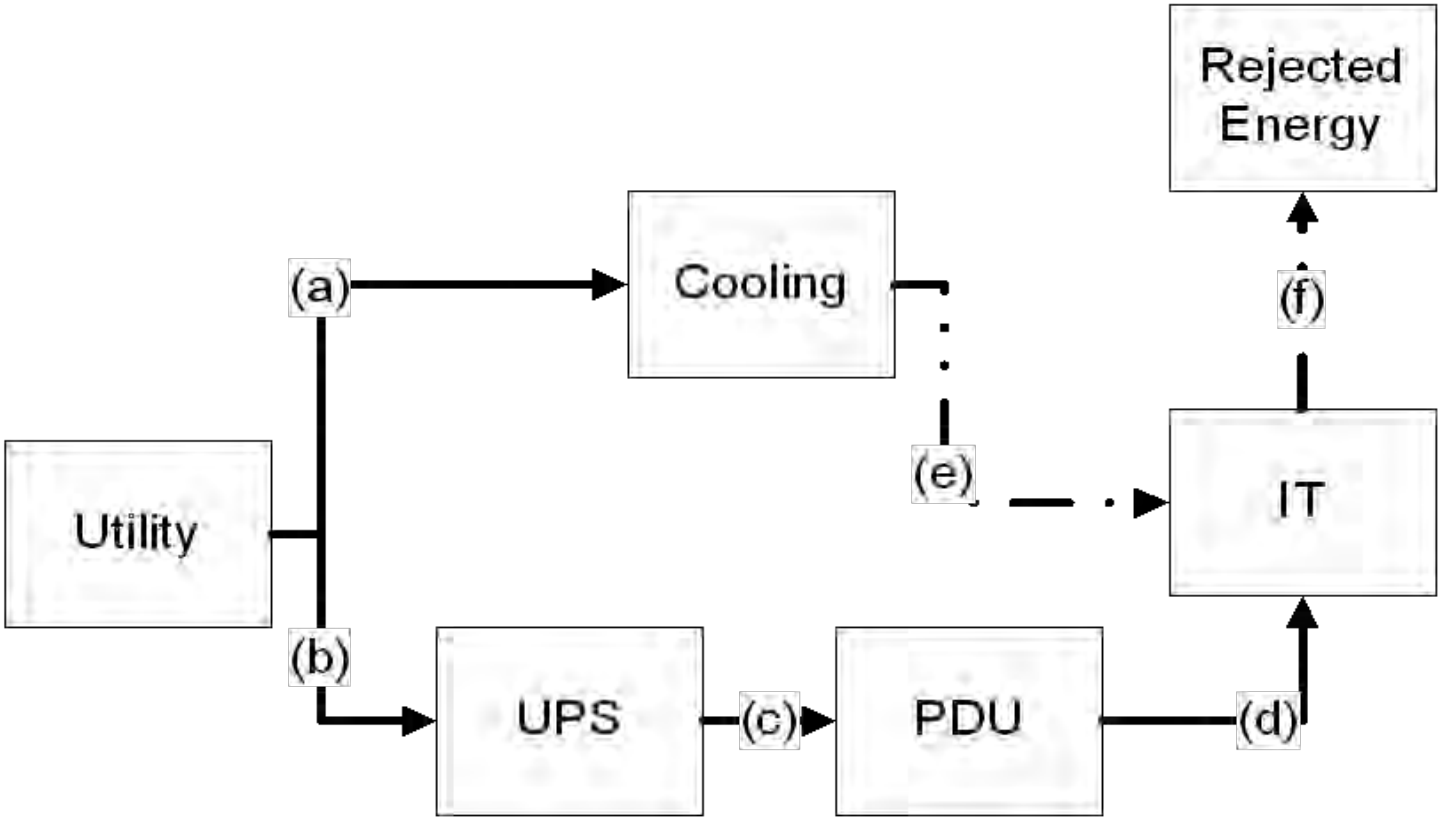
Metrics Overview and Update

Michael K Patterson, PhD, PE, DCEP

Data Center and Connected Systems Group

PUE – simple and effective



$$PUE = \frac{Total\ Energy}{IT\ Energy} = \frac{Cooling + PowerDistribution + Misc + IT}{IT} = \frac{a+b}{d}$$

PUEs: Reported and Calculated

	PUE
EPA Energy Star Average	1.91
Intel Jones Farm, Hillsboro	1.41
ORNL CSB	1.25
T-Systems & Intel DC2020 Test Lab, Munich	1.24
Google	1.16
Leibniz Supercomputing Centre (LRZ)	1.15
National Center for Atmospheric Research (NCAR)	1.10
Yahoo, Lockport	1.08
Facebook, Prineville	1.07
National Renewable Energy Laboratory (NREL)	1.06

PUEs: Reported and Calculated

	PUE
EPA Energy Star Average	1.91
Intel Jones	41
ORNL CSB	25
T-Systems &	24
Google	16
Leibniz Sup	15
National Ce	10
Yahoo, Lockport	1.08
Facebook, Prineville	1.07
National Renewable Energy Laboratory (NREL)	1.06

It's all about the "1".

