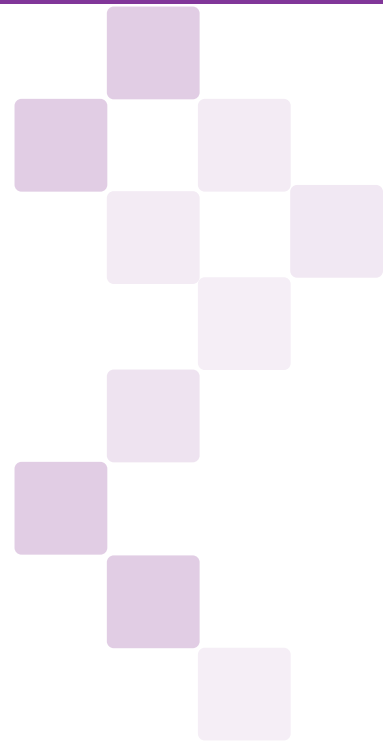


EBOOK

Power Usage Effectiveness (PUE): What You Need to Know



Sunbird[®]

DCIM that's easy, fast, and complete

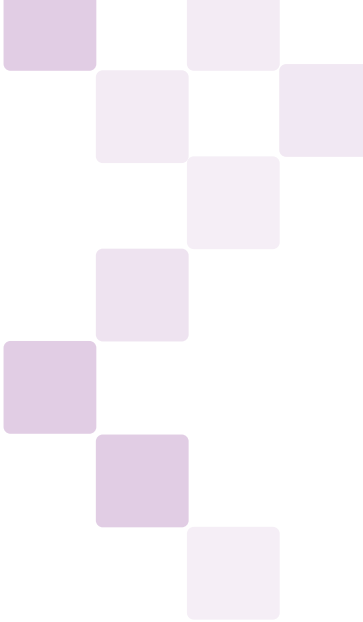
Introduction

Since its introduction, **Power Usage Effectiveness (PUE)** has been widely adopted as a standard metric for evaluating and benchmarking the energy efficiency of data centers worldwide.

The purpose of this eBook is to provide data center professionals with a comprehensive understanding of PUE, why it is important, how it is calculated, how it can be improved, and why it has limitations.



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Understanding PUE

PUE was introduced in 2007 by The Green Grid, a consortium dedicated to advancing energy efficiency in data centers. Since its inception, PUE has been globally adopted and widely reported with its methodology standardized under ISO/IEC 30134-2:2016 and EN 50600-4-2:2016.

PUE is one of the most popular metrics in evaluating the energy efficiency of data center operations. It is expressed as the ratio of total facility energy consumption to the energy consumed by IT equipment. A PUE of 1.0 indicates a perfectly efficient data center in which all of the energy coming into the facility is used by IT equipment and none of it is lost through the power chain or spent on cooling.

Reasons for PUE's Popularity

PUE has reached widespread adoption because it is:

- **Easy to understand.** PUE condenses complex energy consumption data into a simple number that enables stakeholders at all levels to quickly grasp and communicate the efficiency of a data center.
- **Widely applicable.** Most organizations are concerned with energy efficiency as it relates to cost savings, reduced environmental impact, and compliance with regulatory requirements. PUE provides a common metric for assessing energy efficiency across data center environments of all types and sizes.
- **Good for benchmarking.** PUE can be compared across sites or against industry benchmarks to evaluate efficiencies. This enables organizations to set realistic targets, fosters healthy competition, and incentivizes innovation in energy efficiency.
- **Easy to trend.** PUE can easily be measured over time to monitor the effectiveness of energy efficiency initiatives, identify areas for improvement, and reveal how seasonal demand variations and weather patterns impact energy consumption.

