BiTS Burn-in & Test Socket Workshop 2011 **Keynote Speaker**

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THERMAL MANAGEMENT APPLIED TO DATA CENTERS WITH FOCUS ON ENERGY EFFICIENCY

by

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ABSTRACT

Recent surveys of CIO's have shown that energy is one of the leading concerns in the operation of data centers. The IT industry ranks 6th in overall energy use compared to other large industries, and if the manufacturing of IT equipment, which ranks 11th, is included with the power required to drive all the IT equipment, then this industry is 3rd on the list of industries which use the most energy in the US.

The EPA issued a report to the US Congress in August, 2007, as requested through the House of Representatives, assessing opportunities for energy efficiency improvements to computer servers and data centers in the United States. Two points stand out in this report: 1) the infrastructure support of the IT equipment within a data center contributes over one-half of the overall power used for maintaining a data center, and 2) the rate of growth of data center energy usage is significant.

Since that report a number of organizations have created technologies and best practices that can improve data center energy use significantly. There have been some significant improvements made to data centers but much more needs to be done.

Some of the new technologies and best practices applied to data centers will be described in this talk, along with some thoughts on what the future holds for power and cooling of data centers, and how some of these will affect the design of servers of the future. Data center technologies and best practices, which include the deployment of co-generation, higher server ambient temperatures, DC power, liquid cooling, and use of renewables, will be described.

Thermal Management Applied to Data Centers with Focus on Energy Efficiency

Roger Schmidt, IBM Fellow
Chief Engineer - Data Center Energy Efficiency

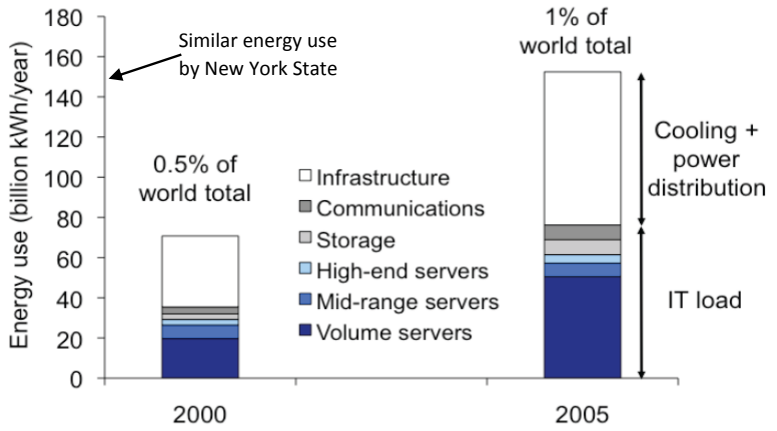
Agenda

- ✓ Data center energy use
- ✓ IT technology energy improvements
- ✓ IT equipment operating envelope
- ✓ Infrastructure to support IT equipment
- ✓ Data center designs
- ✓ Big issues
- ✓ Q & A

Data centers use electricity How much?

❖ More video was uploaded to YouTube in the past 2 months than if ABC, CBS and NBC had been airing content 24/365 since 1948

World Data Center Electricity Use



Source: Koomey 2008

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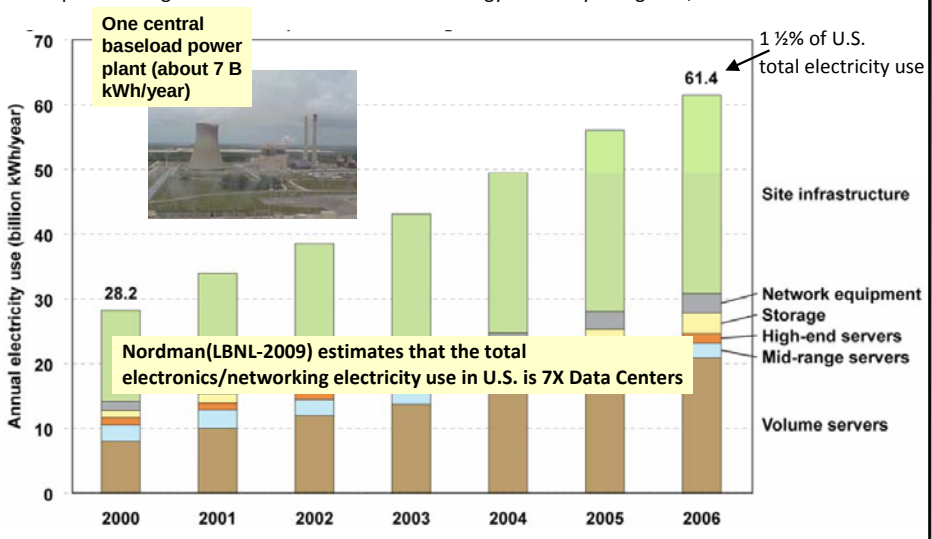
U.S. Data Center Electricity Use 2000 - 2006