1.06? Should we....
Focus on driving the 0.06 down?
Or work on the 1.0?

“I am re-using waste heat from my data center on another part of my site and my PUE is 0.8!”

“I am reusing waste heat from my data center on another part of my site and my PUE is 0.8!”

- While re-using excess energy from the data center can be a good thing to do, it should not be rolled into PUE. The definition of PUE does not allow this.

- There is a new metric to do this; ERE

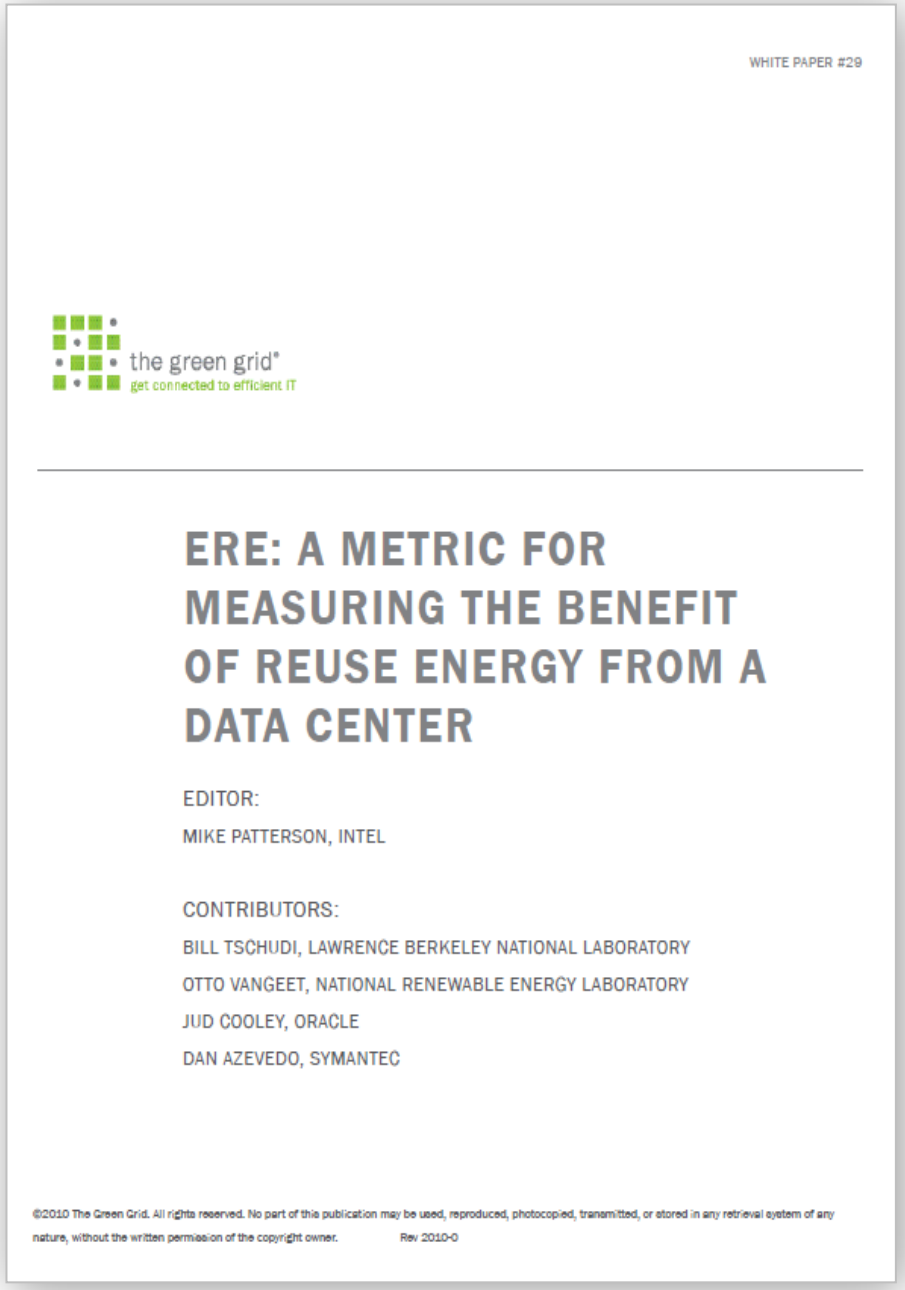
Energy Reuse Effectiveness

A new energy efficiency metric

Similar to PUE but accounts for reuse energy

PUE and ERE can both provide insight

- Different perspectives on efficiency vs reuse



WHITE PAPER #29

the green grid®
get connected to efficient IT

ERE: A METRIC FOR MEASURING THE BENEFIT OF REUSE ENERGY FROM A DATA CENTER

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Rev 2010-0

ERE Definition

$$PUE = \frac{\text{Total Energy}}{\text{IT Energy}}$$

$$PUE = \frac{\text{Cooling} + \text{Power} + \text{Lighting} + \text{IT}}{\text{IT}}$$

$$ERE = \frac{\text{Total Energy} - \text{Reused Energy}}{\text{IT Energy}}$$

$$ERE = \frac{\text{Cooling} + \text{Power} + \text{Lighting} + \text{IT} - \text{Reused}}{\text{IT}}$$