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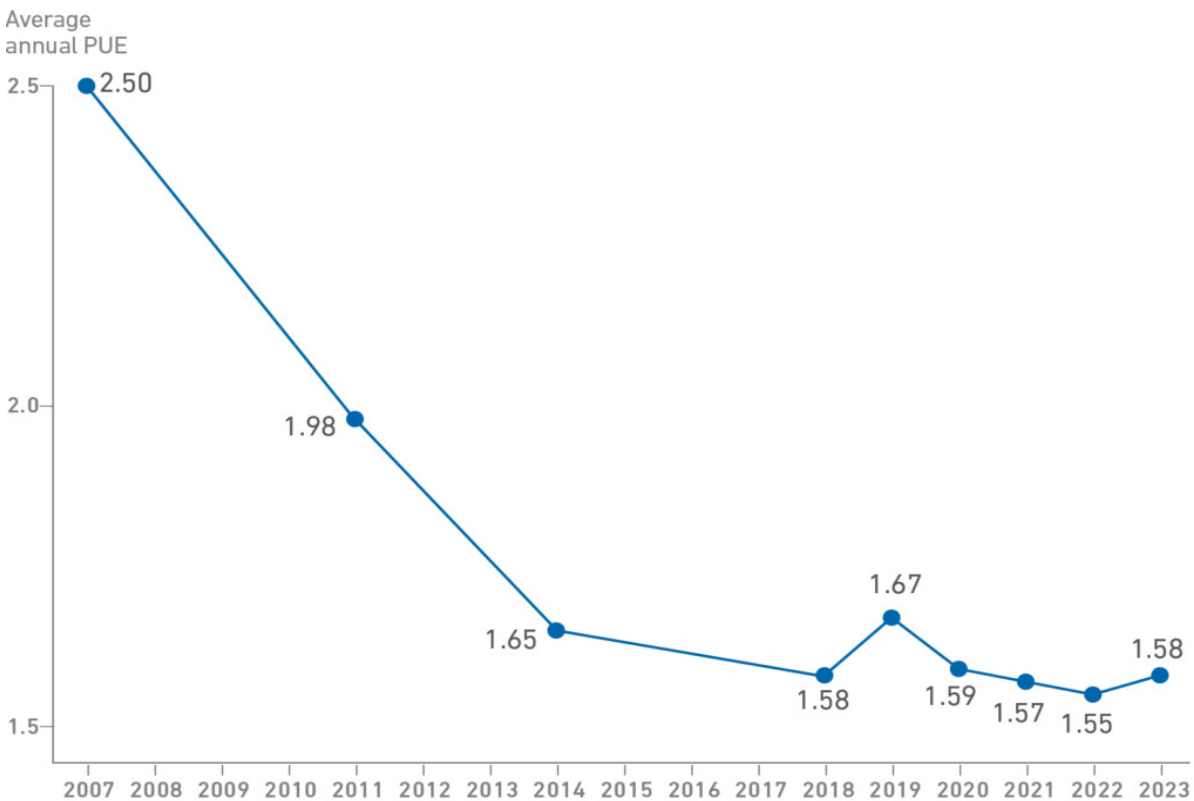
Understanding PUE (continued)

PUE Trends and Benchmarks

When the PUE metric was introduced in 2007, the average PUE industry-wide was 2.5. As PUE became more widely adopted and optimized, it steadily declined down to 1.65. Since then, the average PUE has remained fairly flat, landing at 1.58 in 2023. Many organizations, however, have placed a renewed focus on PUE as sustainability regulations become more stringent.

The average PUE for new, state-of-the-art data centers typically ranges around 1.2 to 1.6. Older data centers or those with less efficient designs and equipment have higher PUEs, sometimes exceeding 2.0.

The most sustainability-minded organizations often target a PUE of 1.2 or less.



Source: [Uptime Institute](#)

Factors That Influence PUE

A multitude of factors play a significant role in determining the PUE of a data center. Understanding these factors is crucial for optimizing energy efficiency and minimizing environmental impact.

The key influences that impact PUE are:

- **IT equipment efficiency.** Modern, energy-efficient servers, storage systems, and networking devices consume less power compared to older, less efficient hardware. Upgrading to more efficient IT equipment can lower the overall power consumption of the data center, shaping its PUE.
- **Cooling systems efficiency.** Since cooling accounts for a substantial portion of a data center's energy consumption, the efficiency of cooling systems directly impacts PUE. Implementing strategies such as containment systems, economizers, and optimized airflow management can enhance cooling efficiency and reduce facility energy usage, thereby lowering PUE.
- **Facility design and layout.** The design and layout of the data center facility influence its energy efficiency and, consequently, its PUE. Factors such as the location of air intakes and exhausts, the arrangement of hot and cold aisles, and the use of efficient building materials all contribute to the overall energy performance of the facility. Well-designed data centers that minimize air mixing and optimize airflow patterns tend to have lower PUE values.
- **Power distribution and conversion losses.** Power distribution infrastructure, including uninterruptible power supply (UPS) units and power distribution units (PDUs), introduce inefficiencies through conversion losses and standby power consumption. Minimizing these losses through the use of high-efficiency components and optimizing power distribution architectures can help reduce overall energy consumption and improve PUE.
- **Operational practices.** Efficient utilization of IT resources, such as server virtualization and workload consolidation, can reduce overall power demand. Additionally, implementing energy-saving practices such as adjusting cooling setpoints based manufacturer and industry guidelines can contribute to lower PUE values.
- **Geographic location and climate.** The local conditions surrounding a data center can impact its cooling requirements and energy efficiency. Data centers located in cooler climates may require less mechanical cooling, resulting in lower energy consumption and PUE. Conversely, data centers in warmer climates or regions with high humidity levels may face greater cooling challenges and higher energy costs.
- **Data accuracy.** Accurate metering of IT and facility energy consumption, proper allocation of IT and non-IT loads, and consistent data collection practices are all necessary for accurate PUE calculations.