Report to Congress on Server and Data Center Energy Efficiency – August 2, 2007



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Electricity Use of U.S. Servers

Electricity use rank among U.S. industries	Industry	Electricity Use(Billion kWh/year)
1	Chemical Manufacturing	151
2	Primary metal manufacturing	137
3	Food manufacturing	79
4	Paper manufacturing	75
5	Plastics and rubber products manufacturing	66
6	US servers and data centers	59
7	Transportation Equipment	58
8	Fabricated metal product manufacturing	53
9	Petroleum and coal products manufacturing	49
10	Nonmetallic metal products manufacturing	46
11	Computer and electronic product manufacturing	35

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Data center Inputs/Outputs

- Over 31 billion google searches were performed – last month – vs 2.6 billion 3 years ago.

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Control Volume for IT Equipment

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Information Technology is becoming more energy efficient at a furious pace

- The computer in your cell phone today is a million times cheaper, and a thousand times more powerful and about a hundred thousand time smaller than the one computer installed at MIT in 1965

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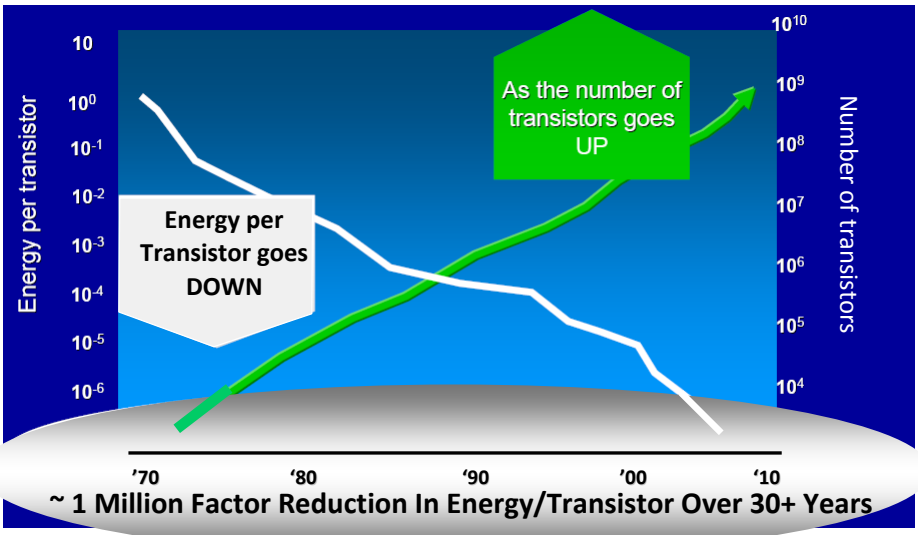
Incredible performance improvements



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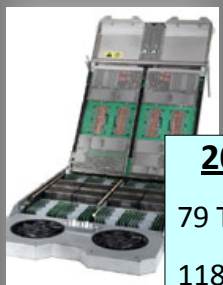
Moore's Law: Delivering DC Performance

