Environmentally-driven Energy Efficient Data Centers

Michael K Patterson, PhD, PE
Senior Power & Thermal Architect
Eco-Technology Program Office
Intel Architecture Group

November, 2010

Start from where you are…

- **<u>Understand the site</u>**
- Temperature ranges
- Humidity consideration
- Site specifics; constraints and opportunities

- **<u>Understand the building</u>**
- New construction
- Retrofit
- Expansion
- Space, airflow, cooling, power, weight

Don’t force it, take the best option available to you

Examples of letting the site "choose for you" in retrofits….

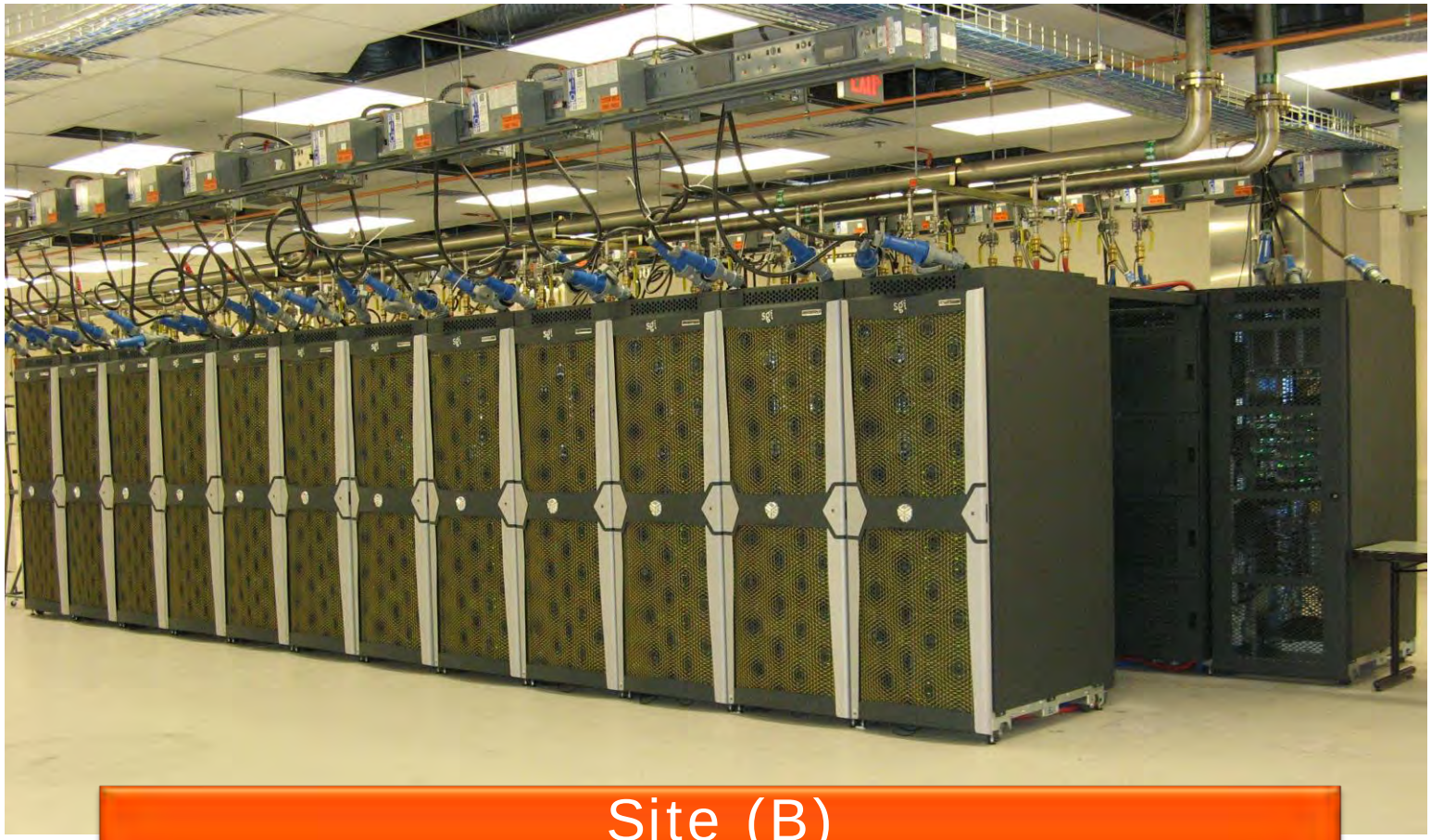
- Site (A)
  - Existing building available for re-use
  - Part of an old semiconductor fabrication facility
  - Extensive fans and air-handling equipment
- Site (B)
  - Existing building available for re-use
  - Empty space in an old assembly plant
  - High capacity process cooling water system
- Site (C)
  - Available trailers in the parking area
  - Air-handlers suited for mixing with outdoor air (air-side economizer)
  - Moderate climate at altitude, dry, some high temperatures

Air-cooled 30kW cabinets

w/ chimney cabinets

Site (A)

