GREEN COOLING

Sustainable Design Approaches for Data Centers

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CALLISON

Agenda

Data Center Power Usage
IT Approaches
Infrastructure Approaches
Unintended Consequences

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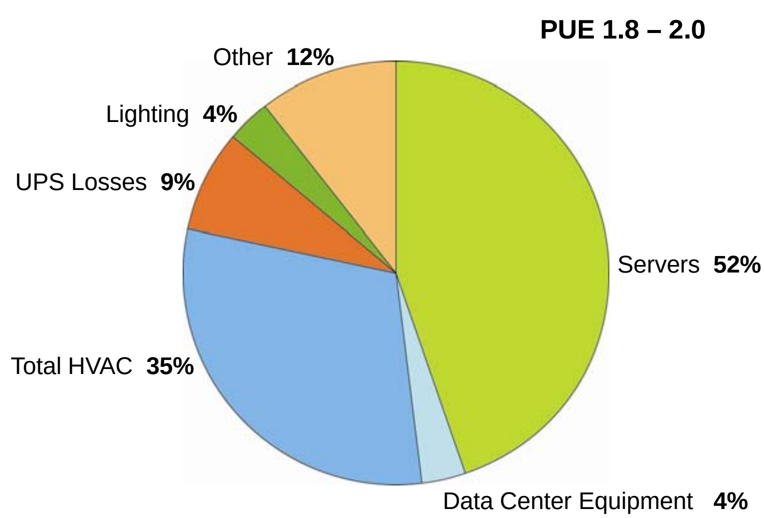
Historical Data Center Power Usage

- According to 2007 EPA Report to Congress, Data Centers Consumed **61 billion** kilowatt-hours (kwh) in 2006, equal to **1.5% of total** US energy consumption.
- Total Peak Load on Power Grid is approx. **7 gigawatts** (GW)
- Typical Data Centers Operating with a **PUE of 1.8** or higher

Typical Data Center Power Usage



Source: Lawrence Berkeley National Laboratory

Future Power Usage Trends

At Current Growth Rate

- Total Consumption Estimated to Increase to **100 billion kwh** from 61 billion kwh by 2011.
- Total Peak Load on Power Grid grows to **12 gigawatts** (GW)

Potential Annual Savings by Using Increased Efficiencies

- Improved Operations: Save **23** billion kwh in 2011
- Best Practices: Save **60** billion kwh in 2011
- State of the Art: Save **74** billion kwh in 2011

Energy Use Comparison

Annual Savings in 2011 by Scenario

(Compared to Current Efficiency Trends)

Scenario	Electricity consumption savings (billion kWh)	Electricity Cost Savings ($billion 2005)	Carbon dioxide emissions avoided (MMTCO)
Improved Operation	23	1.6	15
Best practice	60	4.1	38
State-of-the-Art	74	5.1	47

