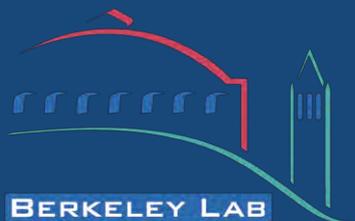


PUE in the Past; Towards TUE in the Future



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Outline

PUE

- Background
- Components
- PUE Definition and Visualized
- Examples, Base Case
- pPUE (partial PUE)
- PUE Not Perfect

ITUE & TUE

- Introduction/Concept/Definition
- Example: How Does TUE Work?
- Does TUE Address PUE's Weaknesses?

- Conclusions

PUE Background

Power Usage Effectiveness (PUE) introduced in a paper by Chris Malone and Christian Belady 2006 [1]

PUE for a dedicated building is the total facility energy divided by the IT equipment energy. PUE is an end-user metric used to help improve energy efficiency in data center operations [2].

PUE is a simple metric used to measure energy use efficiency for data centers.

Base Definition

$$\text{PUE}^* = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}}$$

[1] Belady, Christian, Chris Malone, 2006, *Efficiency Metric Called PUE*, Digital Power Forum

[2] From: PUE™: A COMPREHENSIVE EXAMINATION OF THE METRIC – 2012 The Green Grid: WP#49

PUE Components

Examples: Data Center Facility Power Consuming Equipment:

“Infrastructure”

- Uninterruptable Power Supply (UPS) inefficiency
- Switch gear
- Backup generators including block heating and fuel
- Power line distribution
- Data center lighting
- Office space electrical loads if dedicated to data center support
- Chillers
- Cooling tower fan and pumping
- Computer room air conditioners (CRACs) or CRAHs

“IT Equipment”

- IT Equipment (servers, tape drives, JBODs, networking)
- KVM switching devices
- Laptops or PCs used to monitor and control data center equipment

PUE Definition

$$\text{PUE}_{a,b} = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}}$$

Data Point Collection Frequency

“Y” averaged over a year

“M” averaged over a month

“W” averaged over a week

Metering Placement

“L1” Basic (UPS output)

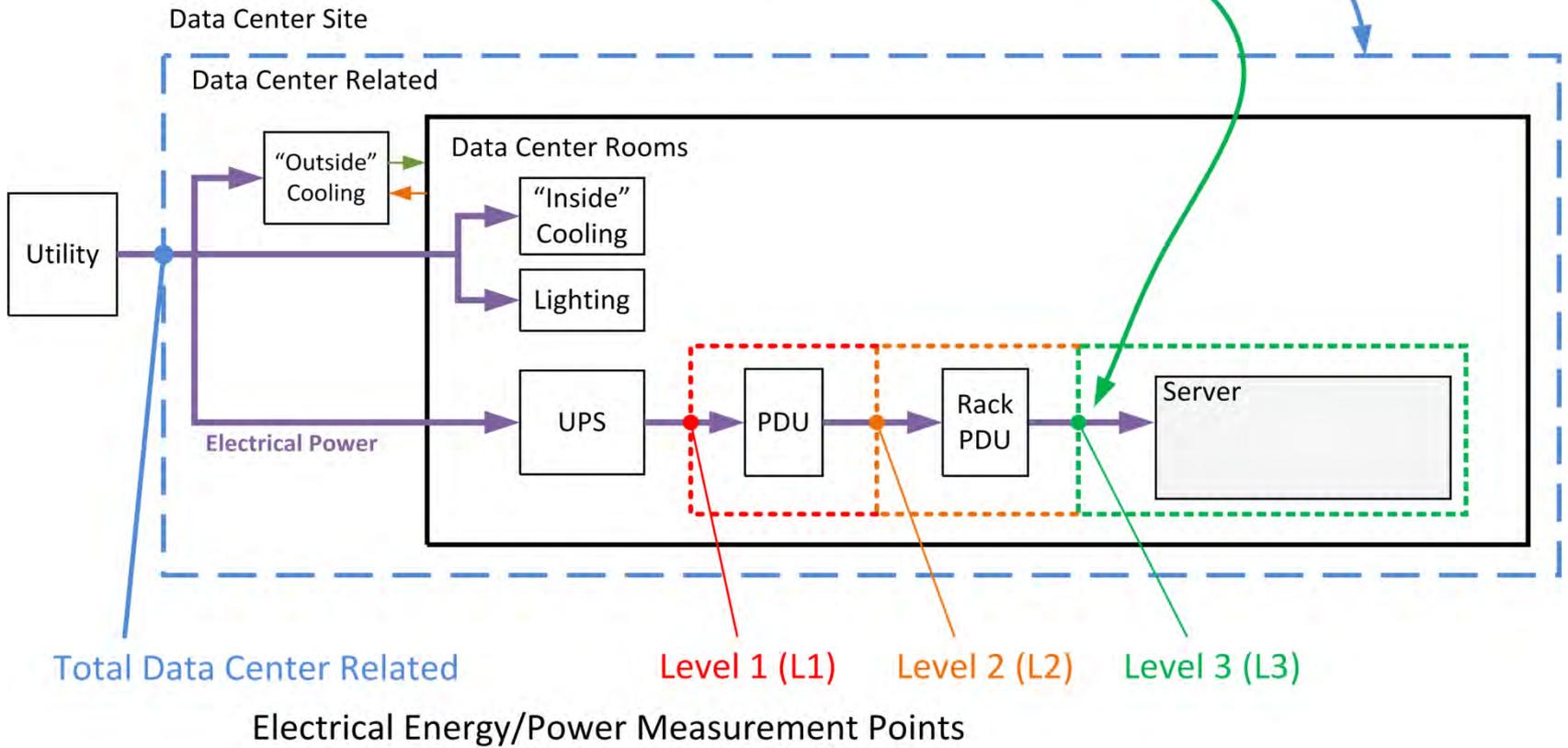
“L2” Intermediate (PDU output)