power5 575



2004

79 TFlops

118 racks

10,000 ft²

3.5 MW

power6 575

2008

79 TFlops

9 racks

300 ft²

0.5 MW

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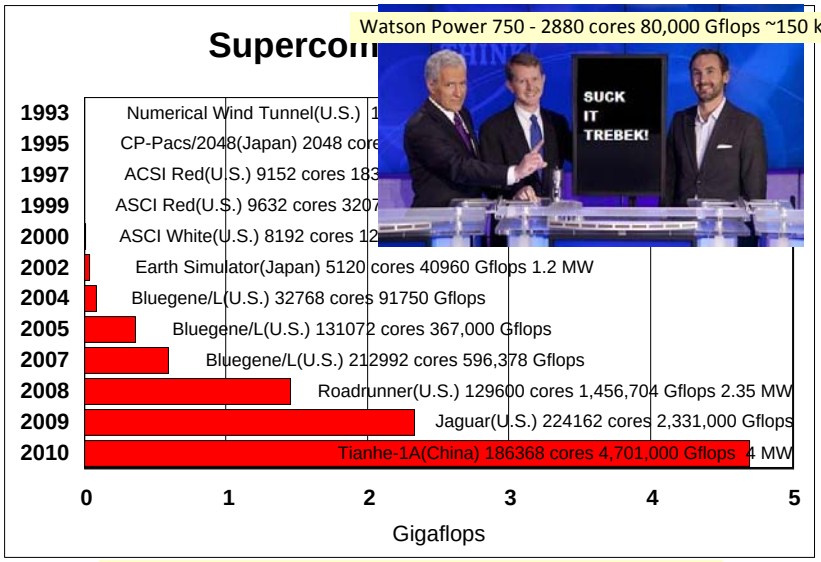
Supercomputer Trends



Watson Power 750 - 2880 cores 80,000 Gflops ~150 kW

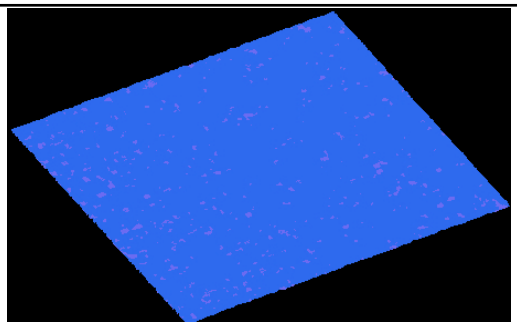
A 1 exaflop(1,000,000,000 Gflops) may require 100's of MW to power

Boundary Conditions

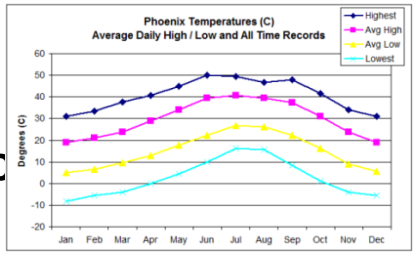
- The Environmental Envelope for operation of IT Equipment is becoming critically important

Heat Flow Path

Transistor
Chip
Module
Card
Drawer
Rack
Room
Atmc



Source:Hendrick Hamann, IBM Research



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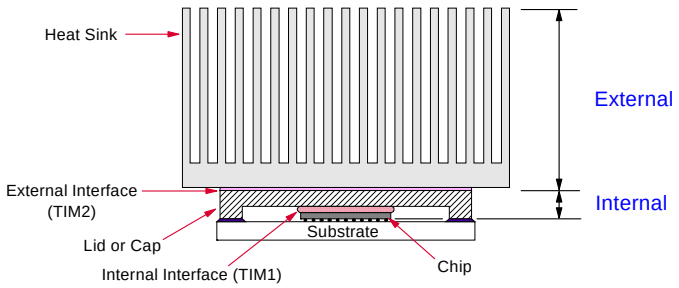
Module Level Cooling



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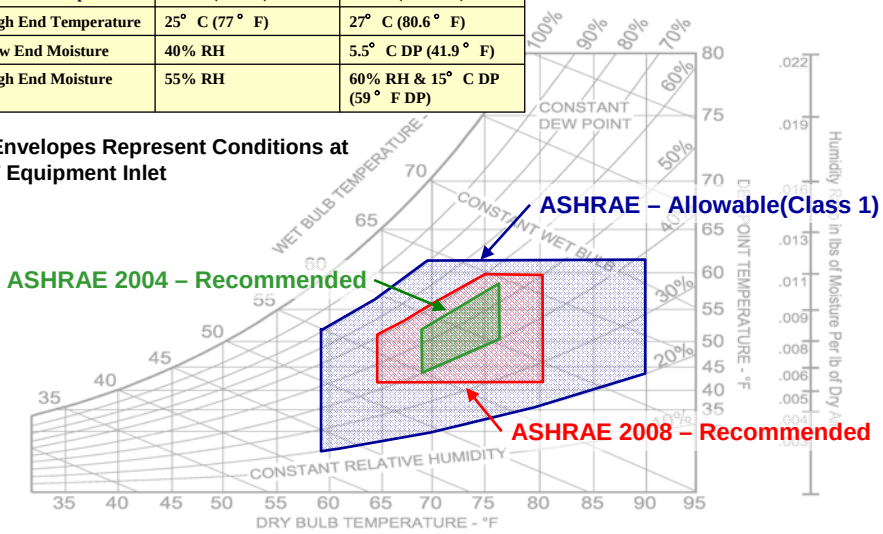
ASHRAE IT Equipment Environment