ERE Alternate Development

Define energy reuse factor (ERF) as:

$$ERF = \frac{\text{Reuse Energy}}{\text{Total Energy}}$$

Then:

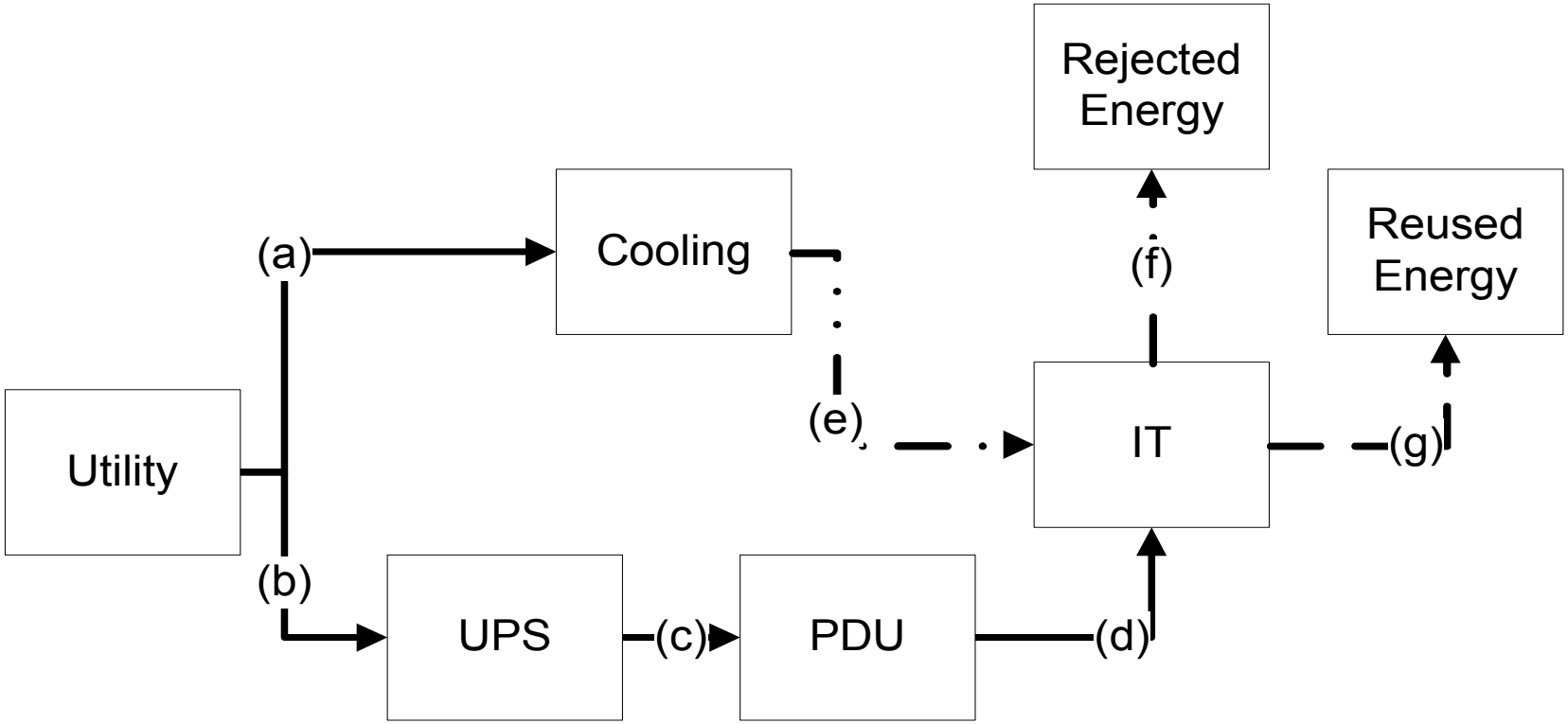
$$ERE = (1 - ERF) \times PUE$$

And finally:

$$ERE = \frac{Cool + Pwr + Light + IT - Reused}{IT} = (1 - ERF) \times PUE$$

ERF and PUE are mathematically related, but differ and need to defined and reported clearly.