“L3” Advanced (at IT equip.)

From: PUE™: A COMPREHENSIVE EXAMINATION OF THE METRIC – the green grid: WP#49

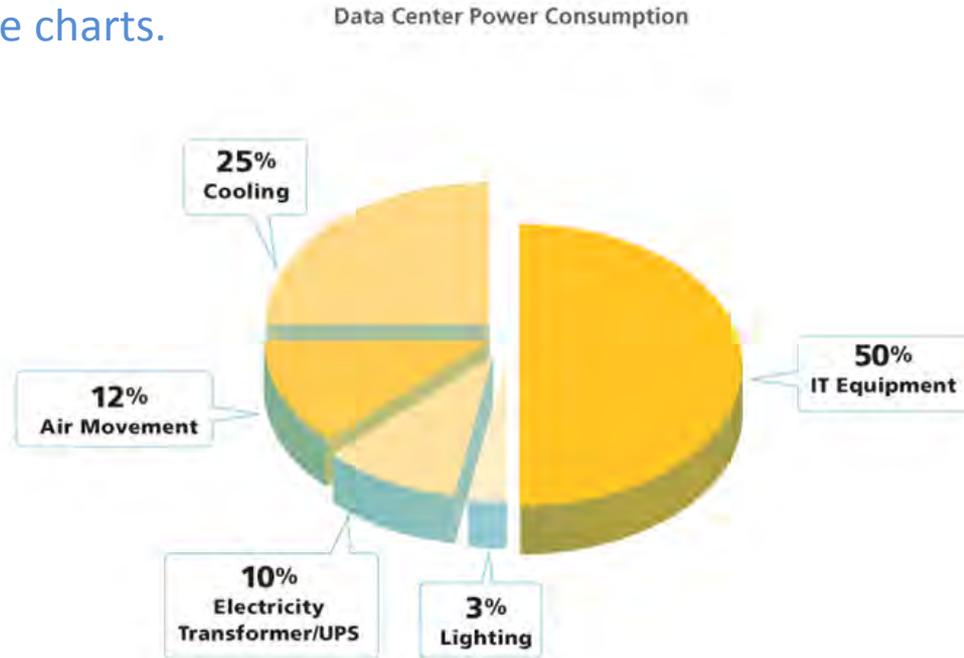
PUE Visualized

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



PUE Example

For those that like pie charts.



