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Improving Efficiencies by Integrating Data Center Systems

August 30th, 2012

Architectural Effects on Efficiencies

- Raised floor and room air tightness
- Humidity control – vapor barrier
- Ceilings as return air plenums
- Raised floor as supply air plenums
- Containment – coordination, tightness
- Large areas required to reduce static pressure and accommodate ducts and louvers

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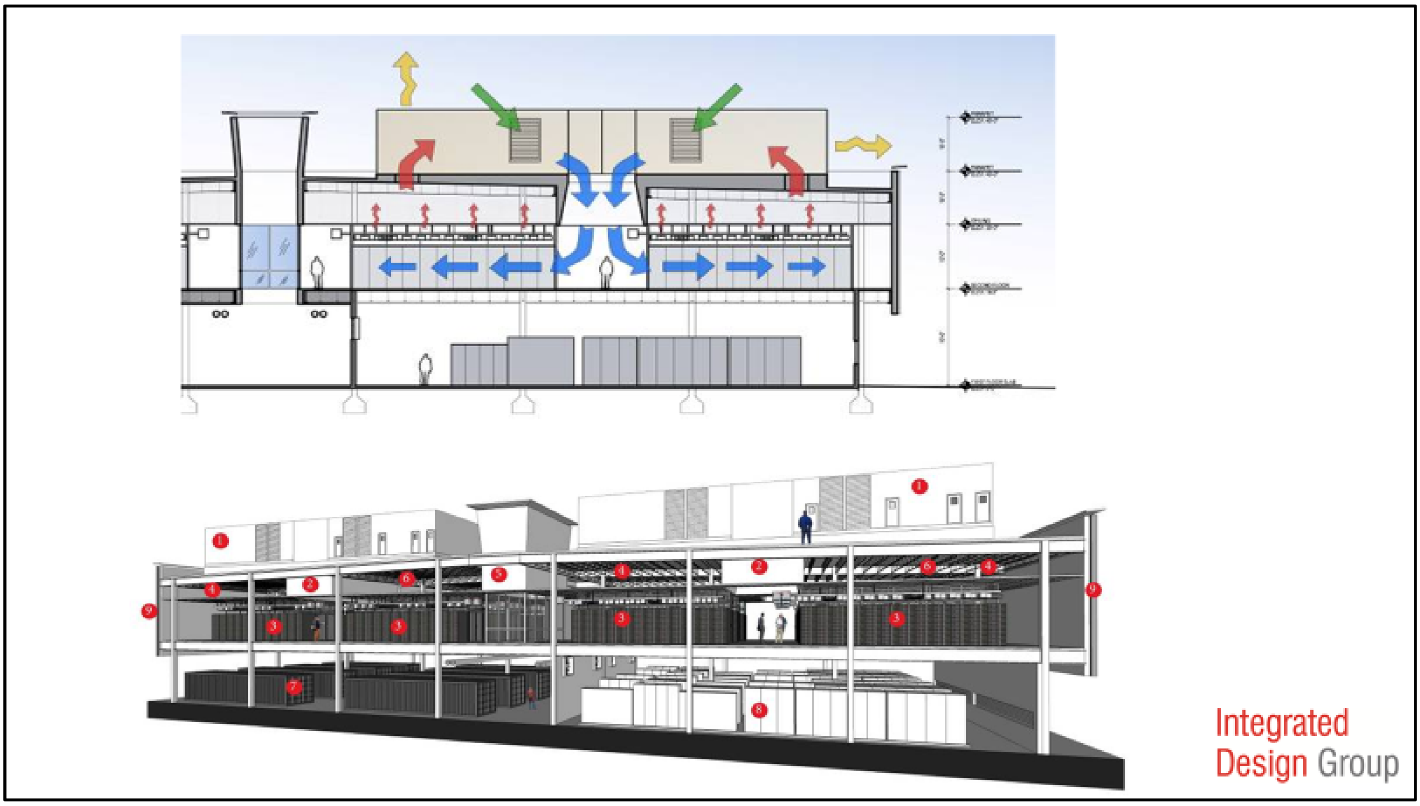
- Maximum 10 % air leakage, preferably 5%. The intent is to provide cooling air only where required for IT equipment.
- Raised floor to be coordinated with equipment and cabinets to minimize cuts and maximize floor layout efficiency.
- Ceilings could be supply and return air plenums or used for ductwork.
- Raised floor provides flexibility for equipment layouts, easier air flow changes, and provides space to route cabling, chilled water or refrigerant piping.
- Multiple types of containment – full, end doors only, between cabinet and ceiling.



- Large openings and pathways for air flow to enhance natural ventilation and minimize fan power.