ERE – adds energy reuse to the PUE concept



$$ERE = \frac{Total\ Energy - Reuse\ Energy}{IT\ Energy}$$

$$= \frac{Cooling + PowerDistribution + Misc + IT - Reuse}{IT} = \frac{a + b - g}{d}$$

Comparison with PUE

One view of PUE is that is the "tax" or burden in energy costs you must pay above the IT load to run the Data Center; ERE allows the same vision

PUE = 1.0 means 100% of the energy you bring in to the *data center* goes to the IT

ERE = 1.0 means you only need to bring into the *site* an amount equal to 100% of the IT energy to support the Data Center

<u>We need both!</u>

Case 1	Case 2
PUE = 2.0	PUE = 1.2
ERF= 0.55	ERF=0.25
ERE = 0.9	ERE=0.9

Case 1 focus on PUE, Case 2 focus on ERF

Towards the Net-Zero Data Center: Development and Application of an Energy Reuse Metric

Technical Paper presented last June: ASHRAE Summer Meeting, Montreal

Towards the Net-Zero Data Center: Development and Application of an Energy Reuse Metric

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Member ASHRAE

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William Tschudi, PE
Member ASHRAE

Dan Azevedo

ABSTRACT

Data Centers are an ever increasing user of energy in our economy. While the performance per watt of our IT equipment continues to increase exponentially, this energy performance improvement is still outstripped by increasing demand. Because of this, the efficiency of data centers must continue to improve. Beyond just efficiency, many data centers now are working towards reuse of their waste energy in other areas in the data center or on the site or campus. How to account for this, through metrics and measurements, is the topic of this paper. The Energy Reuse Effectiveness metric or ERE is discussed; both the development and application of the metric are looked at in detail. The use of ERE in conjunction with PUE (Power Usage Effectiveness) is also considered.

INTRODUCTION

ASHRAE (2009) defines Net-Zero as: "Buildings which, on an annual basis, use no more energy than is provided by on-site renewable energy sources" Net-Zero Energy Buildings or NZEBs are a fundamental part of reducing societies impact on the energy grid, being electricity, natural gas, or district cooling. Buildings in the United States consume a full 40% of the primary energy. Reducing that thru making more buildings grid neutral can have a significant impact on any countries overall energy efficiency and carbon footprint.

Data Centers are a fundamental part of the *information economy*, housing the heart of the IT infrastructure for significant portions of our industries and daily lives. The EPA has recently suggested that IT energy represented 3% of the United States energy consumption, with datacenters and the resident IT equipment being half of that or 1.5% of the nation's energy use. Those datacenters are found in essentially all parts of the economy from finance, to manufacturing, to media, and to science and education. As a significant user of energy, one would consider applying the Net-Zero goal to data centers. The ability to accomplish this easily will depend first on the size of the data center. Many buildings today have some central IT capacity, ranging from a few servers in a mid-sized office complex to thousands of servers in a large high performance computing (HPC) or Internet Portal datacenter. Incorporating the few servers into the overall energy plan in an office building will become common place as NZEBs become more main-stream. The datacenter with thousands of servers will be quite a different challenge.

Michael K Patterson is a Thermal Architect at Intel Corporation, Dupont, WA. **Otto VanGeet** is a Energy Research Engineer at the National Renewable Energy Laboratory, Golden, CO. **William Tschudi** is an Energy Efficiency Researcher at Lawrence Berkeley National Laboratory, Berkeley, CA Commercial Company, City, State. **Dan Azevedo** is IT Director at Symantec Corporation, Springfield, OR

PUE & ERE resorted….

