The Efficient Datacenter

Improving Datacenter Efficiency Through Intel Technologies and High Ambient Temperature Operation

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Agenda

- Datacenters Today
- The High Ambient Temperature (HTA) Datacenter
- HTA Examples
- What Else Do You Need to Build a More Efficient Datacenter?
  - Intel solutions to achieve high temp operation
- Near-Future Technologies
- Summary

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Today

- Datacenters are estimated to consume 1.5% of total world power and rising rapidly
  - Equivalent to 50 power stations
- Generating 210 M metric tons of CO_2
  - Equivalent to 41 M cars
- Using ~300 B Litres of Water
  - Equivalent to nearly 250,000 Olympic sized swimming pools
- Many datacenters still use CFC's in their chillers
- $27 B annual server energy cost

*See slide in backup for substantiation

2014

2X

*See slide in backup for substantiation

Photo: Samuel Mann

Why are datacenters cooled to 18-21°C?

- Because they always have been
- Non-homogeneous environment
- SLA's and Warranties
- Legacy Systems Engineered to 21^{0}C
- Over-engineered hot spot avoidance

Photo: Drew Avery

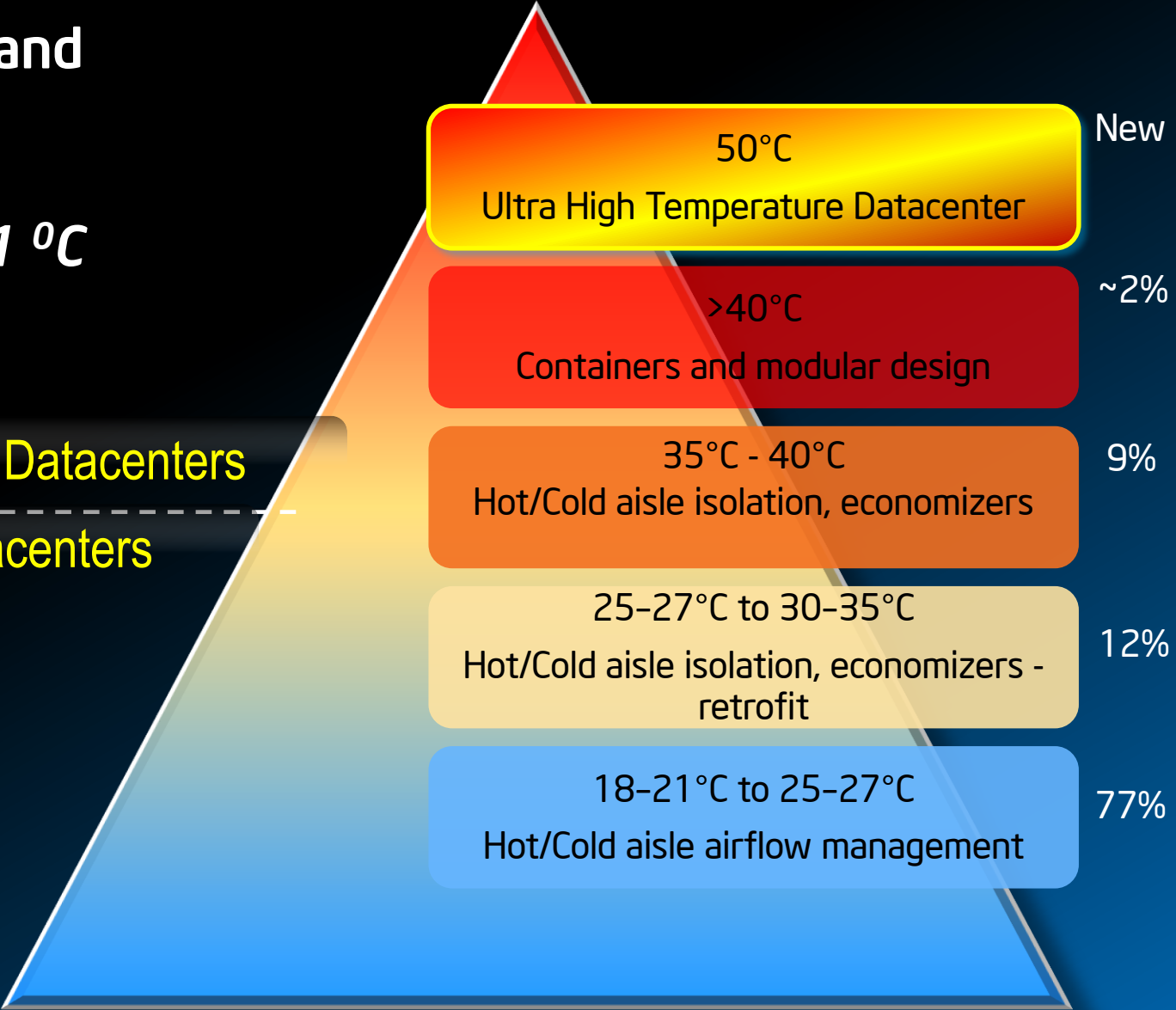# THE HIGH AMBIENT TEMPERATURE (HTA) DATACENTER

High Temperature Operation

- Datacenter operating at a raised operating temperature designed to decrease cooling costs and increase power efficiency

- *4% operational savings from cooling for every 1 ^0C increase in operating temperature* [2]

New / Modular Datacenters

Existing Datacenters

Class and Upper Temperature Limit Recommended by ASHRAE				
Recommended	Allowable			
All 'A' Classes	A1	A2	A3	A4
27°C (81°F)	32 °C (90°F)	35 °C (95°F)	40 °C (104°F)	45 °C (113°F)

50°C
Ultra High Temperature Datacenter — New

\>40°C
Containers and modular design — ~2%

35°C - 40°C
Hot/Cold aisle isolation, economizers — 9%

25–27°C to 30–35°C
Hot/Cold aisle isolation, economizers - retrofit — 12%

18–21°C to 25–27°C
Hot/Cold aisle airflow management — 77%

*Intel Internal Estimate with conceptual feedback from IDC and Gartner
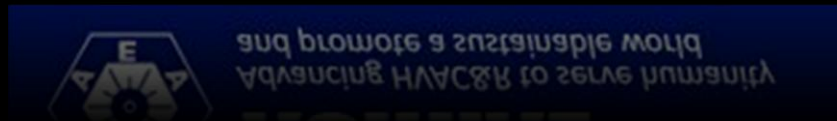
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Leading adoption of datacenter efficiency standards

- Code of Conduct on Data Centres Energy Efficiency
- Aligned with ASHRAE working towards DC operating at 40°C by 2012