PUE Measurement and Reporting

Accurate measurement and reporting of PUE are essential for effectively assessing and optimizing energy efficiency in data centers. Plus, PUE reporting may be a component of compliance with regulatory requirements and industry standards. Familiarize yourself with relevant regulations and standards governing energy efficiency reporting in your jurisdiction, such as ASHRAE guidelines or local energy efficiency regulations.

PUE Measurement Levels

There is a three-level approach to measuring PUE. Each level includes more granular energy consumption data for more accurate PUE calculations.

- **Level 1 (Basic).** The IT load is measured at the UPSs, the facility energy is measured at the utility service, and measurements are manually collected monthly.
- **Level 2 (Intermediate).** The IT load is measured at the floor PDUs or branch circuits, the facility energy is measured at the utility service, and measurements are collected daily.
- **Level 3 (Advanced).** The IT load is measured from outlet-metered intelligent rack PDUs or directly from the devices, the facility energy is measured at the utility service, and measurements are automatically collected every 15 minutes or less.

| How often do I measure? | | Basic | Intermediate | Advanced |
|------------------------------|---|----------------|---------------------------|---|
| IT Equipment Energy | Required | UPS outputs | PDU outputs | IT equipment input |
| Total Facility Energy | Required | Utility inputs | Utility inputs | Utility inputs |
| | Additional recommended measurements* | | UPS inputs/outputs | PDU outputs UPS inputs/outputs Mechanical inputs |
| Measurement Intervals | Required | Monthly | Daily | 15 minutes |
| | Additional recommended measurements* | Weekly | Hourly | 15 minutes or less |

Source: [The Green Grid](#)

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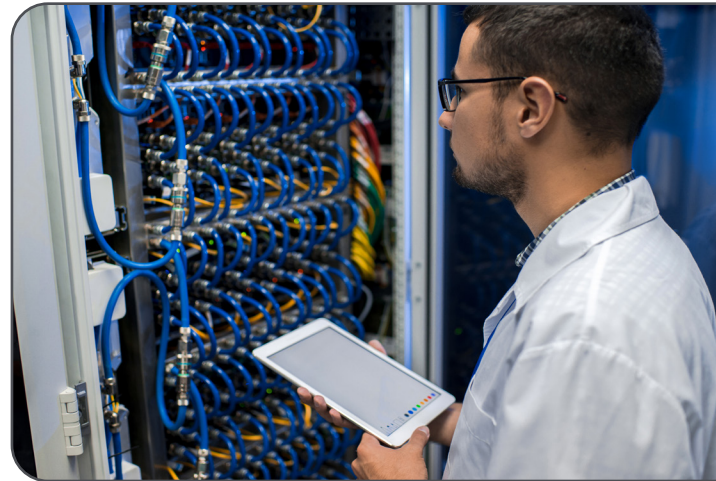
PUE Measurement and Reporting (continued)

Guidelines for Accurate Measurement

- **Define clear boundaries.** Clearly delineate the boundaries of what is an IT load and what is a non-IT load.
- **Rigorous data collection.** Implement robust data collection procedures to capture energy consumption data accurately. Utilize calibrated meters and monitoring devices to measure both total facility energy usage and IT equipment energy consumption.
- **Consistent timeframes.** Use consistent timeframes for collecting energy consumption data to enable meaningful comparisons and trend analysis over time.
- **Transparent reporting.** Clearly document the methodology used for PUE calculation and disclose any assumptions or limitations to ensure transparency in reporting. Regularly reassess PUE measurements to reflect changes accurately.