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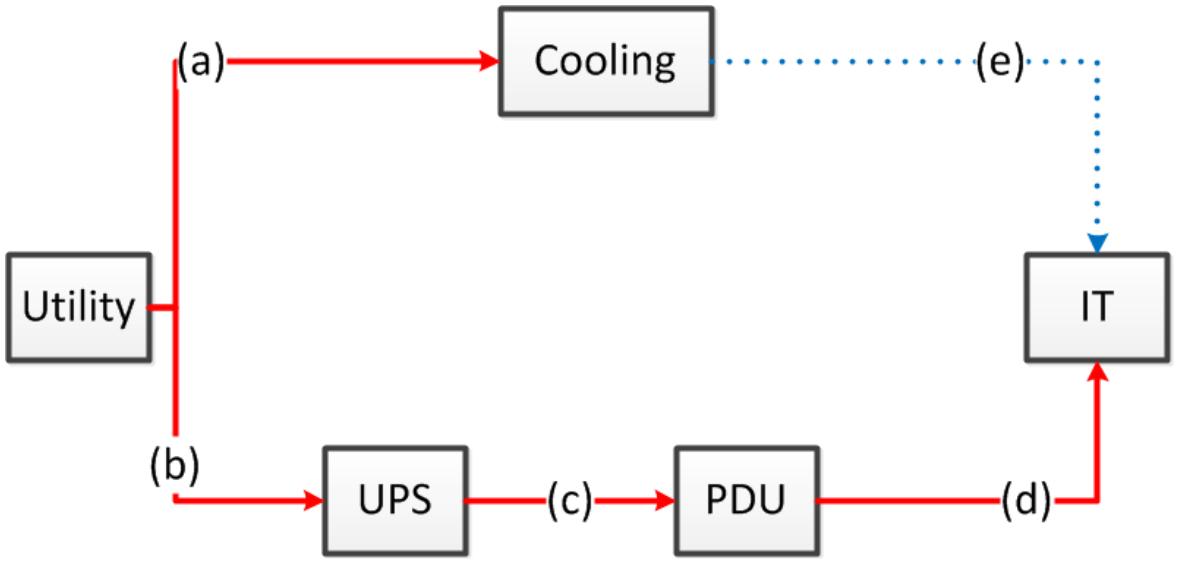
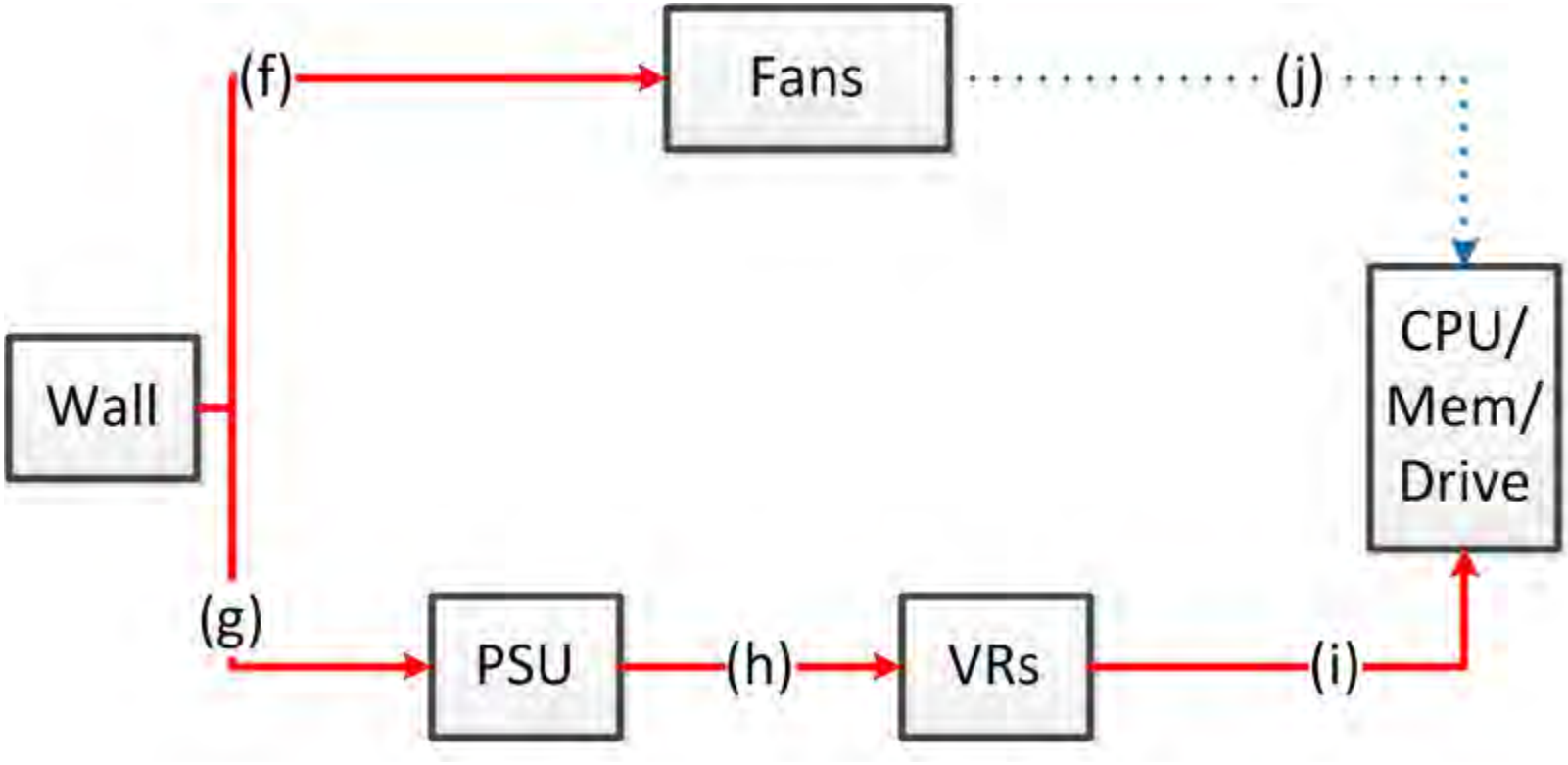
New developments – include the IT energy overhead in a PUE like metric