- 2011 Thermal Guidelines for Data Processing Environments
- Expanded the HTA recommended operating range

- Green Grid Metrics: Describing Datacenter Power Efficiency
- Aligned with ASHRAE
- Working towards enabling additional classes DC operating at 40°C by 2015
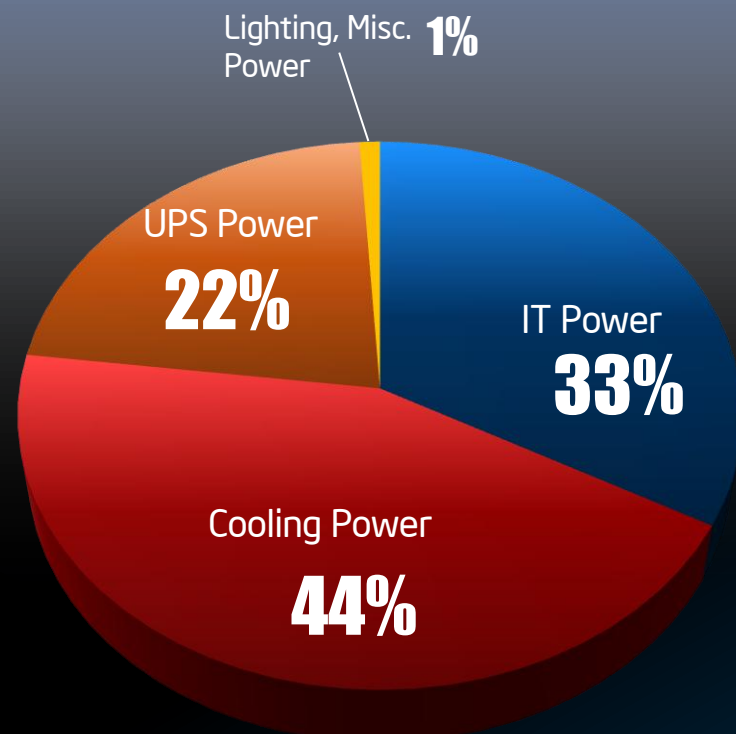
CITR (China)

IDA (Singapore)

The Effect of Increased PUE

$$PUE = \frac{Total\ Datacenter\ Power}{Actual\ IT\ Power}$$

PUE 3
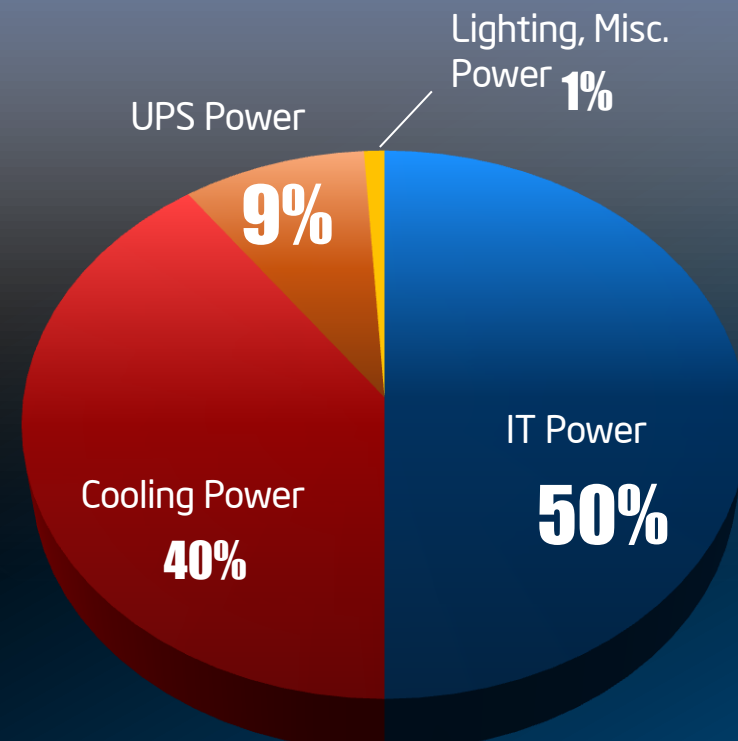
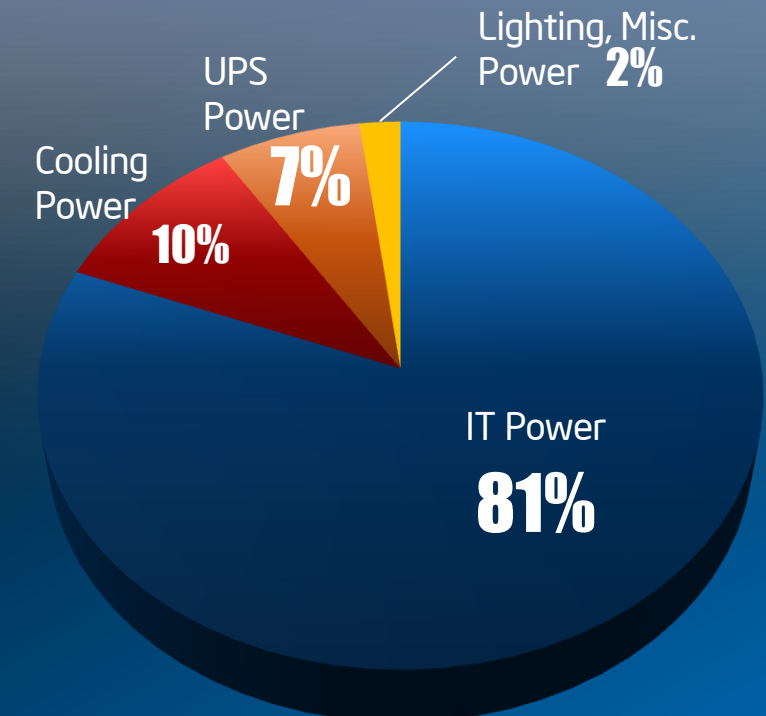- Un-optimized datacenter
- Typical design used in emerging economies