Liquid Cooled 30kW racks



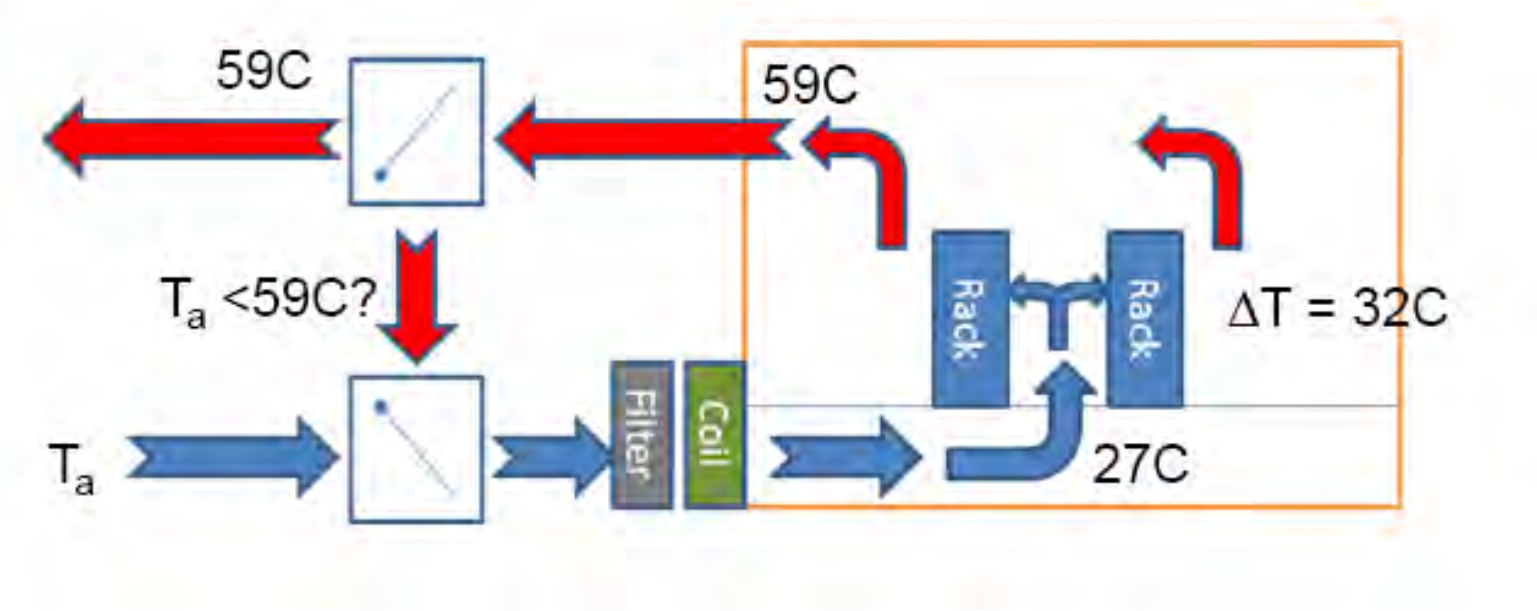
Site (B)

Encanto, New Mexico's Cluster

#32 on the Top500 list, Started at #5

Air-side economizer

- Advanced air-side economization opportunity with good air-flow management



- Blades had 32C ΔT rise
- –If we assume 27C inlet then any time outdoor air is <59C, outdoor supply should be considered (need to also consider humidity and filtration impacts)

Site (C)

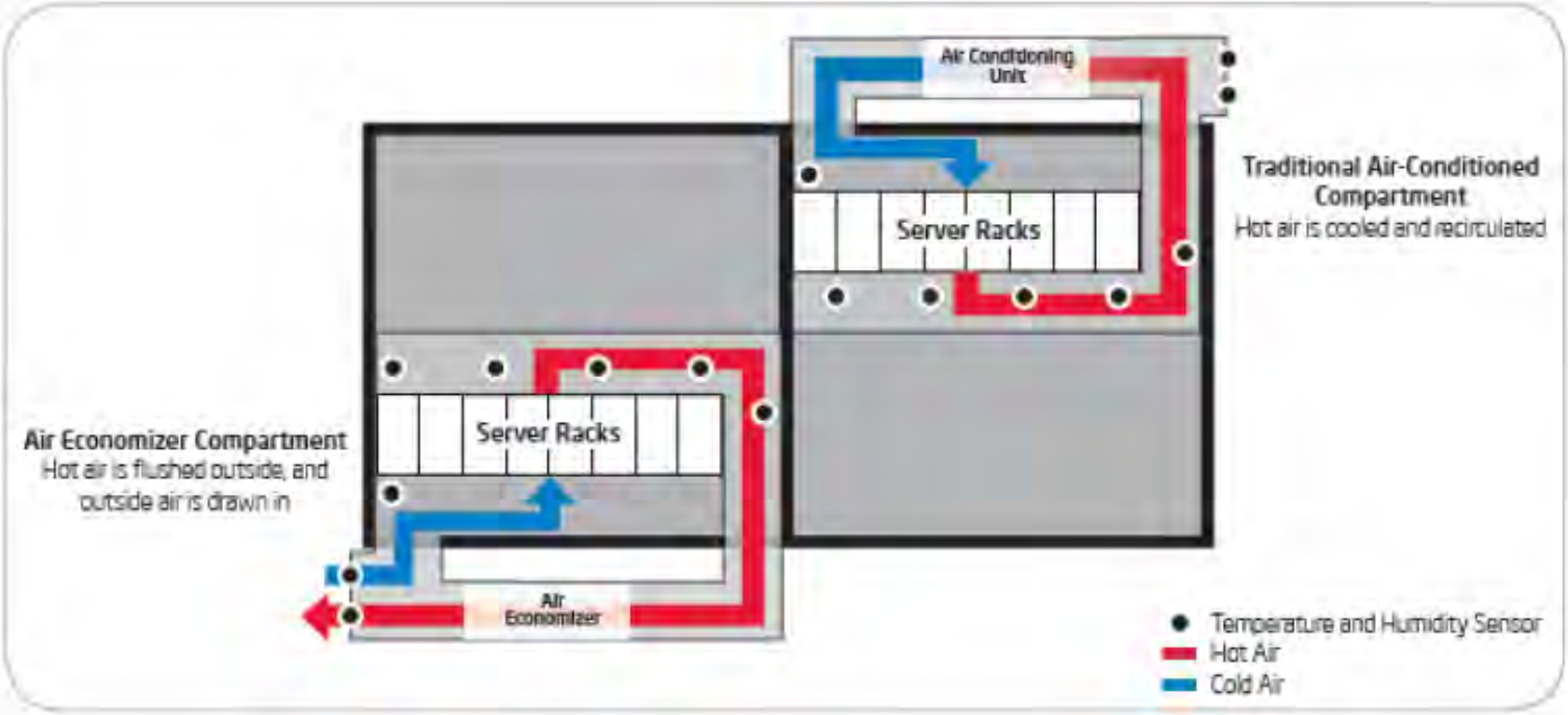
Examples of letting the site "choose for you" in retrofits….