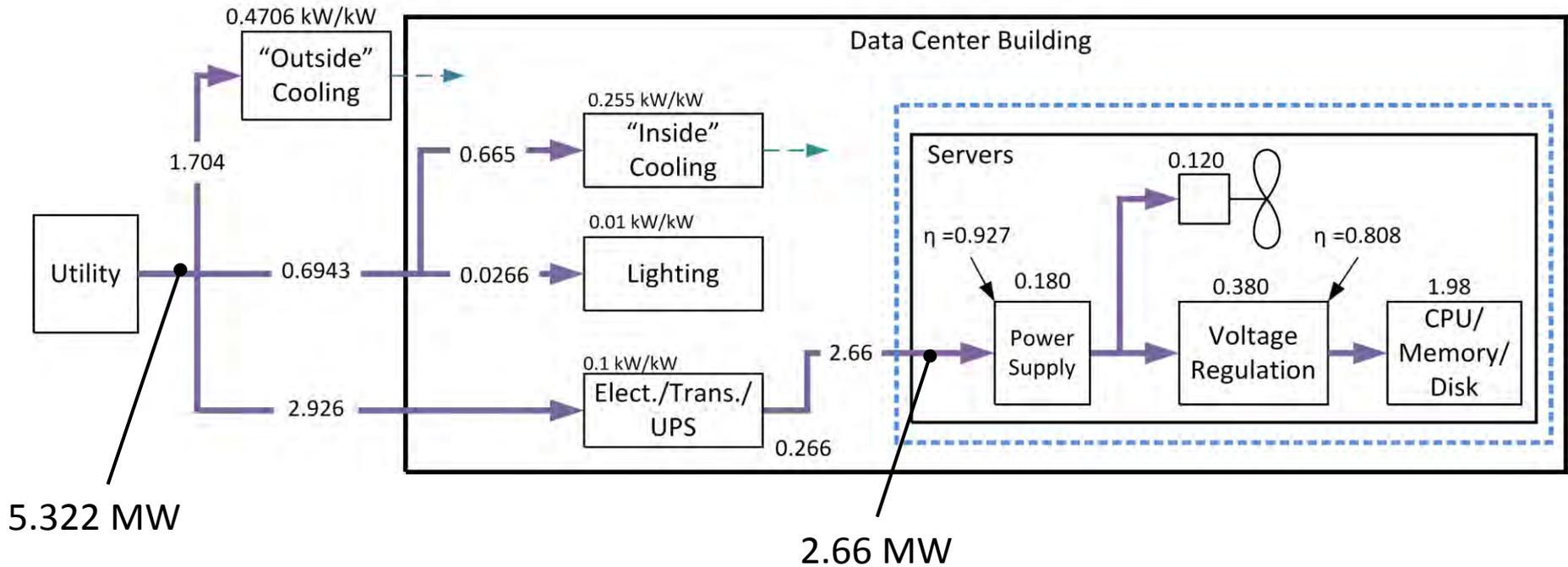
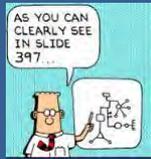
Source: EYP Mission Critical Facilities Inc., New York

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$$\text{PUE} = (25 + 12 + 10 + 3 + 50) / 50 = 2.0$$