Lighting, Misc. Power **1%**

UPS Power **22%**

IT Power **33%**

Cooling Power **44%**

PUE 2

- Retrofitted datacenter
- Hot and cold air aisle separation
- Blanking panels

Lighting, Misc. Power **1%**

UPS Power **9%**
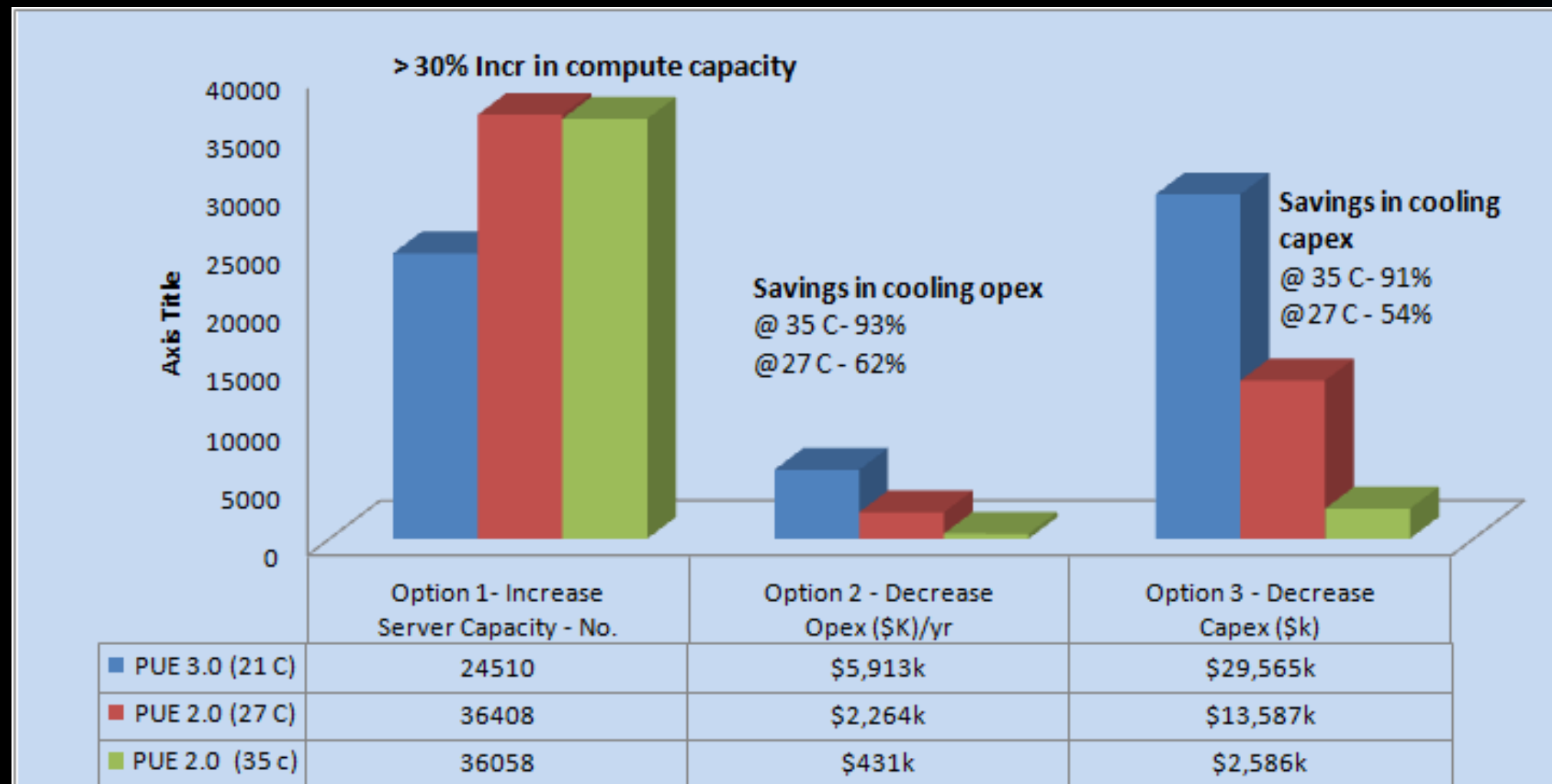
IT Power **50%**

Cooling Power **40%**

PUE 1.25

- Hot aisle containment
- Higher efficiency & reduced UPS
- Higher temperature operation
- Economizers instead of chillers
- Intel Node Manager

Lighting, Misc. Power **2%**

UPS Power **7%**

Cooling Power **10%**

IT Power **81%**

*Intel Internal Data based on whitepaper on High Temperature Server Datacenter POC, June 2010

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Impact of Free Air & HTA – Intel Analysis

- Option 1 – Increase compute capacity by 35% , add ~12K servers with current power
- Option 2 – Decrease cooling operational costs up to 85% or ~$6 M/yr based on exiting computing
- Option 3 – For new datacenters, decrease capital costs up to 39% or ~$50 M in power infrastructure investment

> 30% Incr in compute capacity

Savings in cooling opex
@ 35 C- 93%
@27 C - 62%

Savings in cooling capex
@ 35 C- 91%
@27 C - 54%

	Option 1- Increase Server Capacity - No.	Option 2 - Decrease Opex ($K)/yr	Option 3 - Decrease Capex ($k)
■ PUE 3.0 (21 C)	24510	$5,913k	$29,565k
■ PUE 2.0 (27 C)	36408	$2,264k	$13,587k
■ PUE 2.0 (35 c)	36058	$431k	$2,586k

- Note - Intel Internal estimate, based on HTA optimized system using 60W Romley CPU vs 95W Romley CPU and assume 70% SpecPower workload and 24/7/365 ambient temperature in New Mexico. And for a 15 MW data center, 10 KW rack and 50 – 100% utilization. Assumed 10c/kw as cost of power

HTA EXAMPLES

Industry Examples...

Leading Internet Portal datacenters operating at higher operating temperature – > 80 ^{0}F [4]

Facebook Saves ~229K/yr in energy bill by retooling its Cooling..to 81 ^{0}F [1]

Google: Raise Your Data Center Temperature..80 ^{0}F [2]

Yahoo Computing Coo... Come? [3]
.. The data center operates with no chillers, and will require water for only a handful of days each year
– Estimated PUE - 1.1

- **Sun** – 4% savings in chiller energy costs for 1 ^{0}C in upward change [2]
- **Microsoft** saved 250K/yr energy costs by raising 2-4 ^{0}C [2]
- **Intel IT** raised to 92 ^{0}F, for 10 mo (Proof of concept) [2]