- Site (A)
  - Existing building available for re-use
  - Part of an old semiconductor fabrication facility
  - Extensive fans and air-handling equipment
- S
  -
  -
  -
- Site (C)
  - Available trailers in the parking area
  - Air-handlers suited for mixing with outdoor air (air-side economizer)
  - Moderate climate at altitude, dry, some high temperatures

Site (A) & (B) & (C) are all in Rio Rancho, New Mexico

Data Center Overview – Site (C)

- Two Rental Office Trailers converted to Data Centers
- Cold/Hot aisle isolation
- Low end DX cooling & controls with minimal filtration
- One closed loop standard with standard



Test Set Up

- 2 Year old servers from an Intel Data Center moved to the experimental Data Centers, run for a 3rdyear
- 8 Racks of blade servers, with 4 chassis per rack in each space
- 14 kW racks

- Operational Engineering Computing Data Center
- Utilization ~90%
- Standard Room
- –PUE = 2.23
- Air-side room in free cooling mode
- –PUE = 1.49

Intel's SC4 retrofit; cold aisle containment

14 - 22 kW Racks

6000 w/sq m of raised floor

Liquid Cooled Racks

- Many shapes and sizes
- Applicable in retrofit data centers as well as new
- Ideal for extending legacy DCs where there is cooling, but limited airflow

Graphic courtesy of Knurr

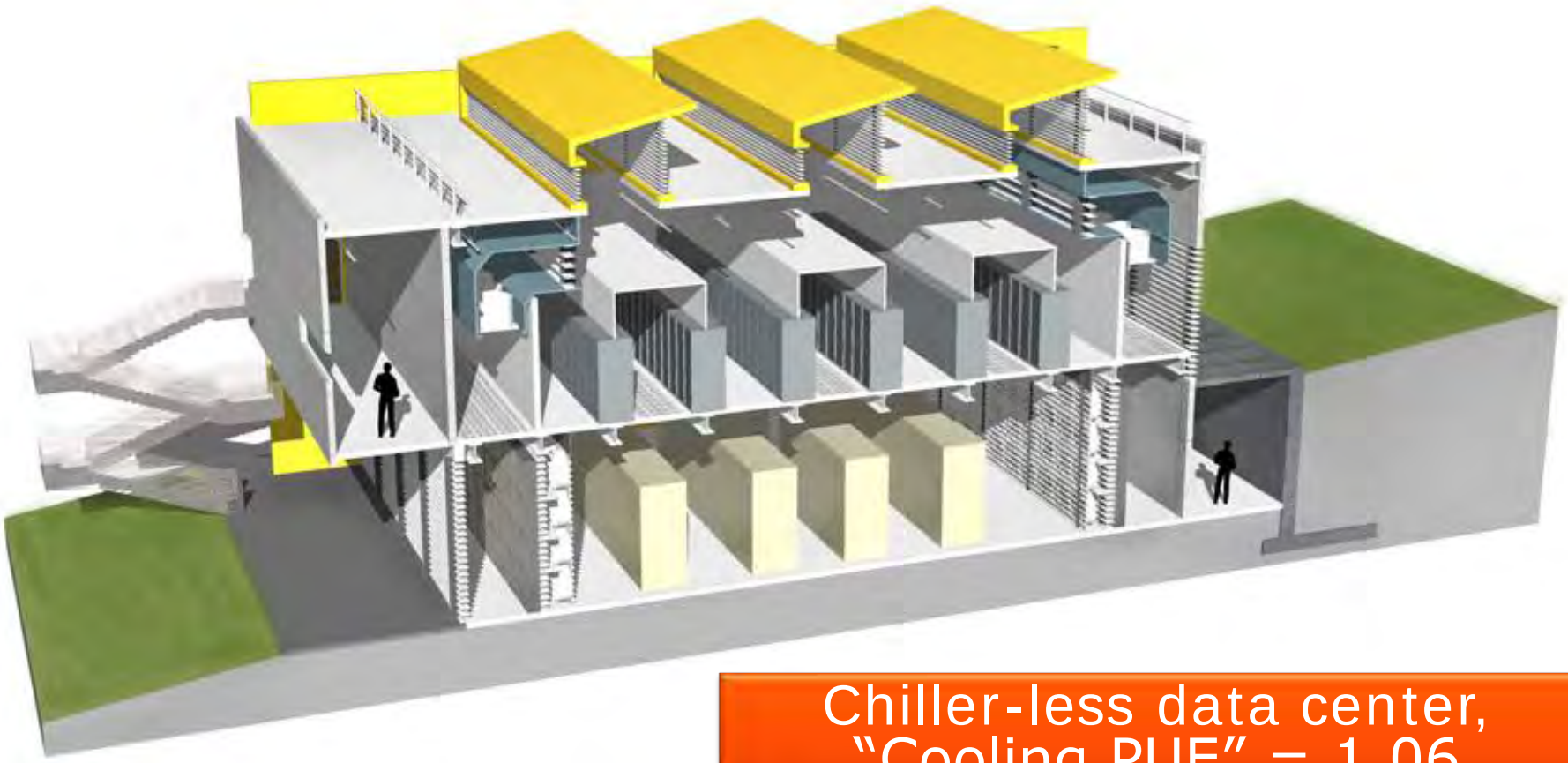
Do you have:
Space? No. Airflow? No.
Power? Yes. Cooling? Yes

Image courtesy of SGI

Examples of "design for your environment" for new construction….

