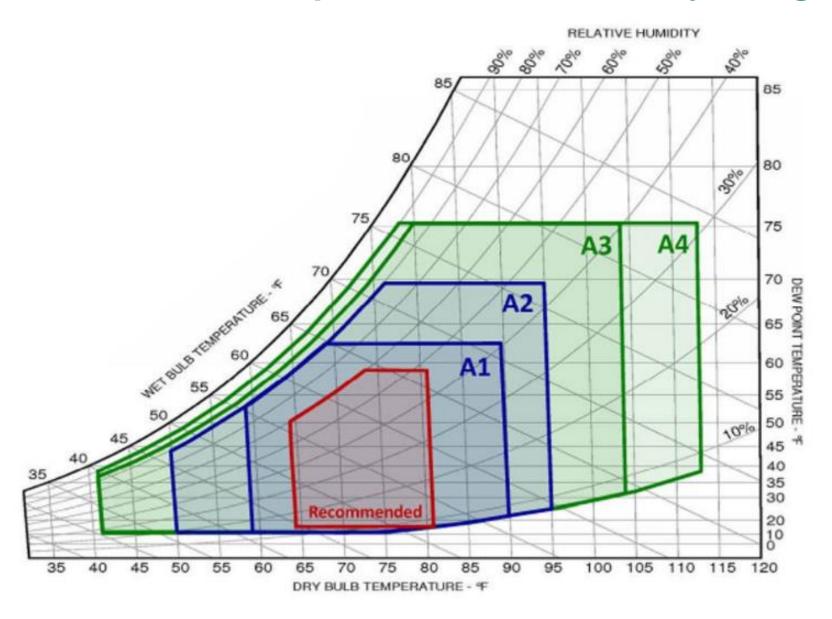
  - Allowable ranges (A1 A4):
     59 to 90° F (A1) ... 41 to 113° F (A4)
- NOT the same as the temperature setpoint for the CRAC (Computer Room Air Conditioner) or CRAH (Computer Room Air Handler), especially for units controlled on return air
- Ensure good air management first before changing control setpoints to avoid hotspots
- Enables savings in chiller or CRAC compressor energy







### 2015 ASHRAE Temperature and Humidity Ranges



#### **Turn off active humidity control**

- Wider ASHRAE range (as of 2015, and retroactive) means that little if any control is required
- Recommended range: 15.8° to 59° F dewpoint temperature (a measure of absolute humidity) and 60% RH (relative humidity) at the IT inlet
- CRACs and CRAHs are often set
  - to 45-55% RH (much too tight)
  - based on the return air (rather than IT inlet or supply air)
- Adjusting setpoints or turning off humidity control results in:
  - Humidification savings
  - Dehumidification savings
  - Often both
  - 28% cooling savings at LBNL eliminated humidity control

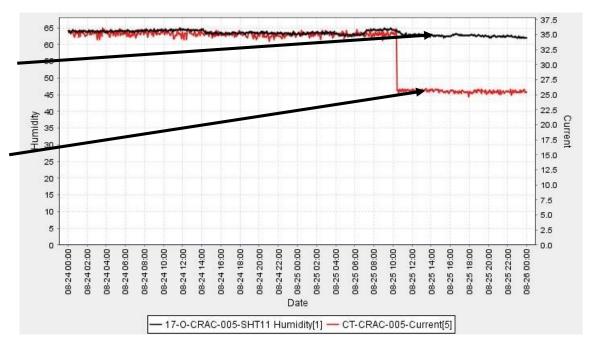
## The Cost of Unnecessary Humidification

	Visalia Probe			CRAC UnitPanel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC 005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC 006	81.8	28.5	46.1	55		37.2	Cooling & Dehumidification
AC 007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC 010	77.5	32.8	46.1	68	45.0	45.9	Cooling
AC 011	78.9	31.4	46.1	70	43.0	46.6	Cooling & Humidification
Min	72.8	27.5	46.1	55.0	32.0	37.2	
Max	84.0	38.5	47.2	76.0	51.0	50.2	
Avg	79.2	31.7	46.4	68.8	43.5	45.5	

