# The “Greening” of the Data Center

**Steven Carlini**
**August 6, 2007**

A new Imperative for business and society

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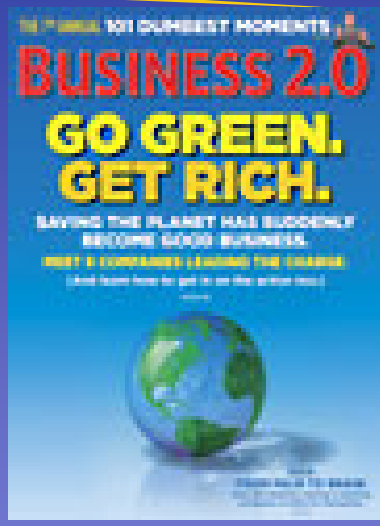
# Why all the Fuss?

- More than 50% of the power going into a typical data center goes to the power and cooling systems and NOT to the IT loads.
- A 1MW data center takes 177,000,000 KW-Hr of electricity worth about $17,000,000 over its 10 year life (at $0.10 per KW-Hr)
- Each data center MW is equivalent to about 4300 cars of carbon
- The typical 1MW data center is continuously wasting about 1000 cars worth of carbon due to poor design
  - DOE estimates that we can save about 4,000,000 cars worth of carbon by 2015 by better data center design, (equivalent to the electrical energy consumed by 1.8 million American homes).

# Organizing….

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# Standards Coming

- United States Environmental Protection Agency
  - Public Law 109-431 “Report to Congress on Server and Data Center Energy Efficiency”
- United States Department of Energy
  - Energy Efficiency and Renewable Energy
  - Industrial (Process Engineering and Manufacturing) Technology Program
- Standards Bodies and Associations
  - ASHRAE (American Society of Heating, Refrigeration and Air Conditioning)
  - DMTF (Distributed Management Task Force)
  - LEEDS (Leadership in Energy and Design)
  - ANSI (American National Standards Institute)
  - US GBC (Green Building Council)

# Why Now? The Impending Power Crisis

Insatiable demand for useful computing

- **"50% of the Data Centers in 2008 will have insufficient power and cooling capacity to meet demand"**
  - **Michael Bell, Gartner**

Power costs are rising

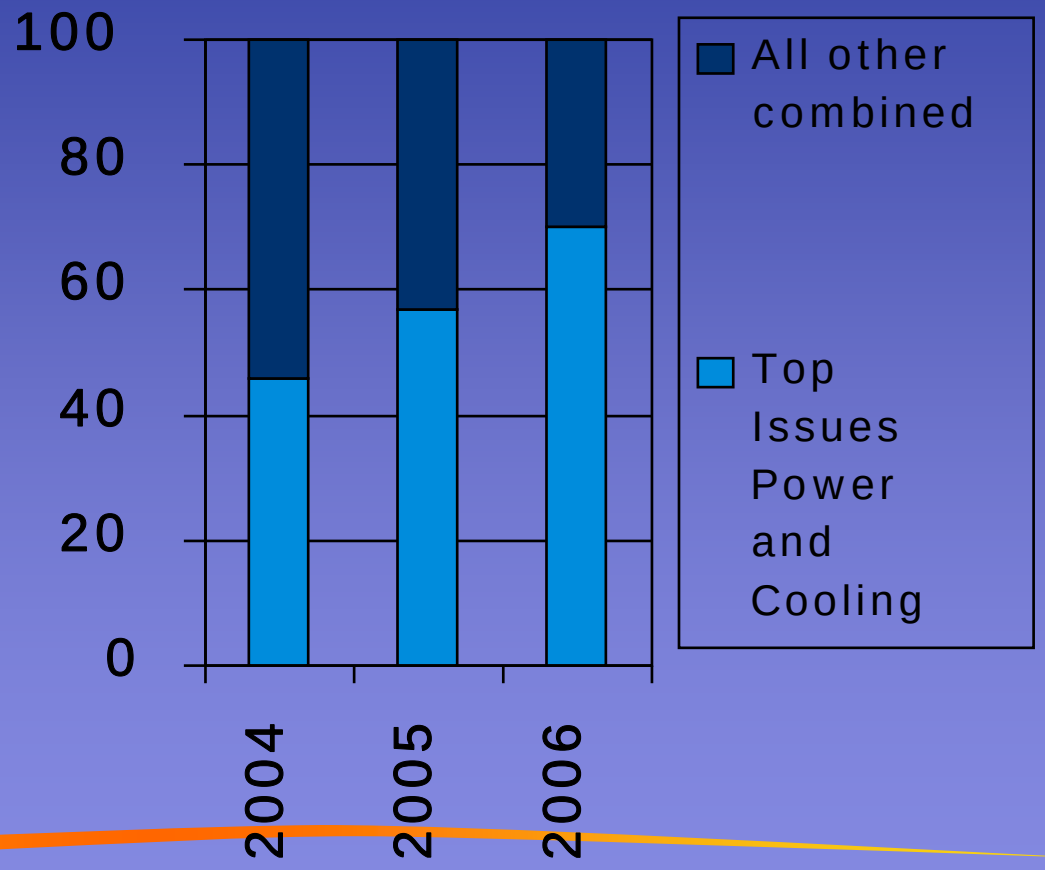
- **Gartner estimates that through 2009, energy costs will emerge as the second highest operating cost (behind labor) in 70% of the Data Center facilities worldwide**
  - **Michael Bell, Gartner**