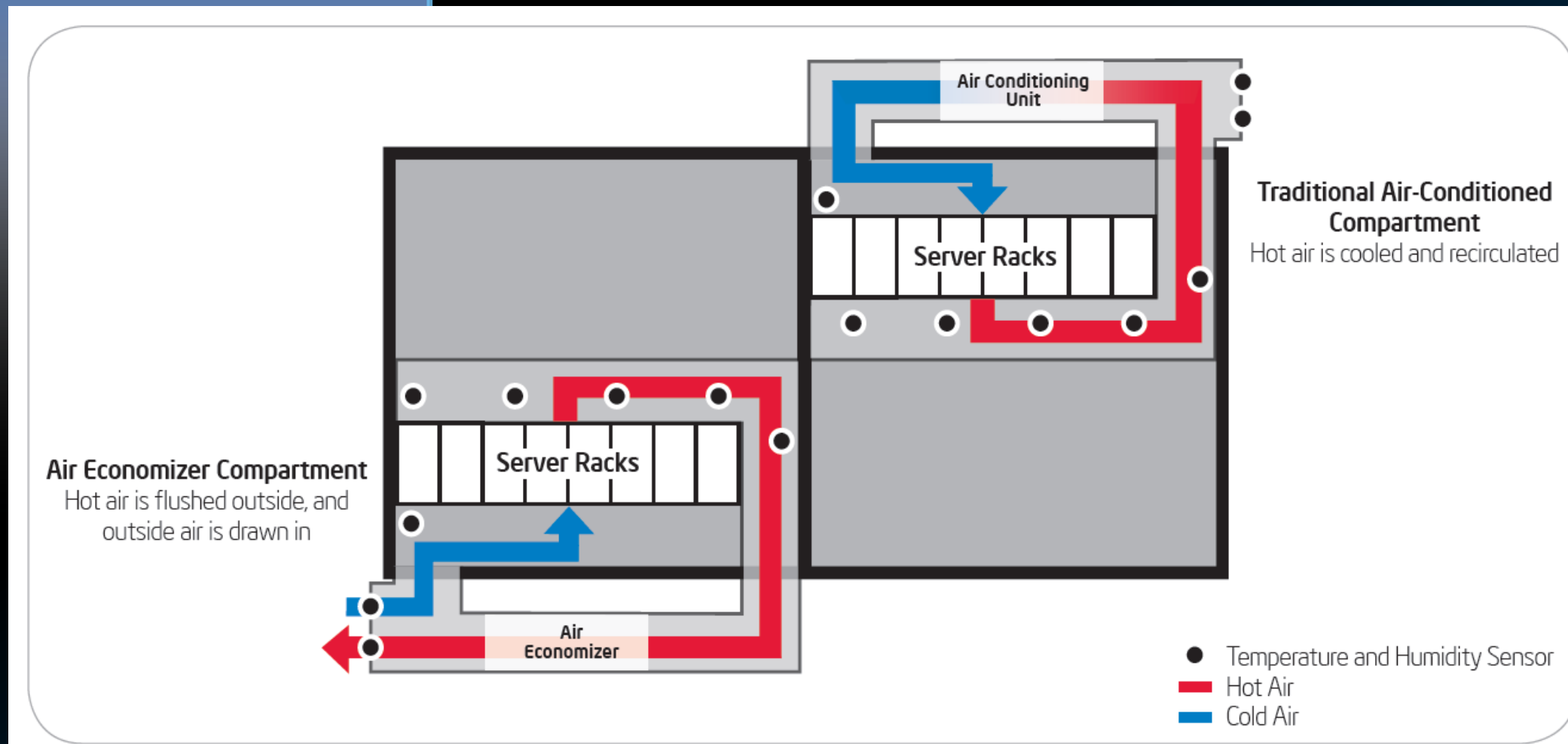1) http://www.datacenterknowledge.com/archives/2010/10/14/facebook-saves-big-by-retooling-its-cooling/
2) http://www.datacenterknowledge.com/archives/2008/10/14/google-raise-your-data-center-temperature/
3) http://www.datacenterknowledge.com/archives/2010/04/26/yahoo-computing-coop-the-shape-of-things-to-come/
4) Intel internal estimate and based on market data analysis

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Intel IT New Mexico Proof of Concept

- 900 production servers
- 100% air exchange at up to 92°F/33°C
  - No humidity control
  - Minimal air filtration
- 67% estimated power savings
- Estimated annual savings of $2.87 million in a 10MW DC

Traditional Air-Conditioned Compartment
Hot air is cooled and recirculated

Air Conditioning Unit

Server Racks

Air Economizer Compartment
Hot air is flushed outside, and outside air is drawn in

Server Racks

Air Economizer
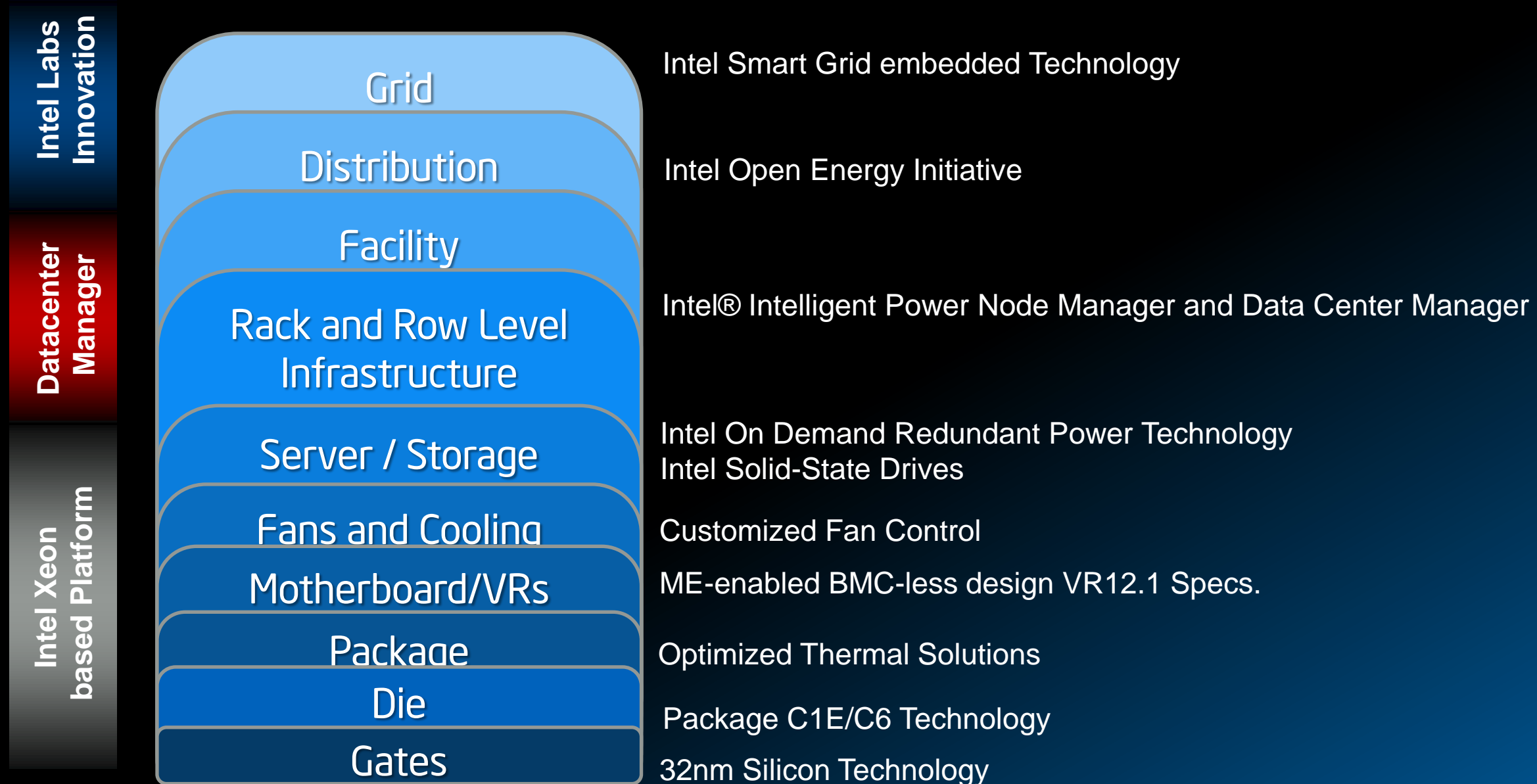
● Temperature and Humidity Sensor
▬ Hot Air
▬ Cold Air

