Intentionally Sustainable Modular Infrastructure

June 2023

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White Paper

Abstract

This white paper highlights Dell's modular data center designs, prioritizing IT performance and reducing infrastructure, power usage, and waste. Learn about energy efficiency, financial savings, and empower yourself to make sustainable decisions.

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Introduction

For over 15 years, Dell has taken an intentionally sustainable approach to modular data center (MDC) design. This started with a focus on the IT and then working out to understand the critical components and processes required to ensuring IT reliability and performance. The approach prioritized a reduction in the facility infrastructure and its associated power consumption and improved time to operation for the end customers. The results helped pioneer the use of fresh air cooling, demonstrated peak partial Power Usage Effectiveness (pPUE) of less than 1.05, and reduced the packaging waste by delivering the MDCs fully integrated with IT. This white paper quantifies the intentionally sustainable approach using some industry-accepted values and provides a formula to determine your potential savings. This paper also calls out the scope and category associated with how these efficiencies can help reduce greenhouse gas emissions.

Understanding PUE

Power Usage Effectiveness (PUE) is a common industry metric used to quantify data center energy efficiency.

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

Ideally PUE has a value of 1.0, meaning that each watt from the utility is used to power the IT. However, this is usually not the case as there is facility overhead for everything from cooling to lighting that can drive energy inefficiencies, and using PUE can help to quantify those inefficiencies. The average annual PUE has remained relatively flat since 2014, with a current average PUE of 1.55. For more information, see the Uptime Institute Global Data Survey 2022.

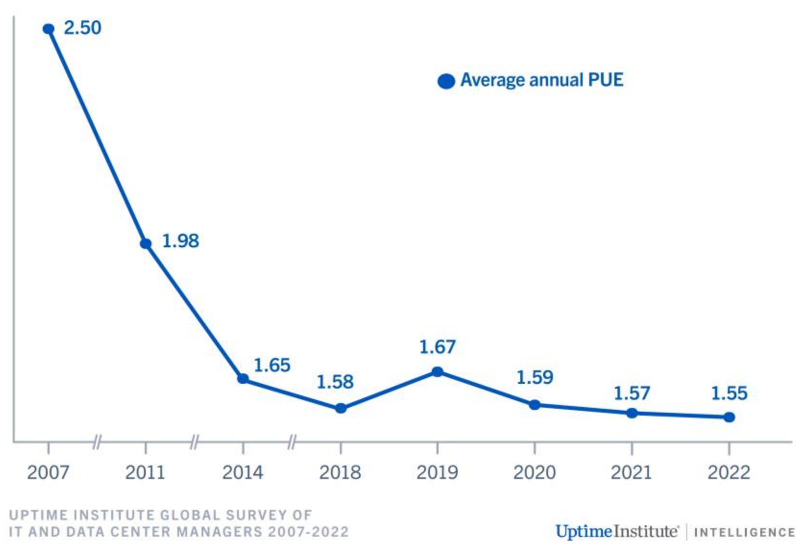

Figure 1. Average annual PUE per Uptime Institute, Intelligence Global Survey of IT and Data Center Managers 2007 to 2022

A PUE of 1.55 indicates that for every 100 watts (W) of IT Power, an additional 55 W is consumed by something other than IT.

Although PUE is a useful metric, it does have some limitations. For example, it does not reward efficiency improvements in the IT design or overall system-level improvements in which an inefficiency in the IT might be moved to the facility to achieve that task at an overall lower total power consumption. Examples of this include removing or reducing fan power from the IT and transferring that task to larger and more efficient facility fans, or by utilizing liquid cooling systems at the facility level.

PUE can and will change based on where the boundaries of the system are drawn. The PUE will worsen in a system that includes all losses out to the substation and will improve if the boundaries are drawn closer to the IT. This latter, partial view of the total system is denoted by pPUE.

Value of improved efficiency

Metrics can provide valuable performance insights but require a knowledge of and familiarity with the metric to understand its implications. For this reason, this paper translates watts to financial impacts.