Data center efficiency becoming a bottom line focus

- **"… power will be the number one issue for most large company IT executives to address in the next 2-4 years. Ignoring this issue will NOT be an option. Power consideration must be incorporated into data center planning. " (Robert Francis Group)**

# Gartner CIOs: Undeniable Trends

- 70% report power and/or cooling issues are now their single largest problem facing their data centers
- Projections are 48% of data center budget spent on energy, up from 8%



# Consumption of a 1MW Data Center

- 177,000,000 kW-Hr of Electricity
- 60,000,000 Gallons of Water
- 145,000 lbs of Copper
- 21,000 lbs of Lead
- 33,000 lbs of Plastic
- 73,000 lbs of Aluminum
- 12,000 lbs of Solder
- 377,000 lbs of Steel

*10 year life; Tier 4; Power, Cooling, Racks, and IT equipment; does not include building; includes 2 IT refreshes

# Controlling Electrical Costs

Social Responsibility

Reducing data center overheating

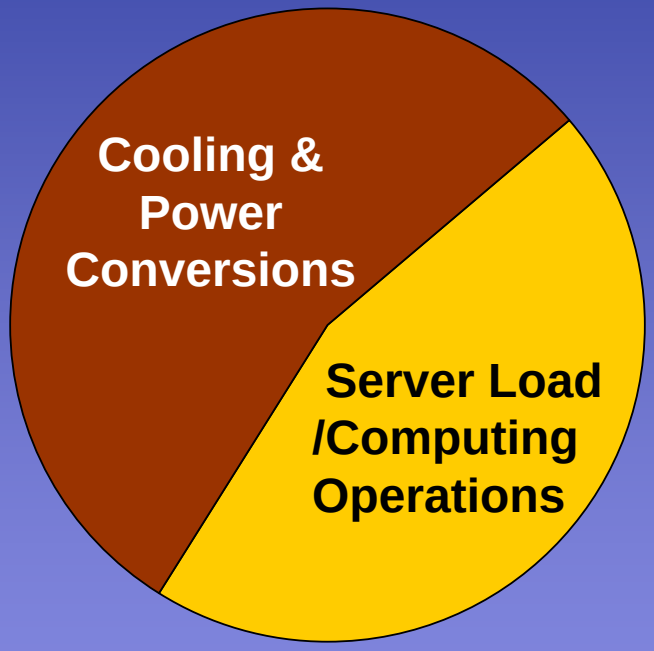
Regulations

Releasing power and cooling capacity

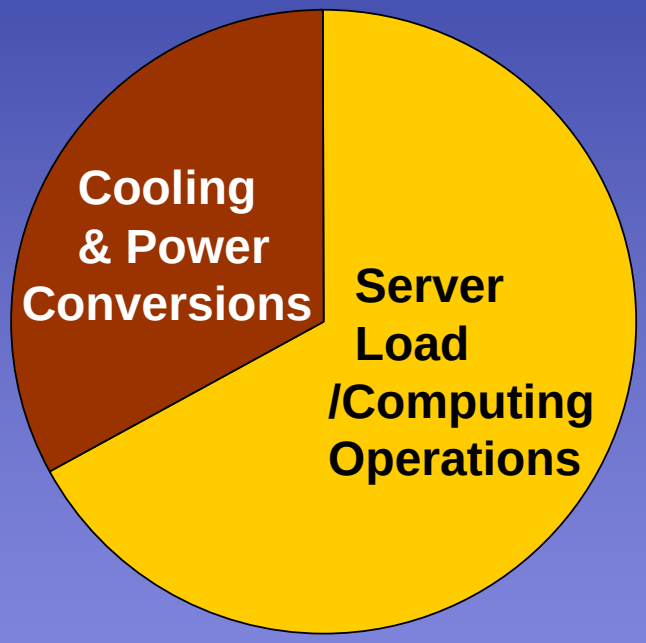
Incentives

Fulfilling carbon commitments

# Data Center Cooling and Power Conversion Performance Varies




**Typical Practice**




**Better Practice**

# Elements needed to improve energy efficiency

- Practical solutions for improving data center efficiency
- Establishing within organizations the process, capability, and goals for improving electrical efficiency

# What is roadmap to efficiency improvement?

- Setting numeric targets for data center performance?
  - No benchmark data available
  - Poor understanding of current conditions
  - Depends on IT model (HPC, Mixed, Heavy storage, etc)
  - Depends on redundancy
  - Depends on geographic location
- Focus on process capability?
  - Independent of metrics
  - Makes investments more efficient