- Swiss National Supercomputing Centre
  - Lugano, Switzerland
  - long periods of warm humid weather
  - advanced level of civic planning and a large, deep, cool lake: phase 1-provide cooling water from the lake, phase 2 – provide heating water to the community (schools, swimming pool, district heating)
- Stanford
  - Palo Alto, California
  - reasonably cool, with low absolute humidity
- NCAR-Wyoming Supercomputing Center
  - Cheyenne, Wyoming
  - range of temperatures (cold to hot), but usually very dry
- Intel
  - Hillsboro, Oregon
  - Temperate climate, very dry when it's warm

Scientific Research Computing Facility
Stanford University



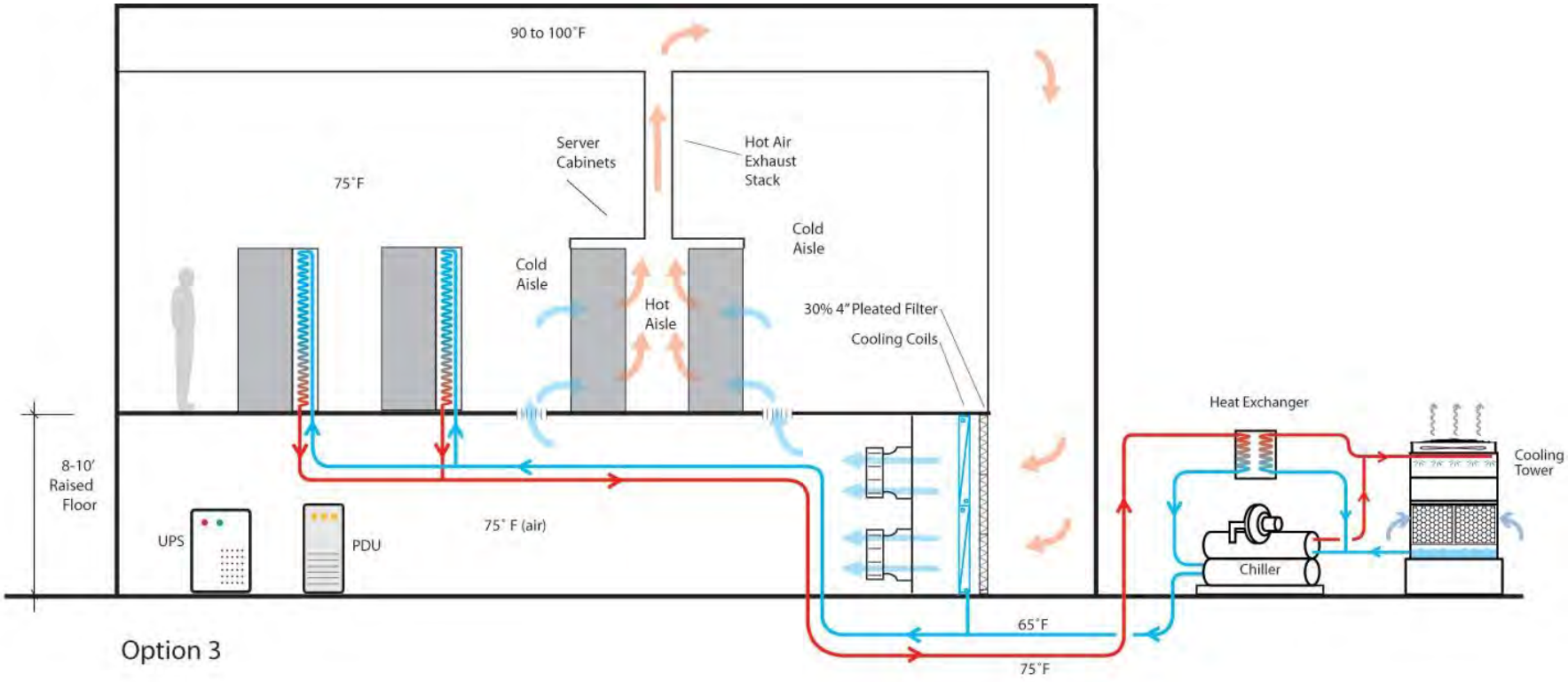
Chiller-less data center,
"Cooling PUE" = 1.06

