A White Paper from the Experts
in Business-Critical Continuity™

Energy Logic:
Calculating and Prioritizing Your Data Center IT Efficiency Actions

EMERSON
Network Power

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Executive Summary

Emerson Network Power's Energy Logic[1] white paper provided a holistic, prioritized roadmap for reducing data center energy consumption. Energy Logic did not address data center *efficiency* directly because there is no universally accepted metric for data center output that could be used as the basis for this analysis. Now, the time has come for the industry to take the next step forward in achieving a true understanding of data center efficiency.

The lack of a true data center efficiency metric is challenging to IT and data center managers as they try to justify much needed IT investments to management. It also adds to the difficulty data center managers have in comparing efficiencies across their data centers to prioritize where efficiency-improving actions will have the greatest impact. In addition, they need to be able to track data center efficiencies over time.

This paper not only shows how IT and data center managers can use an efficiency metric to address these challenges, but also provides a prioritized set of actions to gain the greatest improvement in efficiency.

In the interest of furthering discussion on this critical subject, Emerson Network Power used the available information on IT performance improvement and analyzed it to see what insights can be gained. While there is no universally accepted metric for server and data center output, there is significant industry information available on the increase in the "performance" of servers and chips over the past several years. For example, Christian Belady, principal power and cooling architect at Microsoft, has stated that "raw performance" of IT has improved 75-fold in the 10-year period from 1998 to 2007.[2] What has not been clarified by the industry is the specific measure for this performance.

As a first step, Emerson introduces the concept of CUPS, or Compute Units per Second, as a *temporary or placeholder* name for what will eventually be the sought-after universal metric for IT and data center output. Another way to understand what CUPS represents is to think of it as the metric for "performance" referred to in the previous paragraph.

The analysis, which is described in more detail in the body of this white paper, leads to powerful insights in three major areas of importance to all stakeholders and end-users in the IT and infrastructure industries.

First, while there has been a significant increase in energy consumption in IT and data center environments, these increases are considerably overshadowed by dramatic gains in data center output and efficiencies over the last five years. Second, applying the results of the computing performance analysis to Emerson's Energy Logic model yields clear strategies for improving data center efficiency. Third, the analysis leads to a clear direction on the *criteria to be used* for arriving at a universally accepted metric for IT and data center output.

The analysis shows that while energy consumption in data centers nearly doubled in the last five years, data center compute output increased *fourteen-fold*, and data center efficiency increased *eight-fold* over the same period.

While data center energy consumption justifiably gets attention in the industry, the gains in output and efficiency deserve a similar level of consideration. To put this in perspective, if the compute output in 2007 had stayed at the same level as 2002, data center energy consumption in 2007 would have been less than one-eighth of the 2002 level. This increase in compute output directly contributes to business and personal productivity and economic output; reduces travel and other non-value-added activities; enables real-time information for better decision making; and supports the globalization of the economy.

For IT and data center managers, Energy Logic provides a means to identify, justify and prioritize data center efficiency improvement projects as well as specific recommendations for actions that can be taken *today*. The analysis shows that implementing the 10 Energy Logic strategies increases data center efficiency by *3.6 times*. To get the most bang for the buck, the three actions of *faster replacement of IT technologies, virtualization and high density architecture* have the largest impact, improving data center efficiency by 3.1 times.

For the IT industry, this analysis reinforces the urgent need for the industry to move aggressively to define and adopt a measure of IT performance that is scalable to the data center. The analysis also shows that it is not necessary to develop an ideal or perfectly “fair” measure for IT and data center output. The miles-per-gallon (MPG) measure used in the automobile industry is not the fairest measure, but it serves its purpose and works. The three basic criteria for the right metric are: will it drive the right behavior; will it be available and published at the IT device level (to help buyers make the right choice); and is it scalable from the IT device to the data center level.

For IT and data center managers, Energy Logic provides a means to identify, justify and prioritize data center efficiency improvement projects as well as specific recommendations for actions that can be taken today.

Advancing the State of Data Center Efficiency

With the demand for computing rising sharply, and with more of that computing being consolidated in larger facilities, data center energy consumption hit a tipping point in 2005. What had once been a secondary issue suddenly became a priority for data center managers, a hot topic for the media and an area of interest for regulators.

Technology associations and vendors responded by publicizing best practices for improving efficiency, and promoting more efficient technologies. Some of this information was used in the U.S. Environmental Protection Agency's 2007 report to Congress, which concluded that best practices could reduce data center energy consumption by 50 percent by 2011[3]. The report also included a list of the Top 10 Energy Savings Best Practices as identified by the Lawrence Berkeley National Lab.

The EPA report set a clear target for the industry. What was needed was a set of quantified recommendations based on a holistic view of the data center that allowed for prioritization. This need was addressed by Emerson Network Power with the introduction of Energy Logic in 2007.