Common Challenges and Pitfalls

- **Inaccurate data collection.** Incomplete or inaccurate data collection can lead to misleading PUE values. Ensure comprehensive data collection covering all relevant energy sources and loads.
- **Manual effort.** Data collection and PUE calculations can be a manual and time-consuming process.
- **Boundary issues.** Incorrectly defining the boundaries of the data center facility can distort PUE calculations. Exercise care in delineating boundaries to accurately represent energy usage.
- **Variability in IT loads.** Fluctuations in IT workload can impact PUE values. Normalize PUE calculations to account for variations in IT equipment utilization and workload.
- **Operational changes.** Changes in data center operations or infrastructure can affect PUE values. Regularly reassess PUE measurements to reflect changes accurately.
- **Data integrity.** Safeguard against data manipulation or errors to maintain data integrity and ensure the reliability of PUE reporting.



The traditional method of manually collecting energy consumption data and calculating PUE is prone to human error and time-consuming. Fortunately, there is a better way.

DCIM Software and PUE

Leading data center professionals leverage Data Center Infrastructure Management (DCIM) software to simplify data center management and improve energy efficiency, uptime, and productivity. DCIM software can take the manual effort out of data collection and PUE calculations while offering robust functionality to help increase energy efficiency and drive PUE lower.

Automatic PUE Calculations and Reporting

Modern DCIM software does the hard work for you with:

- **Enterprise-class data collection.** DCIM software gathers live measured readings from intelligent rack PDUs, busways, floor PDUs, UPSs, RPPs, branch circuits, and building meters.
- **Easily configurable settings.** Users can set whether individual inlets, outlets, and circuits count toward total power, IT power, both, or neither for each site.
- **Automatic calculations.** The software automatically sums up power readings on a daily and monthly basis and calculate an accurate PUE value.
- **Zero-configuration charts.** An out-of-the-box gauge chart displays the PUE of any site for the time period and granularity that the user selects. In addition, a PUE trend charts displays how a data center's PUE has changed over a time period the user selects.
- **Data-driven collaboration.** PUE charts can be shared on personalized dashboards, in automatically created and scheduled email reports on a recurring basis, and securely posted to your corporate portal.



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DCIM Software and PUE (continued)

More Efficient Facilities to Reduce PUE

- **Real-time monitoring.** DCIM software continuously monitors power usage and environmental conditions in real-time and helps identify areas of inefficiency, allowing data center professionals to quickly address issues and optimize energy usage.
- **Informed capacity planning.** Pre-configured capacity dashboards with real-time gauge charts by resource type let you know your available capacity at a glance. By accurately forecasting capacity requirements and maximizing resource utilization, organizations can minimize stranded capacity and energy waste.
- **Cooling optimization.** With precise temperature monitoring and easy-to-understand cooling charts, you can identify which cabinets are outside of industry or manufacturer guidelines and correctly adjust set points reduce the cooling load and improve energy efficiency.
- **Billback reports.** Energy reports by customer allow you to incentivize energy conservation and accountability and potentially identify power hogs and areas where efficiency can be improved.



PUE and Sustainability

Reducing PUE often aligns with sustainability goals. Data center sustainability aims to reduce environmental impact through efficient energy use, minimizing waste, and maximizing resource utilization.

The Role of Metering and Monitoring in PUE and Sustainability

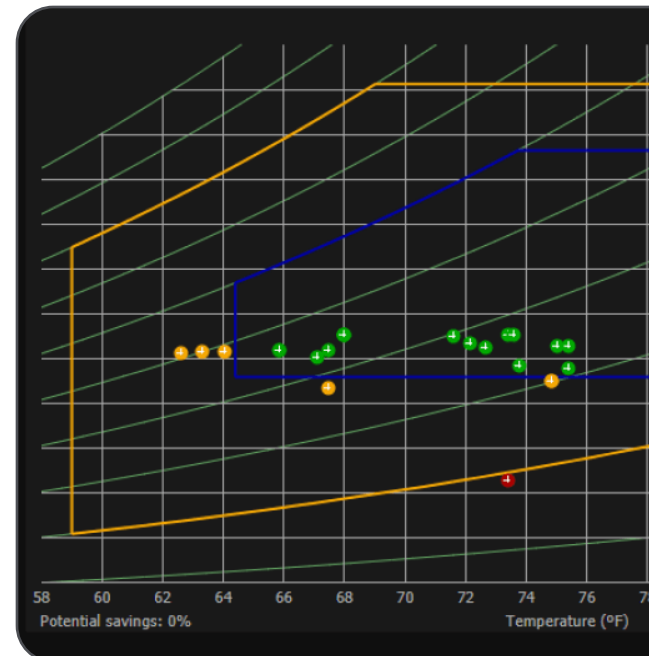
To accurately measure PUE and identify opportunities for improvements, data centers need precise data on energy consumption.