Graphic courtesy of Stanford University

NCAR-Wyoming Supercomputing Center

Graphic courtesy of H+L Architects & NCAR

NWSC Cooling Plan



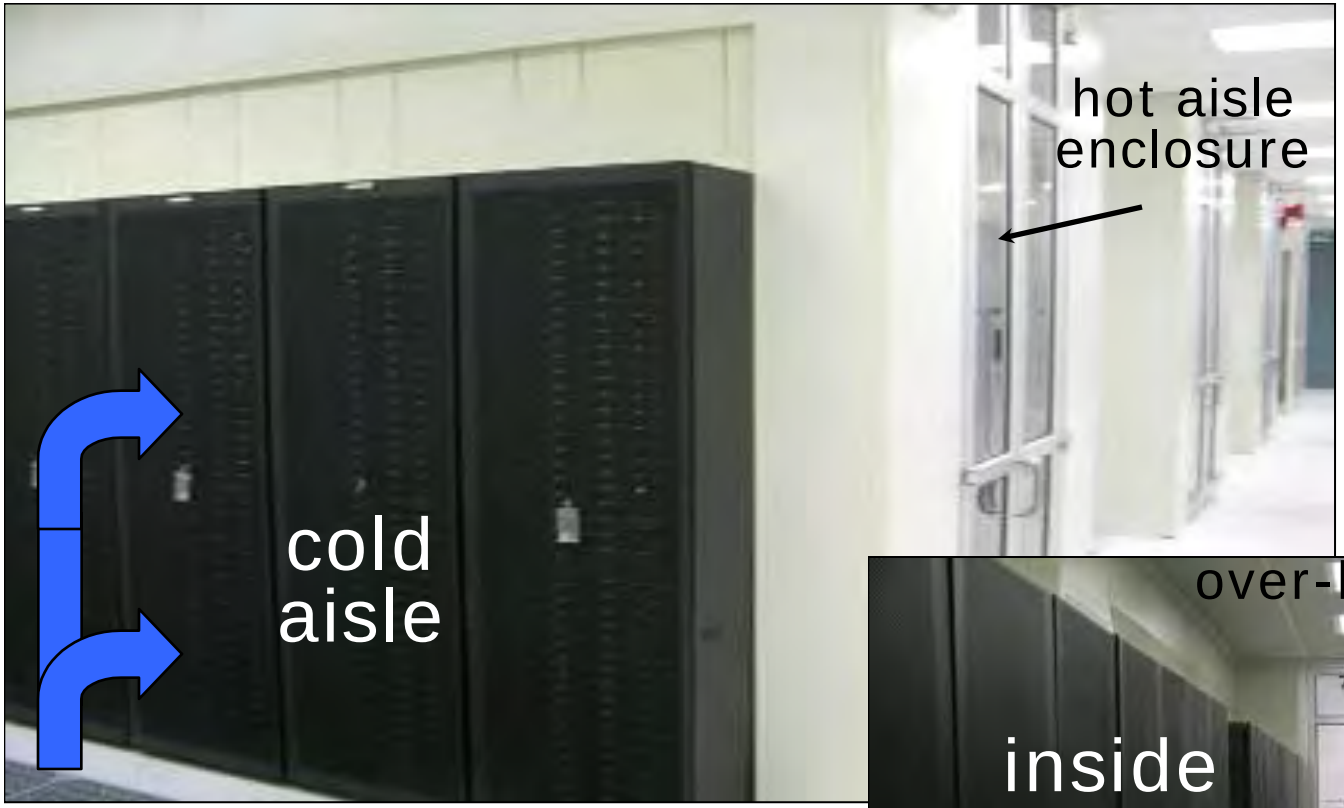
Design by Rumsey Engineers, Inc.

Intel's Jones Farm Data Center

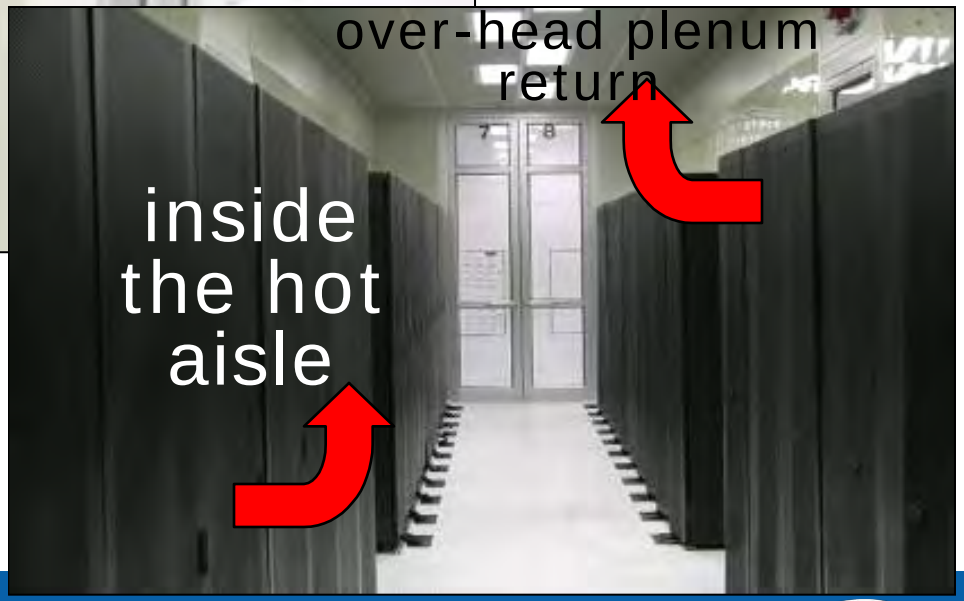
Two Story Vertical Flow-Through
High Performance Data Center

Actual Cross Section of JFS1

State-of-the-art air-flow management



- Entire space becomes the cold aisle
- Raised floor optional



- Best for new construction
- Very efficient when combined with economizer
- Self balancing, low fan energy

More resources…

- Airside Economizers
- ASHRAE Guidelines and Books
- Green Grid Tools

e-mail for references…
michael.k.patterson@intel.com

Economizer resources

Proceedings of IPACK2009
InterPACK'09
July 19-23, 2009, San Francisco, California, USA

IPACK2009-89358

EVALUATION OF AIR-SIDE ECONOMIZER USE IN A COMPUTE-INTENSIVE DATA CENTER

Michael K Patterson
Eco-Technology Program Office
Digital Enterprise Group
Intel
Hillsboro, Oregon, USA

Don Atwood
Regional Data Center Manager
Information Technology
Intel
Rio Rancho, New Mexico, USA

John G Miner
IT Innovation Center
Intel
Rio Rancho, New Mexico, USA

ABSTRACT

Moore's Law continues to drive increased compute capability and greater performance per watt in today's and future server platforms. However the increased demand for compute services has outstripped these gains and the energy consumption in the data center continues to rise. The challenge for the data center operator is to limit the operational costs and reduce the energy required to run the Information and Communications Technology (ICT) equipment and the supporting infrastructure.