Energy Logic is a vendor-neutral roadmap for reducing data center energy consumption based on a holistic analysis of the data center. Energy Logic revealed the "cascade effect" that occurs when the energy consumption of core technology systems is reduced, creating a cascade of savings across all supporting systems. Based on a detailed model of a 5,000 square foot data center, Energy Logic demonstrated that a savings of 1 watt at the server component level creates a reduction in facility energy consumption of approximately 2.84 watts (Figure 1).

This allowed energy-saving activities to be prioritized based on their overall impact on data center energy consumption and resulted in a roadmap consisting of the 10 energy saving strategies that deliver the greatest savings (Figure 2).

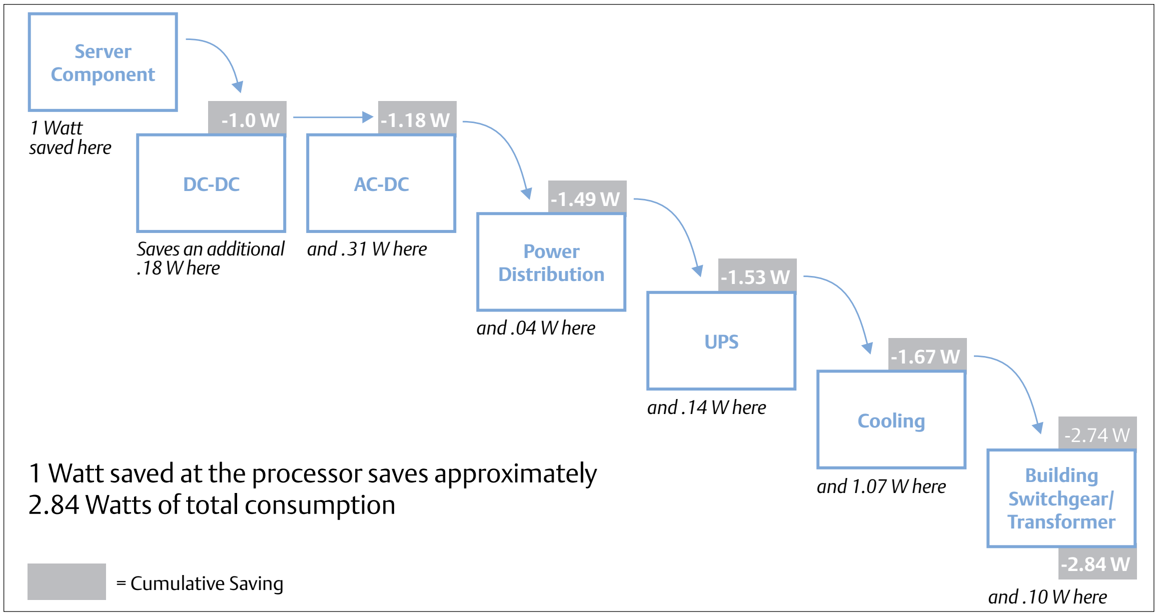

Figure 1. Energy Logic demonstrated how savings at the server component level cascade across supporting systems, increasing their impact.

Energy Logic has been successful in changing the way many organizations view the challenge of data center efficiency. But it did not directly address the issue of efficiency, focusing instead on consumption, because a universally accepted metric for data center work or output is required to support that analysis.

Developing such a metric has proven challenging because of the different types of work data centers perform, from processing-intensive tasks, such as those required for scientific and financial applications, to data transfer-intensive work such as that required to support Web-based applications. Moreover, the requirements of a data center can change over time as the mix between the processing and data transfer workload shifts.

These same issues are hindering efforts by the U.S. EPA to apply ENERGY STAR ratings to servers. Following a July 2008 ENERGY STAR Computer Server Specification Stakeholder Meeting, the agency announced that because there is no accepted measure of server output, initial server ENERGY STAR ratings will not include performance measures but consider only server power supply efficiency and idle power consumption.

The fact that the task is difficult doesn't mean it can be ignored. This metric is the keystone in the industry-wide effort to effectively address the challenge of efficiency. Without it, users lack the means to optimize data center efficiency and the industry lacks the language to communicate effectively about energy efficiency.

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Energy Saving Action	Savings with the Cascade Effect			Payback Period
	Savings (kW)	Savings (%)	Cumulative Savings (kW)	
Lower power processors	111	10%	111	12 to 18 mo.
High efficiency power supplies	124	11%	235	5 to 7 mo.
Power management features	86	8%	321	Immediate
Blade servers	7	1%	328	TCO reduced 38%*
Server virtualization	86	8%	414	TCO reduced 63%**
Higher AC voltage power distribution	20	2%	434	2 to 3 mo.
Cooling best practices	15	1%	449	4 to 6 mo.
Variable capacity cooling	49	4%	498	4 to 10 mo.
Supplemental cooling	72	6%	570	10 to 12 mo.
Monitoring and optimization	15	1%	585	3 to 6 mo.

