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GREEN GRID METRICS: DESCRIBING DATACENTER POWER EFFICIENCY

TECHNICAL COMMITTEE WHITE PAPER

ABSTRACT

The Green Grid is an association of IT professionals seeking to dramatically raise the energy efficiency of datacenters through a series of short-term and long-term proposals. For the short term, The Green Grid is proposing the use of Power Usage Effectiveness (PUE) and Datacenter Efficiency (DCE) metrics, which enable datacenter operators to quickly estimate the energy efficiency of their datacenters, compare the results against other datacenters, and determine if any energy efficiency improvements need to be made. In the long term, The Green Grid is proposing the Datacenter Performance Efficiency (DCPE) metric and a refined version of the PUE metric be adopted for all major power-consuming subsystems in the datacenter. To promote these metrics and drive greater datacenter energy efficiency for businesses around the world, The Green Grid will publish future white papers that provide detailed guidance on using these metrics. We will also continue to collaborate with organizations such as the EPA and ECMA that promote a similar goal and vision.

BACKGROUND

The Green Grid is a non-profit trade organization of IT professionals that addresses power and cooling requirements for datacenters and the entire information service delivery ecosystem. The Green Grid does not endorse any vendor-specific products or solutions, but instead provides recommendations on best practices, metrics, and technologies designed to improve overall datacenter efficiency.

INTRODUCTION

The Green Grid believes that several metrics can help IT organizations better understand and improve the energy efficiency of their existing datacenters, as well as help them make smarter decisions on new datacenter deployments. In addition, these metrics provide a dependable way to measure their results against comparable IT organizations.

Why the need for greater energy efficiency? Because datacenter power and cooling are two of the biggest issues facing IT organizations today, and growing companies need a way to control these costs while enabling future expansion. With more efficient datacenters, IT organizations can better manage increased computing, network, and storage demands, lower energy costs, and reduce total cost of ownership (TCO)—all while remaining competitive and able to meet future business needs.[1]

SHORT TERM (TACTICAL)

The Green Grid recognizes the importance of establishing metrics for datacenter efficiency, and offers guidance on technologies that claim to improve performance-per-watt. Ideally, these metrics and processes will help determine if the existing datacenter can be optimized before a new datacenter is needed.

The Green Grid supports two related metrics that have been recently introduced to the industry. These new metrics are Power Usage Effectiveness (PUE)[2] and Datacenter Efficiency (DCE)[2,3].

Power Usage Effectiveness (PUE) and Datacenter Efficiency (DCE)

The PUE is defined as follows:

$$PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

and its reciprocal, the DCE is defined as,

$$DCE = \frac{\text{IT Equipment Power}}{\text{Total Facility Power}}$$

For equations 2 and 3, the Total Facility Power is defined as the power measured at the utility meter—the power dedicated solely to the datacenter (this is important in mixed-use buildings that house datacenters as one of a number of functions). The IT Equipment Power is defined as the equipment that is used to manage, process, store, or route data within the raised floor space. It is important to understand the components for the loads in the metrics, which can be described as follows:

1. **IT Equipment Power.** This includes the load associated with all of the IT equipment, such as compute, storage, and network equipment, along with supplemental equipment such as KVM switches, monitors, and workstations/ laptops used to monitor or otherwise control the datacenter.
2. **Total Facility Power.** This includes everything that supports the IT equipment load such as:
    - Power delivery components such as UPS, switch gear, generators, PDUs, batteries, and distribution losses external to the IT equipment.
    - Cooling system components such as chillers, computer room air conditioning units (CRACs), direct expansion air handler (DX) units, pumps, and cooling towers.
    - Compute, network, and storage nodes.
    - The decreased efficiency of UPS equipment when run at low loads.
    - Other miscellaneous component loads such as datacenter lighting.

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The PUE and DCE provide a way to determine:

- Opportunities to improve a datacenter's operational efficiency.
- How a datacenter compares with competitive datacenters.
- If the datacenter operators are improving the designs and processes over time.
- Opportunities to repurpose energy for additional IT equipment.

