

TUE, a new look at PUE

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This presentation adapted from our presentation at ISC 13...

TUE, a new energy-efficiency metric applied at ORNL's Jaguar

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EE HPC WG

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TUE, a new energy-efficiency metric applied at ORNL's Jaguar

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Abstract. The metric, Power Usage Effectiveness (PUE), has been successful in improving energy efficiency of data centers, but it is not perfect. One challenge is that PUE does not account for the power distribution and cooling losses inside IT equipment. This is particularly problematic in the HPC (high performance computing) space where system engineers are moving cooling and power subsystems into or out of the chassis. This paper proposes two new metrics: TUE (IT power usage effectiveness), similar to PUE but "inside" the IT and TUE (total power usage effectiveness), which combines the two for a total efficiency picture. We conclude with a demonstration of the method, and a case study of measurements at ORNL's Jaguar system. TUE provides a ratio of total energy, internal and external support energy used and the specific energy used in the HPC. TUE can also be a means for comparing HPC site to HPC site.

Keywords: HPC, energy-efficiency, metrics, data center

1 Introduction

This Whitepaper is a collaborative effort of the Metrics team of the Energy Efficient HPC Working Group (EEHPC WG). It reviews successes and issues with Power Usage Effectiveness (PUE) and explores some of the gaps in the metric. It demonstrates the metric, applies the same simple logic to the IT, and then to the whole, including the IT and infrastructure. This methodology is shown to produce two new metrics, with the higher level metric being a combination of PUE and IT power usage effectiveness (ITUE) yielding total power usage effectiveness (TUE). These new metrics can be used to understand the entire energy flow from the utility to the silicon. It can reveal the entire energy stack and allow exploration of how trade-offs in the infrastructure or the IT can help change the total efficiency. Previously that total efficiency could neither be measured nor traded without these proposed metrics.

White Paper 1, 2011
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The Board of Directors of the
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- Michael K. Patterson
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- Don Maxwell
- William Tschudi
- Henry Coles
- David J. Martinez
- Natalie Bates

for their outstanding scientific work

„TUE, a new energy-efficiency metric
applied at ORNL's Jaguar“

Leipzig, June 17, 2013

Prof. Dr. Michael M. Resch
Chairman of the International Award Committee
Chairman of the BoD, GCS

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Motivation

- HPC Cluster and Data Center energy use is a challenge; possibly constraining Industry growth
- We can't manage what we don't measure
- Metrics allow tracking and trending of our performance and comparison to others
- PUE has helped but has limitations, what is the next step towards better energy efficiency?

Overview

- PUE Definition and Development
- Issues with PUE
- Defining new metrics
 - ITUE: IT-power usage effectiveness
 - TUE: total-power usage effectiveness
- Metrics demonstration and example
- Case Study at Jaguar
- BoF