*Source for blade impact on TCO: IDC. **Source for virtualization impact on TCO: VMware.

Figure 2. Using a model of a 5,000 square-foot data center consuming 1127 kW of power, the actions in the Energy Logic approach work together to produce a 585 kW, or 52% reduction, in energy use.

CUPS represents a proxy for a universal measure of computing output.

Creating a Meaningful Measure

To continue to drive the discussion of data center efficiency forward in a productive way, Emerson Network Power addressed the questions:

- Is it possible to fill the gap that exists in efficiency metrics with a proxy measure for data center output?
- If so, what insights could be gained from such a measure?

There are various measures of performance that have been developed for IT equipment. A summary of these measures is provided in Appendix C.

Server metrics provide the best foundation for a meaningful measure of data center output as they correlate more directly with data center power consumption and output. However, none of the current server performance measures have been widely adopted and it is virtually impossible to find good data on server performance using existing metrics.

It is *not* the objective of this paper to propose or advocate a specific metric of computing output. Our mission is to determine what insights can be gained from a metric and to move the industry closer to adopting such a measure. In addition, changes in software and application efficiency are outside the scope of this paper.

This paper introduces the term *Compute Units per Second (CUPS)*. CUPS represents a proxy for a universal measure of computing output. One MegaCUPS (10^6 CUPS) is equal to the average server performance in 2002. (The performance reference was set as 1 MegaCUPS per server because the objective of the analysis was to understand the impact on efficiency as measured in CUPS/watt. Given that the server power draw is in hundreds of watts, using MegaCUPS as a measure of server performance allowed server efficiency as measured in CUPS/watt to be expressed on an integer rather than a fractional scale.)

CUPS can serve as the numerator in the equation that determines Compute Efficiency, with the power draw as the denominator:
Compute Efficiency = CUPS/Watts Consumed

Although there is a lack of good data on existing server metrics, it is possible to draw reasonable conclusions about how CUPS has changed during the last five years:

- Christian Belady, principal power and cooling architect at Microsoft, has published information that charts an improvement of 650 percent in performance of IT equipment between 2002 and 2007 (Figure 3).[2]

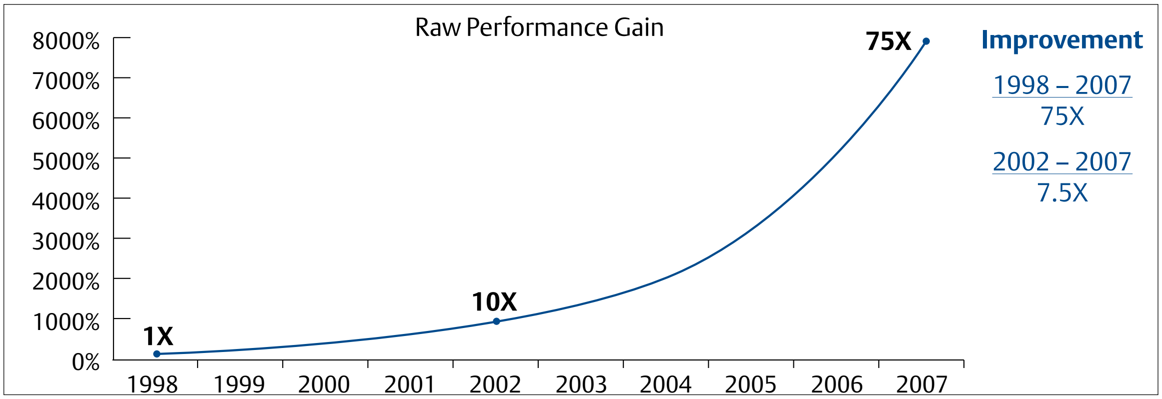


Figure 3. Christian Belady, principal power and cooling architect at Microsoft, stated that IT performance increased 650 percent between 2002 and 2007.

- Information from Intel allows this data to be extrapolated to the device level. According to the company, one x-86-based server in 2007 produced the same number of FLOPS (Floating Point Operations per Second) as 10 x-86-based servers in 2002. This represents an 870 percent improvement in FLOPS/device (Figure 4).

This is consistent with what would be expected from Moore's Law (Figure 5).

Intel x86	2002	2007
TFLOPS	3.7	3.7
Servers	512	53 blades
GFLOPS/server	7.2	69.8

Source: Intel

Figure 4. Intel has calculated the change in the IT hardware required to produce 3.7 TFLOPS in 2002 and 2007. The same output was produced in 2007 with approximately one-tenth the number of servers required in 2002.

Based on these data points, a relatively conservative 600 percent (7x) increase in server performance (MegaCUPS/server) from 2002 to 2007 was used for this analysis.

In the same time period, annual global server shipments increased from 4.59 million to 8.75 million units (Source: Emerson estimates), driving total compute capacity shipped annually from 4.6 TeraCUPS in 2002 to 61.2 TeraCUPS in 2007 (Figure 6).