Source: EPA Report to Congress August, 2007

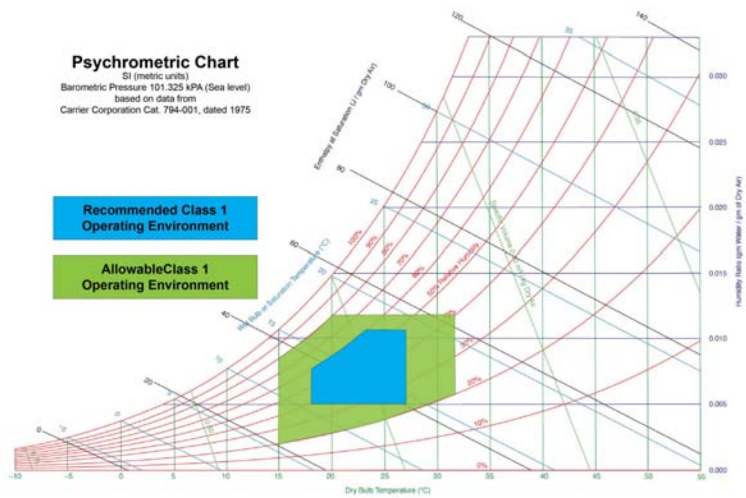
IT Approaches Efficiency Strategies

- More Efficient Servers
  - Many Existing Data Centers Performing at 10% - 30% Utilization of Overall Server Capacity
  - Many Applications Mapped "One to One" (One Application per Server)
  - Newer Generation of Servers Utilize Variable Power Settings to Reduce Power Consumption at Idle and Low Processing Loads
- Logical Virtualization
  - Increase Processor Utilization by Creating "Multi-Tasking" Capability by Running Multiple Applications on Each Server
  - Decreases Energy Demand by More Fully Utilizing Processor Capacity

Infrastructure Efficiency Strategies

- Change the Operating Environment by Using ASHRAE TC 9.9 "Allowable Operating Conditions".
  - Temperature 15 deg. C to 32 deg. C (59 deg. F to 89 deg. F)
  - Humidity 20% to 80% RH (Relative Humidity)
- Benefits
  - Reduces demand for mechanical refrigeration
  - Increases available hours for Free Cooling
  - Enables Alternative Cooling Strategies
- Issues
  - Operations at higher supply temperatures potentially creates less time to respond to adverse conditions
  - Need to address staff perceptions of working in the Hot Aisle
  - Moisture control in exterior walls is extremely critical