$$\text{PUE} = (100) / 50 = 2.0$$

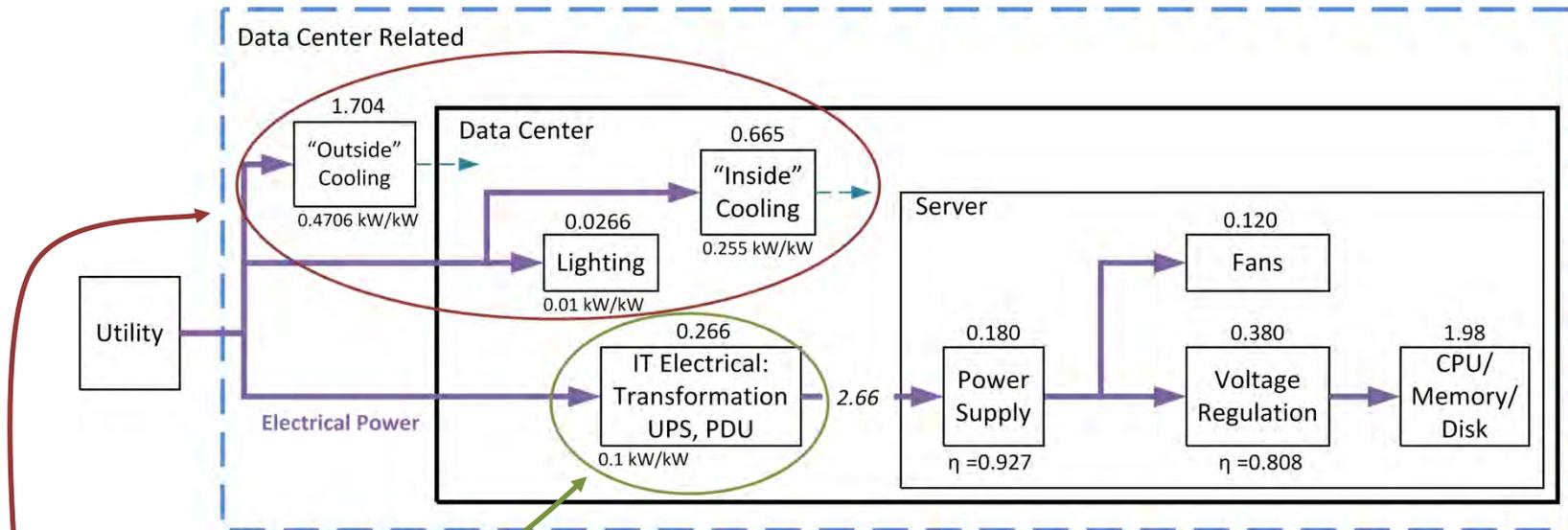
Data Center Base Case



$$\text{Base Case PUE} = (1.704 + 0.665 + 0.0266 + 0.266 + 2.66) / 2.66 = 2.000$$

$$\text{Base Case PUE} = 5.322 / 2.66 = 2.000$$

Partial PUE (pPUE) Calculation



$$pPUE_{\text{electrical IT}} = (0.266 + 2.66) / 2.66 = 1.100$$

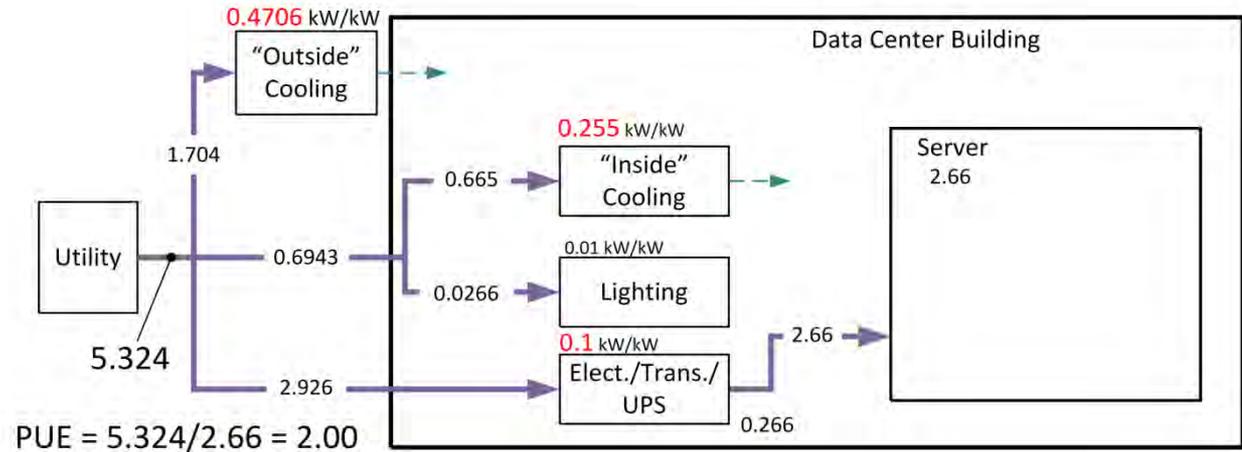
$$pPUE_{\text{cooling and lighting}} = (1.704 + 0.665 + 0.0266 + 2.66) / 2.66 = 1.900$$