***The smartest thing to do is get yourself on a track for improvement, rather than set arbitrary goals***

# Energy Efficiency Management Capability Scorecard

| | | |
|---|---|---|
| 1 | *Performed* | Random improvement activities, driven by individuals, results uncertain. |
| 2 | *Managed* | Efficiency data measured and reported. As-built systems are accurately documented. Specific unique projects or actions taken to improve. Projects are planned, tracked, and reported to management |
| 3 | *Defined* | Benchmarks exist. Efficiency management is part of the standard operating practice across the entire organization |
| 4 | *Quantitatively Managed* | The results of improvement activities are accurately measured and are reliably predicted in advance using models. |
| 5 | *Optimizing* | An efficiency improvement plan is enacted, spanning other business processes outside the data center |

Adapted from the Capability Maturity Model (CMMI), SEI, sei.cmu.edu/cmmi/

# Get your attack plan

*Focus on getting organized for systematic, long term improvement, instead of randomly picking short term projects*

# Practical solutions for improving data center energy efficiency

Examples of methods and technologies to improve the efficiency of facility infrastructure

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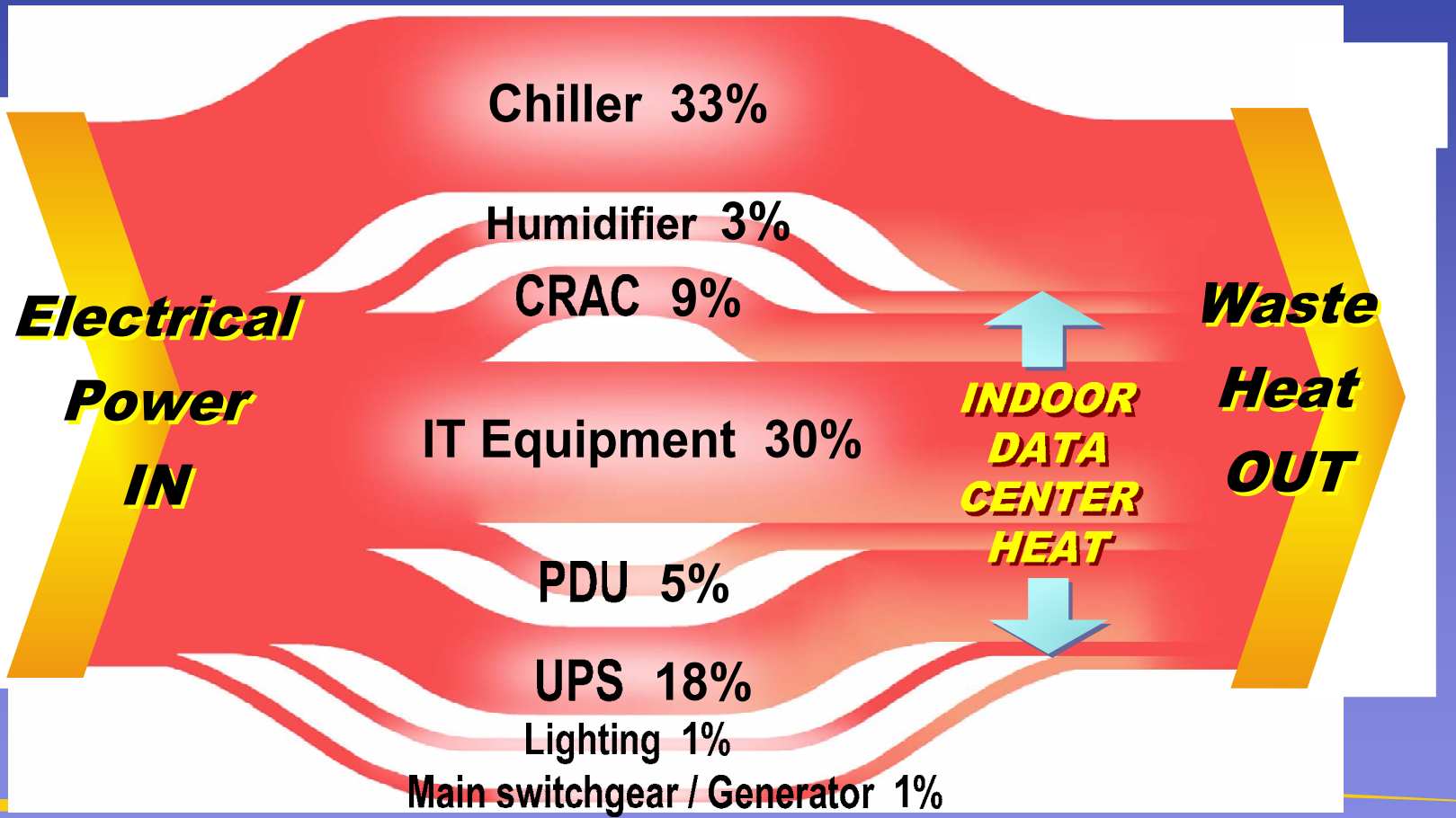
# Opportunities for improvement

| | Power, Cooling, and Lighting | IT |
|---|---|---|
| **Fraction of total power used** | 40-70% | 30-60% |
| **Technologies** | Modularity, Hi-E design, In-row cooling, Hi-E UPS, Hi-E Lighting | Virtualization, turning off servers, blades |
| **Practical magnitude of total energy consumption reduction** | 20-30% | 20-80% |
| **Side effects** | Reduces heat generation. Allows more IT in same building power envelope | Reduces needs for power and cooling equipment. Allows more IT applications in same building power envelope |