Infrastructure **Efficiency Strategies**

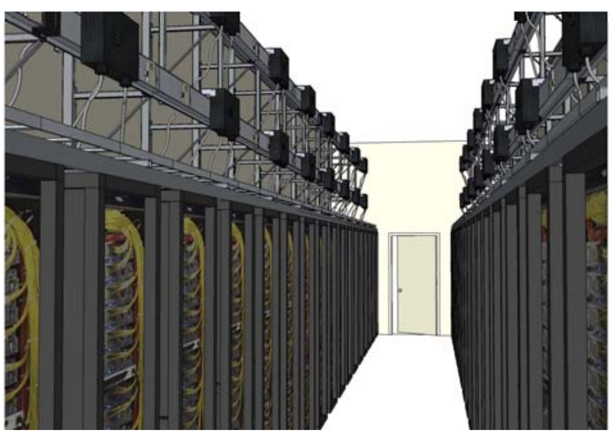


ASHRAE TC 9.9 Class 1 Operating Environment Guidelines

Infrastructure **Efficiency Strategies**

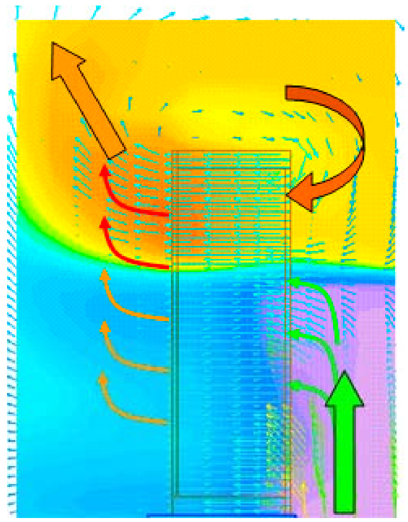
Contained Hot Aisle

- Separates Cool Supply Air from Hot Return Air



Infrastructure **Efficiency Strategies**

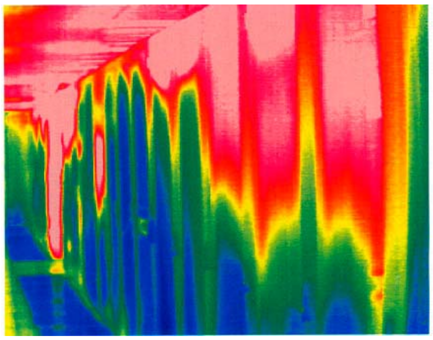
Contained Hot Aisle



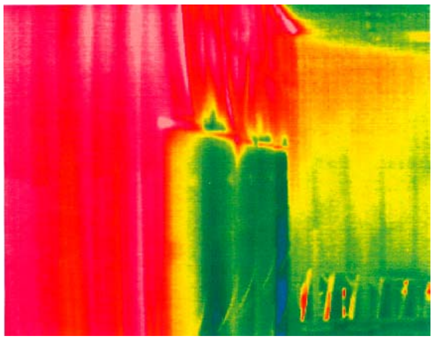
BYPASS AIRFLOW IN
UNCONTAINED HOT AISLE

Infrastructure **Efficiency Strategies**

Contained Hot Aisle



THERMOGRAPHIC IMAGE OF
UNCONTAINED HOT AISLE



THERMOGRAPHIC IMAGE OF
CONTAINED HOT AISLE

Infrastructure Efficiency Strategies

Contained Hot Aisle

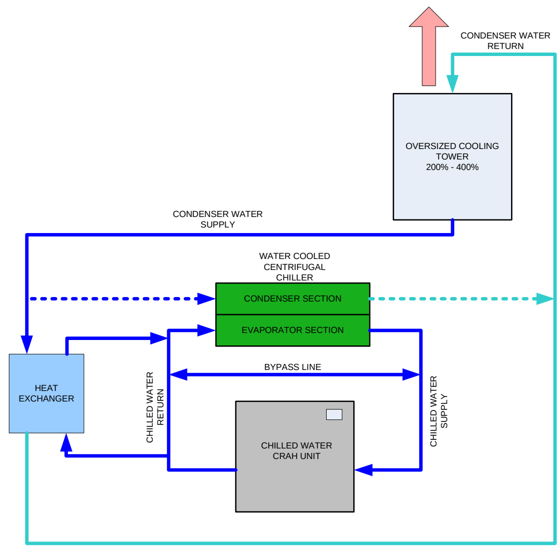
- Benefits
  - **Prevents Blending of Return Air with Supply Air**
  - **Prevents Return Air Bypass into Top of Racks**
  - **Allows Increased Supply Air Temperature**
  - **Decreases Need for Mechanical Refrigeration**
  - **Extends Available Hours for Free Cooling**
  - **Enables Use of Alternative Cooling Strategies**
  - **Allows Overhead Supply – Can Eliminate Raised Floor**
- Issues
  - Managing Openings in Containment System is Critical (Cables, Power, etc.)
  - Need to address staff perceptions of working in the Hot Aisle
  - Requires Denser Installation of Sprinkler Heads
  - Need to Manage Phased Deployment to Maintain Temperature Separation

Infrastructure Efficiency Strategies

Water Side Economizer

- Water Side Economizer Used with Centralized Chilled Water Plant or Water Cooled CRAC's
  - Cooling Towers Provide Chilled Water at Ambient Temperature Below 40 deg. F WB, bypassing the Use of Mechanical Refrigeration
  - Chillers Provide Chilled Water at Ambient Temperatures Above 40 deg. F WB