$$PUE_{\text{total}} = 1.100 + 1.900 - 1 = 2.000$$

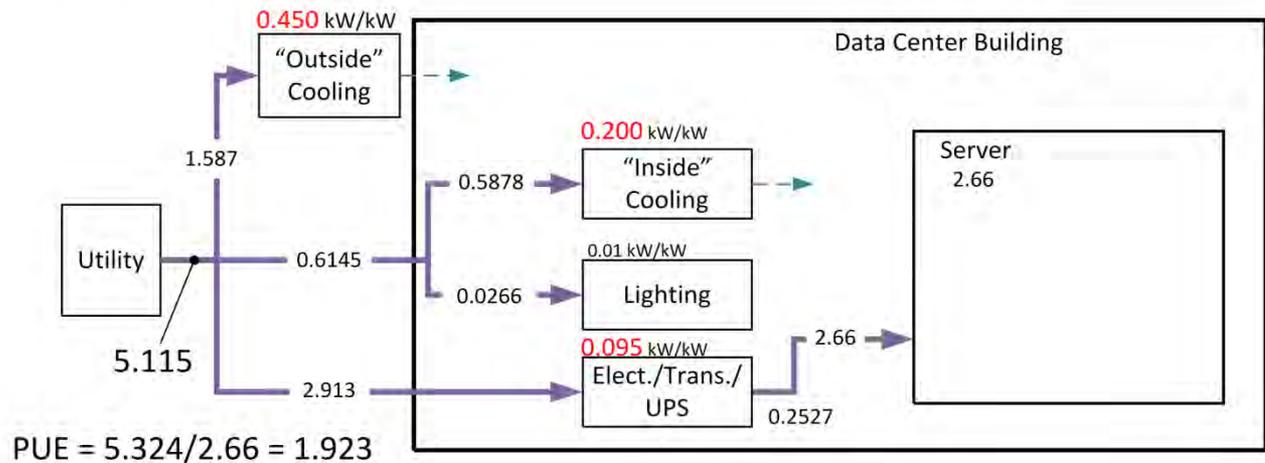
How Do We Think of PUE Values?

(Lower is Better?)

Is Lower Better?