Controls

- Pressurization
- Contamination – Smoke, Pollen, Diesel
- Temperature reset on cooling equipment to control Humidity.
- Select controls based on type of air management

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- Control pressurization to not damage roof or prevent doors from operating correctly and safely during all operational events including:
    - Economizer start up, power switch to and from generator, sudden load change, etc
- Sensor location and accuracy is important. Consider solar gain for exterior sensors.
- How is air economizer system controlled when there is exterior smoke? Heavy pollen or other particles? Diesel fumes? Pollution?
    - Bringing in smoke may shut down Computer room due to an external event.
    - Concern with diesel generator operation
    - Concern with bringing in outdoor air and feeding an interior fire when on economizer.
- Consider efficiencies and cost for air economizer when outdoor air is too hot or too humid or too dry.
    - Cost of adding humidity when to outdoor air is too dry.
    - How to dehumidify the room when outdoor air raises room dew point too high.
- Consider temperature reset of cooling system and chilled water to control humidity or improve cooling capacity.

Electrical

- High voltage distribution – 208, 230, 277V
- High efficiency equipment (or Eco mode UPS)
- Take heat producing equipment out of computer room
- Let Electrical and UPS rooms operate at higher temperatures
- Lighting control

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- NEMA TP-1 and CSL-3 transformers
- Efficient UPS systems – transformerless, IGBT, Eco mode, line interactive, increase loading (VMMS)
- Locate PDUs and UPSs outside of Computer room
- Let Electrical and UPS rooms operate at a higher temperature.
- Lighting – time clock control, occupancy sensor, high efficiency, LED in ceiling, LED on cabinet at doorways

Mechanical

- Raise Computer room temperatures to ASHRAE recommendations/allowable limits
- Increase allowable humidity levels
  - consider cost to add humidity
- Raise chilled water temperatures
- Use VSD pumps and fans to reduce power
- Use redundant equipment to increase efficiencies

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- High return air temperatures raises CRAH/CRAC capacity
- Higher chilled water temperatures reduces CRAH/CRAC capacity
- Higher chilled water temperatures raises chiller efficiency and increases economizer hours.

- Energy is reduced using variable speed drives (VSD) per a cube relationship. Operating 4 fans at part load uses less energy then 3 fans at full load.
- CFM (Fan speed) must be adequate for the load.

Mechanical

- High efficiency economizer systems
  - Air
  - Water
  - Refrigerant
- Adiabatic cooling systems
- Right size cooling system operation
- ASHRAE 90.1-2010 code requirements
  - Typical DX type units may not meet minimum efficiencies

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Mechanical

- PUE varies by system and geography
- Fan power is a big influence

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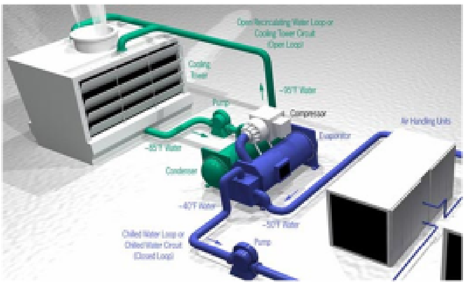
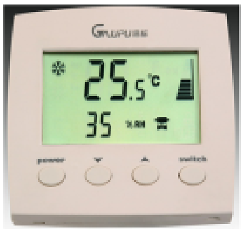
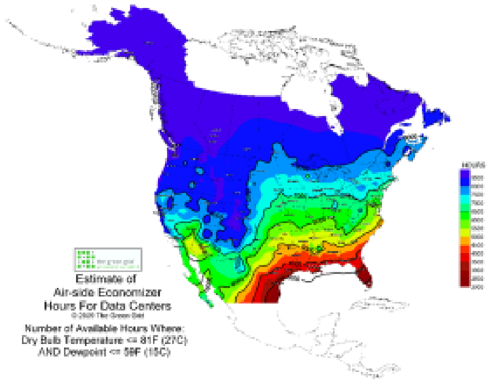
Key Factors for PUE