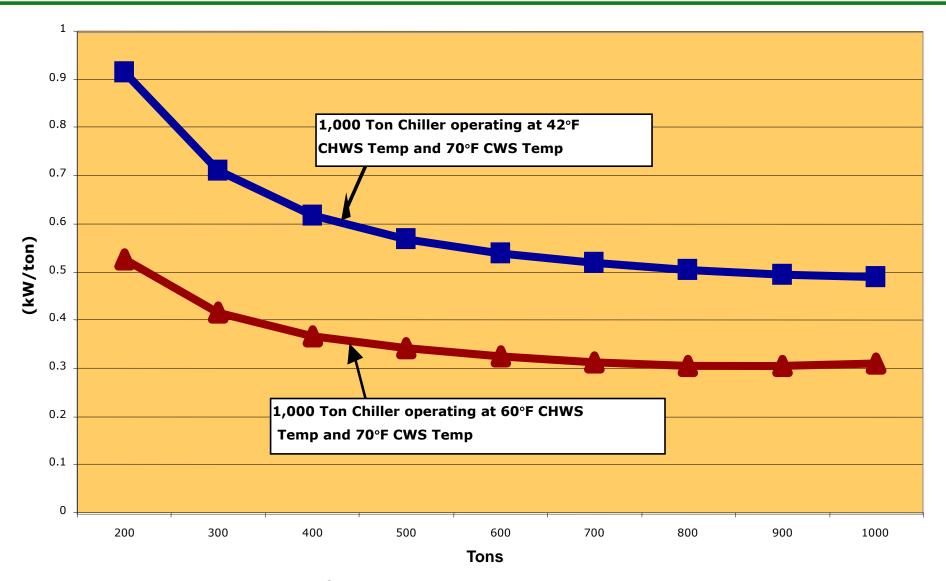


Humidity down 2%

CRAC power down 28%



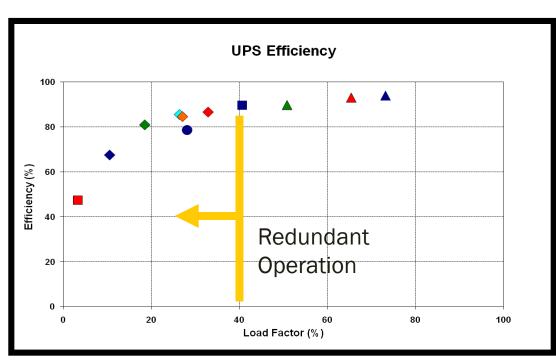
## **Increase Temperature of Chilled Water**



Data provided by York International Corporation

#### Minimize Uninterruptible Power Supply (UPS) requirements

- Unnecessary redundancy leads to inefficiency
- Many applications can be shut down and restarted without adverse effects
- Critical applications should be considered for moving to a larger data center or the cloud
- Analyze UPS needs
  - Minimize number and size
  - Use ENERGY STARUPS units
  - Use Eco-mode
  - Savings can range from~10 50% of IT load



Source: LBNL Benchmarking study

# Questions



#### Still simple, a little more work

- Refresh the oldest IT equipment with new high-efficiency equipment
- Consolidate and virtualize applications

## Refresh the oldest IT equipment with new high-efficiency equipment

- New equipment is more powerful and gets more computing per watt plus better power management
- More virtualization potential
- Energy and software cost savings typically justifies a faster refresh rate

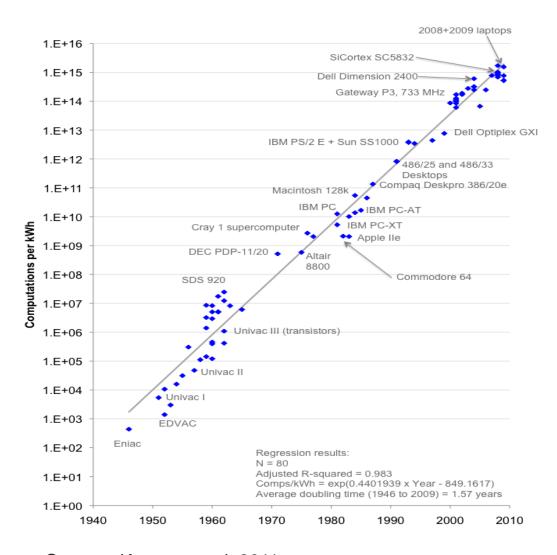
#### What to do – Procure:

- ENERGY STAR
  - Servers
  - Networking equipment
  - Storage
- Solid-state drives (vs. hard disks)
- 80-Plus power supplies (ENERGY STAR requirement)
  - ~5-20% savings possible with more efficient power supplies



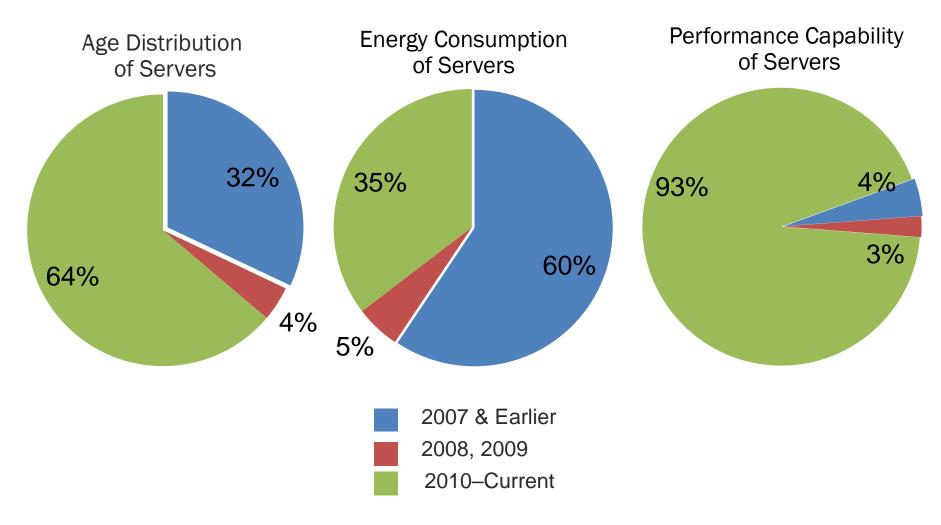


#### **Computing Efficiency Increases 100x Every Decade**



Source: Koomey et al. 2011

## Old servers consume 60% of energy, but deliver only 4% of performance capability



Data collected at a Fortune 100 company; courtesy of John Kuzma and William Carter, Intel

## **Use Efficient Power Supplies**

#### 80 PLUS Certification Levels

Level of Certification	Efficiency at Rated Load							
	115V Internal Non- Redundant			230V Internal Redundant				
	20%	50%	100%	20%	50%	100%		
80 PLUS	80%	80%	80%	n/a	n/a	n/a		
80 PLUS Bronze	82%	85%	82%	81%	85%	81%		
80 PLUS Silver	85%	88%	85%	85%	89%	85%		
80 PLUS Gold	87%	90%	87%	88%	92%	88%		
80 PLUS Platinum	90%	92%	89%	90%	94%	91%		
80 PLUS Titanium	92%	94%	90%	94%	96%	91%		