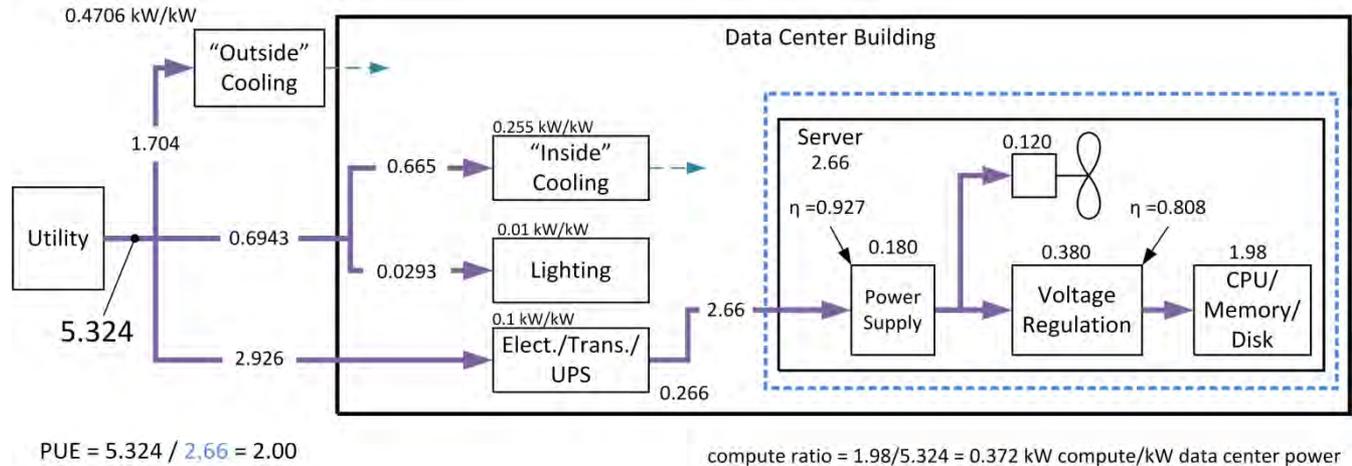


Yes, Lower is Better!

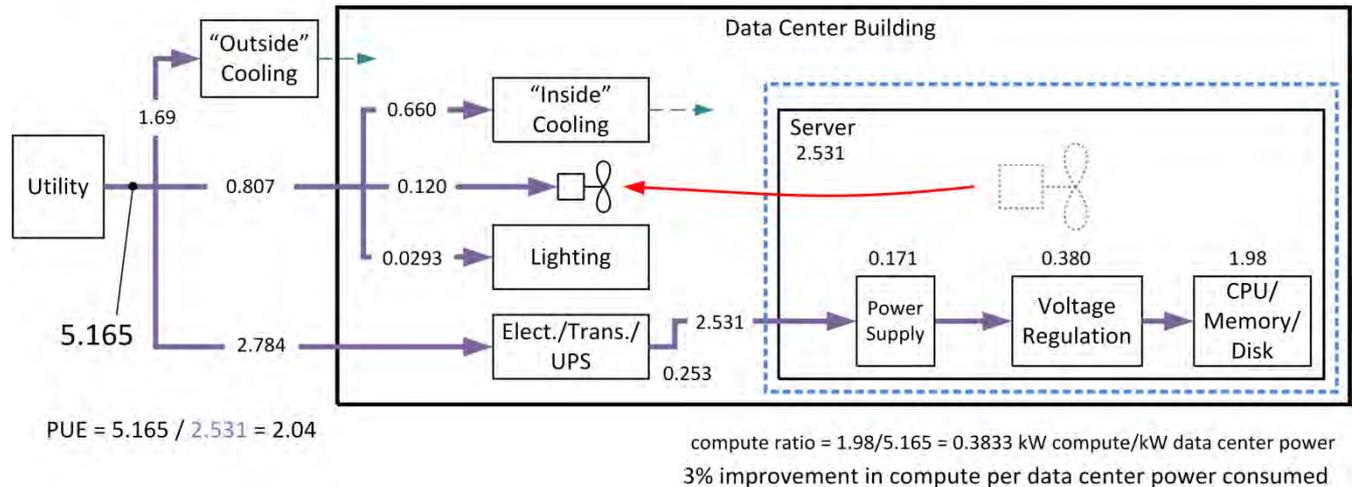


PUE Not Perfect: Move Fans Example

Data Center A



Data Center B



Data Center B uses less power BUT has a higher PUE

Dr. Michael Patterson (Intel) and EEHPCWG Propose a New Metric
(Energy Efficient HPC Working Group)

ISC13 Gauss Award Winner – Most Outstanding Paper: TUE, a new energy-efficiency metric applied at ORNL's Jaguar

1 - Introduce ITUE: *ITUE* is a “PUE-type” metric for the IT equipment.

2 - Introduce TUE - a proposed new metric that uses *ITUE* and PUE.

TUE is a calculated value. $TUE = ITUE \times PUE$

ITUE Definition

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

Hypothesis: TUE values are more accurate and consistent compared to PUE values.

Let's See If This is True.

ITUE Components

First : Review Components of ITUE

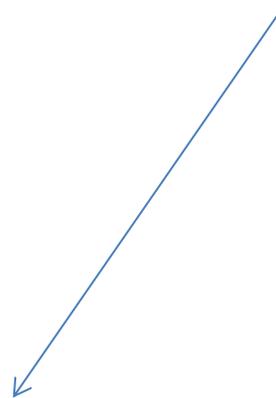
Like PUE, ITUE has Infrastructure and “productive” components.