- System
- Location
- Operating Conditions





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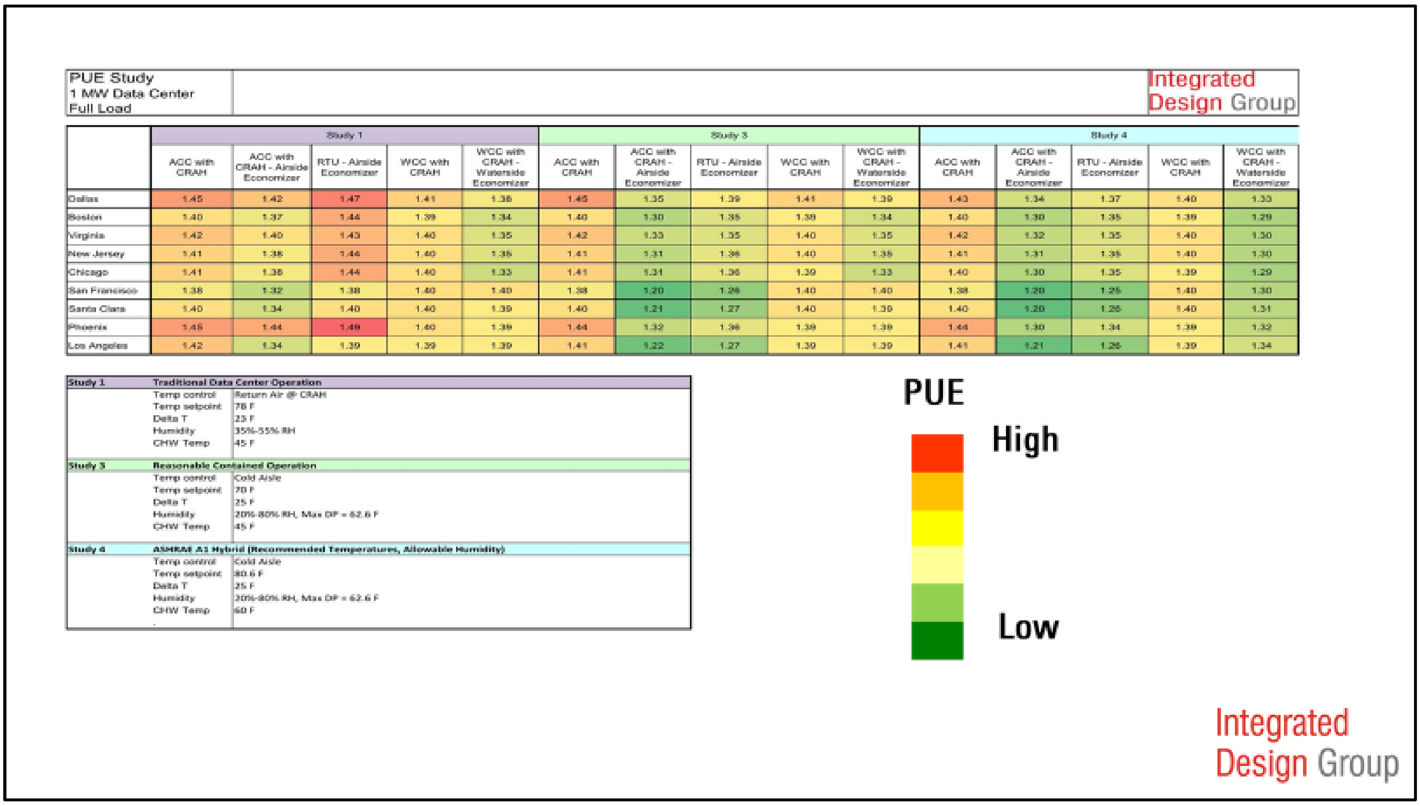
- The 3 major factors that impact PUE are: Infrastructure Systems Selection, Location & IT Space Operating Conditions.
- The 3 factors make it difficult to say which is the most important.



PUE Study 1 MW Data Center Full Load	Study 1					Study 3					Study 4				
	ACC with CRAH	ACC with CRAH - Airside Economizer	RTU - Airside Economizer	WCC with CRAH	WCC with CRAH - Waterside Economizer	ACC with CRAH	ACC with CRAH - Airside Economizer	RTU - Airside Economizer	WCC with CRAH	WCC with CRAH - Waterside Economizer	ACC with CRAH	ACC with CRAH - Airside Economizer	RTU - Airside Economizer	WCC with CRAH	WCC with CRAH - Waterside Economizer
Dallas	1.45	1.42	1.47	1.41	1.38	1.45	1.35	1.39	1.41	1.39	1.43	1.34	1.37	1.40	1.33
Boston	1.40	1.37	1.44	1.39	1.34	1.40	1.30	1.35	1.39	1.34	1.40	1.30	1.35	1.39	1.29
Virginia	1.42	1.40	1.43	1.40	1.35	1.42	1.33	1.35	1.40	1.35	1.42	1.32	1.35	1.40	1.30
New Jersey	1.41	1.38	1.44	1.40	1.35	1.41	1.31	1.36	1.40	1.35	1.41	1.31	1.35	1.40	1.30
Chicago	1.41	1.38	1.44	1.40	1.33	1.41	1.31	1.36	1.39	1.33	1.40	1.30	1.35	1.39	1.29
San Francisco	1.38	1.32	1.38	1.40	1.40	1.38	1.20	1.26	1.40	1.40	1.38	1.20	1.25	1.40	1.30
Santa Clara	1.40	1.34	1.40	1.40	1.39	1.40	1.21	1.27	1.40	1.39	1.40	1.20	1.26	1.40	1.31
Phoenix	1.45	1.44	1.49	1.40	1.39	1.44	1.32	1.36	1.39	1.39	1.44	1.30	1.34	1.39	1.32
Los Angeles	1.42	1.34	1.39	1.39	1.39	1.41	1.22	1.27	1.39	1.39	1.41	1.21	1.26	1.39	1.34

