SUSTAINABLE DATA CENTERS ROADMAP

TEXT BOX

Data Center Energy Efficiency Metrics

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Over the past two decades, numerous data center energy efficiency metrics have been proposed, yet arguably only one has been adopted on a widespread basis across data center operators, regions and data center types.

This metric is known as **"power usage effectiveness" or PUE**. First introduced in 2007 by the Green Grid,[1] and later institutionalized in the ISO/IEC 30134-2 standard,[2] PUE is calculated as the ratio of a data center's total energy use to the energy use of its IT equipment alone (see Chapter 2.3 of this Roadmap). As such, it provides a measure of how much energy goes to non-IT end uses that do not provide business value. Its theoretical lower limit is 1.0. Several hyperscale operators (e.g., Google, Meta and AWS) regularly achieve fleet averages approaching PUEs of 1.1.

However, PUE does not capture the efficiency of IT equipment nor the efficiency of IT workloads in the data center. Indeed, two data centers with the same PUE can have substantially different IT equipment and workload efficiencies, meaning that PUE cannot be used as a stand-alone comparison between data centers.[3] (See Chapter 2.1 of this Roadmap).

The **"IT power usage effectiveness" (ITUE)** metric aims to better capture how much rack power results in useful computations. It is calculated as the ratio of total energy into IT equipment to the energy use of IT compute components alone. Multiplying ITUE by PUE results in a metric known as **"total power usage effectiveness" (TUE)**, which is the ratio of total data center energy use to the energy use of IT compute components alone. While ITUE and TUE were proposed and demonstrated around 15 years ago, reporting of either is difficult to find.[4,5]

ITUE and TUE can capture the efficiency of providing power to compute components; however, they fall short of measuring the useful work actually done by these components. To address this gap, several metrics have been proposed to quantify workload-level energy efficiencies, including the Green Grid's **"data center energy productivity" (DCeP)**,[6] which is calculated as useful work produced divided

by total energy consumed by the data center, and **"server energy productivity" (SEP)**,[7] which compares the energy consumption of a server in relation to the share of compute work the server is performing. Like ITUE and TUE, however, reporting of these metrics by data center operators is difficult to find.

Most recently, the Green Grid has provided additional guidance for standardizing the calculation of server work capacity for use in "work per unit energy" metrics and reporting moving forward. This metric is known as "**IT Work Capacity (ITWC)**."[8]

Importantly, these metrics and indexes do not accurately capture key environmental parameters, including water consumption or energy-related greenhouse gas emissions. Other metrics have been proposed to quantify, for example, cooling efficiency, waste heat reuse, and energy-related factors like carbon utilization effectiveness and shares of renewable energy. For a detailed review of metrics, see Sustainable Digital Infrastructure Alliance (SDIA) (2025).[7]

References

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