“Infrastructure”

- Power Supplies
- Voltage Regulators
- Fans

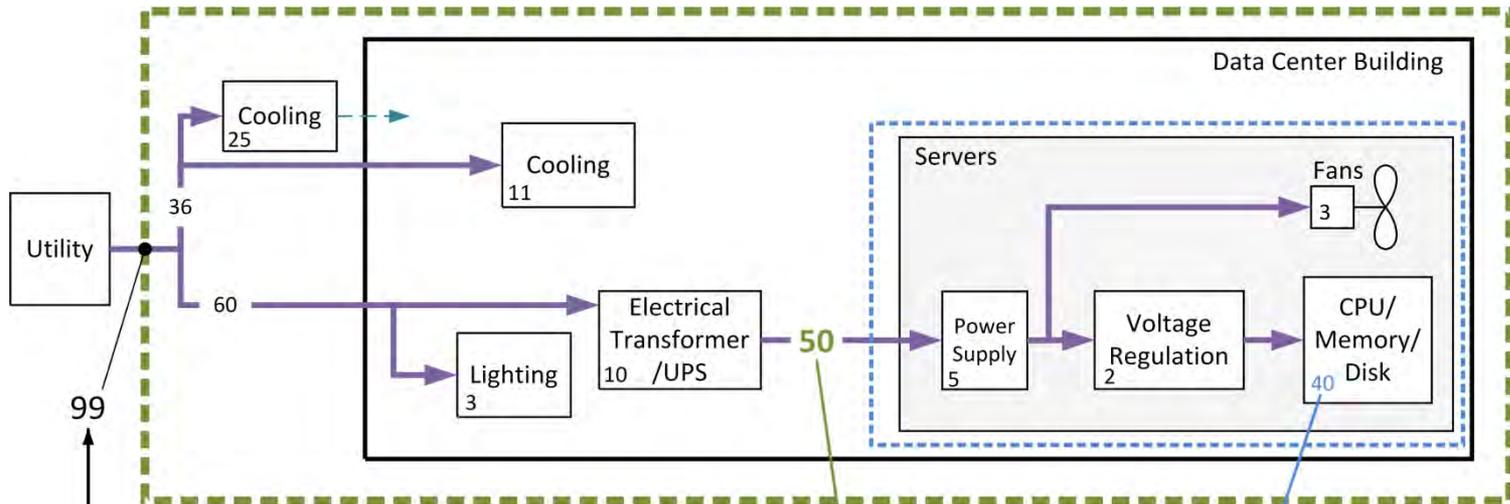
Compute Equipment

- CPUs
- Memory
- Storage
- Networking



How Does TUE Work?