# Power Flow in a Typical Data Center

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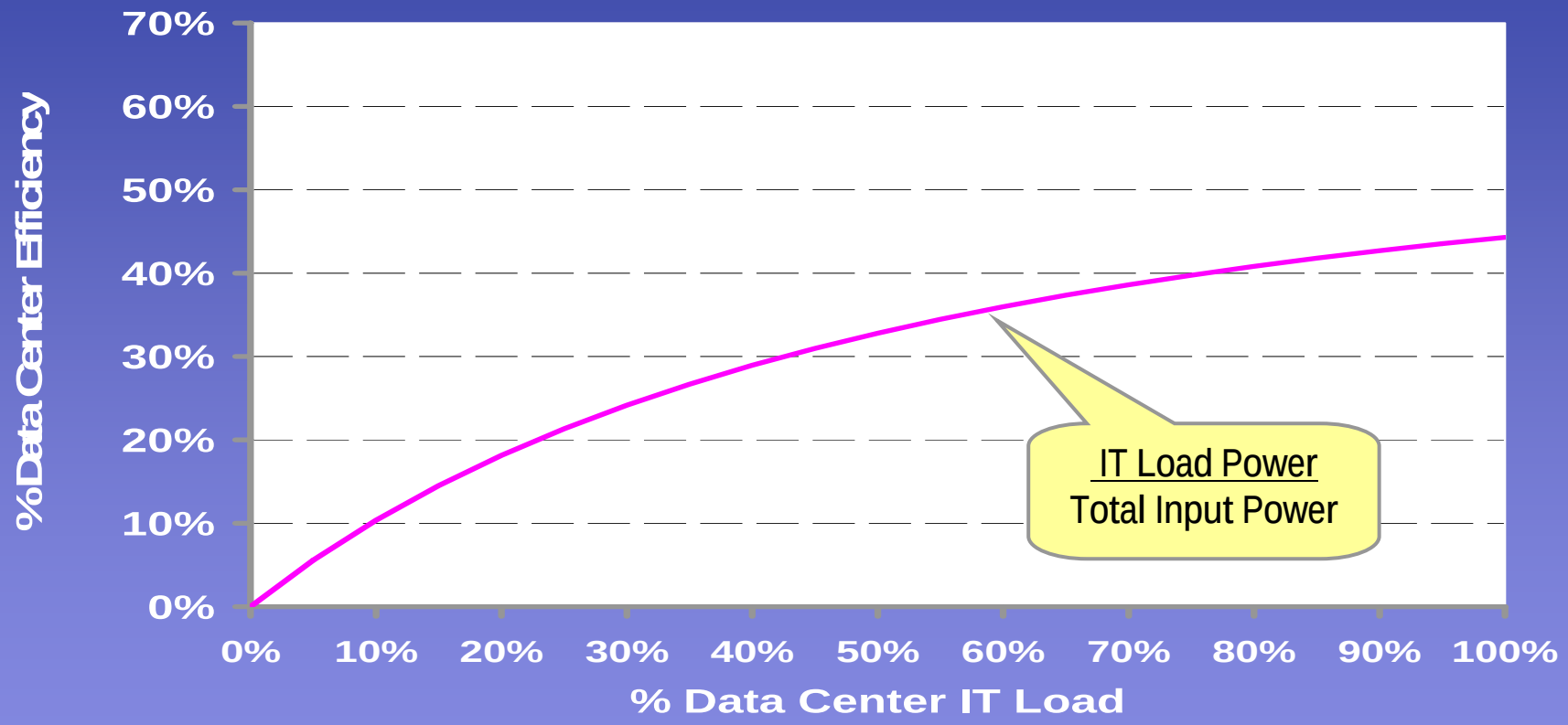
# 5 Elements of an improved High Efficiency data center power and cooling architecture

- Ultra High efficiency UPS
- High Voltage AC power distribution
- In-row cooling
- Scalable power and cooling equipment
- Power and Cooling Capacity Planning and Management software