Infrastructure **Efficiency Strategies**



WATER SIDE ECONOMIZER

Infrastructure **Efficiency Strategies**

Water Side Economizer

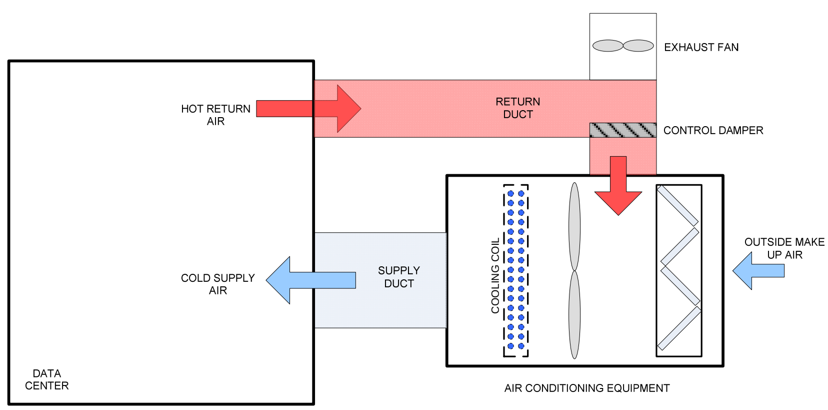
- Benefits
  - Reduces demand for mechanical refrigeration during cold weather
  - Allows for seasonal central plant maintenance window in cold weather
  - Very effective if outside air conditions are marginal, i.e., salt air environment
  - Widely used in high rise buildings
  - PUE Range: **1.7 – 1.75**
- Issues
  - Increased first cost: Heat exchangers, upsizing of cooling towers, additional coils for CRAC units
  - Works best in cold & dry climates

Infrastructure **Efficiency Strategies**

Air Side Economizer

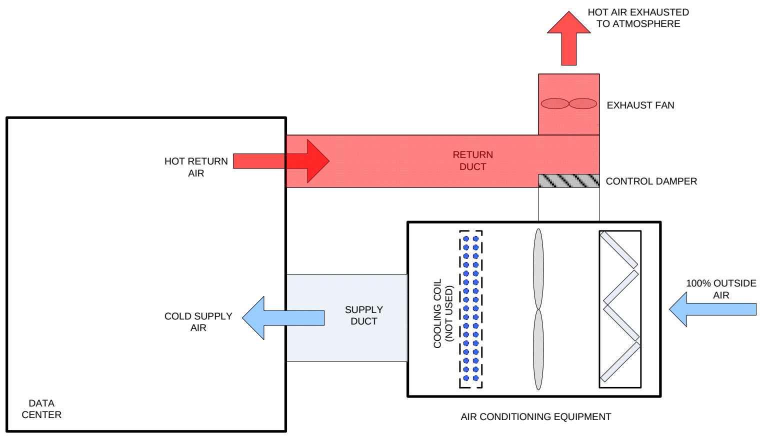
- Air Handling Units Provide 100% Outside Air to Meet Cooling Demand When Ambient Air Temperature is Below Desired Supply Air Temperature
- Amount of Outside Air Can Be Modulated to Extend Hours of Economizer Operation

Infrastructure **Efficiency Strategies**



AIR SIDE ECONOMIZER SYSTEM NORMAL OPERATION

Infrastructure **Efficiency Strategies**



AIR SIDE ECONOMIZER SYSTEM ECONOMIZER OPERATION

Infrastructure **Efficiency Strategies**

Air Side Economizer

- Benefits
  - Amount of Outside Air Can Be Modulated to Extend Hours of Economizer Operation
  - Usable with multiple HVAC systems (As long as outside air can be accessed)
  - Creates seasonal cooling plant maintenance window
  - Applicable to large and small data centers
  - Adds another level of robustness, i.e., maintaining air supply with a chiller plant failure
  - PUE **1.3 – 1.45**
- Issues
  - Humidity Control: Use low energy centralized humidification
  - Mechanical and Architectural design needs to accommodate volume and area for introduction of outside air
  - Particulate control, important but very manageable with standard filtration.