The average data center

By using the average annual PUE of 1.55 provided by the Uptime Institute, and normalizing this to 1 kilowatt (kW) of IT, the total power consumption would be 1.55 kW on average.

$$PUE * 1\ kW = 1.55\ kW$$

Multiplying this power value by the number of hours per year provides the annual kilowatt-hour (kWh) required to support 1 kW of IT.

$$1.55\ kW * \frac{8760\ hours}{year} = 13{,}578\ kWh$$

Multiply the annual kWh by your energy price to determine the cost to power 1 kW of IT annually based on the average PUE of 1.55. The U.S. national average commercial electricity rate was $0.1252/kWh, and the U.S. national average industrial electricity rate was $0.0791/kWh according to the [U.S. Energy Information Administration for March 2023]().

$$13{,}578\ kWh * \frac{\$0.1252}{kWh} = \$1{,}699.97\ annually\ per\ kW\ of\ IT\ (Commercial)$$

$$13{,}578\ kWh * \frac{\$0.0791}{kWh} = \$1{,}074.02\ annually\ per\ kW\ of\ IT\ (Industrial)$$

Divide the cost value by 1000 to normalize this to a W.

$$\$1{,}699.97\ \div 1000 = \$1.70\ annually\ per\ Watt\ of\ IT\ (Commercial)$$
$$\$1{,}074.02\ \div 1000 = \$1.07\ annually\ per\ Watt\ of\ IT\ (Industrial)$$

The efficient data center

The same methodology can be applied to an energy-efficient data center for comparison. For an example of an efficient data center, we used information from one of Dell's MDC architectures that has been deployed in high volume. The most thermally challenging environment in which the solution was deployed was Phoenix, Arizona, where the PUE of the MDC was measured at 1.043 on a day with a temperature of 115°F in August and measured at 1.018 on a cooler day in February. For more information, see the [Dell Technologies case study.]()

This was a 100 percent fresh air-cooled design (no chiller or other mechanical cooling), which means the PUE included all power to cool and all power transformation below 480 VAC. The upstream elements not captured in these values were UPS (2 to 4 percent losses are typical) and additional transformation and distribution losses. These additional values were not captured in the efficient data center case, so we estimated a 6 percent energy loss for a total PUE of 1.10.

Note: There are no added losses associated with office space for support staff. Dell MDCs are fully autonomous and often deployed in a 'lights out' manner (managed remotely and require a minimum level of human access).

The average data center presented in this white paper yields:

$$PUE * 1\ kW = 1.10\ kW$$

$$1.10\ kW * \frac{8760\ hours}{year} = 9{,}636\ kWh$$

$$9{,}636\ kWh * \frac{\$0.1252}{kWh} = \$1{,}206.43\ annually\ per\ kW\ of\ IT\ (Commercial)$$
$$9{,}636\ kWh * \frac{\$0.0791}{kWh} = \$762.21\ annually\ per\ kW\ of\ IT\ (Industrial)$$

$$\$1{,}699.97\ \div 1000 = \$1.21\ annually\ per\ Watt\ of\ IT\ (Commercial)$$
$$\$1{,}074.02\ \div 1000 = \$0.76\ annually\ per\ Watt\ of\ IT\ (Industrial)$$

Comparison

The difference in the annual price per W for the two scenarios determines annual savings.

$$\$1.70/W - \$1.21/W = \$0.49/\mathrm{W}\ (Commercial)$$
$$\$1.07/W - \$0.76/W = \$0.31/\mathrm{W}\ (Industrial)$$

Normalize this value to MW to determine total savings.

$$\$490{,}000/MW\ per\ year\ (Commercial)$$
$$\$310{,}000/MW\ per\ year\ (Industrial)$$