The total amount of computing output was then derived by combining the total compute capacity shipped with the average server utilization rate. Assuming an average server utilization rate of 16 percent, Total Compute Output increased from 0.7 TeraCUPS in 2002 to 9.8 TeraCUPS in 2007.

For purposes of the analysis, the average server utilization rate was held constant over the time period analyzed. A case can be made that this rate varies over time as newer, higher performing servers are cycled into operation and older servers are cycled out. It should be

Assuming an average server utilization rate of 16 percent, Total Compute Output increased from 0.7 TeraCUPS in 2002 to 9.8 TeraCUPS in 2007.

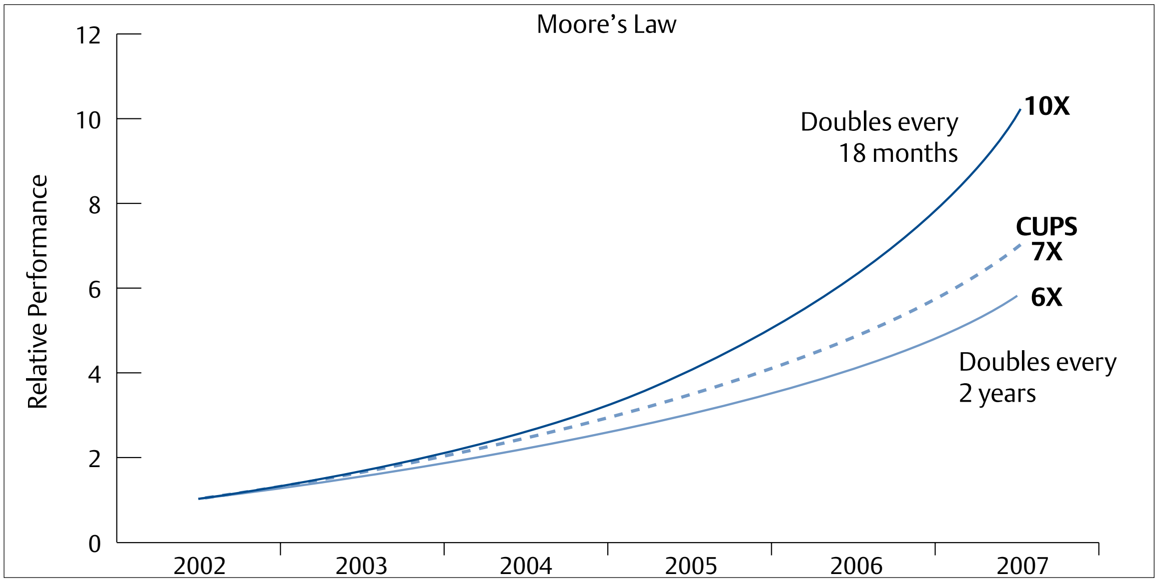


Figure 5. Moore's Law predicts a 10x improvement in processor performance between 2002 and 2007 if performance doubles every 18 months; 6x if performance doubles every 24 months. CUPS is assuming a 7x improvement.