PUE

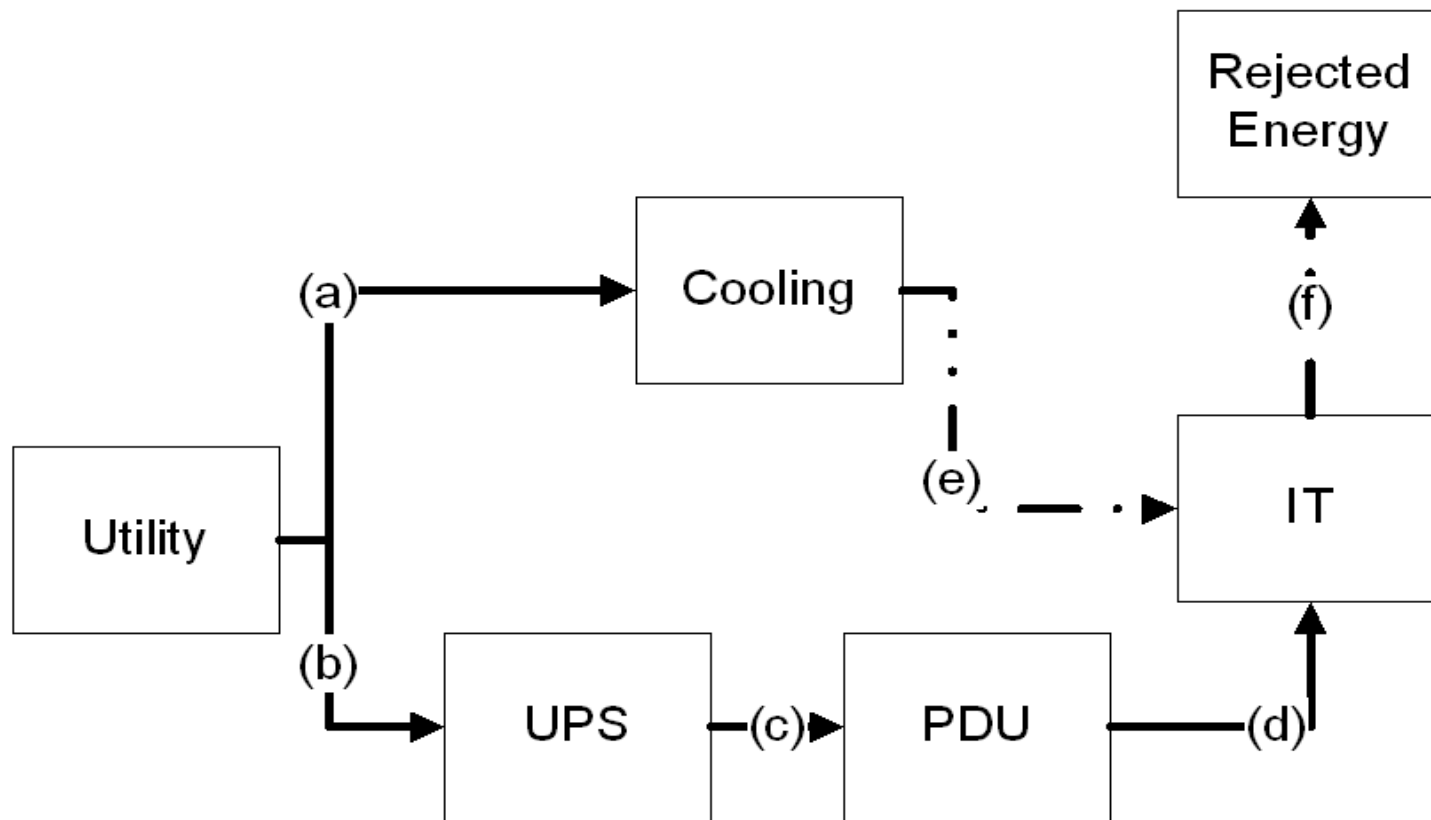
$$PUE = \frac{\textit{Total Data Center Annual Energy}}{\textit{Total IT Annual Energy}}$$

- Introduced in 2006 by Malone and Belady
- Developed and agreed to by EU Code of Conduct, DOE, EPA, Green Grid, ASHRAE, etc...
- Has led Energy Efficiency drive in Data Centers
 - PUE Average in 2007 ~ 2.5
 - Best in Class 2013:

NREL= 1.06, LRZ= 1.15, NCAR~1.2,

ORNL= 1.25, TU Dresden < 1.3

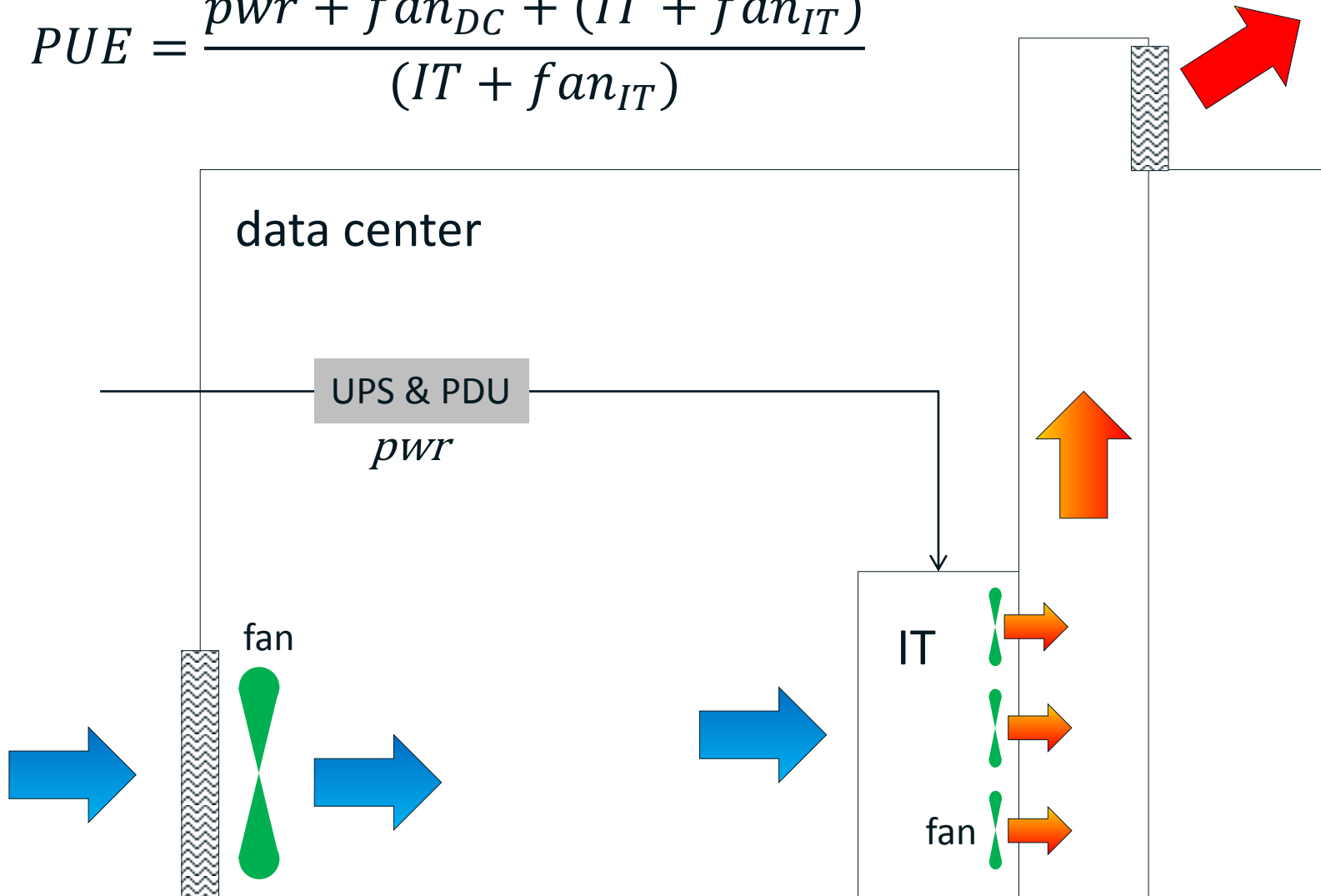
PUE Definition



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

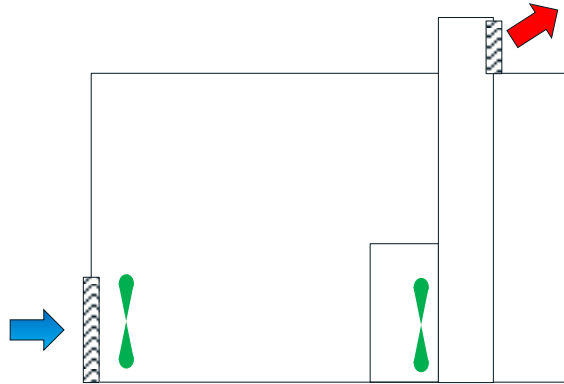
but PUE isn't perfect, consider.....

$$PUE = \frac{pwr + fan_{DC} + (IT + fan_{IT})}{(IT + fan_{IT})}$$



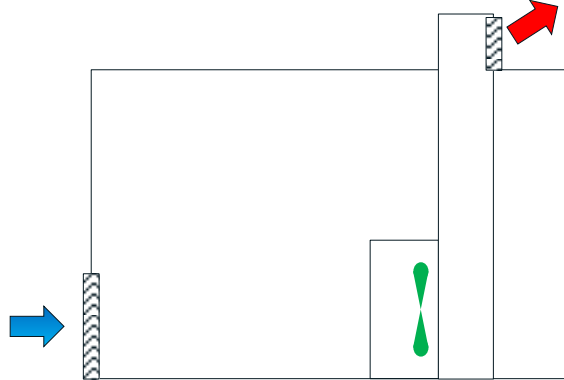
Three variations...