#### **Consolidate and virtualize applications**

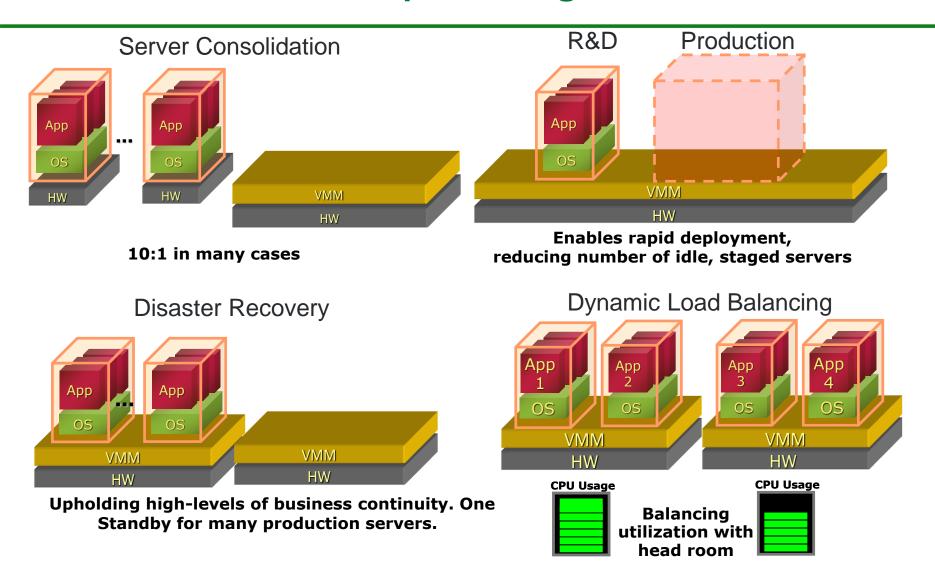
- Most servers operate with very low utilization (5-15% on average)
- Servers at typical loads (5-15% utilization) use roughly 75% of average peak power
- Big opportunities:
  - Virtualization (running multiple software applications on one physical machine)

Consolidation (using fewer machines to accomplish the computing)

task)

- Energy savings from power and cooling reductions
- Space savings

#### **Virtualization: Workload provisioning**



# Questions



## **Higher-Level Investment, but Very Cost-Effective**

- Move applications and/or hardware to higher-efficiency internal or external data center or to the cloud
- Implement IT and infrastructure power monitoring
- Install Variable-Speed Drives on cooling system fans
- Install rack and/or row-level cooling
- Use air-side economizer
- Implement dedicated room cooling (vs. using central building cooling)

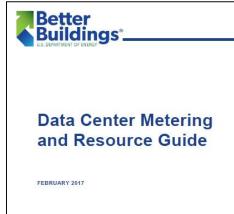
## Move to higher-efficiency internal or external data center or to the cloud

- Energy savings typically possible by moving applications or machines to
  - Larger data center
  - Co-location center
  - The cloud
- Better security
- Better redundancy
- Better efficiency
- In evaluating options, consider
  - Mandates
  - Moving cost
  - Total ongoing cost of staying vs. moving



### Implement IT and infrastructure power monitoring

- Doesn't save energy by itself, but it informs the process
- Track performance of power and cooling systems and monitor IT
- Power Usage Effectiveness (PUE) as a metric
  - Ratio of total data center energy to IT energy
  - Measure of infrastructure energy overhead
    - Over 2.0—large opportunity
    - Under 1.5—good
    - Under 1.2--excellent
- Data Center Metering Webinar and Resource Guide
  - Guide: <u>datacenters.lbl.gov/resources/</u> <u>data-center-metering-and-resource-guide</u>
  - Webinar slides: <u>datacenters.lbl.gov/</u> <u>resources/data-center-metering-and-</u> power-usage





#### Install Variable-Speed Drives on cooling system fans

- CRACs or CRAHs typically have constant-speed fans
- Air flows are typically higher than needed, especially once air management is improved
- 20% air flow reduction results in ~50% savings in fan energy
- 22-32% overall cooling system savings in FEMP case studies:

datacenters.lbl.gov/resources/ variable-speed-fan-retrofits-computerroom-air-conditioners