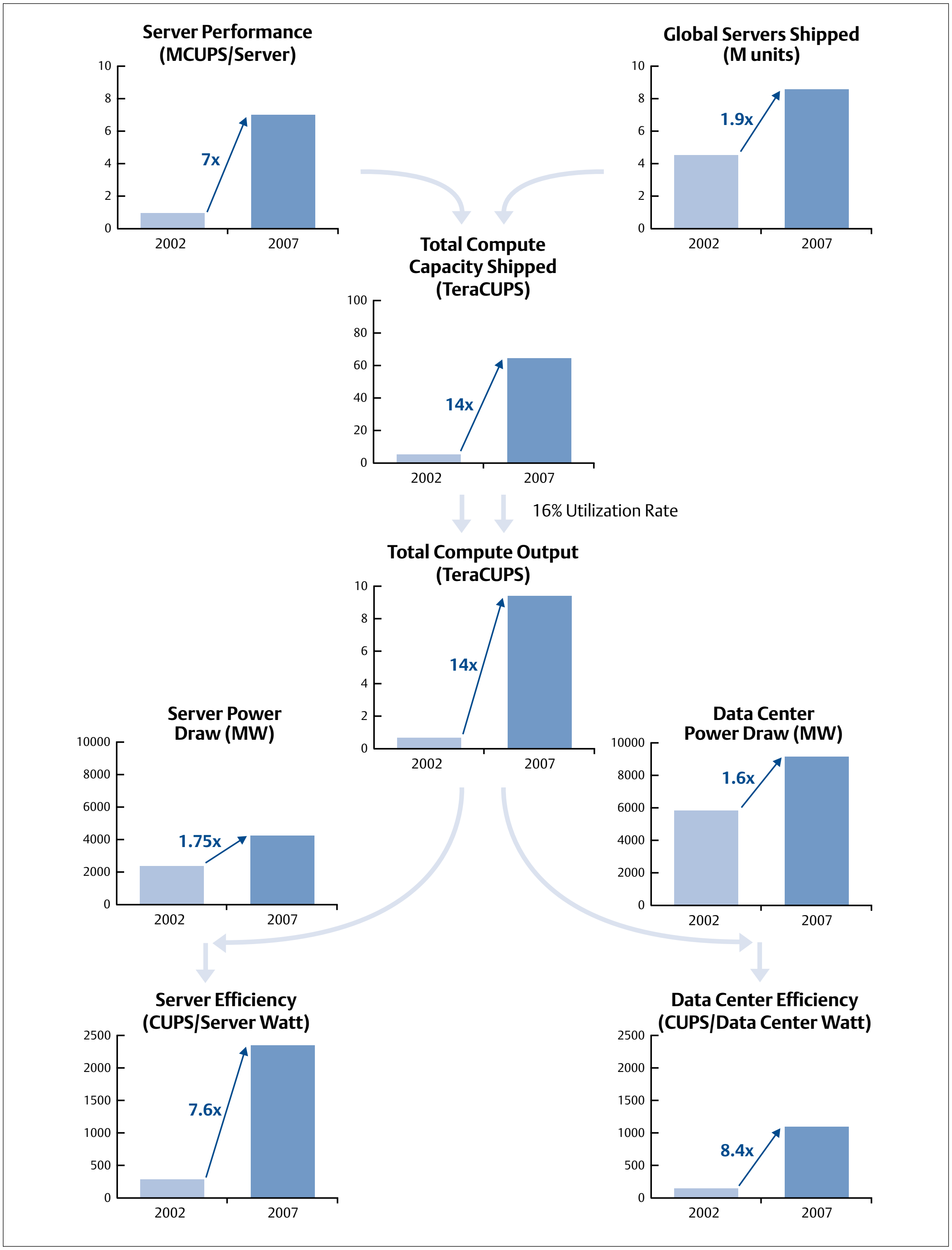


Figure 6. Once the 7:1 ratio between server performance in 2007 and 2002 was established, total server shipments and an assumed 16 percent utilization rate were applied to get an estimate of total TeraCUPS used in 2002 and 2007. This was then divided by server and data center power draw to determine the change in CUPS/Server Watt and CUPS/Data Center Watt between 2002 and 2007.

noted that 16 percent represents an average utilization and incorporating changing utilization rates over time would not materially change the conclusions of the analysis.

This analysis showed an increase in data center power draw of 59 percent between 2002 and 2007. Server power draw rose 76 percent during the same period (Figure 6). This increase has driven much of the recent concern over data center efficiency. However, when it is correlated with CUPS, a clearer picture of IT efficiency emerges:

Server efficiency, measured in CUPS/watt, grew 658 percent (7.6x) between 2002 and 2007. Data center efficiency, aided by infrastructure improvements, achieved even more impressive gains. CUPS/data center watt grew by 738 percent (8.4x) during the same period.

Data center energy consumption is rising because data centers are doing more work—processing and distributing the information that businesses and the economy in general depend on to drive revenue and increase efficiency.

Putting IT Efficiency in Perspective

While the industry focus has been on energy consumption, which rose approximately 9.7 percent annually from 2002-2007, the annual increase in efficiency during this time was 53.1 percent. If the computing demand in 2007 was the same as in 2002, the 2007 power consumption would have been less than one-eighth of 2002 power consumption. Instead, the tremendous increase in computing demand over this time period has been accompanied by an equally impressive increase in computing performance.

This dramatic increase in computing performance has enabled a number of benefits for the global economy and society as a whole.

- Advances in technology have provided for increased collaboration and for automation of data collection and sharing. As a result, the quality and richness of information available has grown exponentially. These advances have resulted in a tremendous increase in productivity, and have reduced the need for business travel.
- Electronic transactions and real-time availability of information has enabled more accurate and efficient decision making. People and companies from around the globe are now connected and have access to higher quality information to make decisions.
- Increasing computing performance has enabled the acceleration of globalization, including global trade, outsourcing, and supply-chain management, and has transformed the world economy.
- Continuing this trend, rapid adoption of 3G technology and advancements in collaboration software is creating strong demand for mobile applications and content.
- The medical industry has moved aggressively to adopt electronic medical records (EMR) systems. Advances in technology are allowing the industry to meet the challenge of having to archive the huge amounts of data being generated by digital diagnostic systems.
- Technology has enabled a multitude of personal convenience services, increasing the quality of life of people around the world.
- The financial sector has been transformed as major stock exchanges adopted all-electronic trading, and businesses and consumers increased their use of electronic banking. Over half the U.S. population now uses online banking.[4]