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WHAT ELSE DO YOU NEED TO BUILD A MORE EFFICIENT DATACENTER?

✓ Choose from a choice of Intel products for high temp operation
✓ Build HTA capable systems based on Intel Platform design guide
✓ Achieve optimal Data center temperature set point using Intel Data center prescriptive guide

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Intel – Gate to Grid

Achieve efficiency by increasing users, compute and performance

Layer	Technology
Grid	Intel Smart Grid embedded Technology
Distribution	Intel Open Energy Initiative
Facility	
Rack and Row Level Infrastructure	Intel® Intelligent Power Node Manager and Data Center Manager
Server / Storage	Intel On Demand Redundant Power Technology Intel Solid-State Drives
Fans and Cooling	Customized Fan Control
Motherboard/VRs	ME-enabled BMC-less design VR12.1 Specs.
Package	Optimized Thermal Solutions
Die	Package C1E/C6 Technology
Gates	32nm Silicon Technology

Intel Labs Innovation

Datacenter Manager

Intel Xeon based Platform

Significant platform features that accelerates data center efficiency

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Platform Innovation – Choice of Intel products

*Range of Best In Class products for high temperature operation*

Optimal Performance & Power Efficiency

- Up to 25% more performance/watt with Intel Xeon 5600 series based processors over prior generation processor[1]

Platform of Choice For High Ambient Operation

- Broad offering – 130W, 95W, 80W , 60 W, 45W & 20W
- Well defined, robust reliability verification
- Processor and memory power/thermal management
- Chipset, with Intel Node Manager for power capping
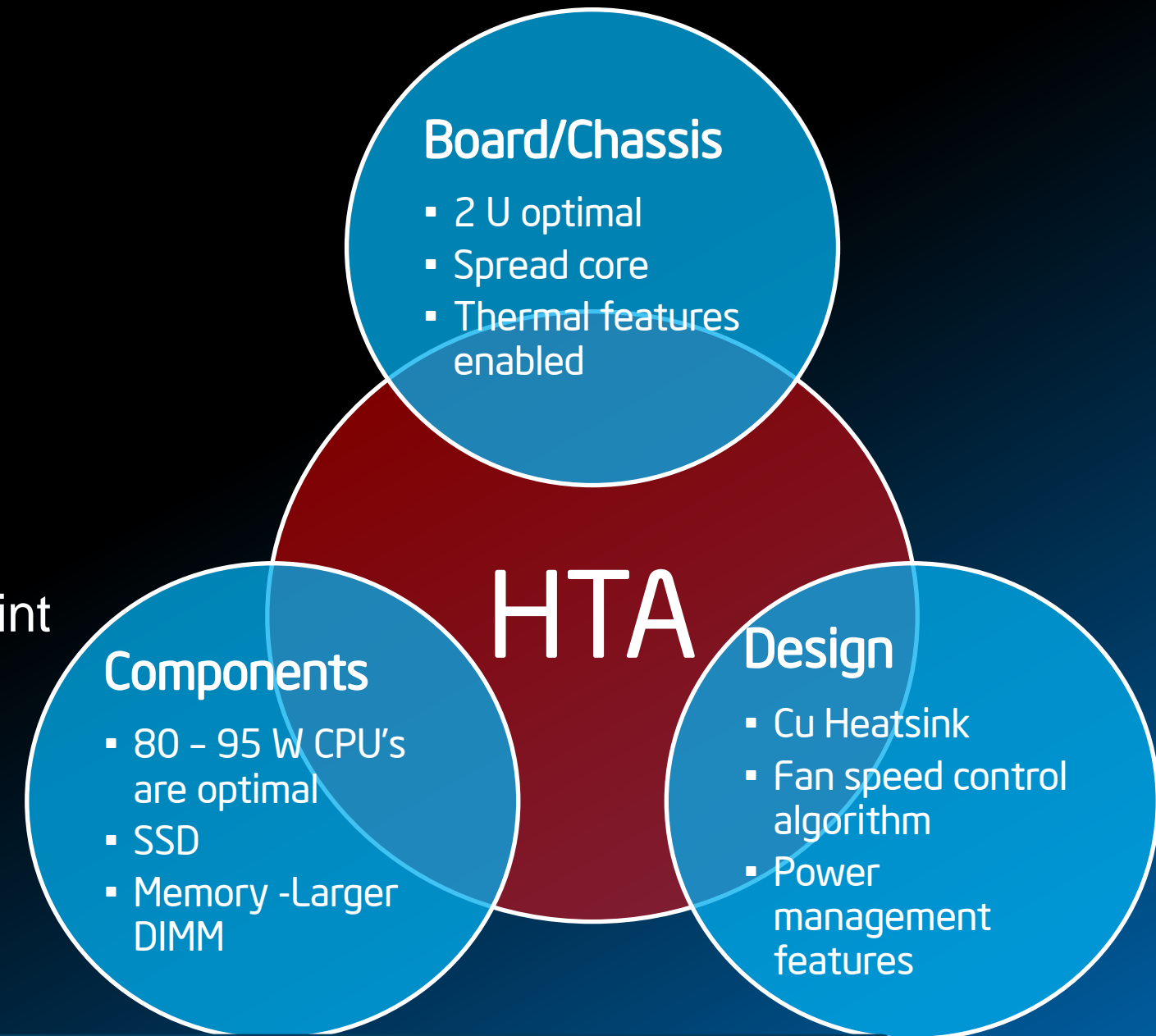- SSDs for higher temperature