#### Variable-Speed Fan Retrofits for Computer-Room Air Conditioners

Prepared for the U.S. Department of Energy Federal Energy Management Program

Technology Case Study Bulletin

By Lawrence Berkeley National Laboratory Steve Greenberg

September 2013



# Install rack and/or row-level cooling

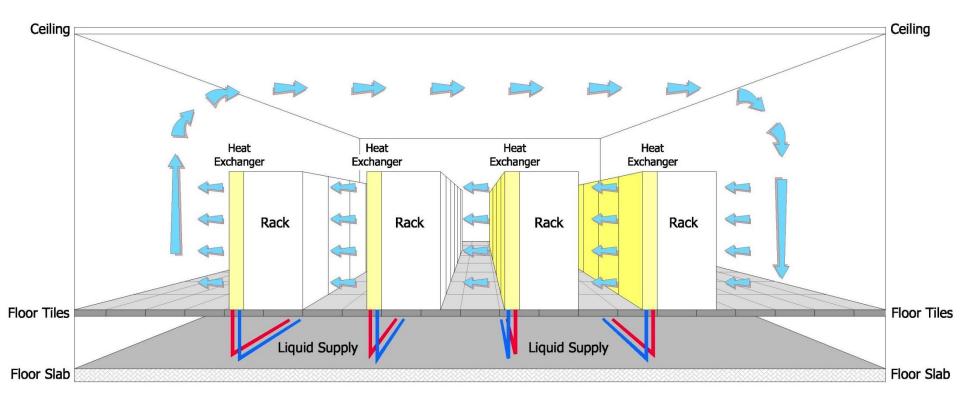
- Applicable when racks are being replaced or newly installed
- Moves cooling closer to the heat source (Closer = More Efficient)
- Various types
  - In-row
  - Rear-door (shown)
  - In-rack

#### Benefits:

- Closer cooling system is more efficient and so generates less heat that needs to be removed
- Higher chilled water temperature:
  - Makes the cooling plant more efficient
  - Allows "free cooling" for more of the year (water-side economizer)

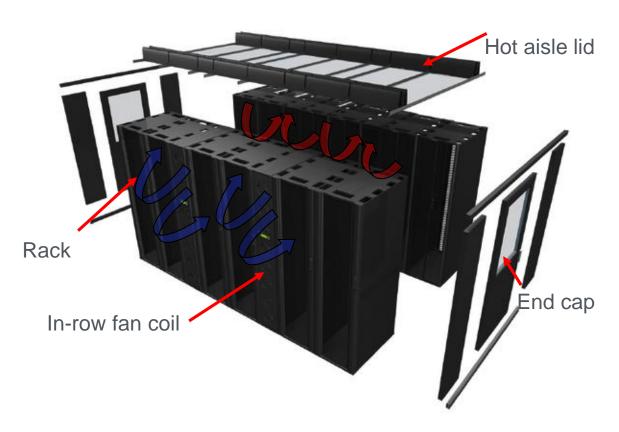


# Rack-Mounted Heat Exchangers ("Rear Doors")



## **In-Row Cooling System**

With hot aisle containment, the general data center space is neutral (75°F–80°F).

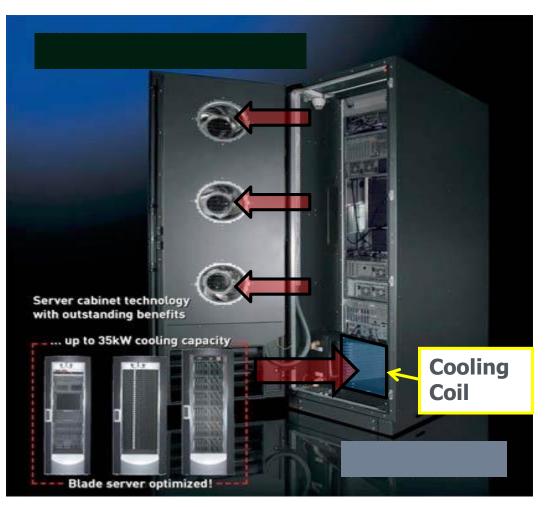


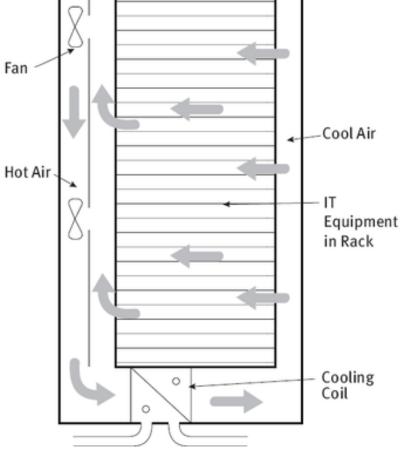


© APC, reprinted with permission

# **In-Rack Liquid Cooling**

Racks with integral coils and full containment:





## Use an air-side economizer

- Uses outside air when conditions are suitable
- Needs outside wall or roof for adequate access to large airflow
- Can be
  - air-handling unit
  - CRAC or CRAH with outside air capability