The cooling systems can represent a large portion of the energy use in the support infrastructure. There is significant focus in industry today on applying advanced cooling technologies to reduce this energy. One potential solution is the use of air-side economizers in the cooling system. This technology can provide a reduction in cooling energy by being able to maintain the required temperatures in the data center with the mechanical refrigeration turned off, significantly reducing the PUE for the data center.

This paper reviews recent industry activities around the recommended environmental conditions in the data center, the impact to the ICT equipment of air-side economizers, where they can best be applied, and provides data from a case study recently concluded at Intel's site in New Mexico. In that case study servers from an engineering compute data center were split into a standard configuration (closed system, tight temperature control) and a very aggressive air-side economization section (open system, significant out-door air quantities, moderate temperature control). Both sections performed equally well over a year long on-line test, with significant energy savings potential demonstrated by economizer side.

The American Society of Air-conditioning Heating and Refrigerating Engineers (ASHRAE) has recently published new ICT-vendor consensus-based recommendations for the environmental conditions in data centers. These new limits are discussed in light of the successful experiment run in New Mexico as the revised operational envelop allows a far greater number of hours per year when a data center can be run in "free-cooling" mode to obtain the energy savings.

Server design features as well as lessons learned from the experiment and their applicability to the potential use of air-side economizers is also discussed.

INTRODUCTION AND ANALYSIS

Server design continues to evolve and improve, reducing the energy per unit of computation. Moore's Law is continuing to provide society with the best energy efficiency gains of any industry or technology sector in history. Yet these gains come with challenges. Namely the power density available in servers

Copyright © 2009 by ASME

Patterson, M.K.

Gaseous and Particulate Contamination Guidelines for Data Centers

Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9
Mission Critical Facilities, Technology Spaces, and Electronic Equipment

This ASHRAE white paper on data center airborne contamination was developed by members of the TC 9.9 committee representing the following IT equipment manufacturers: AMD, Cisco, Cray, Dell, EMC, Hitachi, HP, IBM, Intel, Seagate, SGI, and Sun.

Executive Summary

ASHRAE TC 9.9 committee recently published the 2008 ASHRAE Environmental Guidelines for Datacom Equipment which extended the temperature-humidity envelope to provide greater flexibility in data center facility operations, particularly with the goal of reducing energy consumption. The recommended temperature limits are from 18°C (64.4°F) to 27°C (80.6°F). The humidity is limited to less than 60% with the lower and upper dew point temperatures of 5.5°C (41.9°F) and 15°C (59°F).

The recent increase in the rate of hardware failures in data centers high in sulfur-bearing gases, highlighted by the number of recent publications on the subject, led to the need for this white paper that recommends that in addition to temperature-humidity control, dust and gaseous contamination should also be monitored and controlled. These additional environmental measures are especially important for data centers located near industries and/or other sources that pollute the environment.

Effects of airborne contaminations on datacenter equipment can be broken into three main categories: Chemical effects, mechanical effects and electrical effects. Two common chemical failure modes are copper creep corrosion on circuit boards and the corrosion of silver metallization in miniature surface mounted components. Mechanical effects include heat sink fouling, optical signal interference, increased friction, etc. Electrical effects include changes in circuit impedance, arcing, etc. It should be noted that the reduction of circuit board feature sizes and the miniaturization of components, necessary to improve hardware performance, also makes the hardware more prone to attack by contamination in the data center environment. Manufacturers are in a constant struggle to maintain the reliability of their hardware with ever shrinking feature sizes, without taking the added costly measure of hardening all their IT equipment, most of which is not installed in corrosive environments where it can be exposed to higher risk of failure.

Most data centers are well designed and are in areas with relatively clean environments and most contamination is benign. Most data centers should not experience particulate or gaseous contamination related hardware failures. This paper is primarily targeted at a minority of data centers which may have harmful environments arising from the ingress of outdoor particulate and/or gaseous contamination. In some rare instances, contamination has been known to be generated within the data center.

It is incumbent on the data center managers to do their part in maintaining hardware relisibility by monitoring and controlling the dust and gaseous contamination in their data centers. Data centers must be kept clean to ISO 14644-1 Class 8. This level of cleanliness can generally be achieved by an appropriate filtration scheme as outlined here:

1. The room air may be continuously filtered with MERV 8 filters as recommended by ANSI/ASHRAE Standard 127-2007, Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners.
2. Air entering a data center may be filtered with MERV 11 or MERV 13 filters as recommended by ASHRAE book titled, "Particulate and Gaseous Contamination in Datacom Environments".