	2004 Version	2008 Version
Low End Temperature	20° C (68° F)	18° C (64.4° F)
High End Temperature	25° C (77° F)	27° C (80.6° F)
Low End Moisture	40% RH	5.5° C DP (41.9° F)
High End Moisture	55% RH	60% RH & 15° C DP (59° F DP)

*Envelopes Represent Conditions at IT Equipment Inlet



How do we package electronic within these boundary conditions?

- Movement toward smaller size, greater density in data centers

Packaging Electronics to Meet BC

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Parallel Trends (data center to Test/BI)

- Increasing emphasis on energy efficiency of test and Burn-In equipment
- Emerging trend of green initiatives and marketing from test equipment vendors
  - higher efficiencies in power delivery and thermal management and utilization
- Equipment marketed based on Total Cost of Ownership models
  - including energy efficiency
- Silicon and packaging trends to increasing power density
  - Higher compute density on-board, 3D packaging
- Trends to fewer chips/components of higher complexity and higher compute capability
  - net = performance vs. power gains
- Growing Test/BI complexity due to on-chip and system power management infrastructure
  - on-board voltage regulation, power throttling, sleep modes, nap modes, power/thermal monitoring and control, high performance modes, etc.
- Higher importance of low power silicon technologies and power/performance trade-offs
- Emphasis on high performance and high efficiency power/thermal management (HW and methods)
  - Starting at die level, flowing to package level ….all the way to the data center environment

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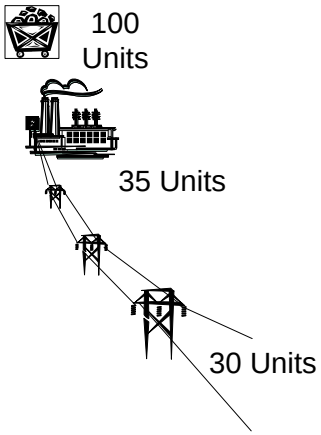
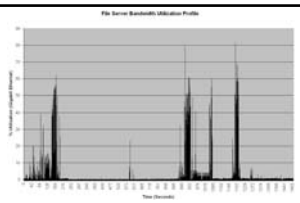
What infrastructure is required to support the electronics for a mission critical data center

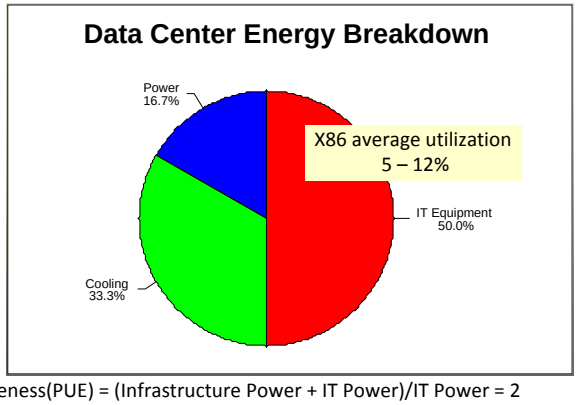
Mission critical facilities – must operate absolutely reliably around the clock, 365 days per year, under any circumstances