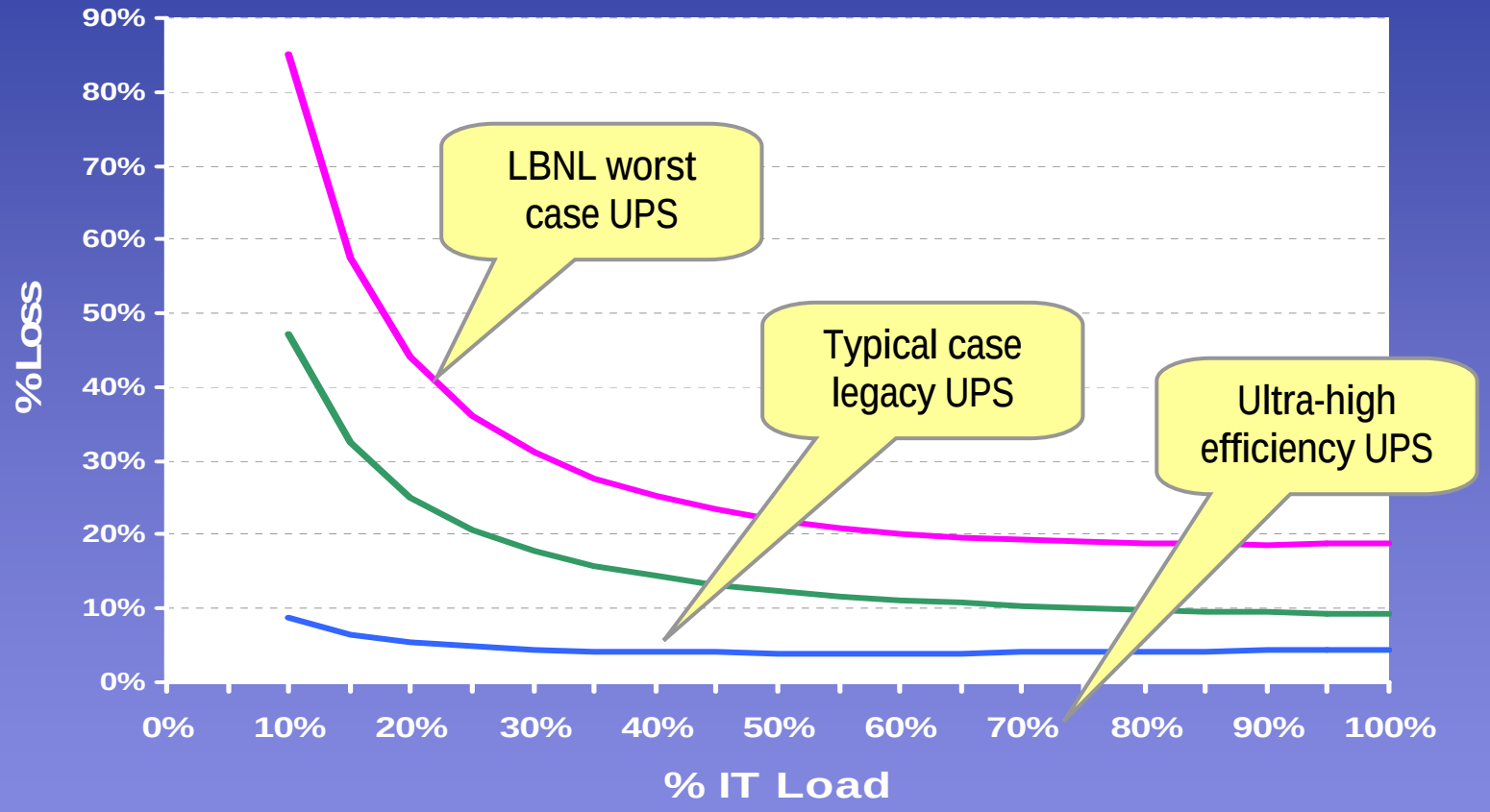
# Efficiency curve for a typical data center



# Element #1: Ultra high efficiency UPS

- New double-conversion inverter technology
  - MOSFET/IGBT hybrid inverter
  - 3-state inverter
  - Symmetrical low proximity-effect inductors
- Inverter design reduces proportional losses by over 50% compared with past designs
- Low loss control, drive, and snubber circuits reduce no-load loss by 70% compared with past designs
- Efficiency further improved by using scalable UPS power modules
- By-product is that UPS is also virtually silent

# UPS loss comparison



# Element #2: High Voltage AC Power Distribution

- Distributes voltage to loads at 400/230 instead of conventional US 208/120
- Eliminates the need for PDU transformers and associated losses
- Reduces copper requirements
- Overall efficiency pickup of over 5% for a high availability data center
- By-product is that 4,000lbs of copper and 30,000lbs of PDUs are saved per MW, reducing floor loading and saving space
- Details in APC White Paper #128

# High Voltage AC Power Distribution NAM

480V to 208/120V
(Isolation Transformer)

150 kW

29”

36”

3000 lbs

12”

36”

500 lbs

480V to 415/240V
(Auto Transformer)

277 kW

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# High V DC vs High V AC architecture

| | High V DC benefit vs Traditional Design | High V DC benefit vs New High Efficiency Architecture |
|---|---|---|
| UPS/Rectifier | 5% | None |
| Power Distribution | 5% | None |
| IT Load | 2.5% | 2.5% |
| **Total Advantage** | **12.5%** | **2.5%** |

***The hypothetical efficiency benefits of DC can be obtained today using available AC technologies***

# High Voltage DC challenges

- Loads that cannot accept DC input require a parallel AC distribution system (storage, routers, tape, legacy IT)
- Difficulty of clearing, duration, and bus drop-outs of faults
- Cost of distribution equipment (breakers, connectors, panels)
- Size of distribution equipment (breakers, connectors, panels)
- Coordination and current limiting of protective switchgear
- Regulatory requirements (spacings, access areas, protective gear, non-uniform standards)
- Lack of trained design and installation professionals