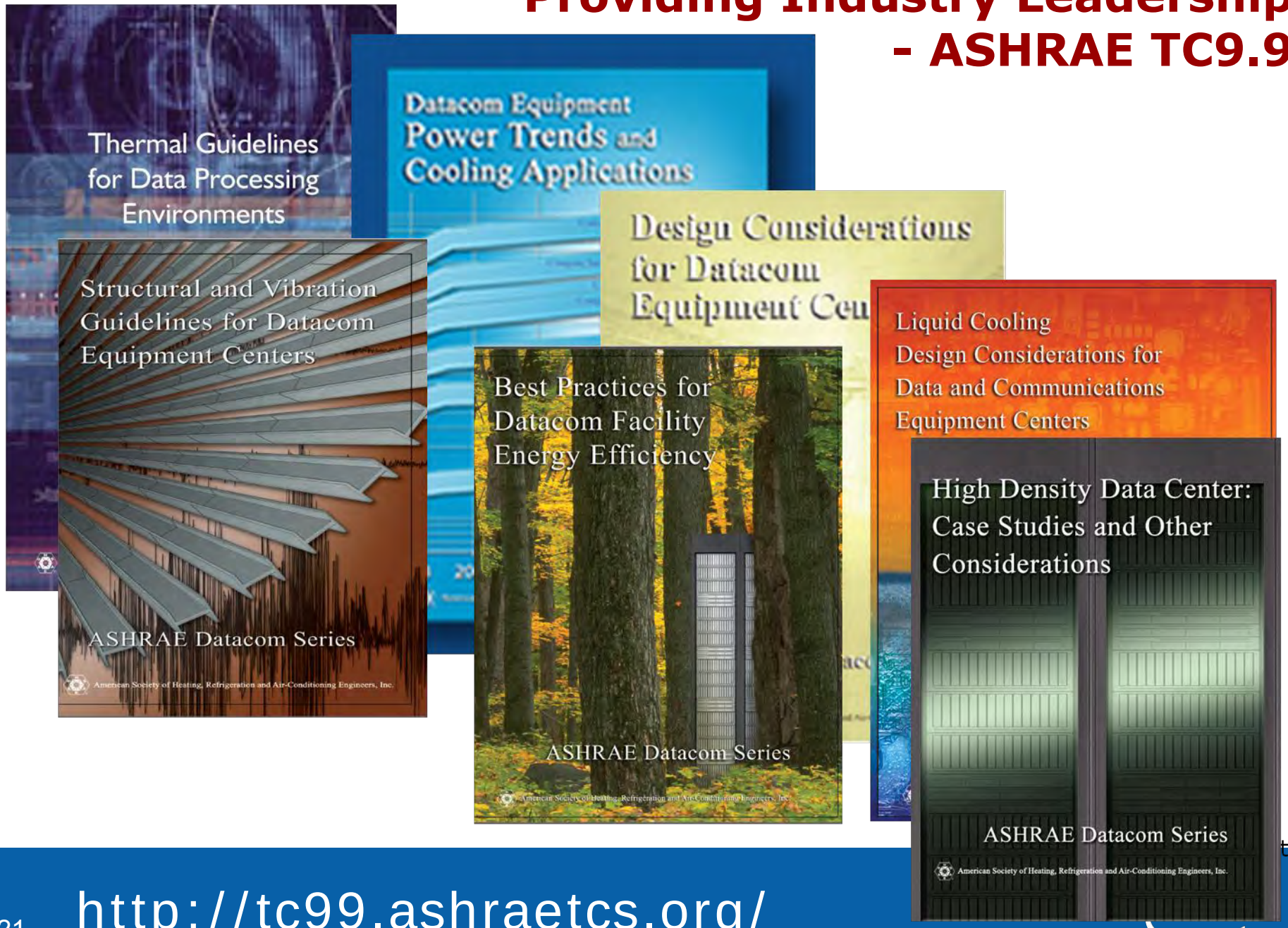
Sources of dust inside data centers should be reduced. The gaseous contamination should be within the modified ANSI/ISA-71.04-1985 severity level G1 that meets:

1. A copper reactivity rate of less than 300Å/month, and
2. A silver reactivity rate of less than 300Å/month.

For data centers with higher gaseous contamination levels, gas-phase filtration of the inlet air and the air in the data center is highly recommended.