a)
both
fans



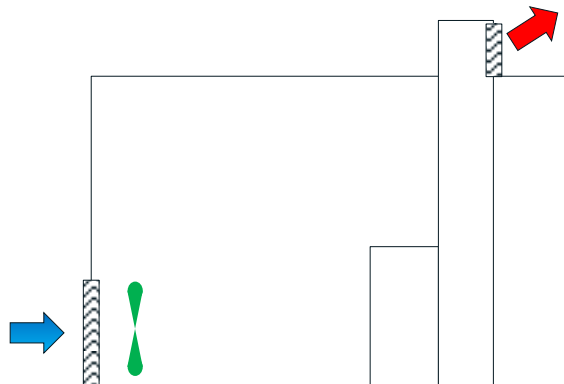
$$PUE_a = \frac{pwr + fan_{DC} + (IT + fan_{IT})}{(IT + fan_{IT})}$$

b)
IT
fans
only



$$PUE_b = \frac{pwr + (IT + fan_{IT})}{(IT + fan_{IT})}$$

c)
bldg
fan
only



$$PUE_c = \frac{pwr + fan_{DC} + IT}{IT}$$

$PUE_b < PUE_a < PUE_c$ but is (b) best?
We don't know....

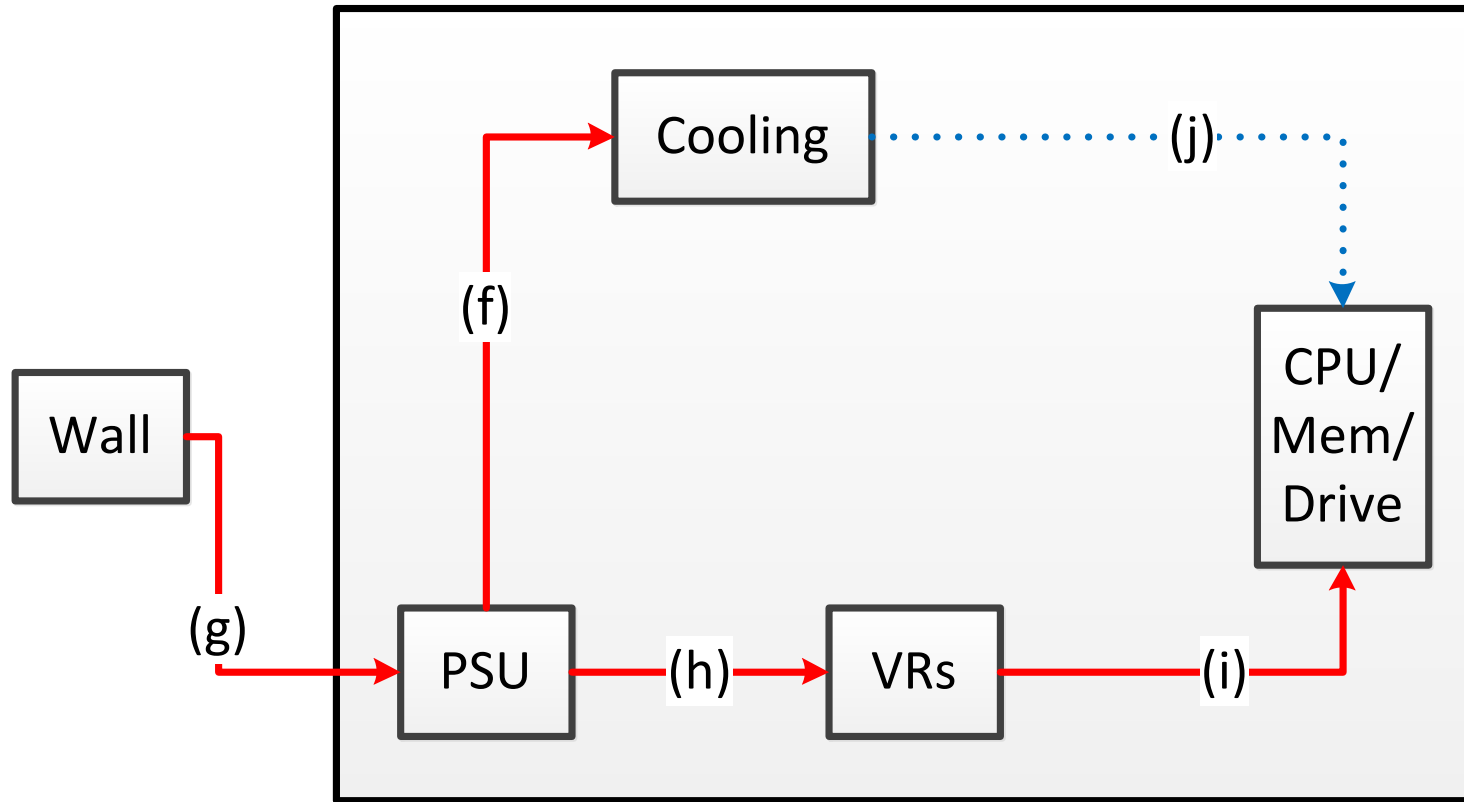
Can we define a “server-PUE”? Maybe ITUE?