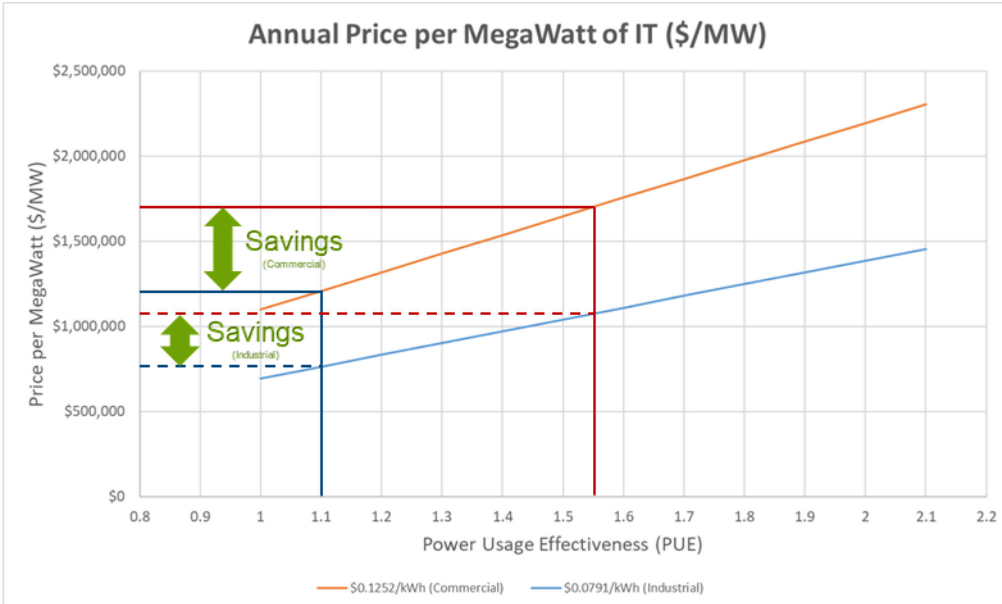

Figure 2. Annual energy savings associated with Data Center Efficiency

Even using the lower price per kWh associated with the industrial sector and neglecting any price increase over time, the 20 year total cost of ownership (TCO) savings associated with energy consumption would be $6,200,000/MW and a reduction in Scope 2 emissions for the user. For more information about Scope emissions, see World Resources Institute and World Business Council: Greenhouse Gas Protocol.

Value of improved efficiency: An alternate approach

The cost savings associated with reducing energy consumption is beneficial, however many customers are primarily concerned with how efficiently they can use the energy that is available to them. This means that for each MW available to them, customers want to use as much of that MW for the IT that runs and supports their applications and data, as opposed to the facility infrastructure. This goes beyond the real-time energy savings associated with infrastructure economization and looks at the reserved power required for the peak consumption of the supporting infrastructure.

This analysis assumes a common data center building block of 1 MW of total available power.

$$PUE = \frac{Total\ Facility\ Energy}{IT\ Equipment\ Energy} = \frac{1{,}000{,}000\ Watts}{IT\ Equipment\ Energy}$$

Use the PUE value to solve for IT Equipment Energy by rearranging the formula and substituting the average data center and efficient data center PUE values from the previous analysis.

$$IT\ Equipment\ Energy = \frac{1{,}000{,}000\ Watts}{PUE}$$

$$IT\ Equipment\ Energy = \frac{1{,}000{,}000\ W}{1.55} = 645{,}161\ W\ (Average\ Data\ Center)$$

$$IT\ Equipment\ Energy = \frac{1{,}000{,}000\ W}{1.10} = 909{,}091\ W\ (Efficient\ Data\ Center)$$

In this analysis, the average data center PUE of 1.55 is annualized instead of the maximum power consumption or peak PUE. A true comparison of peak PUEs would show that more power capacity is allocated to the power or cooling infrastructure for the average data center. This equation demonstrates that the efficient data center allows 40.9 percent more IT in the same power footprint.

$$\frac{|645{,}161 - 909{,}091|}{645{,}161} = 40.9\%\ increase\ in\ deployable\ IT$$

Figure 3 provides a breakdown of the Dell MDC (efficient) PUE and a reasonable estimation of a breakdown of the PUE for the average data center. This estimation assumes that electrical switching, transformation, UPS, and distribution losses are well understood and the primary variation in data center PUE is associated with cooling and additional overhead for office and support personnel and processes.