Typical Data Center Energy End Use



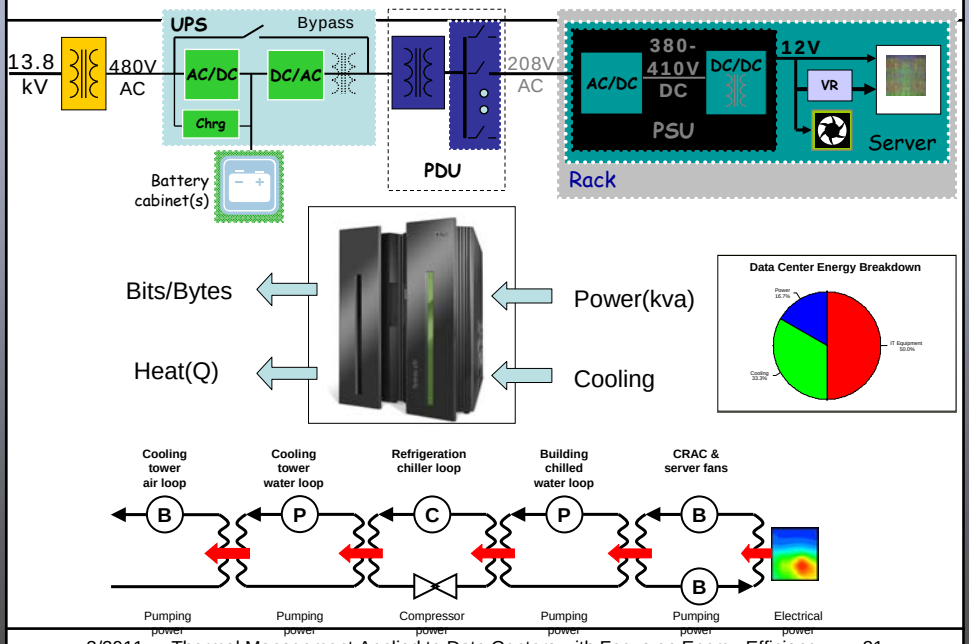
- File server link utilization (daytime) *(Bennett, 2006)*





Power Usage Effectiveness(PUE) = (Infrastructure Power + IT Power)/IT Power = 2

IT Infrastructure



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Infrastructure to Support IT Equipment

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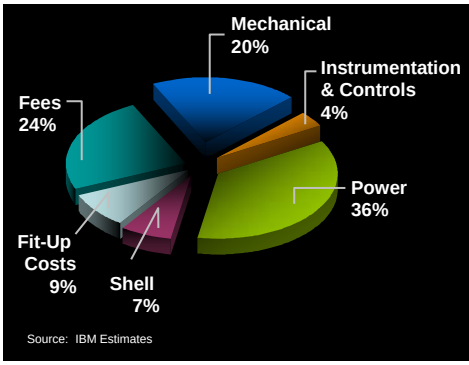
Holistic View
-Total Cost of Ownership-

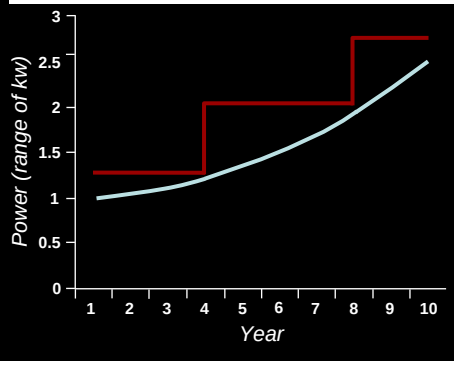
- Monitoring and reporting on energy consumption will be expected by 2012

Capital Cost of Data Center

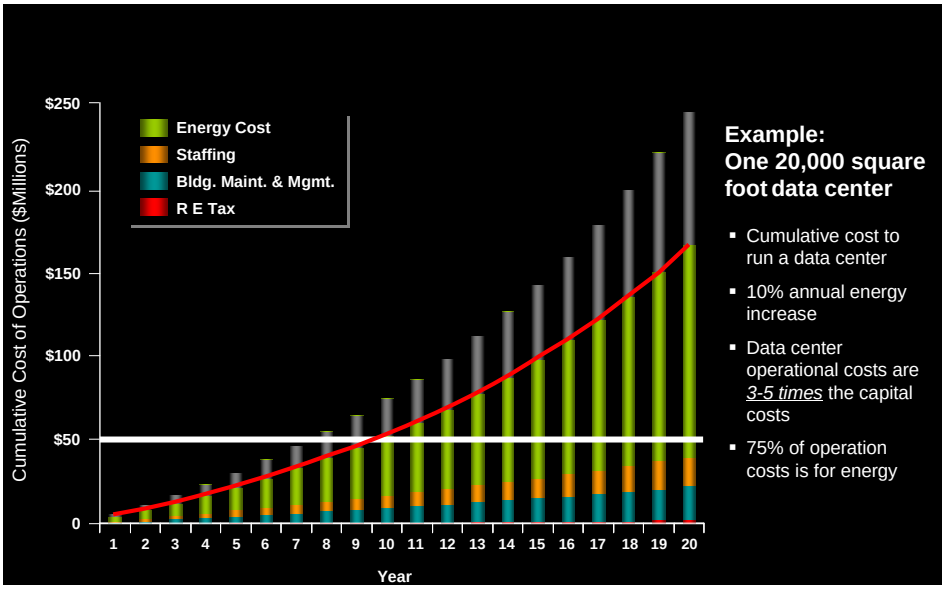
Data center capital costs
60% costs from mechanical / electrical systems