While both of these metrics are essentially the same, they can be used to illustrate the energy allocation in the datacenter differently. For example, if a PUE is determined to be 3.0, this indicates that the datacenter demand is three times greater than the energy necessary to power the IT equipment. In addition, the ratio can be used as a multiplier for calculating the real impact of the system's power demands. For example, if a server demands 500 watts and the PUE for the datacenter is 3.0, then the power from the utility grid needed to deliver 500 watts to the server is 1500 watts. DCE is quite useful as well. A DCE value of 0.33 (equivalent to a PUE of 3.0) suggests that the IT equipment consumes 33% of the power in the datacenter.

In Figure 1, Total Facility Power is measured at or near the facility utility's meter(s) to accurately reflect the power entering the datacenter. This should represent the total power (for which the utility charges) consumed in the datacenter. The datacenter-only portion of a building utility meter should be measured since power not intended to

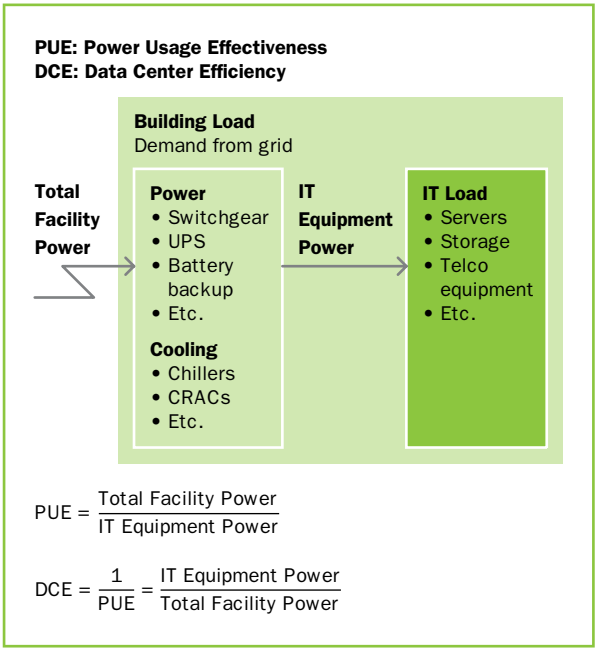

Figure 1: Illustration of How PUE and DCE Would Be Calculated In A Datacenter

be consumed in the datacenter would result in faulty PUE and DCE metrics. For example, if a datacenter resides in an office building, total power drawn from the utility will be the sum of the Total Facility Power for the datacenter, and the total power consumed by the non-datacenter offices. In this case the datacenter administrator would have to measure or estimate the amount of power being consumed by the non-datacenter offices (an estimation will obviously introduce some error into the calculations).

IT Equipment Power would be measured after all power conversion, switching, and conditioning is completed and before the IT equipment itself.

The most likely measurement point would be at the output of the computer room power distribution units (PDUs). This measurement should represent the total power delivered to the compute equipment racks in the datacenter.

The PUE can range from 1.0 to infinity. Ideally, a PUE value approaching 1.0 would indicate 100% efficiency (i.e. all power used by IT equipment only). Currently, there are no comprehensive data which show the true spread of the PUE for datacenters. Some preliminary work indicates that many datacenters may have a PUE of 3.0 or greater, but with proper design a PUE value of 1.6 should be achievable[4]. This theory is supported by measurements completed by Lawrence Berkley National Labs[5] which shows that the 22 datacenters measured had PUE values in the 1.3 to 3.0 range. Other research indicates that PUE values of 2.0 are achievable with proper design[6]. However, there is currently no comprehensive industry data set that shows accurate PUE statistics for datacenters. Furthermore, there is no general agreement on what constitutes an efficient or inefficient datacenter. In the future The Green Grid will offer values that profile target PUE and DCE metrics for a variety of typical datacenter configurations.