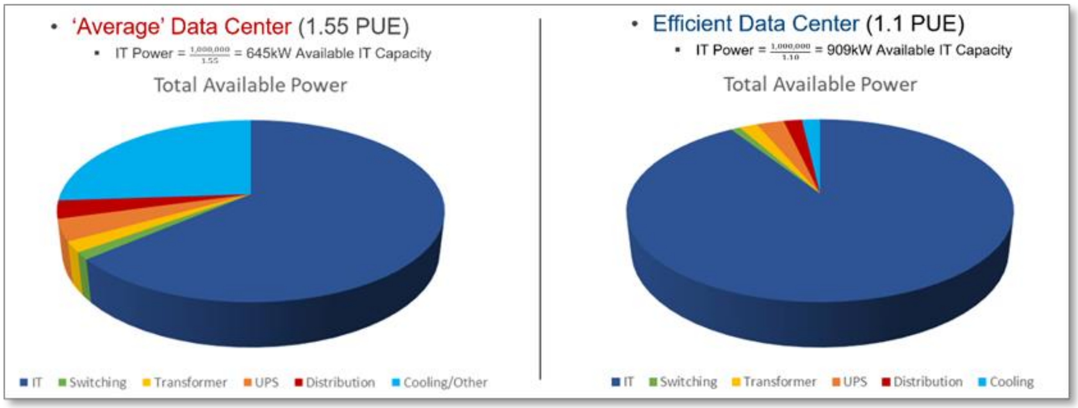

Figure 3. Data center efficiency comparison by category

Non-operational efficiencies

While the efficiency analysis in the previous section primarily focuses on the Scope 3 Category 11 operational savings, there are many Scope 3 Category 1 non-operational efficiencies that will qualitatively be considered below. For more information about Scope emissions, see World Resources Institute and World Business Council: Greenhouse Gas Protocol.

The first non-operational efficiency is that Dell provides the MDCs fully populated with IT. This reduces the time to operation and removes or reduces the labor associated with deploying IT onsite. Additionally, this reduces or eliminates the packaging that would normally accompany each piece of IT equipment and the dependency of a person or persons onsite to recycle appropriately.

Additionally, Dell MDCs are built in a factory where integration processes are performed in parallel, reducing overall time to operation and maintaining consistent quality control across the solutions. This enables a more accurate calculation of materials, using only what is needed and reducing manufacturing waste.

This modular approach goes beyond just building a data center out of ISO containers or purpose-built modular enclosures. Similar to how Dell designs IT, Dell MDCs start with a set of engineered components of various capacities, resiliencies, and technologies that can then be assembled in various form factors to allow for a configurable solution that meets customers' requirements. This means that not only does the customer have the freedom to choose their configuration, but they can also customize and right-size each MDC to the task without requiring additional engineering commonly associated with customization.

Conclusion

This paper explored concepts of sustainability in data centers. Dell's intentionally sustainable approach to MDC design has not only resulted in impressive energy efficiency and cost savings but also offers additional benefits in terms of reduced environmental impact, streamlined deployment, and flexibility in meeting various customer requirements. By quantifying the potential savings and emphasizing the value of improved efficiency, this paper provides insights and a formula for organizations to assess their own data center sustainability and make informed decisions.

We value your feedback

Dell Technologies and the authors of this document welcome your feedback on the solution and the solution documentation. Contact the Dell Technologies Solutions team by email.

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Contributors: Ava English

Note: For links to additional documentation for this solution, see the Dell Technologies Solutions Info Hub.

References

For additional information, see the following documentation:

From the data center floor to the rooftop, eBay drives down transaction costs with Dell Data Center Solutions

Metrics to Characterize Data Center & IT Equipment Energy Use. Proceedings of the Digital Power Forum

GREEN GRID METRICS: Describing Datacenter Power Efficiency

The Green Grid: Forum - eBay Case Study

U.S. Energy Information Administration Monthly Electric Power Industry Report 2023

Uptime Institute Global Data Center Survey 2022

World Resources Institute and World Business Council: Greenhouse Gas Protocol