Carbon Usage Effectiveness (CUE): A Green Grid Data Center Sustainability Metric

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Executive Summary

The Green Grid (TGG) is a global consortium of companies, government agencies, and educational institutions dedicated to advancing energy efficiency in data centers and business computing ecosystems. In this paper, The Green Grid proposes the use of a new metric to complement the series of metrics that TGG has introduced in the past few years, which includes power usage effectiveness (PUE), data center energy productivity (DCeP), energy reuse effectiveness (ERE), and others. The new metric addresses data center–specific carbon emissions, which is emerging as an extremely important factor in the design, location, and operation of these facilities today and in the future. This white paper introduces the carbon usage effectiveness (CUE) metric. CUE, combined with PUE, enables data center operators to quickly assess the relative sustainability of their data centers, compare the results, and determine if any energy efficiency and/or sustainable energy improvements need to be made. Since PUE has received broad adoption in the industry, the CUE metric is a natural extension of PUE and drives a family of *x*UE metrics.

In addition to the *x*UE family of metrics that will address several key energy and sustainability elements in the data center, The Green Grid also is developing more advanced metrics, such as those pertaining to data center productivity. To promote all these metrics and encourage greater data center energy efficiency for businesses, academia, and governments around the world, The Green Grid will continue to create white papers, technical briefs, books, and articles. The Green Grid also will host and support technical forums that provide detailed guidance on using its metrics and develop alliances with government agencies and non-governmental organizations (NGOs) that promote similar goals and visions.

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I. Introduction

The Green Grid believes CUE and PUE can help IT organizations better understand and improve the sustainability and energy efficiency of their existing data centers, as well as help them make smarter decisions on new data center deployments. In addition, these metrics provide a way for organizations to compare results with similar data centers.

Why the need for improved sustainability? Because data center power footprint, energy usage, and carbon emissions are affecting companies' decisions on growth, building locations, and outsourcing strategies. Because PUE has proven to be an effective industry tool for measuring infrastructure energy efficiency, The Green Grid believes that it is extremely important for the industry to promote efficiencies in other dimensions to maximize operational efficiency and reduce negative impacts on resources and the environment. With more sustainable data centers, IT organizations can better manage increased computing, network, and storage demands; decrease energy costs; and reduce total cost of ownership (TCO)—all while remaining competitive and able to meet future business needs. Clearly, the site-location risks of carbon taxation and energy prices are major factors in decision making for multiple areas related to data centers. Organizations that focus proactively on these issues will lower their business risks, increase their potential for growth, and better manage their environmental costs.

II. A New Sustainability Metric: CUE

The Green Grid recognizes the importance of establishing metrics for data center sustainability. Ideally, these metrics and their related processes will help organizations determine if an existing data center can be optimized before a new data center is needed. For this reason, The Green Grid proposes the use of a new metric, carbon usage effectiveness (CUE), to address carbon emissions associated with data centers. The impact of operational carbon usage is emerging as extremely important in the design, location, and operation of current and future data centers. When used in combination with the power usage effectiveness (PUE) metric, data center operators can quickly assess the sustainability of their data centers, compare the results, and determine if any energy efficiency and/or sustainability improvements need to be made. CUE represents

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the second metric (along with PUE) in the family of *x*UE metrics designed to help the data center community better manage the energy, environmental, societal, and sustainability-compliance parameters associated with building, commissioning, operating, and de-commissioning data centers.

Like PUE, CUE uses the familiar value of total IT energy as the denominator. Once determined for PUE, the same value should be used as the denominator for the new metric as well. This commonality of structure will not only simplify CUE use, but it also will ensure that the metric stays linked to the *x*UE family and speed its adoption.

Unlike PUE, CUE has dimensions while PUE is unit-less; its value is energy divided by energy. Another important difference is the range of values. PUE has an ideal value of 1.0, implying that all energy used at the site goes to the IT equipment, and there is no theoretical upper boundary for PUE. CUE has an ideal value of 0.0, indicating that no carbon use is associated with the data center's operations. Like PUE, CUE has no theoretical upper boundary.