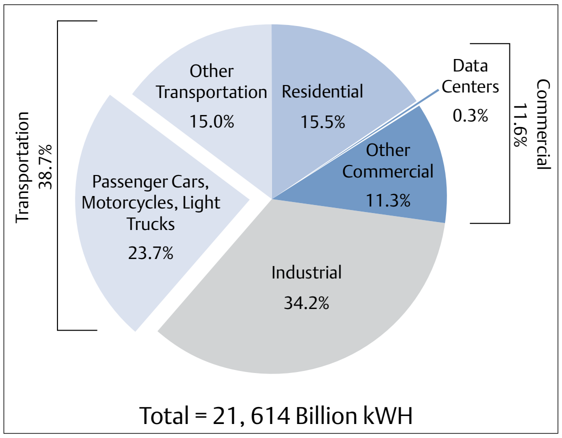
Given that compute output has increased 14 times from 2002 to 2007, the 59 percent increase in data center energy consumption is

Data center energy consumption is rising because data centers are doing more work—processing and distributing the information that businesses and the economy in general depend on to drive revenue and increase efficiency.

Even with the growth that has occurred, data center energy consumption accounts for less than one-half percent of U.S. consumption.

relatively small. And, when the improvement in data center efficiency is compared to other industries, it is difficult to understand why the improvement in data center efficiency is not getting more attention.

The first thing to note is how relatively little energy IT consumes compared to other industries—especially considering the growing role it now plays in business and personal productivity. Even with the growth that has occurred, data center energy consumption accounts for less than one-half percent of U.S. consumption (Figure 7).



Source: Energy Information Administration/Annual Energy Outlook 2008. U.S. EPA Report to Congress. Bureau of Transportation Statistics.

Figure 7. Data center energy consumption accounts for just 0.3 percent of the more than 21 billion kWH of energy consumed in the U.S. annually. This ties in with the EPA's assessment that data centers consume 1.5 percent of total U.S. electric power.

To add perspective to the discussion, the improvements in computing efficiency can be compared to those in the automobile industry. The automobile industry's miles-per-gallon (MPG) standard is often held up as an example of an effective and universally adopted measure of work delivered per unit of energy consumed, and is a convenient metric by which to compare computing efficiency with automobile efficiency.

Figure 8 compares improvements in computing efficiency as measured by CUPS/watt with automobile efficiency as measured in MPG.

While auto efficiency achieved a modest 0.8 percent compound annual growth rate, data center efficiency grew by 53 percent annually. If fuel efficiency had kept pace with data center efficiency improvements, the current generation of automobiles would average 163 MPG.

This analysis is in no way intended to be critical of the efficiency improvements of the

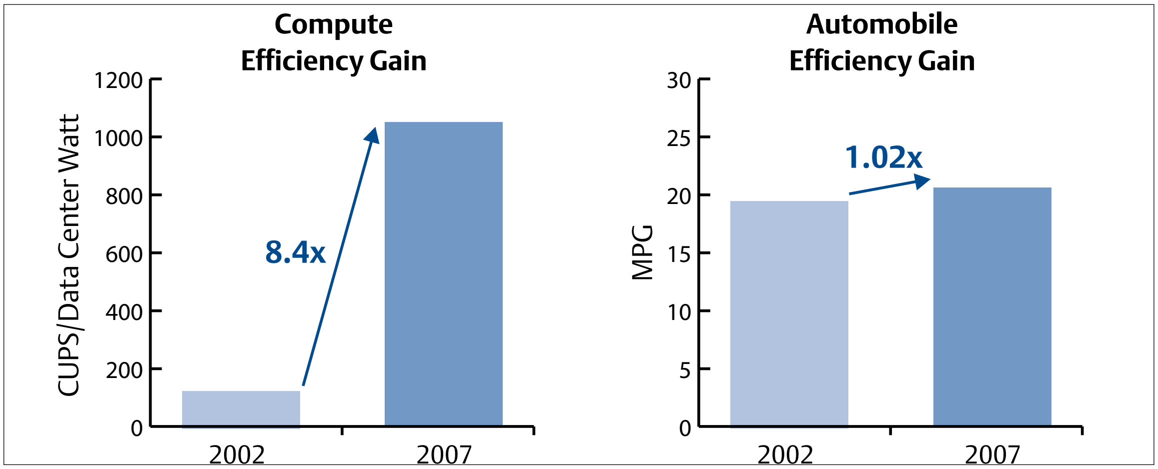


Figure 8. The advances in computing efficiency appear even more dramatic when compared to other industries.

auto industry, but rather is presented to add context to the improvements the computing industry has made.

Our analysis shows that the IT industry has not done enough to share the tremendous energy efficiency gains that have occurred over the last five years in computing.

This is not to discourage efforts to reduce data center energy consumption. Where inefficiencies exist, they should be identified and corrected. But it is critical to ensure data center productivity or output is factored into discussions of data center efficiency and to provide better information to organizations seeking to optimize data center efficiency.