 Exhaust fan with inlet air SUPPLY FAN Large energy savings from reduced OUTSIDE operation of AIR cooling COOLING compressor FCONOMI7FR COIL **DAMPERS** Relief Fan ✓ RETURN >

AIR

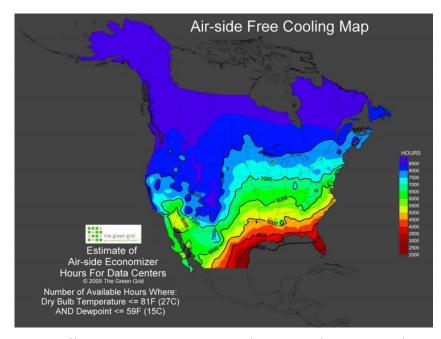
## **Outside Air (Air-Side) Economizers**

#### Advantages

- Lower energy use
- Added reliability (backup for cooling)

#### **Potential Issues**

- Space (retrofit projects difficult)
- Outside dust
  - Not a concern with MERV 13 filters
- Outside gaseous contaminants
  - Not widespread
  - Impacts normally cooled data centers as well
- Shutdown or bypass if smoke or other contaminant is outside data center



http://cooling.thegreengrid.org/namerica/WEB\_APP/calc\_index.html

## **Use a Water-Side Economizer**

- Easier retrofit
- Added reliability (backup in case of chiller failure)
- No contamination issues
- Put in series with chiller ("integrated")
- Uses tower or dry cooler



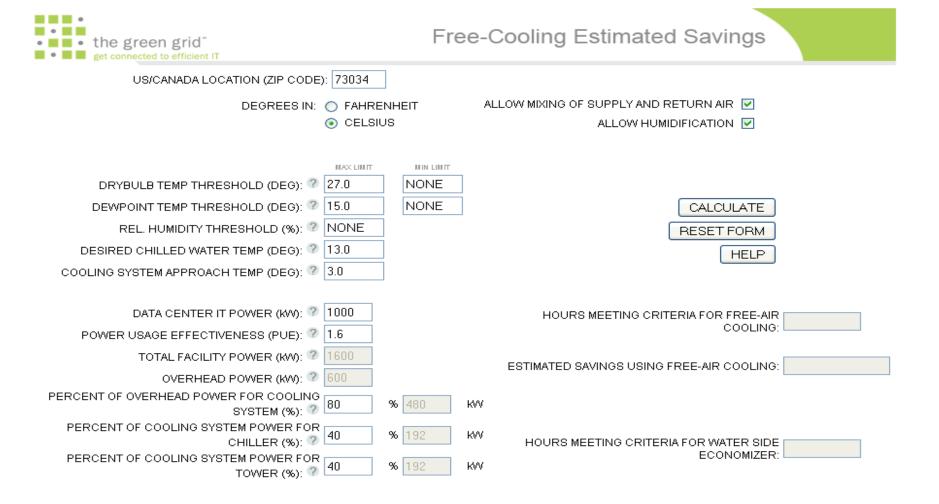


Cooling tower and HX = Water-side Economizer





## **Economizers: The Green Grid Tool**



# Implement dedicated room cooling (vs. using central building cooling)

- Dedicated unit allows main building system and plant to operate on normally occupied schedule instead of continuously
  - Allows for cooling operations independent from rest of the building
  - A small, imbedded data center can cause a central plant to operate when the rest of the building doesn't require it

#### What to do:

- Use high-efficiency unit high SEER (Seasonal Energy Efficiency Ratio)
- Specify outside-air economizer
- Control based on IT inlet temperature



## **Sources of Training for Facilities and IT Staff**

- Utility companies
- ASHRAE: <u>www.ashrae.org</u>
- Federal Energy Management Program (FEMP): <a href="http://eere.energy.gov/femp/training">http://eere.energy.gov/femp/training</a>
- Center of Expertise for Energy Efficiency in Data Centers
- Data Center Energy Practitioner
  - Required by the Data Center Optimization Initiative
  - datacenters.lbl.gov/dcep

## **Data Center Energy Practitioner (DCEP) Program**

U.S. DOE certificate process for energy practitioners qualified to assess energy consumption and energy efficiency opportunities in data centers.