Pay as you grow
Modular approach aligns capacity to business need



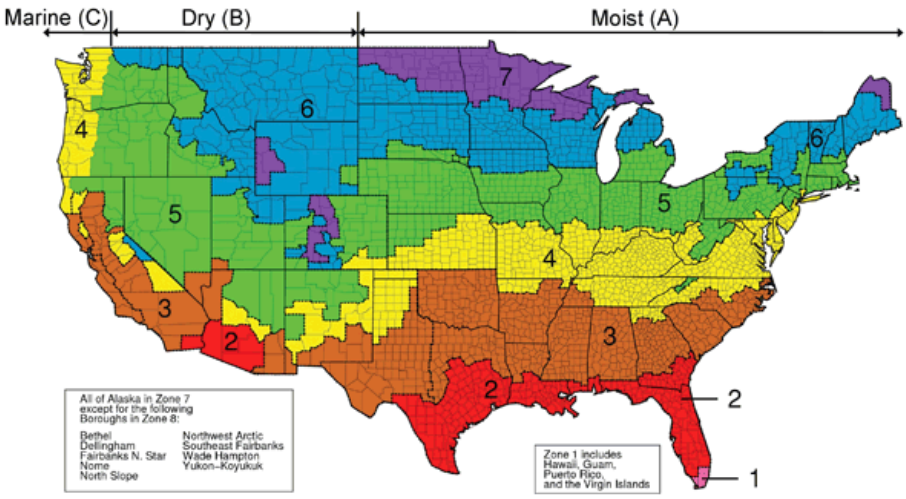
Optimize lifecycle costs



In spite of our progress in improving energy efficiency of data centers, there is still significant potential for much more

- Data centers can consume 40 to 100 times more energy than the office they support

Different climate zones - different solutions



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Some Ways to Cool/Power Data Centers

Water Cooled Central Chiller system - traditional

Air side economizer

Water side economizer

Evaporative cooling

Tri-gen – electricity, cooling, heating

Geo-thermal steam plant

Geo-thermal cooling

Photovoltaic

Fuel Cells

Enthalpy Wheel

Liquid Cooled IT Equipment

High Voltage DC

Many of these technologies are more common for commercial or industrial applications and have not been readily accepted or applied for data centers

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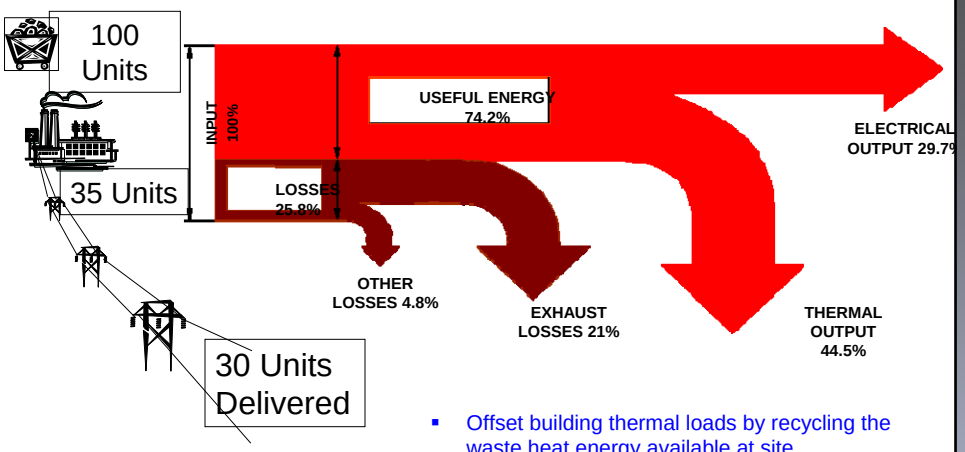
Three Data Center examples