$$PUE = \frac{\text{Total Energy}}{\text{IT Energy}} = \frac{Pwr + Cooling + Misc + IT}{IT} = \frac{\text{Infrastructure Burden} + IT}{IT}$$

	Data Center	Server
Power dist losses	UPS, line losses, PDUs	PSU, VRs, board losses
Cooling losses	Chiller, CRAC, Pumps, Fans	Fans, Pumps
Misc losses	Security, Lighting, Building Control	Indicators, Platform Control
IT	Servers, Storage, Network	Processor, Memory, Disk

$$ITUE = \frac{\text{Infrastructure Burden} + \text{Compute}}{\text{Compute}} = \frac{Pwr + Cooling + Misc + \text{Compute}}{\text{Compute}}$$

$$ITUE = \frac{\text{Total Energy into the IT Equipment}}{\text{Total Energy into the Compute Components}}$$



$$ITUE = \frac{\text{total energy into the IT equipment}}{\text{total energy into the compute components}} = \frac{g}{i}$$

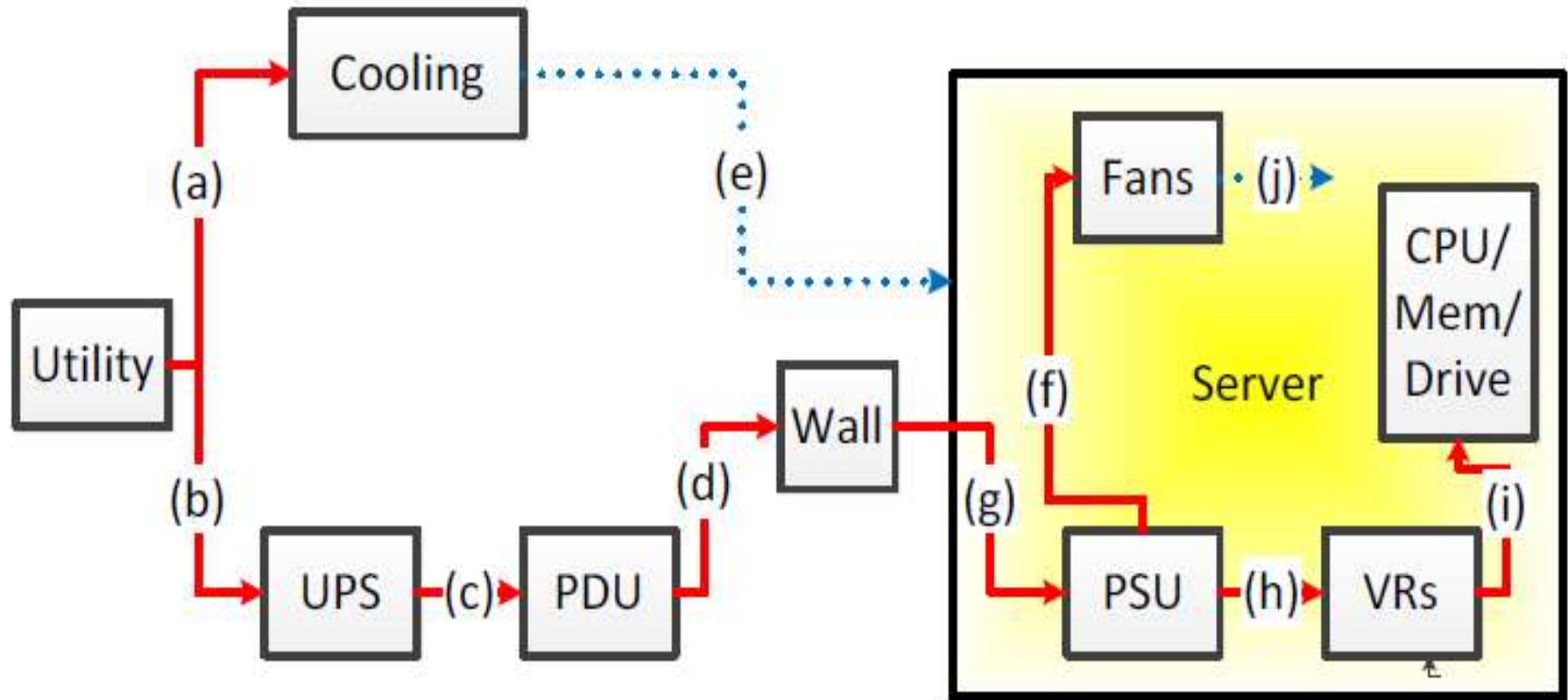
The next step...