## Key objective:

- 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)

### Resources

#### Small Data Center Guide:

betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/
Better Buildings Data Center
Accelerator - Small Data Center
Energy Savings Guide.pdf



Small Data Centers, Big Energy Savings: An Introduction for Owners and Operators

APRIL 2017

FINAL REPORT

ENERGY

## **More Resources**

#### **DOE Better Buildings**

- Tool suite & metrics for base-lining
- Training
- Showcase case studies
- Recognition of high energy savers

#### **Federal Energy Management Program**

- Workshops
- Federal case studies
- Federal policy guidance
- Information exchange & outreach
- Qualified specialists
- Technical assistance

#### **EPA**

- Metrics
- Server, UPS, network equipment performance rating & ENERGY STAR label
- Data center benchmarking

### **Industry**





- Training
- Best practice information
- Best-in-Class guidelines
- IT work productivity standard











the green grid"

Uptime



**Better** 

## **More Resources**

Better Buildings Solutions Center: betterbuildingssolutioncenter.energy.g ov/challenge/sector/data-centers

Center of Expertise for Energy Efficiency in Data Centers: datacenters.lbl.gov





## **Resources: Center of Expertise (CoE)**



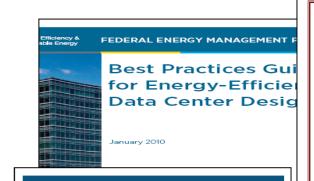
Usage Effectiveness (PUE).

https://datacenters.lbl.gov/

data center over time.

## **Data Center Resources**

- **Best Practices Guide**
- Benchmarking Guide
- Data Center **Programming Guide**
- Technology Case Study Bulletins
- Procurement Specifications
- Report Templates
- Process Manuals
- **Quick-Start Guide**





As data center energy densities in power-use per square foot increase. energy savings for cooling can be realized by incorporating liquid-cooling devices instead of increasing airflow volume. This is especially important in a data center with a typical under-floor cooling system. An airflow-capacity limit will eventually be reached that is constrained, in part, by under-floor dimensions and obstructions.

Data Center Rack

Heat Exchanger

#### 1 Introduction

Liquid-cooling devices were installed on server racks in a data center at Lawrence Berkeley National Laboratory (LBNL) in Figure 1. The passive-technology device ves heat generated by the servers from the airflow leaving the server rack. This heat is usually transferred to cooling water circulated from a central chiller plant. However at LBNL, the devices are connected to a treated water system that rejects the heat directly to a cooling tower through a plate-and-frame heat exchanger, thus nearly eliminating chiller energy use to cool the associated servers. In addition to cooling with passive heat exchang-ers, similar results can be achieved with airflow outlet of a server rack.

Server rocks can also be cooled with competing technologies such as modula overhead coolers; in-row coolers; and close-coupled coolers with dedicated

#### 2 Technology Overview The rear door heat exchanger (RDHx) devices reviewed in this case study are referred to as passive devices because

they have no moving parts; however, the do require cooling water flow. A passivestyle RDHx contributes to optimizing nergy efficiency in a data center facility in several ways. First, once the device is installed, it does not directly require infrastructure electrical energy to operate Second, RDHx devices can use less chiller energy since they perform well a warmer (higher) chilled water set-points. Third, depending on climate and pip-ing arrangements, RDHx devices can eliminate chiller energy because they can use treated water from a plate-and-frame heat exchanger connected to a cooling tower. These inherent features of a RDHx help reduce energy use while minimizing

#### an automobile radiator, is placed in the

on proper waterside maintenance The RDHx device, which resemble

Reduce Maintenance Because passive RDHx devices have no moving parts, they require less main tenance compared to computer room air conditioning (CRAC) units. RDHx devices will require occasional cleaning of dust and lint from the air-side of the coils. RDHx performance also depend

During operation, hot server-rack airflow

is forced through the RDHx device by the server fans. Heat is exchanged from the

hot air to circulating water from a chiller

or cooling tower. Thus, server-rack outlet air temperature is reduced before it is discharged into the data center.