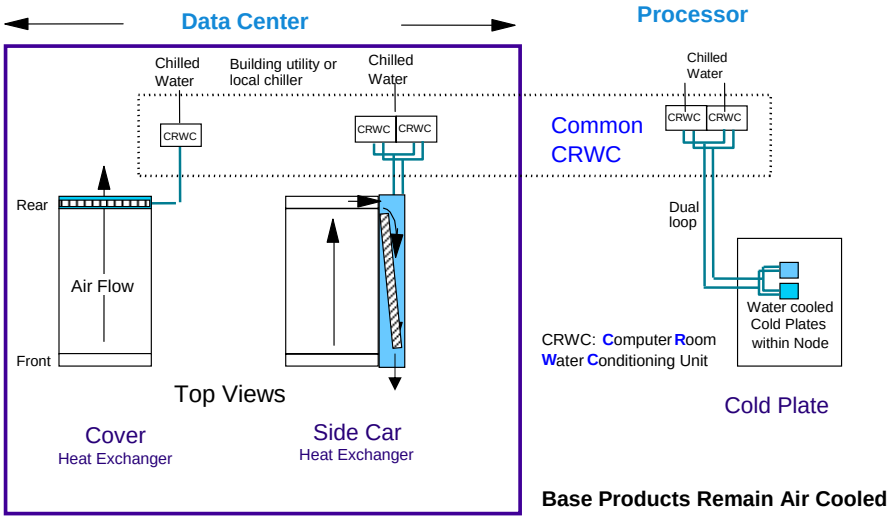
- Future – it will be about compute power/kw

The Co-gen Concept–deployed at Syracuse U.



- Offset building thermal loads by recycling the waste heat energy available at site
- Reduces costs and increases reliability
- Increases efficiency and reduces fossil fuel combustion

Rack / Data Center Water Cooling



Base Products Remain Air Cooled

Why Water Cooling(vs Air Cooling)?

✓ **Water Advantages**
- Order of magnitude lower unit thermal resistance
- 3500X heat carrying capacity
- Total control of the flow
- Lower temperature
  - o Lower power(less leakage)
  - o Better reliability

Greater Performance

Greater Efficiency

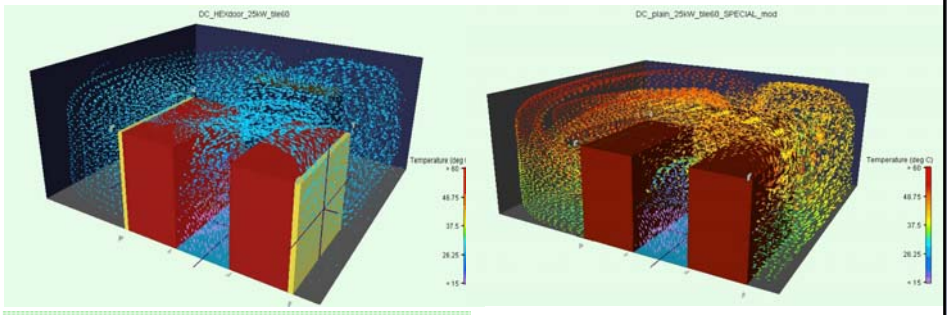
Better Quality

✓ **Water Disadvantages**
- Added complexity
- Added cost(but not necessarily cost/performance)
- The perception of water cooling

In Rack Water Cooled Rear Door Heat Exchanger

In-Rack Cooling Heat Exchanger – Rear Door

Water cooling is 3500x more energy efficient than air



Capabilities

- Designed to remove heat generated from the back of your computer systems before it enters the room
- Patented "rear heat exchanger" can reduce heat at the source
- Utilizes chilled water to dissipate heat generated by computer systems while requiring no additional fans or electricity!