Applying CUPS/Watt to Energy Logic

Emerson Network Power applied CUPS/watt to the Energy Logic model to analyze how Energy Logic actions impact data center efficiency. The Energy Logic model is based on a 5,000-square foot data center with a total compute load of 600 kW spread across 200 racks. The server refresh rate is assumed to be 4 to 5 years so the data center is supporting a mix of servers from new to four-years old. Blade servers and virtualization are not in use as part of the base model. The facility is protected by two 750 KVA double-conversion UPS systems arranged in a 1+1 configuration. A traditional floor-mount cooling system delivers cooling through a raised floor to equipment racks arranged in a hot-aisle/cold-aisle configuration.

Figure 9 shows the impact of Energy Logic activities on the efficiency of this model data center using CUPS/watt. Two points become clear from this analysis:

1. The Energy Logic roadmap represents a valid approach to increasing efficiency as well as reducing consumption. Using the model and the proxy measure, Emerson Network Power calculated that *Energy Logic can reduce data center consumption by approximately half while increasing efficiency 3.6 times!*

The single biggest driver for data center efficiency improvement is IT equipment efficiency gains. The IT actions taken alone would increase data center efficiency by 2.8x (177 percent).

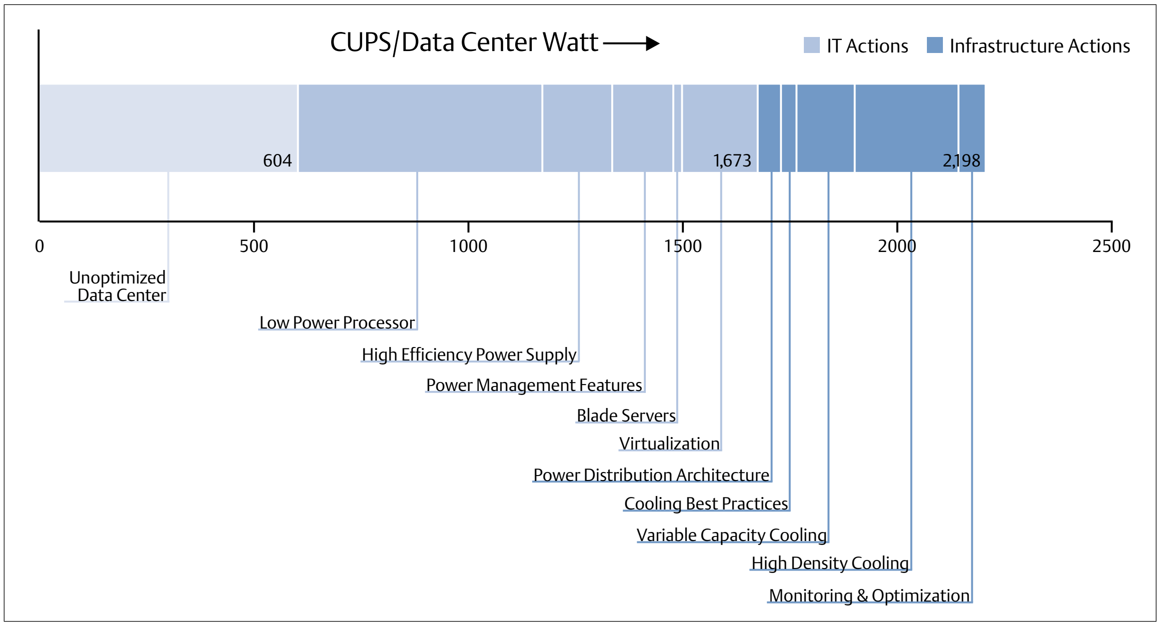


Figure 9. Prior to any enhancements the model data center was able to produce approximately 604 CUPS/watt. The Energy Logic roadmap increased efficiency to 2198 CUPS/watt (3.6x) with the largest increase in efficiency being delivered by adoption of low power processors.

Both the initial Energy Logic analysis and the CUPS-based analysis highlight the value of increasing data center density in optimizing efficiency.

2. The single biggest driver for data center efficiency improvement is IT equipment efficiency gains. The IT actions taken alone would increase data center efficiency by 2.8x (177 percent). Consequently, the most effective approach to increasing data center efficiency is to accelerate the introduction of new server and IT technologies into the data center. This approach allows data center managers to address the issue of rising consumption while still meeting the growing demand for computing performance.

Leveraging the Power of Blades

The initial Energy Logic analysis quantified the energy savings that could be achieved using blade servers. Those savings were relatively small compared to the more dramatic savings available through lower power processors, high-efficiency power supplies and utilization of power management. However, blade servers play a more significant role in optimizing data center energy efficiency than is obvious from this data.

Building on the conclusions from the Energy Logic analysis using CUPS, a case can be made that blade servers are a basic building block of a high-efficiency data center as they support several of the most effective strategies for increasing data center efficiency.