PUE and ITUE are both:

- dimensionless ratios
 - Represent the burden or “tax” of infrastructure
 - “1” is ideal, values larger than 1 are worse
 - Values less than 1 are not allowed
-
- So why not:

$$TUE = PUE \times ITUE$$

TUE



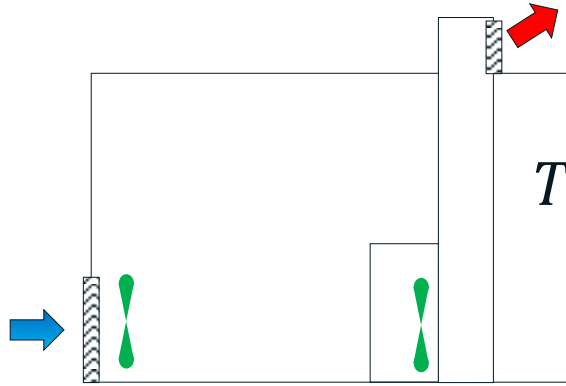
$$PUE = \frac{\text{Total Energy}}{\text{IT Energy}} = \frac{a + b}{d}$$

$$ITUE = \frac{\text{Total Energy}}{\text{Compute Energy}} = \frac{g}{i}$$

$$TUE = ITUE \times PUE = \frac{a + b}{i}$$

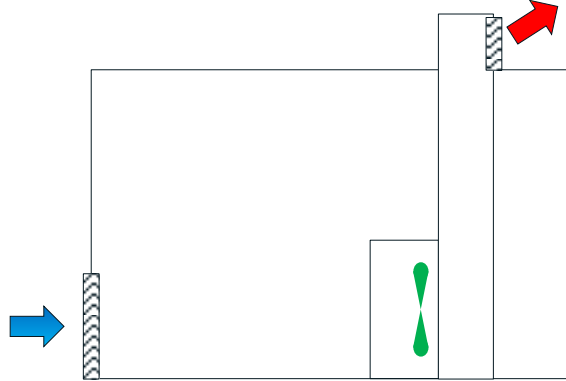
Does it work?

a)
both
fans



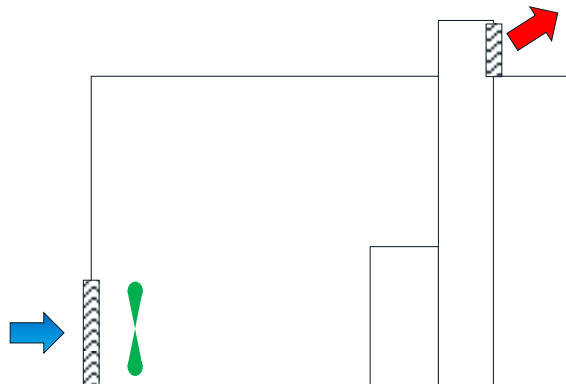
$$TUE_a = \frac{pwr + fan_{DC} + fan_{IT} + compute}{compute}$$

b)
IT
fans
only



$$TUE_b = \frac{pwr + fan_{IT} + compute}{compute}$$

c)
bldg
fan
only



$$TUE_c = \frac{pwr + fan_{DC} + compute}{compute}$$

The lowest TUE yields the lowest energy use. Yes, it works!

Demonstration of the Metrics

- Two Data Centers (a) & (b), identical infrastructure, each w/ PUE = 1.6
- Major refresh, Installing 10,000 new servers
- DC_a getting economy servers, DC_b w/ high efficiency models

	a) Economy (W)	b) High Eff (W)
Proc, Mem, Stor	198	198
PSU	58	18
VRs	56	38
Fans	18	12
Total Platform	330	266

After the refresh, DC_b will have a worse PUE

Example Data Center ITUE

$$ITUE = \frac{\text{Fan} + \text{PSU} + \text{VRs} + \text{Compute}}{\text{Compute}}$$