Intel Node Manager

Intel Datacenter Manager

Intel products support ASHRAE temperature limits of up to 45⁰C
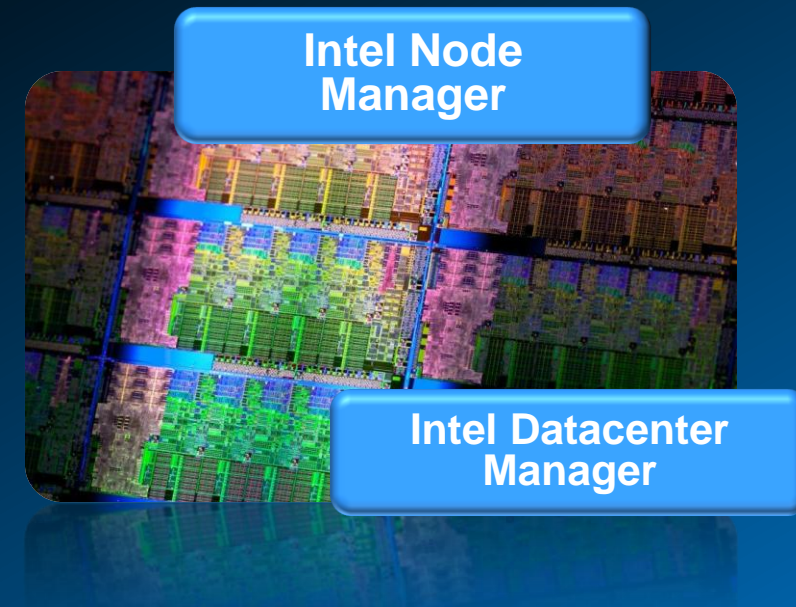
System Design With Intel Platform Guide

- Platform Design Guide – Power reduction Recommendations
  - Spread core layout
  - Processors with 80 – 95 W
  - Efficient copper heat sink

- Datacenter Optimization Guide
  - Predictive modeling to identify optimal set point
  - Recommend - 30 – 35 C for existing datacenters and > 35 C for modular/new datacenters
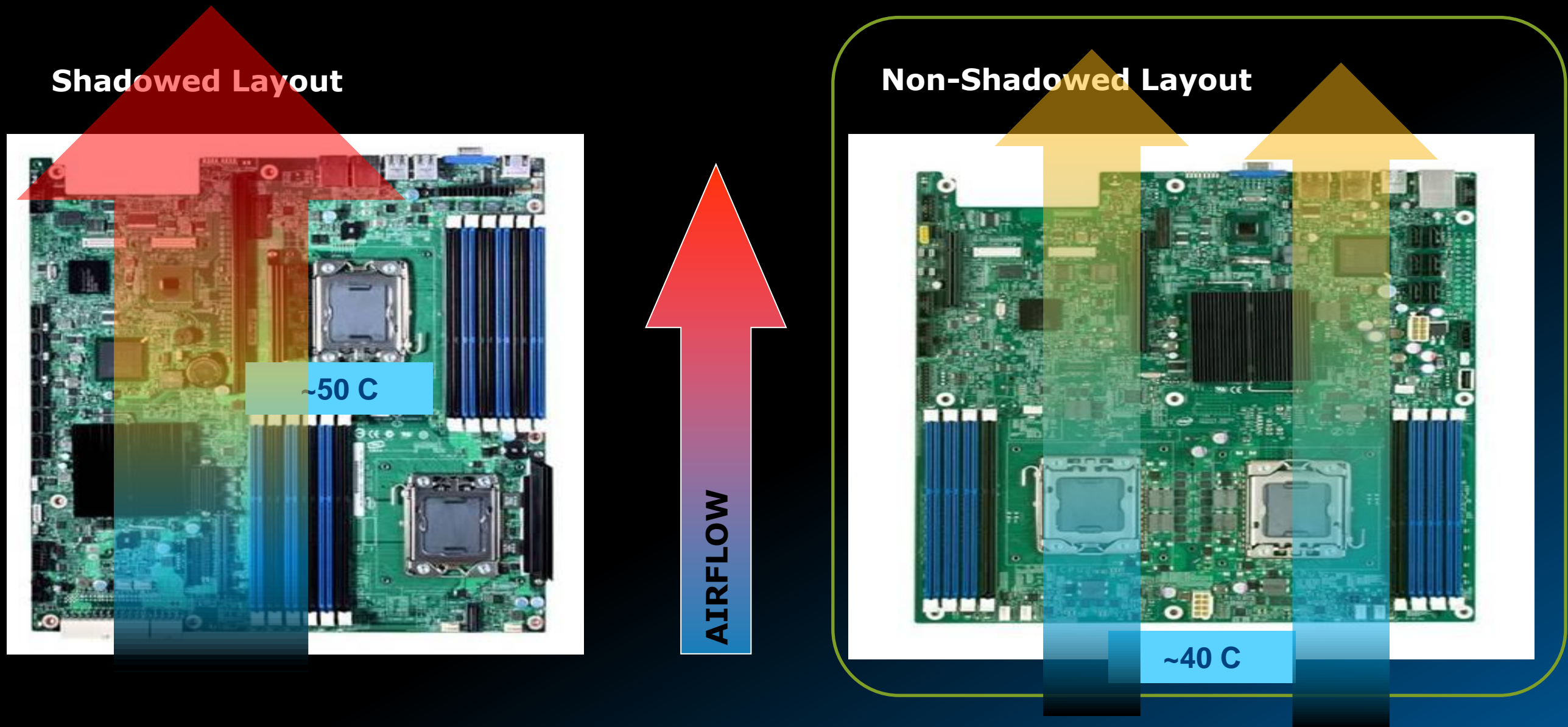
Board/Chassis
- 2 U optimal
- Spread core
- Thermal features enabled

HTA

Components
- 80 – 95 W CPU's are optimal
- SSD
- Memory -Larger DIMM

Design
- Cu Heatsink
- Fan speed control algorithm
- Power management features

Systems optimized on Intel Platform could result in >10% in power savings

- Note - Intel Internal estimate, based on HTA optimized system using 60W Romley CPU vs 95W Romley CPU and assume 70% SpecPower workload and 24/7/365 ambient temperature in New Mexico

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Example Optimizing Server Layout – Thermal Shadowing