Both CUE and PUE simply cover the operations of the data center. They do not cover the full environmental burden of the life-cycle of the data center and IT equipment. For example, attempting to determine the carbon generated in the manufacturing of the IT equipment and its subsequent shipping to the data center would make the metric far too difficult to measure, calculate, or use. The Green Grid considers the full life-cycle to be important to the overall sustainability of the industry but, for practical considerations, they are excluded from this metric. For now, CUE is specifically limited to Scope 1 and Scope 2 emissions.[1]

III. Carbon Usage Effectiveness (CUE)

For data centers that obtain their entire power source from the energy grid and generate no local CO_2, CUE is defined as follows:

$$\text{CUE} = \frac{\text{Total CO}_2\text{ emissions caused by the Total Data Center Energy}}{\text{IT Equipment Energy}} \quad (1)$$

In Equation 1 above, "Total Data Center Energy" is the same value as the numerator of the PUE metric. The numerator in this CUE metric is the total carbon emissions caused by the use of the energy in the PUE metric. The units of the CUE metric are kilograms of carbon dioxide ($kgCO_2eq$) per kilowatt-hour (kWh).

An alternate approach to calculating CUE is to multiply the carbon emission factor (CEF) by the data center's annual PUE:

$$\text{CUE} = \text{CEF} \times \text{PUE} \quad (2)$$

This could also be represented as:

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$$\text{CUE} = \frac{\text{CO}_2 \text{ emitted (kgCO}_2\text{eq)}}{\text{unit of energy (kWh)}} \times \frac{\text{Total Data Center Energy}}{\text{IT Equipment Energy}} \quad (3)$$

In Equation 3 above, PUE is the annual PUE for the data center and CEF is the carbon emission factor[2] ($kgCO_2eq/kWh$) of the site, based on the government's published data[3] for the region of operation for that year. There are numerous sources for such regional information, including reports from the prime utility supplier(s) and various government-based and NGO-based reports. For example, the U.S. Energy Information Administration provides detailed CO_2 and greenhouse gas (GHG) emissions data for all commercial U.S. and many international sources.[4] (Note: CO_2 emissions from operations—as used in the example above—should be derived in accordance with local/regional requirements and published in each company's sustainability report.[5])

For those producing or co-producing electricity on-site or generating CO_2 in other manners (e.g., maintenance operation of diesel generators), the formula remains the same, but the source CO_2 data will come from a combination of:

- The percentage of grid-sourced energy per above sources
- The actual CO_2 emission data from locally produced electricity or generating sources

Ideally, CO_2 emissions data would be gathered from real-time CO_2 meters that collect data from the local power source (natural gas, diesel, fuel oil, coal, turbines/generators/fuel cells, or other). However, if real-time CO_2 emission data is not available, then calculations should be made using the generator manufacturer(s) data for emission and fuel source, calculated for the specific, actual load profile over time. Details for these calculations are not in the scope of this document but will be outlined in future TGG white papers.

Note that, regardless of the existence of on-site generation, CUE is a "source-based" (versus "site-based") metric. Even with on-site generation, that generation is the source of the energy, so it remains a source-based metric, taking into account the carbon generated in the full energy distribution string. A site-based CUE would have little, if any, value.

For Equations 1 and 3, the Total Data Center Energy is defined as the average energy used over a year measured at the point of utility hand-off—the energy that is dedicated solely to the data center. (This is an important distinction in mixed-use buildings that house data centers as one of a number of functions.) The "IT Equipment Energy" is defined as the equipment energy over the year that is used to manage, process, store, or route data within the data center. PUE is the annual PUE. It is important to understand the components for the loads in the metrics, which can be described as follows:

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1. IT Equipment Energy. This includes the load associated with all of the IT equipment, including compute, storage, and network equipment, along with supplemental equipment such as KVM switches, monitors, and workstations/laptops used to monitor or otherwise control the data center. Following the definition of PUE, this value is the annual total.