ASHRAE TC 9.9

Providing Industry Leadership - ASHRAE TC9.9



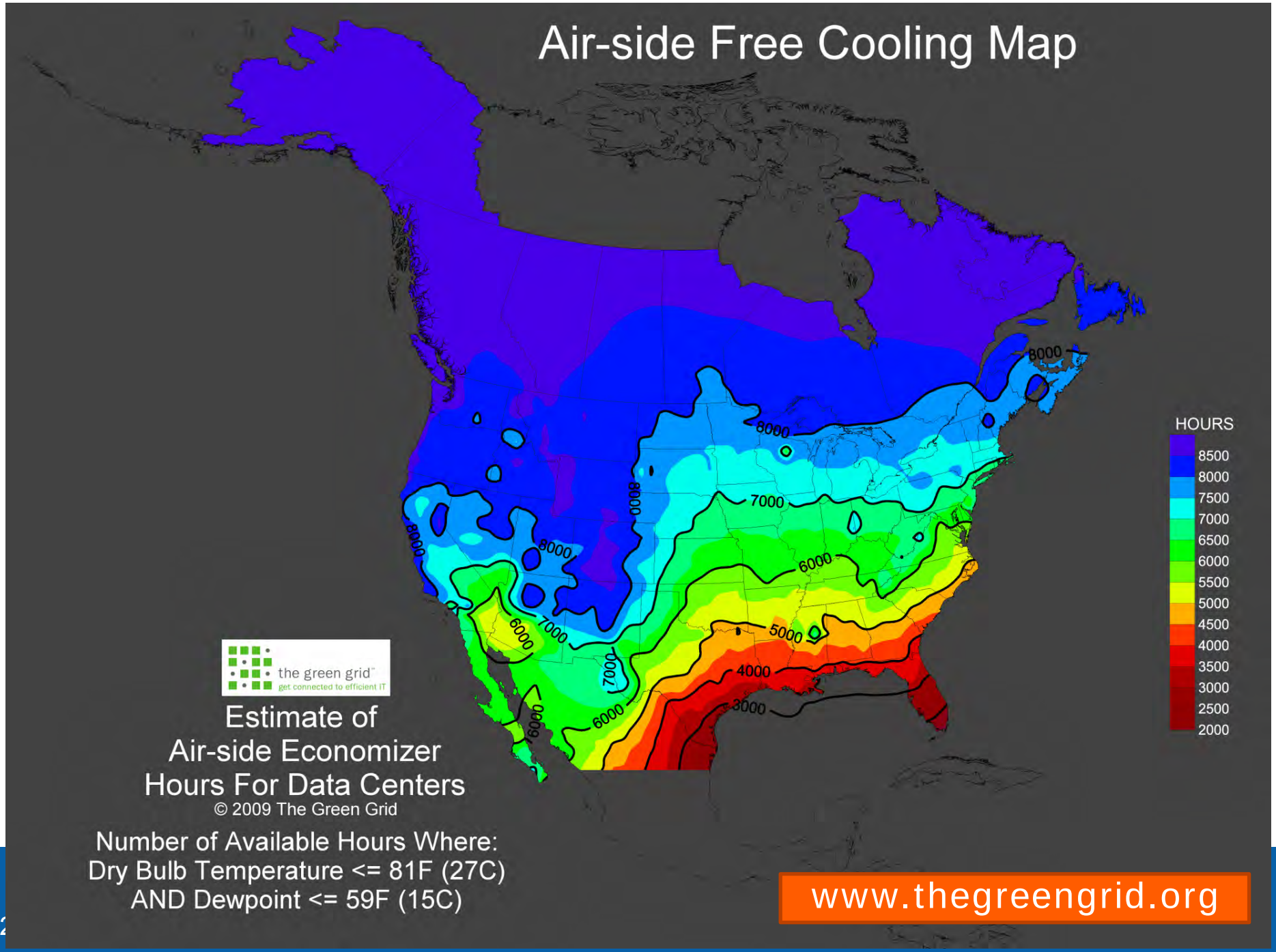
http://tc99.ashraetcs.org/

2008 ASHRAE Environmental Guidelines

	High Limit	Low Limit
Temperature	27C (80.6F)	18C (64.4F)
Humidity	Lower of 60% RH or 15C dewpoint	5.5C dewpoint

Opportunities for expanded temperature and humidity operation of data centers to allow less energy use in the cooling system; lowering PUE

Air-side Free Cooling Map



Estimate of
Air-side Economizer
Hours For Data Centers

© 2009 The Green Grid

Number of Available Hours Where:
Dry Bulb Temperature <= 81F (27C)
AND Dewpoint <= 59F (15C)

www.thegreengrid.org

Calculated Free-Cooling Savings - US/CANADA - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://cooling.thegreengrid.org/namerica/WEB_APP/calc_index.html Go Links

the green grid

Free-Cooling Estimated Savings

US/CANADA LOCATION (ZIP CODE): 97201

DEGREES IN: FAHRENHEIT / CELSIUS

ALLOW MIXING OF SUPPLY AND RETURN AIR ☑

ALLOW HUMIDIFICATION ☑

www.thegreengrid.org

	MAX LIMIT	MIN LIMIT
DRYBULB TEMP THRESHOLD (DEG):	27.0	NONE
DEWPOINT TEMP THRESHOLD (DEG):	15.0	NONE
REL. HUMIDITY THRESHOLD (%):	NONE	
DESIRED CHILLED WATER TEMP (DEG):	13.0	
COOLING SYSTEM APPROACH TEMP (DEG):	3.0	

CALCULATE

RESET FORM

HELP

DATA CENTER IT POWER (kW):	1000			
POWER USAGE EFFECTIVENESS (PUE):	1.6			
TOTAL FACILITY POWER (kW):	1600			
OVERHEAD POWER (kW):	600			
PERCENT OF OVERHEAD POWER FOR COOLING SYSTEM (%):	80	%	480	kW
PERCENT OF COOLING SYSTEM POWER FOR CHILLER (%):	40	%	192	kW
PERCENT OF COOLING SYSTEM POWER FOR TOWER (%):	40	%	192	kW
PERCENT OF COOLING SYSTEM POWER FOR FOR PUMPS/FANS (%):	20	%	96	kW
PERCENT OF OVERHEAD POWER FOR POWER LOSSES and LIGHTING (%):	20	%	120	kW
ELECTRIC COST ($ per kWh)	0.08			

HOURS MEETING CRITERIA FOR FREE-AIR COOLING:	8367
ESTIMATED SAVINGS USING FREE-AIR COOLING:	$ 200,000
HOURS MEETING CRITERIA FOR WATER SIDE ECONOMIZER:	4886
ESTIMATED SAVINGS USING WATER SIDE ECONOMIZER:	$ 120,000

WEATHERBANK, INC.

Internet

intel

Remember to design to your site and situation, there is no single best design

- *Evaluate your situation*
- Consider Power
- Consider Climate
- Consider Building Constraints
  - Space
  - Airflow
  - Cooling plant
- *Higher level of IT and Infrastructure Integration*

- Don't try to force it… or you may wind up with a system you don't like at all

Thank You! Questions?