- **Granular data collection.** Some intelligent PDUs provide detailed energy consumption data at the outlet level. This enables you to monitor the energy use of individual servers and other IT equipment at PUE Level 3.
- **Comprehensive monitoring.** DCIM software aggregates data from various meters and sensors, offering a holistic view of the data center's energy consumption patterns. It tracks real-time power usage, temperature, humidity, and other environmental factors.
- **Identifying inefficiencies.** With detailed information from outlet-metered intelligent rack PDUs and DCIM software, you can pinpoint inefficiencies like energy-consuming ghost servers or overcooled racks.
- **Opportunities for optimization.** The insights gained from metering and monitoring reveal opportunities to increase efficiency. This might include consolidating workloads, adjusting set points, optimizing physical server placement, or upgrading to more energy-efficient hardware.

Enabling Better Sustainability Through PUE Monitoring

Tracking PUE can lead to more sustainable data centers via:

- **Reduced energy consumption.** By identifying and addressing inefficiencies, you can reduce overall energy consumption. This improves sustainability by decreasing carbon emissions.
- **Resource optimization.** Efficient use of space, power, and cooling resources, driven by granular monitoring, ensures that data centers can do more with less, or do more with existing.
- **Long-term planning.** Continuous monitoring, analysis, and action helps in improving efficiency over time. This proactive approach supports long-term sustainability goals by ensuring that the data center remains energy-efficient and environmentally friendly.

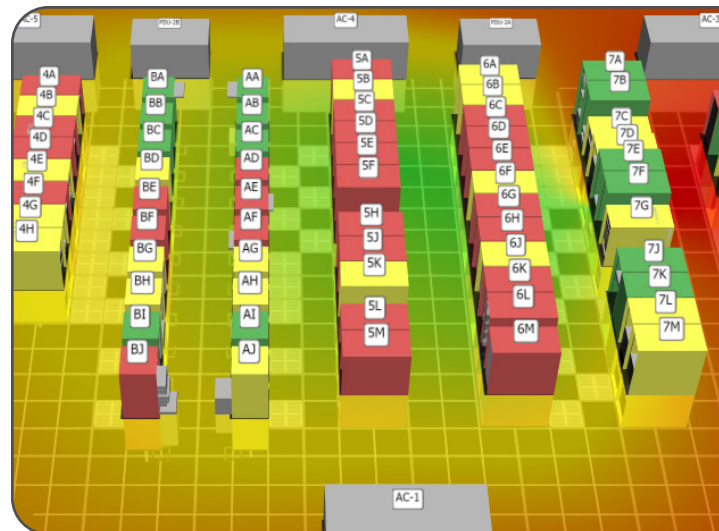


Other Strategies for Improving PUE

Optimizing data center energy efficiency is a multifaceted endeavor that requires a combination of best practices, innovative technologies, and strategic planning.

Consider the following strategies:

- **Implement energy-efficient technologies.** Embrace state-of-the-art hardware solutions such as energy-efficient IT equipment, outlet-metered intelligent rack PDUs with environmental sensors, and modern lighting systems to reduce energy consumption. More modern IT equipment not only consumes less energy, but typically provides more computational power per kW and generates less heat which may reduce the necessary cooling load.
- **Reduce cooling loads and enhance airflow management.** Optimize airflow within the data center by implementing proper hot/cold aisle containment, sealing cable cutouts, and arranging equipment for optimal airflow patterns. Implement temperature and humidity controls to maintain optimal operating conditions without overcooling.
- **Adopt advanced cooling systems.** Explore advanced cooling solutions such as liquid cooling technologies, including direct-to-chip and immersion cooling, to achieve higher energy efficiency and reduce reliance on traditional air-based cooling systems. Investigate the use of free cooling techniques, such as air-side and water-side economizers, to leverage ambient environmental conditions for cooling without the need for mechanical refrigeration.
- **Virtualize and consolidate.** Implement server virtualization and consolidation strategies to maximize resource utilization and minimize the physical footprint of IT infrastructure. Consolidate underutilized servers and decommission outdated or inefficient hardware to reduce the number of physical servers and associated hardware, which may lead to lower requirements for cooling, power distribution, and other support systems.
- **Deploy a modern DCIM solution.** Deploy DCIM software to gain real-time visibility into energy consumption, environmental conditions, and capacity utilization to identify energy optimization opportunities.