Simple TUE Example



$$PUE = (25 + 11 + 3 + 10 + 50) / 50 = 1.98$$

$$\text{Data Center} = 1.98 * 50 = 99$$

$$TUE = ITUE \times PUE$$

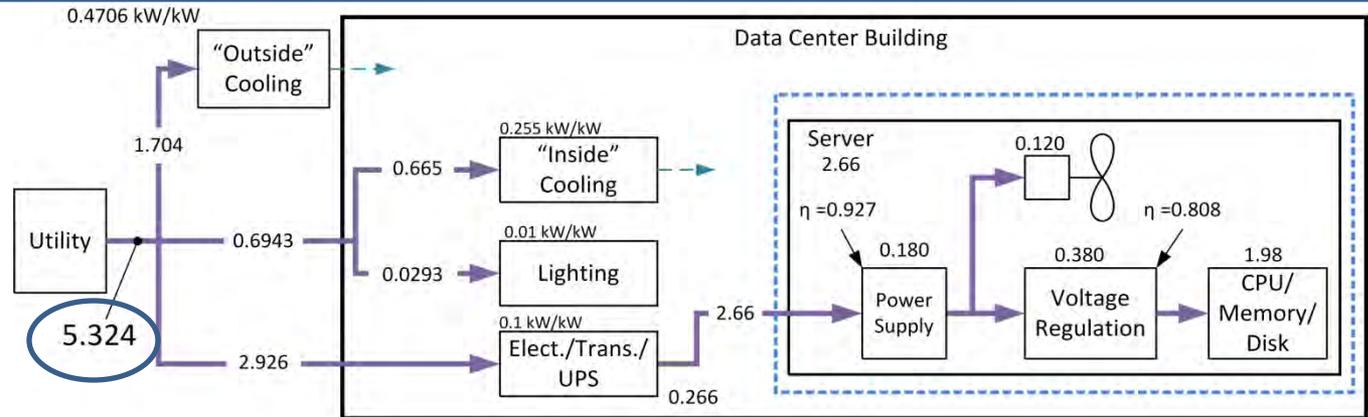
$$TUE = 1.25 \times 1.98 = 2.475$$

$$\text{Data Center} = 2.475 \times 40 = 99$$

$$ITUE = (5 + 2 + 3 + 40) / 40 = 1.25$$

Same Data Center Value
as PUE

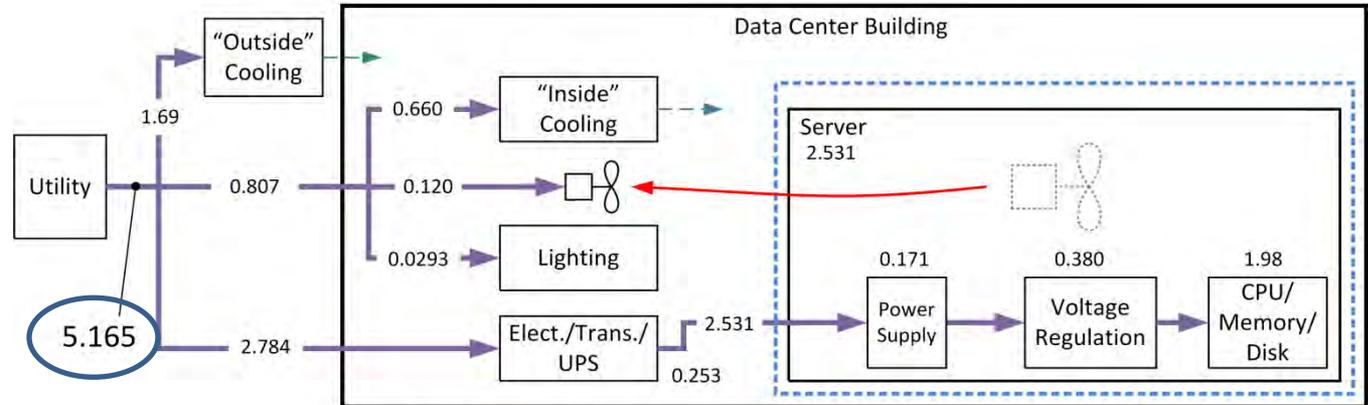
Does TUE Provide The Correct Answer? – Server Fan Move Case



TUE = $(2.00 * 1.343) = 2.68$
 DC Power = $1.98 * 2.68 = 5.32$

PUE = $5.324 / 2.66 = 2.00$ ITUE = $(0.180 + 0.380 + 0.120 + 1.98) / 1.98 = 1.343$

Yes It
Does!



TUE = $(2.04 * 1.278) = 2.61$
 DC Power = $1.98 * 2.61 = 5.16$

PUE = $5.165 / 2.531 = 2.04$ ITUE = $(0.171 + 0.380 + 1.98) / 1.98 = 1.278$

Data Center B uses less power AND has a lower TUE

Conclusions

- PUE is a simple and effective data center energy use efficiency metric, much good has resulted from its use.
- The PUE metric is not perfect for some comparisons.
- A “server-PUE” (ITUE) is introduced and follows the PUE definition.
- ITUE and PUE combine to give TUE. This combination addresses some PUE weaknesses.
- ITUE requires IT equipment internal component information or assumptions

End
Questions?