Shadowed Layout

~50 C

AIRFLOW

Non-Shadowed Layout

~40 C

Non-Shadowed layout enables lower fan power and wider temperature Range

• Note - Intel Internal estimate, based on HTA optimized system using 60W Romley CPU vs 95W Romley CPU and assume 70% SpecPower workload and 24/7/365 ambient temperature in New Mexico

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Intel ® Intelligent Power Node Manager and Intel ® Data Center Manager

1

2

3

Limit aggregated **ROW** power draw

- Report system level energy use
- Limit individual **SERVER** power consumption

- Limit total **RACK** power draw
- More productivity per rack

Aggregated, policy-based power management for the data center

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Intel ® Node Manager & Data Center Manager Results

Power and Thermal Monitoring	Replace IP power strips and serial concentrators, saving ~$400 per rack
Increased Rack Density	Up to 40% more servers and performance per rack
Workload Power Optimization	Up to 30% power optimization without performance impact
Business Continuity	Continued compute availability through power or thermal event

YAHOO!

kt

Baidu 百度

中国电信 CHINA TELECOM

ORACLE

BMW

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Solution Choices For Directed Power Management

Node Manager Servers

ASUS

DAWNING 曙光

DELL
Data Center Solutions

DELL
PowerEdge C

FOXCONN

GIGABYTE

inspur 浪潮

lenovo

MiTAC

PowerLeader 宝德

MSI

Quanta Computer

sgi

SUPERMICRO

TYAN

IeSC

zt Systems

wistron 緯創資通

DCM Enabled Consoles

ASG Software Solutions

PowerLeader 宝德

POWER ASSURE

SiteView

SUPERMICRO

sgi

ZZNode

joulex ENTERPRISE GREEN IT

CFS CONSULTING'S SOLUTION LABS

Growing Choices For Solutions Using Intel® Directed Power Management

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NEAR FUTURE TECHNOLOGIES

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Power & Thermal Aware Scheduling (PTAS)

Platform with Power, Thermal & Workload intelligence to enable dynamic management of resources

Integrate IT and Facilities Management

- Builds upon Intel Node Manager and Data Center Manager
- Lower operational costs ~20% [1]
- Recovery up to 50% of unused cooling capacity[1]
- Reduce DC monitoring instrumentation costs
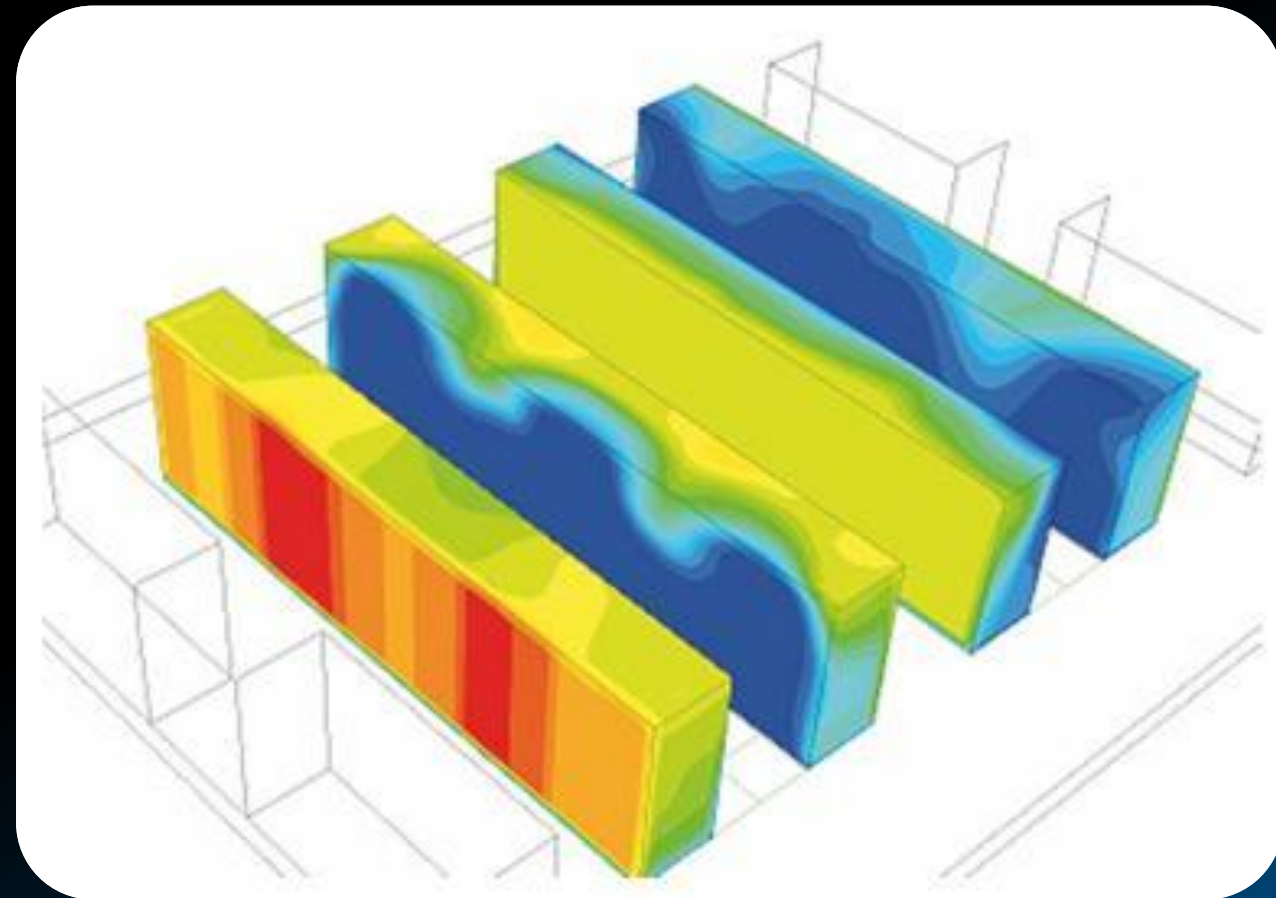
Maximize operational efficiency thru dynamic resource management

1 Source: http://www.computerworld.com/s/article/9195918/Data_center_infrastructure_management_tools_eliminate_inefficiencies?source=rss_datacenter

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Intel® Battery Backup Solution

Build servers or racks with battery backup unit enhanced thru integration with Intel Power Node Manager

Reduce Data Center Capital Costs

- Reduce UPS related capital expenditure costs ~ 5X[1]
- Recover UPS related power efficiency loss – ~30-40%[2]
- Easy deployment and time to market solution

Integrate with Intel Node Manager to increase battery life, reduce battery size ..or for graceful shutdown

[1]Intel internal estimate
[2] APC whitepaper # 108

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What if -

The world used HTA for a 5°C Datacenter Rise?