***If efficiency is the goal, there may be other investments that give a higher return than Hi V DC, particularly related to cooling***

# Element #3: In-row Cooling

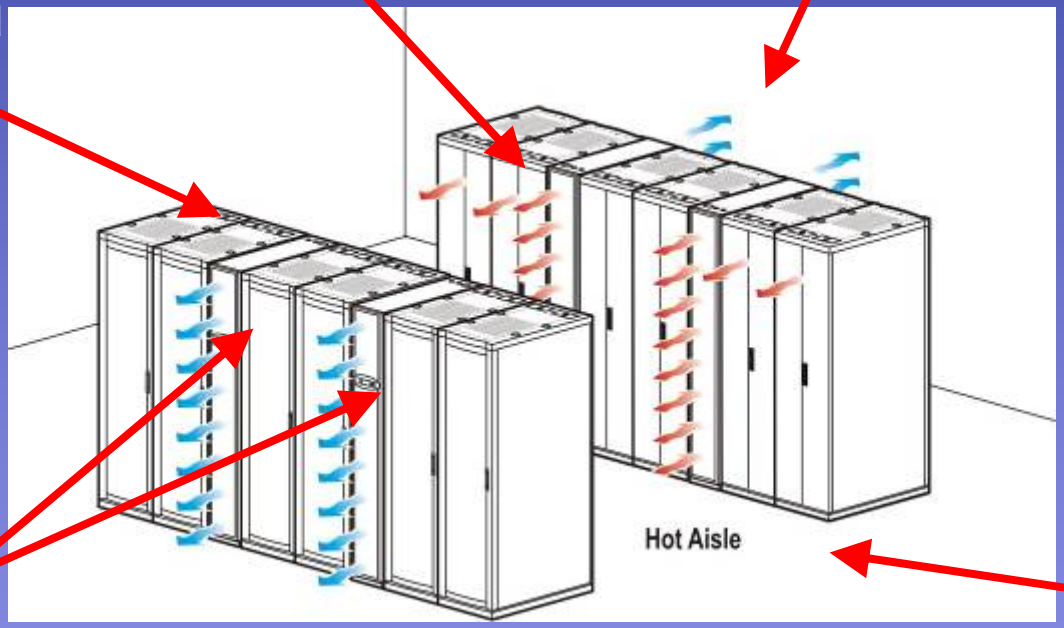
- Cooling systems are placed within IT rows instead of at the room level
- Inherently higher power density capability than room designs
- Fan power is reduced by 50%
- Needless dehumidification / rehumidification is eliminated (saving millions of gallons of water per year per MW)
- Need for high-bay areas and raised floors are reduced or eliminated (particularly for small installations)
- Cooling capacity can “follow” IT loads that move due to Virtualization / server power management