With “economy” hardware:

$$ITUE_a = \frac{18 + 58 + 56 + 198}{198} = 1.67$$

With “high efficiency” hardware:

$$ITUE_b = \frac{12 + 18 + 38 + 198}{198} = 1.34$$

ITUE appropriately reflects the more efficient hardware

Summary of the Metrics

	a) Economy	b) High Eff
Total Platform	3.31 MW	2.67 MW
Infrastructure	1.99 MW	1.99 MW
Total Site Power	5.3 MW	4.66 MW
PUE	1.6	1.74
ITUE	1.67	1.34
TUE	2.67	2.33

The combination of the three metrics paints the whole picture

Jaguar – TUE Case Study



200 Cray XT5 Cabinets (25x8)

48 Liebert XDP Cooling Systems

37kW/cabinet – 7.5MW Total

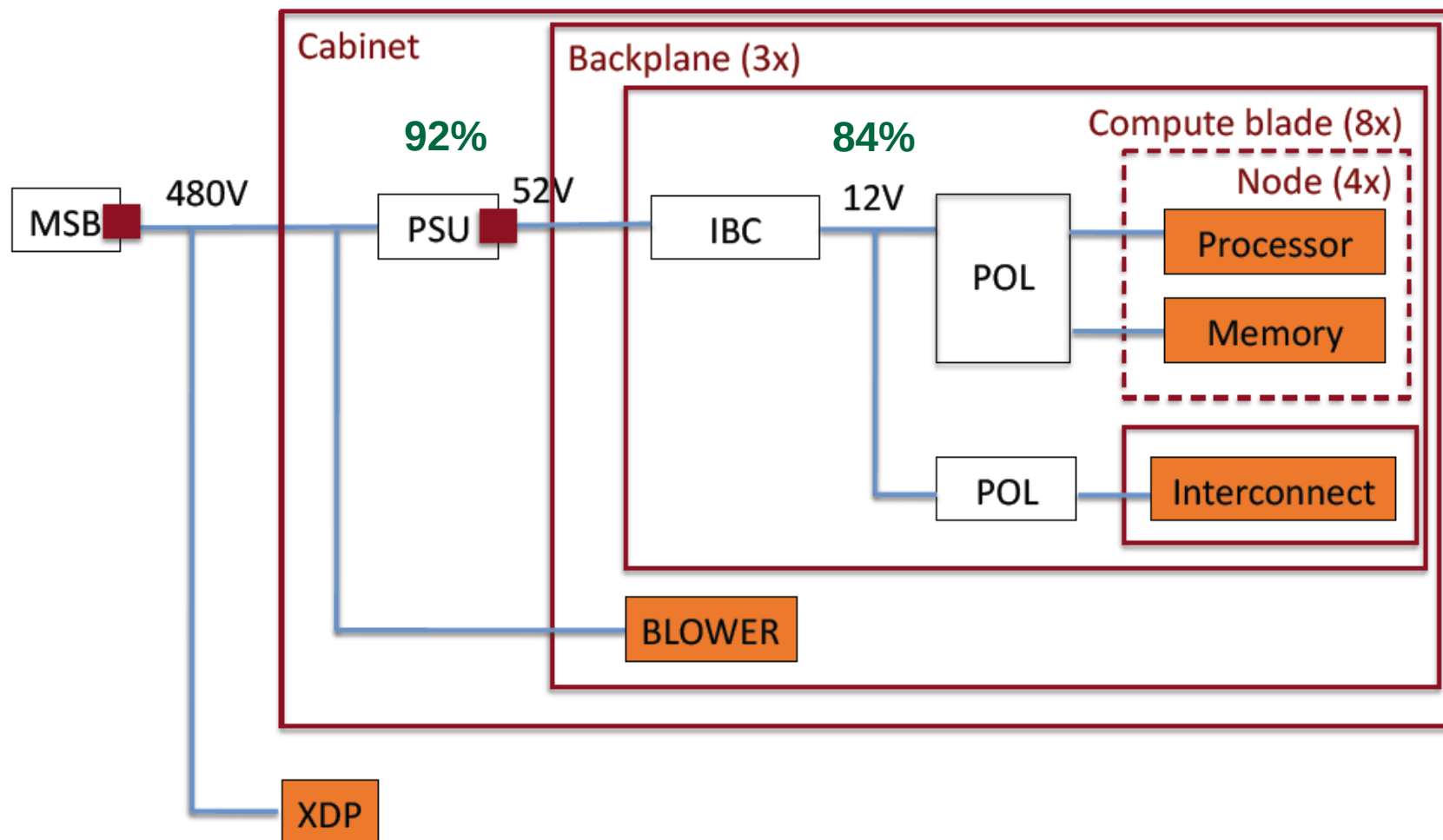
184 ECOPHlex-cooled Cabinets

16 Air-cooled Cabinets

4500 square feet (system min. only)