Study 1	**Traditional Data Center Operation**	
	Temp control	Return Air @ CRAH
	Temp setpoint	78 F
	Delta T	23 F
	Humidity	35%-55% RH
	CHW Temp	45 F
Study 3	**Reasonable Contained Operation**	
	Temp control	Cold Aisle
	Temp setpoint	70 F
	Delta T	25 F
	Humidity	20%-80% RH, Max DP = 62.6 F
	CHW Temp	45 F
Study 4	**ASHRAE A1 Hybrid (Recommended Temperatures, Allowable Humidity)**	
	Temp control	Cold Aisle
	Temp setpoint	80.6 F
	Delta T	25 F
	Humidity	20%-80% RH, Max DP = 62.6 F
	CHW Temp	60 F

•We've modeled 1000's of PUE combinations & found that Space Operating Conditions have the greatest impact.
•Each resulting PUE is Color formatted so that green represents the lowest PUE and red the highest.
•Space Conditions – most restrictive to least restrictive temp & humidity.

Mechanical

- Hot/Cold aisle containment systems
  - Similar operational costs
  - Different control strategies
  - How to keep hot and cold air separated
    - Doors at end of aisles
    - Barriers from cabinets to ceiling
    - Duct from cabinet to ceiling
  - Consider temperature in room
    - OSHA limits on heat exposure

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NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

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OSHA Technical Manual SECTION III: CHAPTER 4 HEAT STRESS

- TABLE III:4-2. PERMISSIBLE HEAT EXPOSURE THRESHOLD LIMIT VALUE

------------- Work Load* ------------			
Work/rest regimen	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)

- *Values are in °C and °F, **WBGT**.

- These TLV's are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C (100.4° F). They are also based on the assumption that the WBGT of the resting place is the same or very close to that of the workplace. Where the WBGT of the work area is different from that of the rest area, a time-weighted average should be used (consult the ACGIH 1992-1993 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1992).

- These TLV's apply to physically fit and acclimatized individuals wearing light summer clothing. If heavier clothing that impedes sweat or has a higher insulation value is required, the permissible heat exposure TLV's in Table III:4-2 must be reduced by the corrections shown in Table III:4-3.
- **Average Web Bulb Globe Temperature (WBGT)**
  – For indoor and outdoor conditions with no solar load, WBGT is calculated as:
    - WBGT = 0.7NWB + 0.3GT

  – WBGT = Wet Bulb Globe Temperature Index
  – NWB = Nature Wet-Bulb Temperature
  – DB = Dry-Bulb Temperature
  – GT = Globe Temperature

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DEFINITIONS.

The American Conference of Governmental Industrial Hygienists (1992) states that workers should not be permitted to work when their deep body temperature exceeds 38°C (100.4°F).

Heat is a measure of energy in terms of quantity.

A **calorie** is the amount of heat required to raise 1 gram of water 1°C (based on a standard temperature of 16.5 to 17.5°C).

Conduction is the transfer of heat between materials that contact each other. Heat passes from the warmer material to the cooler material. For example, a worker's skin can transfer heat to a contacting surface if that surface is cooler, and vice versa.

Convection is the transfer of heat in a moving fluid. Air flowing past the body can cool the body if the air temperature is cool. On the other hand, air that exceeds 35°C (95°F) can increase the heat load on the body.

Evaporative cooling takes place when sweat evaporates from the skin. High humidity reduces the rate of evaporation and thus reduces the effectiveness of the body's primary cooling mechanism.

Globe temperature is the temperature inside a blackened, hollow, thin copper globe. Black Globe Sensor - The Black Globe instrument is a simple instrument used for monitoring the temperature effect of global radiation on an exposed surface. The sensor consists of a temperature sensor mounted inside a copper globe with a matte black surface exterior. It is widely used in the feedlot industry to mimic the effect of radiation on the comfort of cattle. It also can be used for comfort measurements in

other animals and in humans.
Metabolic heat is a by-product of the body's activity.
Natural wet bulb (NWB) temperature is measured by exposing a wet sensor, such as a wet cotton wick fitted over the bulb of a thermometer, to the effects of evaporation and convection. The term natural refers to the movement of air around the sensor.
Dry bulb (DB) temperature is measured by a thermal sensor, such as an ordinary mercury-in-glass thermometer, that is shielded from direct radiant energy sources.