# Basic in-row design

Hot-aisle air enters from rear preventing mixing

Cold air is supplied to the cold aisle

Heat captured and rejected to chilled water

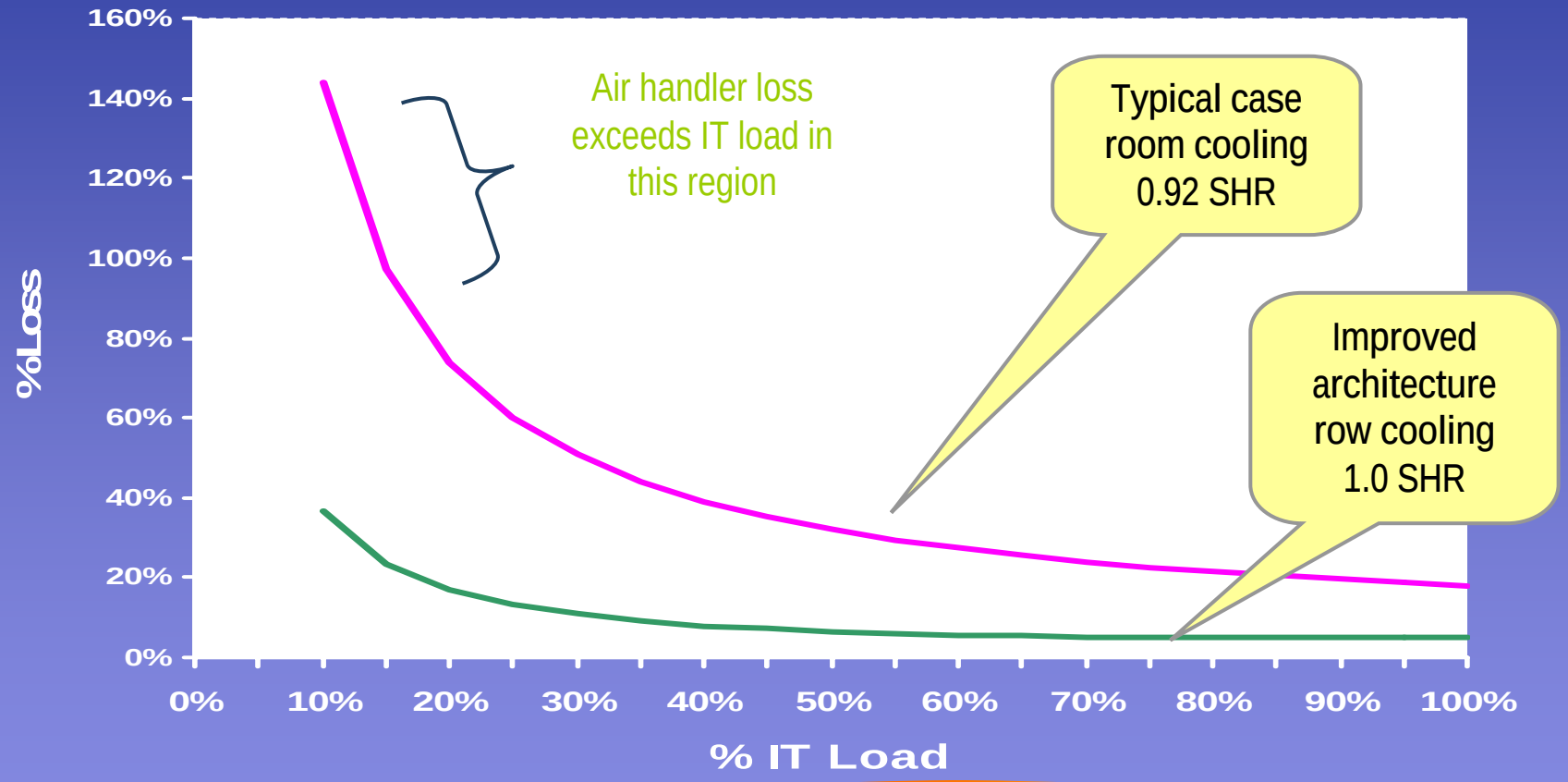



InRow air conditioner

Can operate on hard floor or raised floor

*InfraStruXure® InRow RC*

# Air handler + Humidifier loss comparison



# Recent customer research

*63% of users surveyed expect to be using "in rack" or "in row" cooling in the next two years*

Data Center Polling Results: Power and Cooling
Gartner Research
Feb 2, 2007

# Element #4: Scalable power and cooling

- Over half the power and cooling losses in a data center are *fixed* and do not vary with the IT load (the efficiency degrades as the load declines)
- Oversizing is therefore a primary contributor to inefficiency
- Virtualization and server power management will make this problem worse, as power and cooling are sized to peak IT loads that are not typical
- New power and cooling devices that can scale in capacity and/or be managed to a zero power state, reducing the fixed losses

# 500kW of High-Efficiency Scalable Power Protection

475kW

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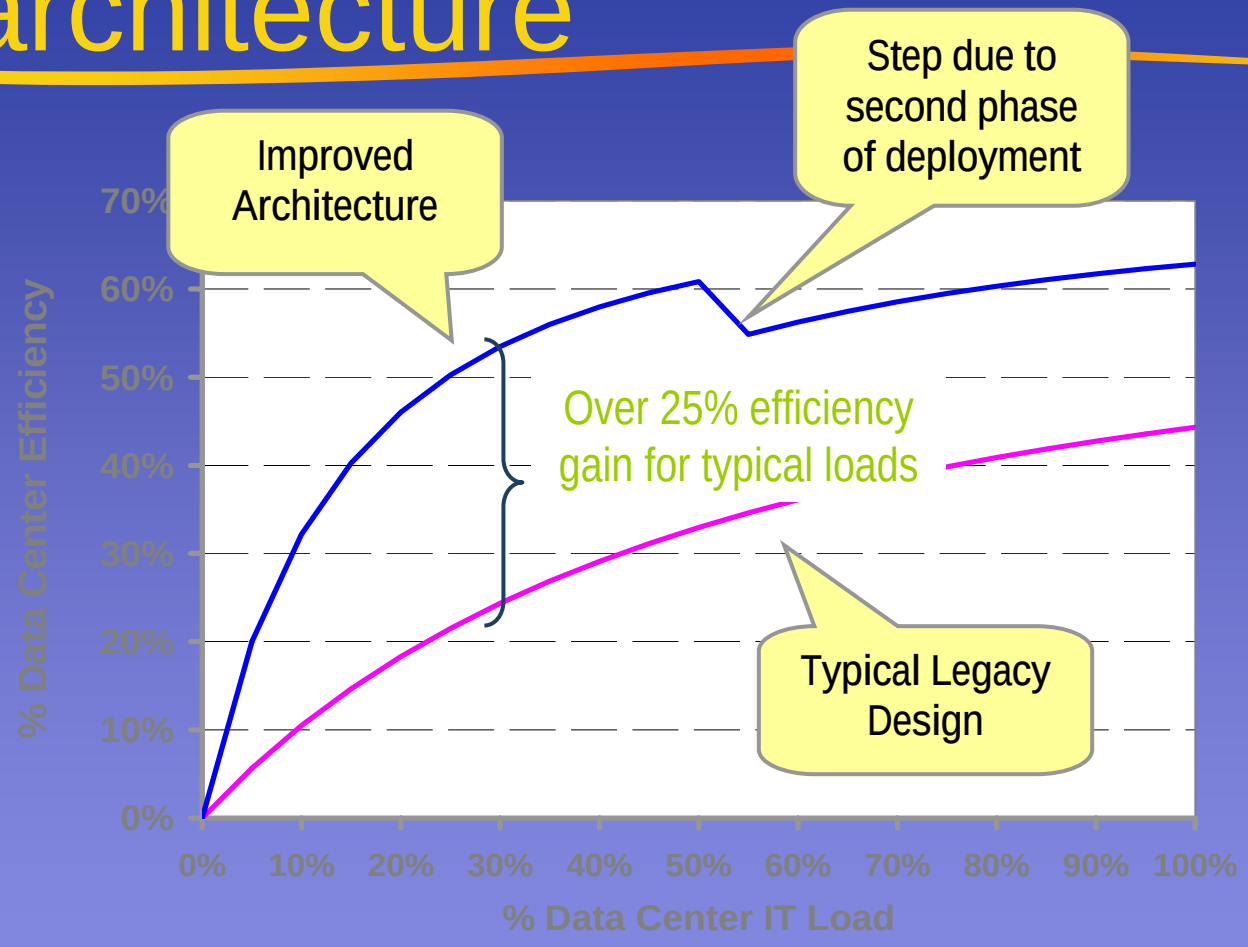
# Element #5: Power and cooling capacity planning and management software