In the short term, The Green Grid suggests that datacenter owners begin using the PUE metric. While the measurement points may not be clearly defined, The Green Grid feels it is important to begin estimating datacenter efficiency, even if the method currently requires data manipulation. In addition, The Green Grid also encourages datacenter owners to share and compare their respective PUE results, which will help each datacenter owner better analyze their PUE methodology as well as understand how their results compare to the rest of the industry.

LONG TERM (STRATEGIC)

A mixed-use building may house any number of functions, such as datacenter(s), labs, offices, etc. For these types of mixed-use environments, determining the power usage of just the datacenter environment is difficult. This is particularly true when the utility power grid enters the building through a single entrance point (e.g., through a utility room) and is then distributed to various building locations. These building configurations also make it difficult to determine the power losses between the power entry into the building and its delivery to the datacenter.

To further complicate the calculation of PUE and DCE, the latest cooling technologies integrate cooling elements such as pumps, refrigeration, blowers, and heat exchangers within the IT equipment itself. These technologies blur the lines between what has traditionally been a clear delineation between facility equipment and IT equipment. However, equipment used to provide power and cooling to the datacenter must be accounted for in the metrics described in this paper.

As part of the effort to promote dramatic efficiency improvements in the datacenter, The Green Grid will provide clearer distinctions between facility and IT equipment and recommend power consumption measuring techniques throughout the datacenter, as well as for the equipment itself.

DATACENTER PERFORMANCE EFFICIENCY (DCPE)

For the long term, The Green Grid proposes the Datacenter Performance Efficiency (DCPE) metric. The DCPE is the natural evolution from PUE and DCE and is described as follows:[4]

$$DCPE = \frac{\text{Useful Work}}{\text{Total Facility Power}}$$

While the DCPE is much more difficult to determine, members of The Green Grid feel that this is a key strategic focus for the industry. In effect, this calculation defines the datacenter as a black box–power goes into the box, heat comes out, data goes into and out of the black box, and a net amount of useful work is done by the black box. This in some ways parallels the work being done with the EPA and Standard Performance Evaluation Corporation (SPEC) at the server level in which the SPEC working group may produce a standard on the performance of a system, and the EPA provides a process by which to measure power consumed by the server. The Green Grid hopes to eventually increase the scope of that work to all IT equipment and will require broad participation from the IT community to help guide and define this work.

FURTHER POWER USAGE EFFECTIVENESS (PUE) DEVELOPMENTS

The Green Grid will also consider the development of metrics that provide more granularity for the PUE metric by breaking it down into the following components:[5]

PUE = Cooling Load Factor (CLF) + Power Load Factor (PLF) + 1.0

Where all factors are ratios that are divided by the IT Load and:

- 1.0 represents the normalized IT Load. Effectively this is the IT Load Factor (ILF) but is always 1.0.
- Cooling Load Factor (CLF) is the total power consumed by chillers, cooling towers, computer room air conditioners (CRACs), pumps, etc. normalized by the IT Load.
- Power Load Factor (PLF) is the total power dissipated by switch gear, uninterruptible power supplies (UPSs), power distribution units (PDUs), etc. normalized by the IT Load.

These metrics will be designed to address the blurring of the lines between the IT equipment and facility infrastructure as discussed above. The Green Grid will look at these and other possible PUE-related metrics in the future.

COMPONENT EFFICIENCY STANDARDS

The Green Grid will also work with the industry to define energy efficiency guidelines for all of the components in the datacenter. Such components include the following:

- Uninterruptible power supplies (UPS)
- Switch gear
- Chillers
- Computer room air conditioners
- Direct expansion (DX) units
- Pumps
- Cooling tower
- Generators
- Distribution losses external to the racks
- Power distribution units (PDUs)
- Batteries
- Lighting
- Servers
- Storage

This effort will require close collaboration with other industry bodies such as the American Society for Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).

CONCLUDING REMARKS

In addition to developing best practices, metrics, guidelines, and standards to help lower IT power consumption, The Green Grid also proposes defining metrics at the rack level as rack-level cooling solutions become more prominent. The group will also offer guidance for measuring both power consumption and "useful work" at both the facility and rack levels, and will continue to provide technical updates as these metrics and measurement techniques evolve.

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