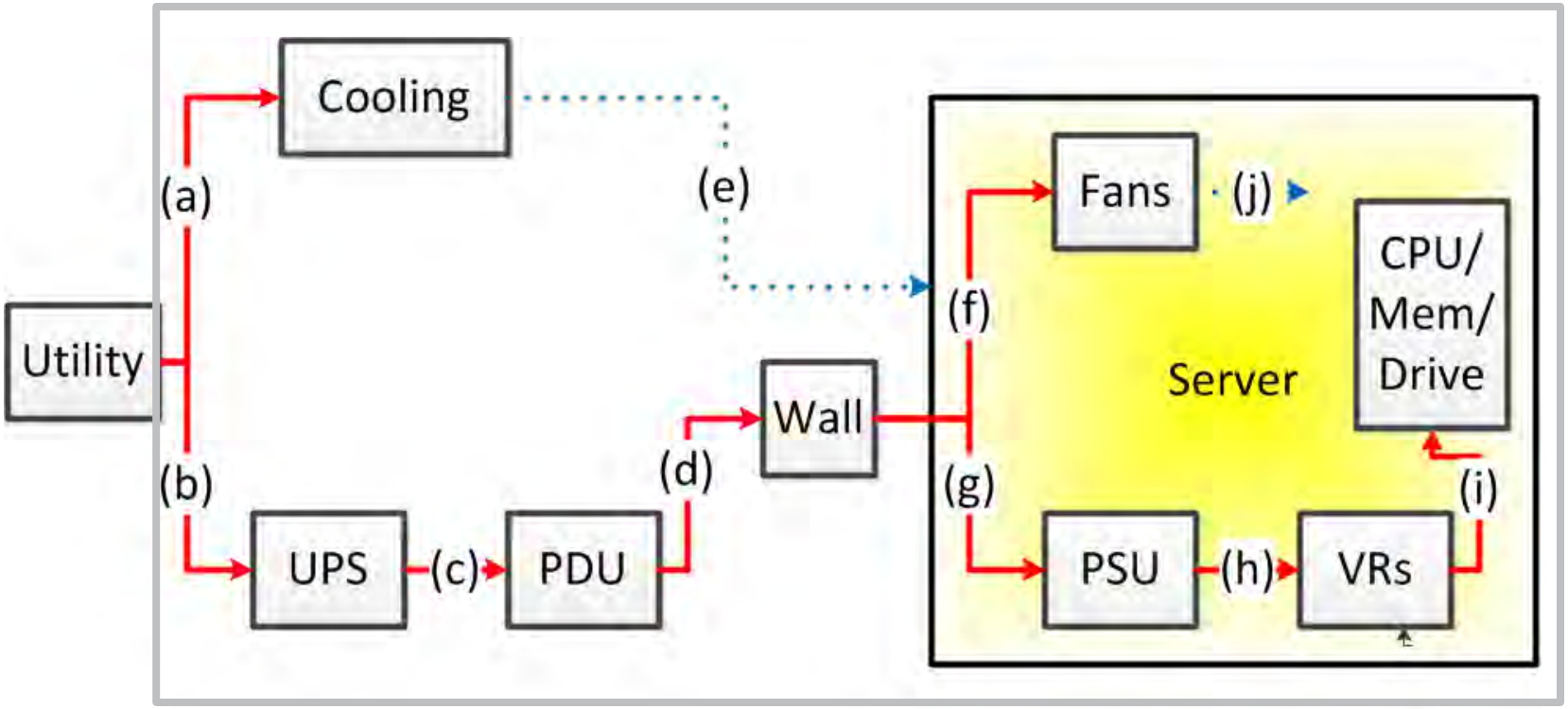
$$PUE = \frac{Total\ Energy}{IT\ Energy} = \frac{Cooling + PowerDistribution + Misc + IT}{IT} = \frac{a+b}{d}$$

IT PUE – the same construct



$$\text{ITPUE} = \frac{Cooling + Pwr\ Dist + Misc + IT}{IT} = \frac{f+g}{i}$$

Combined TotalPUE



$$TUE = DCPUE \times ITPUE = \frac{a+b}{d} \times \frac{f+g}{i} = \frac{a+b}{i}$$

Small EEHPC sub-team exploring this space…..

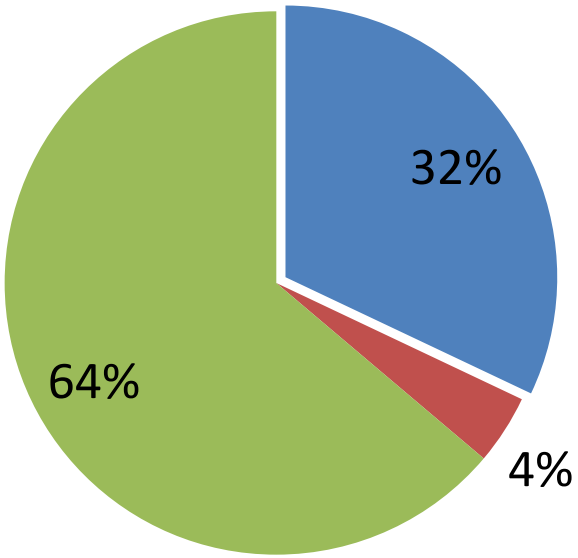
A gap…. A way to measure, compare, and contrast HPC machines and data centers

- Green 500 is a start
  - Limited to Linpack
  - Essentially Top500/~Energy
  - Does NOT include the data center
  - Power/Energy measurement could be better defined
  - Workload to specific
- EEHPC WG has a sub-team focused here