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World HTA 5°C Datacenter Rise

- $2.16 B in annual power savings

- 8% Decrease in world-wide datacenter power consumption

- 24.3 B kWh saved
  - More than month of total energy consumption by Spain, South Africa, Australia or Taiwan.

- 1.7 M metric tons of CO_2

Call to Action

✓ Increasing data center efficiency could significantly reduce spending and have a positive impact on the environment

✓ Leverage Intel Solutions to achieve data center efficiency

  ❖ <u>Range of Intel products -</u> Intel Xeon, Intel power node manager, Intel Datacenter manager....

  ❖ <u>System design guide</u> - Optimize for spread core layout, copper heatsink and usage/workload

  ❖ <u>Data center prescriptive guide –</u> Achieve optimal set point ..up to 35 $^{\circ}$C of higher for data centers

Further Reading

- Intel IT Datacenter Strategy http://www.intel.com/itcenter/tool/DCstrategy/index.htm
- Reducing Data Center Cost with an Air Economizer http://www.intel.com/content/www/us/en/data-center-efficiency/data-center-efficiency-xeon-reducing-data-center-cost-with-air-economizer-brief.html
- Intel IT Data Center Solutions: Strategies to Improve Efficiency http://www.intel.com/content/www/us/en/data-center-efficiency/intel-it-data-center-efficiency-strategies-to-improve-efficiency-paper.html
- IT@Intel: Data Center Solutions http://www.intel.com/content/www/us/en/it-management/intel-it/intel-it-data-center-solutions.html
- The Effect of Data Center Temperature on Energy Efficiency http://www.eco-info.org/IMG/pdf/Michael_K_Patterson_-_The_effect_of_Data_Center_Temperature_on_Energy_Efficiency.pdf

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BACKUP

Environmental Benefits Claims Details

- Today
  - Datacenters consume 1.5% of total world power and rising rapidly
    - Equivalent to 50 power stations
  - Generating 210 Million Metric tons of CO2
    - Equivalent to 41 million cars
  - Using ~300 Billion Litres of Water
    - Equivalent to nearly 250,000 Olympic sized swimming pools
  - $27 billion annual server energy cost
- $2.16 Billion in immediate annual power savings
- 5C Worldwide Raise – What would it mean?
  - 8% Decrease in WW datacenter power consumption
  - 24.3 Billion KWh saved
    - More than month of total energy consumption by Spain, South Africa, Australia or Taiwan.
  - Equivalent to 1.7 Million metric tons of CO2
    - Same as carbon sequestered by 43 Million tree seedlings grown for 10 years

- Total World Power Generation:
  - http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=29 20,260,838,000,000 kWh Total World Electricity Generation /1.5= 303,912,570,000 kWh is total power used by Datacenters
    - CO2 Calculator http://www.epa.gov/cleanenergy/energy-resources/calculator.html
    - 1.5% of World Power – Koomey 2011 http://www.analyticspress.com/datacenters.html
- Water:
  - http://www.hp.com/hpinfo/newsroom/press_kits/2011/HPFortCollins/Water_Efficiency_Paper.pdf
  - 1KWh of DC uses ~2L of water = 303,912,570,000 x 2 = 607,825,140,000 L of water used by WW DC's.
  - 1 Olympic Swimming pool uses 2,5M Litres.
- $27 billion annual server energy cost (IDC 2009)
- Data will grow 44 times to 35ZB between 2009 – 2020...IDC 2011
- X2 Claim
  - Assumption based on linear extrapolation of data in EPA Report to Congress on Server and Data Center Energy Efficiency; August 2, 2007
  - Total power consumed by datacenters could be ..2-3% of all electricity generated by 2014
  - Source: Extrapolation of EPA Report to Congress on Server and Data Center Energy Efficiency; August 2, 2007
  http://www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf
  - 2011 - ~110 B Kwh/year= 1% decrease = 1.1 Bkwh/hr
- 5C Worldwide Raise
  - http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=29 20,260,838,000,000 kWh Total World Electricity Generation in 2008 /1.5= 303,912,570,000 kWh is total power used by Datacenters
    - 1.5% of World Power – Koomey 2011 http://www.analyticspress.com/datacenters.html
  - **20% decrease** in cooling energy costs. (4% savings for 1 ^{0}c increase in temp)·
  http://www.datacenterknowledge.com/archives/2008/10/14/google-raise-your-data-center-temperature/
  - Carbon Calculator: http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results
  - Electricity Generation by country from CIA World Factbook
  http://en.wikipedia.org/wiki/List_of_countries_by_electricity_production

Data center Savings Claims Backup – Intel Analysis

15 MW Facility,   Temperature range of 21 - 35 C
10 KW rack, Utilization - 50% and 100%

	Option 1- Server Capacity	Option 2 - Opex ($K)/yr	Option 3 - Capex ($k)
PUE 3.0 (21 C)	543	$216,000k	$7,096k
PUE 2.0 (27 C)	856	$178,000k	$4,078k
PUE 2.0 (35 c)	848	$149,500k	$3,093k
PUE 2.0 (35 C) Advanced	845	$153,500k	$1,030k

Increase capacity (Server count)	% change	Cooling Opex Savings ($K)/yr	% Savings	Cooling Capex ($k)	% Savings
12507	37%	3018.0	43%	23461.0	20%
12198	36%	4003.0	56%	49192.5	42%
12045	36%	6065.4	85%	45738.8	39%

- Data center populated with 50000 1U servers
- Assumed $0.10/kWh power cost and no chiller power required at 35C ambient, will vary based on location
- 60W Romley CPU used in all servers, except for "wrong" CPU design choice which used 95W Romley CPU
- Assume 70% SpecPower workload and 24/7/365 ambient temperature

Key system layout considerations – layout, heatsink, fan speed

Node Manager Claims Back Up

Extreme Efficiency: Power Management

- Rack density statement based on Baidu proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-4212.
- Power Optimization claims based on BMW proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-4040

Increasing Rack Density Proof Points

- Baidu statement based on proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-4212.
- Oracle statement based on proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-3977

Increasing Rack Density Proof Points

- Baidu statement based on proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-4212.
- BMW statement based on proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-4040
- Oracle statement based on proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-3977
- Intel IT and FSI results based on Intel internal testing of Intel Xeon Processor 5500 series whiteboxes in an NDA environment.

Increasing Rack Density Model Baidu Proof Point

Baidu statement based on proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-4212.

Power Optimization Model Oracle Proof Point

Oracle statement based on proof of concept results documented in Intel legally approved whitepaper posted at http://communities.intel.com/docs/DOC-3977

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