Infrastructure **Efficiency Strategies**

Air Side Economizer

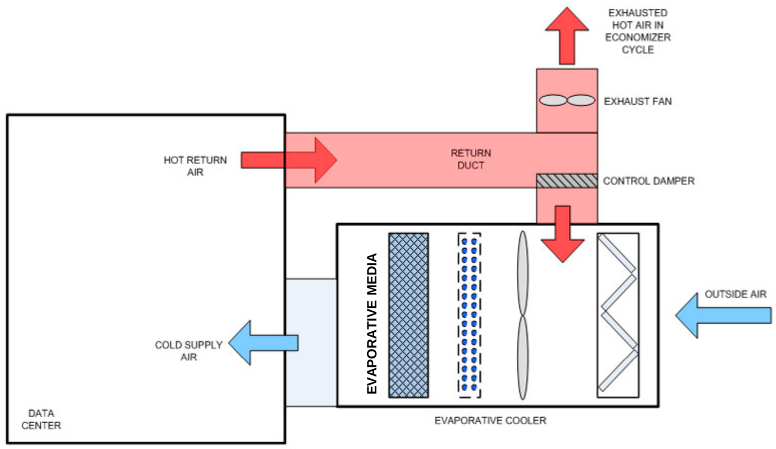
- Intel Proof of Concept
  - Test environment: DX Cooling Data Center vs. Air Economizer Data Center
  - 200 watts per sf, 90% server utilization
  - Supply air varied from 64 deg. F to 92 deg. F
  - No humidity control used, varied from 4% RH to 90% RH
  - Used standard "residential" filters, servers became layered with dust
- Results
  - Cooling power reduced from **111.78** kw to **28.9** kw in economizer section, 74% reduction in energy consumption
  - Server failure rates increased from 3.83% in normal data center to 4.46% in economizer section

Infrastructure **Efficiency Strategies**

Evaporative Cooling

- Evaporative Cooling Units Provide Adiabatic Cooling
- Evaporative Cooling Units Must Be Configured to Provide 100% Outside Air to Meet Cooling Demand When Ambient Air Temperature is Below Desired Supply Air Temperature

Infrastructure **Efficiency Strategies**



EVAPORATIVE COOLER SYSTEM

Infrastructure **Efficiency Strategies**

Evaporative Cooling

- Benefits
  - Reduces demand for mechanical refrigeration
  - Amount of Outside Air Can Be Modulated to Extend Hours of Economizer Operation
  - Very Low Energy Demand
  - Very simple and robust system
  - PUE Range: **1.2 – 1.3**
- Issues
  - Must be used with air side economizer system
  - Works best in moderate and dry climates
  - May require supplemental chiller capacity for very high ambient temperatures

Infrastructure Efficiency Strategies

Summary Comparison

Annual savings of PUE Reduction

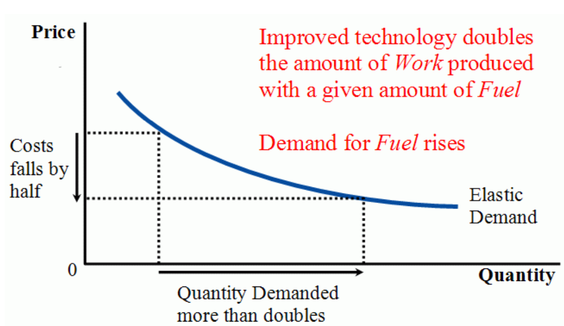
per 1 MW of Critical Load

				Annual Reduction			
Annualized	Critical Load	Total Load	Reduced Load	Demand	Consumption	Cost	CO2
PUE	kW	kW	%	kW	kWh	$$ at 10¢/kWh	tons
1.8	1000	1800	Baseline	Baseline	Baseline	Baseline	Baseline
1.6	1000	1600	11%	200	1,752,000	$ 175,200	2,487,840
1.4	1000	1400	22%	400	3,504,000	$ 350,400	4,975,680
1.2	1000	1200	33%	600	5,256,000	$ 525,600	7,463,520

Unintended Consequences

Jevons Paradox

William Stanley Jevons postulated in 1865 that technological progress that increases the efficiency with which a resource is used, tends to *increase*, rather than decrease, the rate of consumption of that resource.



Recommendations

- Utilize Most Efficient Equipment Possible – Both Mechanical and Electrical
- Use Variable Frequency Drives
- Incorporate A Form of Economizer Function (Geographically Dependent)
- Install Hot Aisle Containment
- Locate New Data Centers in Areas Suitable for Air Side Economizer

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