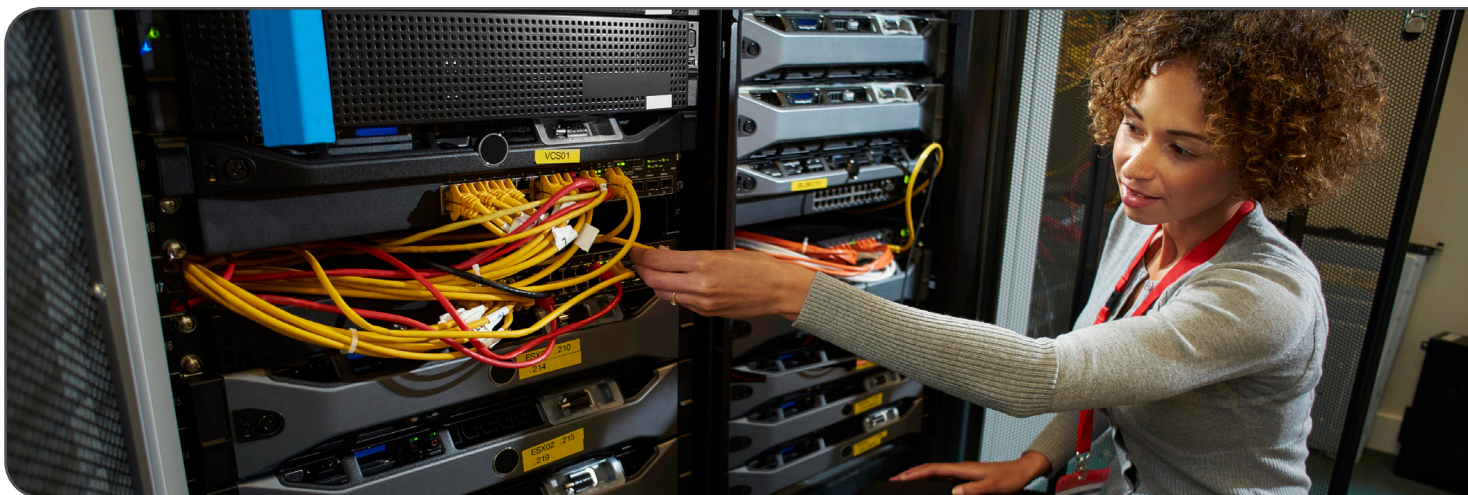


Challenges in PUE Optimization

Optimizing PUE in data center operations is not without its challenges and limitations.

There are several key hurdles that organizations may encounter in their efforts to improve PUE and enhance energy efficiency:

- **Legacy infrastructure constraints and retrofitting challenges.** Legacy data center facilities may pose significant challenges due to outdated infrastructure and design limitations. Retrofitting existing facilities to meet modern energy efficiency standards can be complex and costly, requiring careful planning and investment in upgrades such as cooling system overhauls, equipment replacements, and structural modifications.
- **Balancing performance objectives with efficiency goals.** Striking a balance between performance objectives, such as uptime, reliability, and scalability, and efficiency goals can present a significant challenge. Optimization efforts aimed at improving PUE must take into account the performance and functionality of critical infrastructure systems and applications.
- **Addressing economic considerations.** Economic factors, including capital costs, operational expenses, and return-on-investment projections, play a crucial role in decision-making regarding energy efficiency initiatives. Organizations must carefully assess the cost implications of PUE optimization efforts and evaluate the long-term benefits in terms of energy savings, operational efficiency gains, and potential revenue generation.
- **Evolving regulatory compliance and industry standards.** Data center operators must navigate a complex landscape of regulatory requirements and industry standards governing energy efficiency, environmental sustainability, and data center operations. Adapting to evolving regulations and standards, such as those related to energy efficiency certifications and carbon emissions reporting requires ongoing monitoring and compliance efforts.



Shortcomings of PUE

While PUE is a valuable metric for assessing data center energy efficiency, it is not without its limitations.

Acknowledging these shortcomings is essential for fostering a more nuanced understanding of data center energy efficiency. While PUE provides insights into overall energy consumption and efficiency, it should be complemented by additional metrics and contextual information to provide a comprehensive assessment of sustainability efforts.