2. Total Data Center Energy. This includes the IT equipment energy and everything that supports the IT equipment load, including:

- 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
- Other miscellaneous component loads such as data center lighting
- Total Data Center Energy also includes other energy types beyond electricity, such as the natural gas that runs an absorption chiller

As recommended with PUE, this value is the annual total.

3. Total CO_2 Emissions. This component includes the CO_2 emissions from local and energy grid–based energy sources. Ideally, the CO_2 emissions will be determined for the actual mix of energy delivered to the site (e.g., the electricity may have been generated from varying CO_2-intensive plants—coal or gas generate more CO_2 than hydro or wind. The mix also must include other energy sources such as natural gas, diesel fuel, etc.). The total CO_2 emissions value will include all GHGs, such as CO_2 and methane (CH_4). All emissions will need to be converted to "CO_2 equivalents."[6] As recommended with PUE, this value is the annual total emissions.

CUE provides a way to determine:

- Opportunities to improve a data center's sustainability
- How a data center compares with similar data centers
- If the data center operators are improving the designs and processes over time
- Opportunities for the consideration of renewable power sources
- Tradeoffs in energy efficiency strategies by comparing total CUE under various use scenarios, operating conditions, etc.

In the short term, The Green Grid suggests that data center owners and operators begin thinking about how to adopt the CUE metric to improve the sustainability of their operations. While this metric is not fully detailed at this point, The Green Grid feels it is important to consider carbon emissions in data centers and begin calculating CUE in data center operations, even if the method currently requires estimations and calculations rather than direct measurement. In addition, The Green Grid also encourages data center owners to share and

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compare their respective CUE results, which will help improve the analysis of their measurement methodology as well as understand how their results compare with the rest of the industry.

IV. Long Term

This brief white paper is a first step for laying out the process for how to calculate, measure, and use CUE. The Green Grid plans to expand on CUE and other *x*UE metrics in further detail. However, in the spirit of industry transparency and urgency, TGG released this introductory white paper to encourage industry discussion regarding these metrics. Items already under consideration for future white papers include:

1) Detailed process for determining CUE
2) Measuring CUE for mixed-use buildings
3) Calculating CUE for sites that generate their own power (e.g., using solar panels on the roof of the data center)
4) Dealing with reused or reclaimed energy for other users on the site
5) Determining the CO_2 content of other forms of energy sources (gas, diesel, oil, etc.)
6) Incorporating carbon accounting practices
7) Use of international carbon protocols
8) Life-cycle aspects of carbon and energy (possibly including Scope 3 emissions[7])

One can envision a future scenario where data center location, design, architecture, and infrastructure decisions include PUE, CUE, and other potential metrics as well as the full source energy of delivered, locally produced energy, stored energy, and natural resources.

V. Conclusion

The Green Grid feels that CUE and future *x*UE metrics will have the same positive impact on the industry as did PUE and sees this as a huge opportunity for the industry to rally around. The Green Grid encourages other industry stakeholders to participate in further developing measurement and reporting guidelines for CUE and other *x*UE metrics that The Green Grid creates, adopts, and shares with the industry. Moving forward, The Green Grid recommends the use of CUE even though refinement is needed for this metric.

VI. References

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VII. About The Green Grid

The Green Grid is a global consortium of companies, government agencies, and educational institutions dedicated to advancing energy efficiency in data centers and business computing ecosystems. The Green Grid does not endorse vendor-specific products or solutions, and instead seeks to provide industry-wide recommendations on best practices, metrics, and technologies that will improve overall data center energy efficiencies. Membership is open to organizations interested in data center operational efficiency at the Contributor, General, or Associate member level. Additional information is available at www.thegreengrid.org.

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