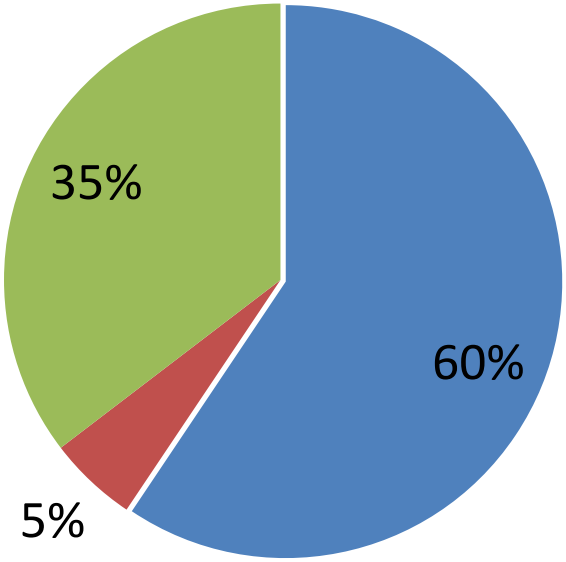
Birds of Feather: "Setting Trends for Energy Efficiency"
Tuesday, 12:15-1:15PM TC 101

An alternate step towards Data Center (not just infrastructure) efficiency…..

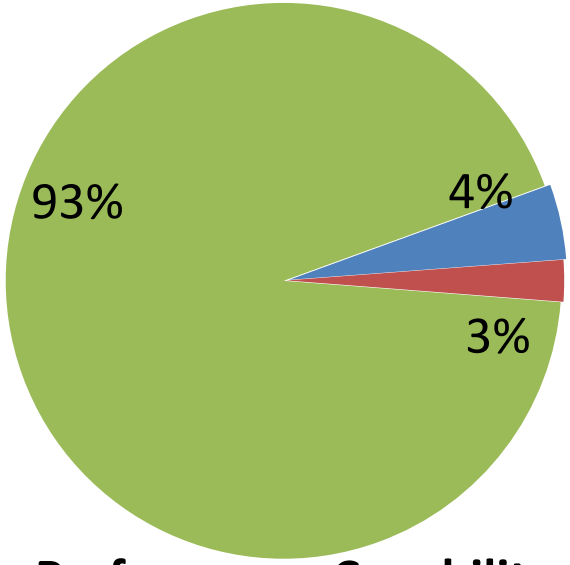
A Real Problem



Age Distribution of Servers



Energy Consumption of Servers



Performance Capability of Servers

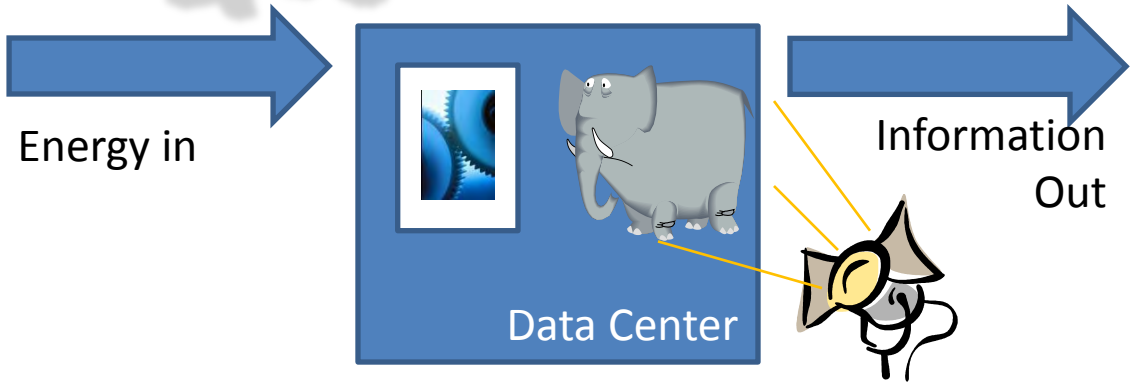
2007 & Earlier
2008, 2009
2010 - Current

Old Servers consume 60% of Energy but deliver only 4% of Performance Capability.

Data collected recently at a Fortune 100 company; courtesy of John Kuzma and William Carter, Intel

Spotlighting the Elephant

- The biggest energy users in an efficient data center are the servers.
- Are your servers efficient?
- How do you know?



Inefficient servers are the Elephant in your data center

SUE Definition

- Define metric like PUE for “Server Utilization Effectiveness”
- Server Utilization Effectiveness

$$SUE \equiv \frac{Ideal\ Server\ Performance}{Actual\ Server\ Performance}$$

- Consistent with PUE
  - 1.0 is ideal
  - Bigger numbers are worse
  - Simple Implementation
  - Simple Interpretation

Calculating SUE, keeping it simple

- Implementation Complexity is a showstopper.
- Efficiency advances of “Moore’s Law” well accepted in the Industry
- “Server Performance Doubles approximately every two years.”

$$SUE = \frac{Ideal\ Server\ Performance}{Actual\ Server\ Performance} \cong \frac{N_{Servers}}{\sum_{Servers} 0.707^{Age}}$$

SUE Maturity Options

$$SUE \equiv \frac{Ideal\ Server\ Performance}{Actual\ Server\ Performance}$$

Maturity Level	0	1	2	4
Performance Measure	0.707^{Age}	Benchmark Data	Productivity Proxy	Actual Workload
Investment	A few hours	Days.	Weeks.	Months to years
Requires	Server Inventory	Correlation of Server config to performance data	Specialized Software	Software development
Scope	Simplified assessment to find big problems	More accurate assessment depending on configuration and benchmarks chosen	Very accurate assessment.	Most accurate assessment.