- Efficiency is improved when more IT load can be supplied by the same power and cooling equipment
- Stranded or unusable power and cooling capacity is often created within data centers by unmanaged change
- Virtualization and server power management will make this problem worse, as power and cooling are sized to peak IT loads that are not typical
- New power and cooling devices that can scale in capacity and/or be managed to a zero power state, reducing the fixed losses

# The five elements combine to deliver major improvement of data center efficiency

- Efficiencies can be determined for real designs when the topology and the device efficiency curves are known
- APC operates a data center efficiency model using the principles described in APC White Paper #113
- Actual device data is used in the calculations
- Calculations were performed for a 1 MW, 2N Power, Dual Power Path, N+1 CRAH, Single Path Cooling Tower system
- Scenarios compared are conventional design, the New ISX high efficiency architecture, and the new architecture plus phasing of the power and CRAH units in a single step when the IT load hits 50% of target capacity.

# Efficiency gain of improved architecture



# Performance of the new high efficiency architecture

- Efficiency is IT power / Total input power
- Efficiency gains of 20% are achieved over a broad range of power
- At 30% IT load, the efficiency increases from 25% to 53%, which is a pickup of 110% in computed efficiency, corresponding to a 28% reduction in losses
- Each of the 5 elements contributes significantly to the calculated gains

# What is the future?

- This coming generation of UPS are so efficient that further gains will have little effect on data center efficiency
- The ability of power and cooling systems to handle IT loads with both high density AND dynamically varying power will be mandatory
- Real-time measurement of data center efficiency will be available soon
- Standardized designs with *system-level efficiency specifications* will become available
- Reduction in consumption of raw materials will become as important as efficiency improvements

***Technology and design tools to dramatically increase data center power and cooling efficiency are available now***

# Data Center Efficiency Model

## Data Center Description

Data Center Load Rating

1,000 kW

Electricity Rate

$0.12/kWhr

IT Load

50%

Heat Rejection System Type

CRAC, Cooling Tower

Air Distribution Type

Room Oriented, Hot Aisle Cold Aisle

| | |
|---|---|
| Single Path Power | Dual Path Power |
| No Standby Generator | Standby Generator |
| Single Path CRAC/CRAH | Dual Path CRAC/CRAH |
| Non-Red. CRAC/CRAH | N+1 CRAC/CRAH |
| Single Path Heat Rejection | Dual Path Heat Rejection |
| No Economizer | Water Side Economizer |
| Typical UPS | High Efficiency UPS |
| Typical PDUs | High Voltage Distribution |
| Typical Lighting | Energy Efficient Lighting |
| Random Tile Placement | Optimal Tile Placement |
| No Blanking Panels | Blanking Panels |
| Independent CRAC/CRAH | Coordinated CRAC/CRAH |
| Typical Raised Floor | Deep Raised Floor |

## Site Infrastructure Power Efficiency

**30.4%**

SIPE Change from Baseline of 30.4%

Annual Electricity Cost

$1,714,868

Electricity Cost Savings

$0

from Baseline of

$1,714,868

Bar

APC | MGE

Critical Power and Cooling Services

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# For More Information

Would you like to know more about this session?

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# Further Information

- APC White Paper #113 “Electrical Efficiency Modeling for Data Centers”
- APC White Paper #114 “Implementing Energy Efficient Data Centers”
- APC White Paper #126 “An Improved Architecture for High Efficiency, High Density Data Centers”
- APC White Paper #154 “Electrical Efficiency Measurement for Data Centers”
- APC White Paper #150 “Power and Cooling Capacity Management for Data Centers”