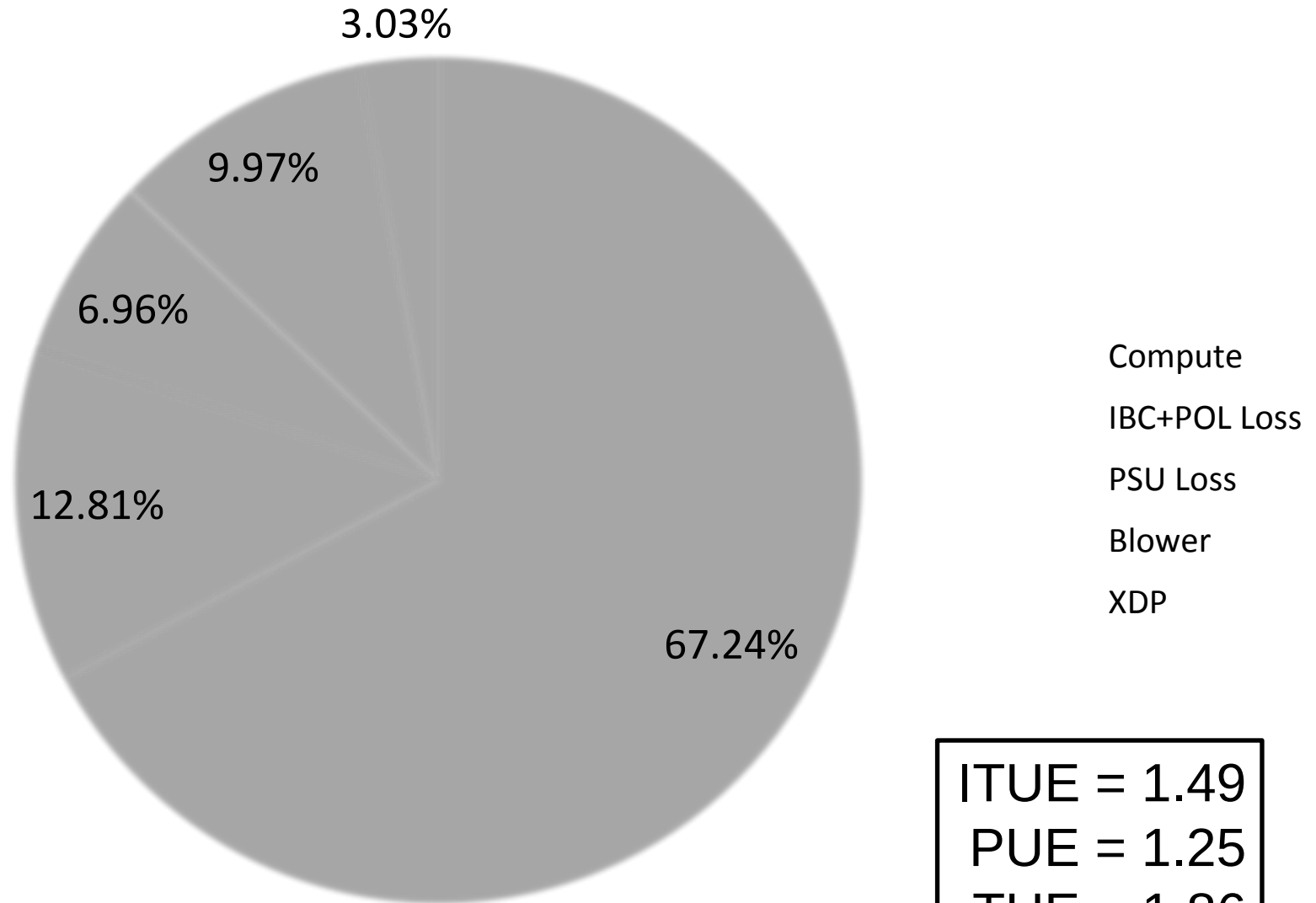
Source: J. Rogers, CUG 2009.

Power Monitoring in Jaguar



■ measurement point

The ITUE of Jaguar for 2011-01



ITUE = 1.49
PUE = 1.25
TUE = 1.86

Want more?

Please attend our BoF:

Total Power Usage

***Effectiveness: A New
Take on PUE***

Wednesday, 12:15-1:15

Room 210/212

Thank You. Questions?