Example: Calculating SUE

Age	0.707^{Age}	Number of Servers	Performance Weighted
0	1.0	100	100
1	.71	50	35
2	.50	100	50
3	.35	50	18
4	.25	100	25
5	.17	100	17
		500	**245**

$$SUE = 500/245 \cong 2.0$$

2X servers needed for workload

All this leads to a proposed new metric

DCUE = PUE X *SUE / Utilization*

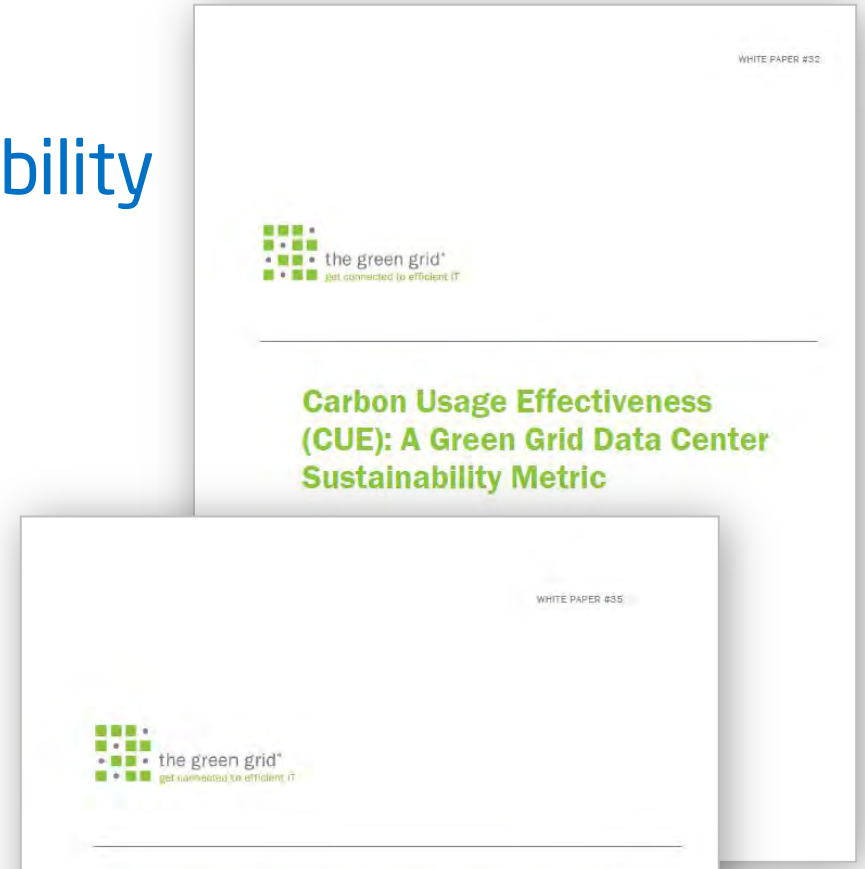
- Includes data center infrastructure efficiency with PUE
- SUE defines efficiency of the IT equipment
- Utilization gives some indication of how efficiently it is run

Water and Carbon – increasing focus on sustainability

Two new metrics for Data Center sustainability

Published by The Green Grid, with Intel leadership

Development of the Metrics will give better focus on Data Center sustainability



New Metrics… all in the PUE family

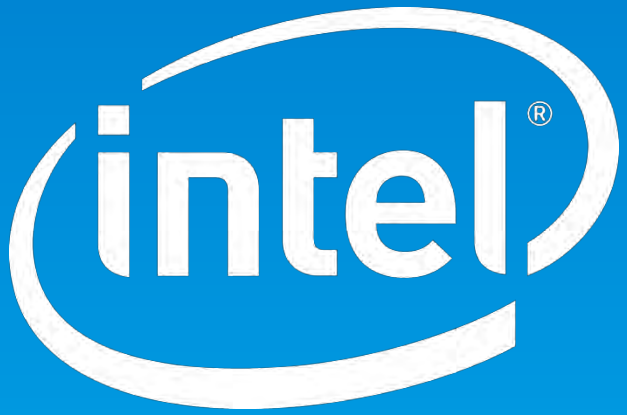
$$PUE = \frac{Total\ Facility\ Energy}{IT\ Energy}$$

$$CUE = \frac{Total\ CO\ emissions\ caused\ by\ the\ Total\ Data\ Center\ Energy}{IT\ Energy}$$

$$WUE = \frac{Annual\ Site\ Water\ Usage}{IT\ Energy}$$

$$WUE_{source} = \frac{Annual\ Source\ Energy\ Water\ Usage + Annual\ Site\ Water\ Usage}{IT\ Energy}$$

Thank You! Questions?


intel