RDHx cooling devices can save energy and increase operational reliability in data centers because of straightforward installa-

tion, simple operation, and low mainte-

make RD8tx a viable technology in both new and retrofit data center designs. It may also help eliminate the complexity

and cost of under-floor air distribution

norless, indirect evaporative cooling

2.2 Technology Benefits

#### Reduce or Eliminate Chiller

RDHx devices pro save energy by either red



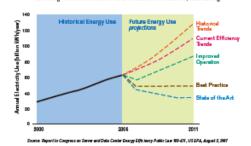
#### Quick Start Guide to Increase Data Center Energy Efficiency

#### A Problem That You Can Fix

#### Data Center energy efficiency is derived from addressing BOTH your hardware equipment AND your infrastructure.

Less than half the power used by a typical data centers powers its IT equipment. Where does the other half go? To support infrastructure including cooling systems, UPS inefficiencies, power distribution losses and lighting. Why does this matter?

- · By 2012, the power costs for the data center equipment over its useful life will exceed the cost of the original capital investment.
- By 2020, the carbon footprint of data centers will exceed the airline
- With today's best practices, 20-50% energy savings are possible, extending the life and capacity of existing data center infrastructure, avoiding millions of metric tons of carbon emissions, and saving.



## Resources, con't.

- DOE Air Management Tools
   <u>datacenters.lbl.gov/tools/5-air-management-tools</u>
- Humidity Control in Data Centers
   datacenters.lbl.gov/resources/Humidity-Control-Data-Centers
- Data Center Metering and Resource Guide <u>datacenters.lbl.gov/resources/data-center-metering-and-resource-guide</u>
- Variable-Speed Fan Retrofits for Computer-Room Air Conditioners

   Case study of 3 small data centers
   datacenters.lbl.gov/resources/variable-speed-fan-retrofits-computer-room-air-conditioners
- Data Center Optimization Initiative (OMB): <a href="https://datacenters.cio.gov/">https://datacenters.cio.gov/</a>
- ENERGY STAR Equipment: <u>energystar.gov/products/office\_equipment/</u>

# **Summary**

- Why small data centers are important
- Simplest Measures
  - Turn off unused servers
  - Improve server power management
  - Improve air management
  - Increase temperature setpoints toward the high end of the range set by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE)
  - Turn off active humidity control
  - Minimize requirements for Uninterruptible Power Supplies (UPS)

# Summary, con't

- Still simple, a little more work
  - Refresh the oldest IT equipment with new high-efficiency equipment
  - Consolidate and virtualize applications
- Higher-level investment, but very cost-effective
  - Move applications and/or hardware to higher-efficiency internal or external data center or to the cloud
  - Implement IT and infrastructure power monitoring
  - Install Variable-Speed Drives on cooling system fans
  - Install rack and/or row-level cooling
  - Use air-side or water-side economizer
  - Implement dedicated room cooling (vs. using central building cooling)
- Training for IT and Facility Staff
- Resources

## **Energy Exchange Pre-Conference Workshop CEU Guidance**

Register with the Whole Building Design Guide (if new): <a href="https://www.wbdg.org/continuing-education/energy-exchange">www.wbdg.org/continuing-education/energy-exchange</a>

Sign IN and OUT when ENTERING and LEAVING the training session.

Stay for the entire session; attendance of the entire session will be confirmed for CEU eligibility. Do not take the quiz if you did not attend the entire session.

On the WBDG website, pass a session quiz (with a minimum score of 80%) and complete a session evaluation <u>no later than October 31, 2018</u>. Available by Tuesday, August  $21^{st}$ .

For **How to Save Money in Your Small Data Center,** complete your quiz at the following link:

http://www.wbdg.org/continuing-education/femp-courses/fempws082020180



# Questions



## **Contact Information**

Dale Sartor, P.E.

DASartor@LBL.gov

(510) 486-5988



Steve Greenberg, P.E.

SEGreenberg@lbl.gov
(510) 486-6971



Lawrence Berkeley National Laboratory
MS 90-3111
University of California
Berkeley, CA 94720
https://datacenters.lbl.gov/