Shortcomings of PUE include:

- **Disregard for local climates.** PUE does not account for variations in local climates, which can have a significant impact on data center energy consumption. Data centers located in different geographic regions may experience varying environmental conditions, such as temperature and humidity levels, which can affect cooling requirements and overall energy efficiency.
- **Inverse relationship with IT load reduction.** PUE values may increase when IT load is reduced, such as through server virtualization or hardware consolidation. While reducing IT load can improve overall energy efficiency, it may result in higher PUE values due to a decrease in the denominator (IT equipment energy consumption) relative to the numerator (total facility energy consumption) unless the non-IT load is reduced as well.
- **Potential misuse as a marketing tool.** PUE may be used as a marketing tool to exaggerate environmental credentials without meaningful improvements in energy efficiency. This practice, known as “PUE abuse,” involves selectively reporting PUE values or manipulating data to create a favorable impression of energy efficiency, potentially misleading stakeholders and consumers.



Sustainability KPIs beyond PUE

While PUE is a good metric for evaluating overall data center energy efficiency, it is important to recognize that sustainability encompasses broader considerations beyond energy consumption. There are many additional KPIs that complement PUE to provide a more comprehensive assessment of data center sustainability.

Other important sustainability KPIs include:

Efficiency Metrics

- **Carbon Usage Effectiveness (PUE).** Evaluates a data center's carbon footprint by comparing carbon emissions to energy consumed by IT equipment.
- **Water Usage Effectiveness (WUE).** Tracks the efficiency of a data center's water usage by comparing water consumption to energy consumed by IT equipment.
- **Cabinets compliant with ASHRAE guidelines.** Measures how much progress is being made towards optimal environmental conditions that minimize energy waste from overcooling.

Resource Utilization

- **Virtualization ratio.** Tracks how many VMs are in the environment for every one host to determine the extent to which virtualization technologies are implemented.
- **Facility utilization.** Measures how much data center space capacity is used.
- **Stranded power.** Quantifies the amount of unused power capacity at the site or rack level, highlighting opportunities to utilize existing resources.
- **Server utilization.** Tracks CPU, memory, and disk utilization rates to provide insights into the efficiency of computing resources.

Renewable Energy Usage

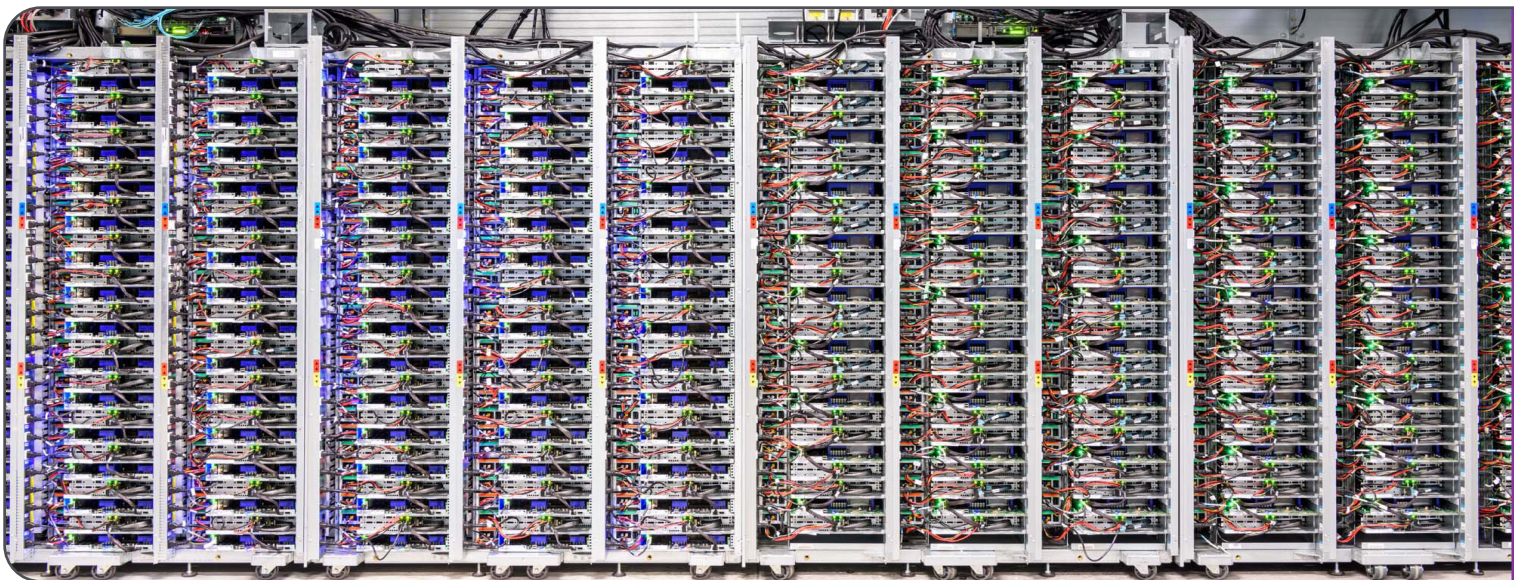
- **Renewable energy percentage.** Indicates the proportion of energy consumed by the data center that comes from renewable resources.
- **Renewable energy capacity.** Measures the installed capacity of renewable energy systems.
- **Carbon emission savings.** Quantifies the reduction in carbon emissions achieved through the use of renewable energy sources.