Benefits

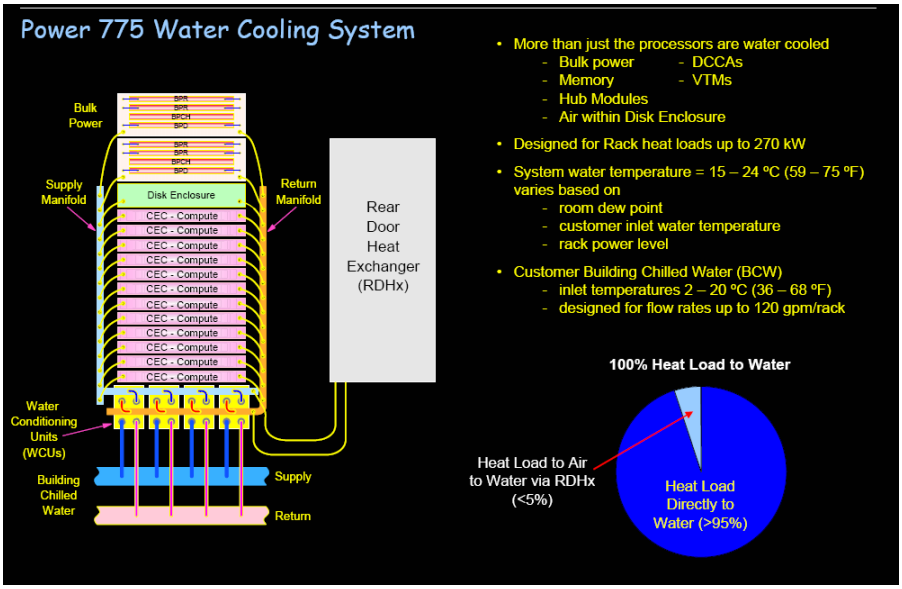
- Increase server density without increasing cooling requirements.
- Effective solution for a data center wishing to deal with computer room "hot spots," or is at the limit of its cooling capacity, but still has useable floor space to add racks of systems.

U. of Illinois/NCSA Green Data Center

Blue Waters will be an unsurpassed national asset, delivering sustained performance of 1 petaflop (that's 1 quadrillion calculations every second) for many science and engineering applications that researchers use every day—not just benchmarks. Blue Waters is being developed and built with a $208 million grant from the National Science Foundation and will be a resource for scientists and engineers across the country.

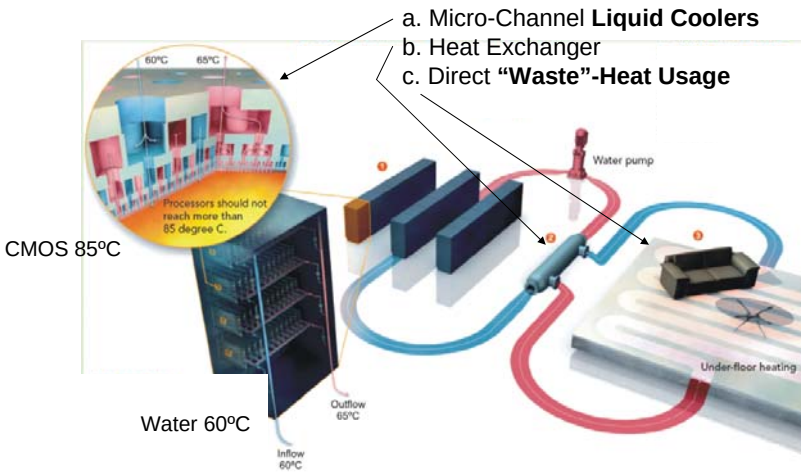
Blue Waters will deploy IBM's POWER7 architecture, which is based on advanced multicore processor technology.

New Power 775 Water Cooled System



Zero-Emission Data Center - IBM Zurich

Hot-water cooled BladeCenter



Big Issues

- ✓ IT demand continues to grow rapidly
- ✓ IT energy efficiency continues to dramatically improve
- ✓ Low IT equipment utilization
- ✓ Low infrastructure efficiency improvements remain
- ✓ Need to take a holistic view of IT & supporting infrastructure
- ✓ Energy cost will continue to be #1 business concern
- ✓ TCO needs to be included in any new technology
- ✓ Embedded carbon/energy vs usage carbon/energy

Q & A

Thank you for your attention