Examples of data centers with low PUE

A PUE ratio of 1.0 is the theoretical best-case scenario, and the greenest data centers around the world have made incredible progress towards this goal.

Some of the most efficient data centers in the world are:

- Google's combined PUE across their global large-scale data centers is 1.10 while their most efficient site is 1.07.
- LinkedIn's Hilltop, OR data center has a PUE of 1.06 by leveraging by using a waterside economizer that communicates with outside air sensors to take advantage of the naturally cool climate for free cooling.
- Microsoft's Project Natick is an experimental underwater data center that achieved a PUE of 1.07.
- Facebook's newest data centers boast a PUE of 1.09.
- United Airlines' Chicago data center has a PUE of 1.09 due to air-to-air heat transfer technology.
- BitFury's data center in Tbilisi, Georgia has a PUE of 1.02 due to two-phase immersion cooling.
- NREL's Golden, CO site has a PUE of 1.04 by using blade servers with variable speed fans and energy-efficient power supplies, virtualizing 70% of their environment, and using low-energy cooling techniques.
- Verne Global's data center in Keflavik, Iceland achieved a PUE of 1.06 by leveraging free air cooling, geothermal steam, and hydroelectricity from glacial rivers.
- Lefdal Mine Data Center in Norway earns a PUE as low as 1.08 by using a fjord for cooling and power.
- Green House Data's data center in Cheyenne, WY has a PUE of 1.2 because of wind energy and free cooling.



A row of racks in Google's St. Ghislain, Belgium data center. Source: [Google](#)

Conclusion

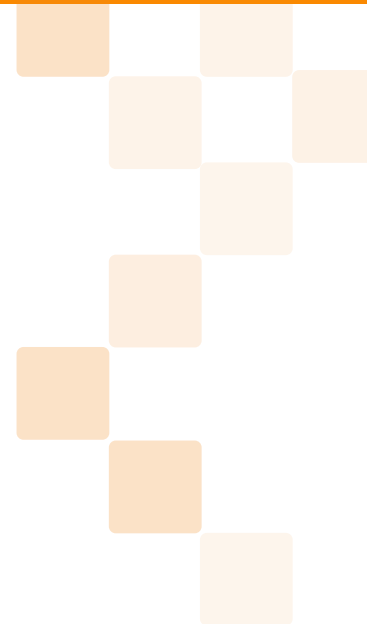
PUE stands as one of the most commonly used metrics for measuring the impact that organizations are making towards more sustainable data centers.

PUE may continue to be relevant as a high-level indicator of energy efficiency, but supplementary metrics may be needed to provide a more granular understanding of energy consumption and efficiency in complex, dynamic data center environments.

By adopting best practices and innovative technologies for data center energy efficiency, automatically calculating PUE with DCIM software, and embracing complimentary metrics, organizations can pave the way for greener data centers.

Other Resources You Might Be Interested In:

- [DCIM Software for PUE Reporting and Optimization](#)
- [How to Measure Data Center Sustainability](#)
- [Top 30 Data Center Sustainability Metrics](#)
- [5 Ways DCIM Software Improves Data Center Sustainability](#)
- [10 Best Practices to Reduce Your Data Center Carbon Footprint](#)



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Schedule a Personalized Demo

Get a one-on-one live tour of our modern data center management software with a DCIM specialist.

[Schedule a Demo Now](#)



DCIM Operations Online Demo

Remote 3D visualizations of all your racks, assets, power, and network connections. View 250+ dashboard charts and reports. Know the capacity of all infrastructure items.

[Try it Free](#)



DCIM Monitoring Online Demo

Remotely monitor rack PDUs, UPSs, branch circuit meters, RPPs, floor PDUs, busways, cameras, door locks, and temperature, humidity, and other sensors. Remote central power control of all servers. See trends, and get alerts.

[Try it Free](#)

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