Our analysis shows that a truly high-efficiency data center can only be achieved with high-efficiency IT systems. It doesn't matter how efficient infrastructure systems are, if technology systems are not optimized the efficiency of the facility will be compromised. This paper has already made the point that the most effective strategy for increasing data center efficiency is to accelerate the replacement of older IT systems with newer, more efficient systems. Blades provide a modular platform for accomplishing this. In addition to being able to upgrade specific components within a blade system—such as power supplies, memory modules, processors and fans—blades allow new technology to be introduced with less administrative burden and with virtually no disruption to operations.

In addition, both the initial Energy Logic analysis and the CUPS-based analysis highlight the value of increasing data center density in optimizing efficiency. High density cooling represents the most effective infrastructure strategy for reducing energy consumption and efficiency. Blades enable a denser environment, optimizing the value of high-density cooling, and also help to alleviate space constraints.

Recommended Actions for IT and Data Center Managers

The Energy Logic CUPS/watt analysis can be used to identify and prioritize your data center efficiency improvement projects.

The first step is to measure and track the efficiency of each of your data center locations using the CUPS/watt metric. Refer to Appendix B "Simple Tool for Assessing Data Center Efficiency" for a sample template and steps to take in order to identify the data center locations that would most benefit from efficiency improvement investment.

Second, determine which projects should be funded given limited IT resources. Energy Logic identifies the four most impactful actions you can take today to improve data center efficiency:

1. *Speed up refresh cycle for IT technology* to take advantage of efficiency improvements that have been made at the server level. With the dramatic gains in efficiency that can be realized,

more aggressive efforts to replace inefficient server processor and power supply technology with more efficient technologies will pay dividends. In addition to their other benefits, blade servers provide an architecture that facilitates module-level replacement, further increasing their role in enhancing efficiency.

2. *Implement server power management policies.* Servers consume a high percentage of peak load power even when the processor is idle. Power management represents an untapped resource that can play a large role in increasing data center efficiency.
3. *Virtualize applications* where appropriate to increase the level of server utilization.
4. *Adopt a high-density architecture.* High-density cooling in particular has the largest impact on data center efficiency outside of actions taken at the server level.

Implications for the IT Industry

The Energy Logic analysis using the placeholder CUPS/watt metric reinforces the urgent need for the IT industry to move aggressively to define and adopt a measure of IT performance that is scalable to the data center.

Pressure on the industry to adopt such a measure will continue to mount from various sources and taking proactive action on this front will enable the industry to showcase the dramatic improvements in efficiency that have been achieved while helping focus future research and development on efforts that will have the greatest impact on improving data center efficiency.

Appendix A

Defining Criteria for Data Center Efficiency Metrics

The gap that exists in terms of IT performance metrics is a function of the complexity of measuring IT output or performance, particularly on the facility level. However, it is also partly a result of striving for a perfect measure when an effective measure is more practical and attainable.

A perfect measure of data center productivity may never be available. At minimum, it is years away. But the criteria for an effective measure of data center efficiency are different than the criteria for a perfect measure of data center efficiency.

Based on the experience with CUPS/watt, there are three criteria that must be met for a metric to fill the gap that exists and allow the industry to effectively measure and optimize data center efficiency.

- First, and most importantly, does it drive the right behavior? Is the result of changes in the metric a data center that is truly more efficient and not simply consuming less energy?

  Consider the case of the Power Usage Effectiveness metric that has been proposed as an interim measure of efficiency. This metric defines the ratio of total data center power to power used by IT systems on the theory that the less power used by infrastructure, the more efficient the data center. However, Energy Logic demonstrates that PUE does not correlate with overall data center efficiency.

  Figure 10 shows the impact of the 10 Energy Logic actions on PUE and Data Center Efficiency as measured by CUPS/Watt. Using the PUE metric to identify and prioritize improvement actions would result in a focus on infrastructure actions first. However, the Energy Logic analysis shows that this is not the optimal strategy for improving efficiency or for reducing energy consumption. At best, a focus on PUE achieves modest reductions in consumption, but it does so by diverting resources away from actions that drive even greater reductions in consumption while improving overall energy efficiency.

- The metric must be published consistently at the device level so that users can evaluate the efficiency of competing technologies using this metric and accurately factor device-level efficiency into the purchase decision.

- Finally, the metric must be scalable to the data center, allowing the output of the devices in the data center to be added together to produce a measure of data center efficiency.

For an example of how effective a less-than-ideal measure can be if it is universally adopted, consider the auto industry's MPG measure. It does not take into account the different types and sizes of vehicle or the number of passengers, and considers only a broad generalization of driving conditions with the City and Highway classification. But users understand these limitations and MPG is widely used in the purchase of automobiles as a way to measure the efficiency of one vehicle against another.

A less-than-ideal measure of server performance could perform a similar function in the IT industry.

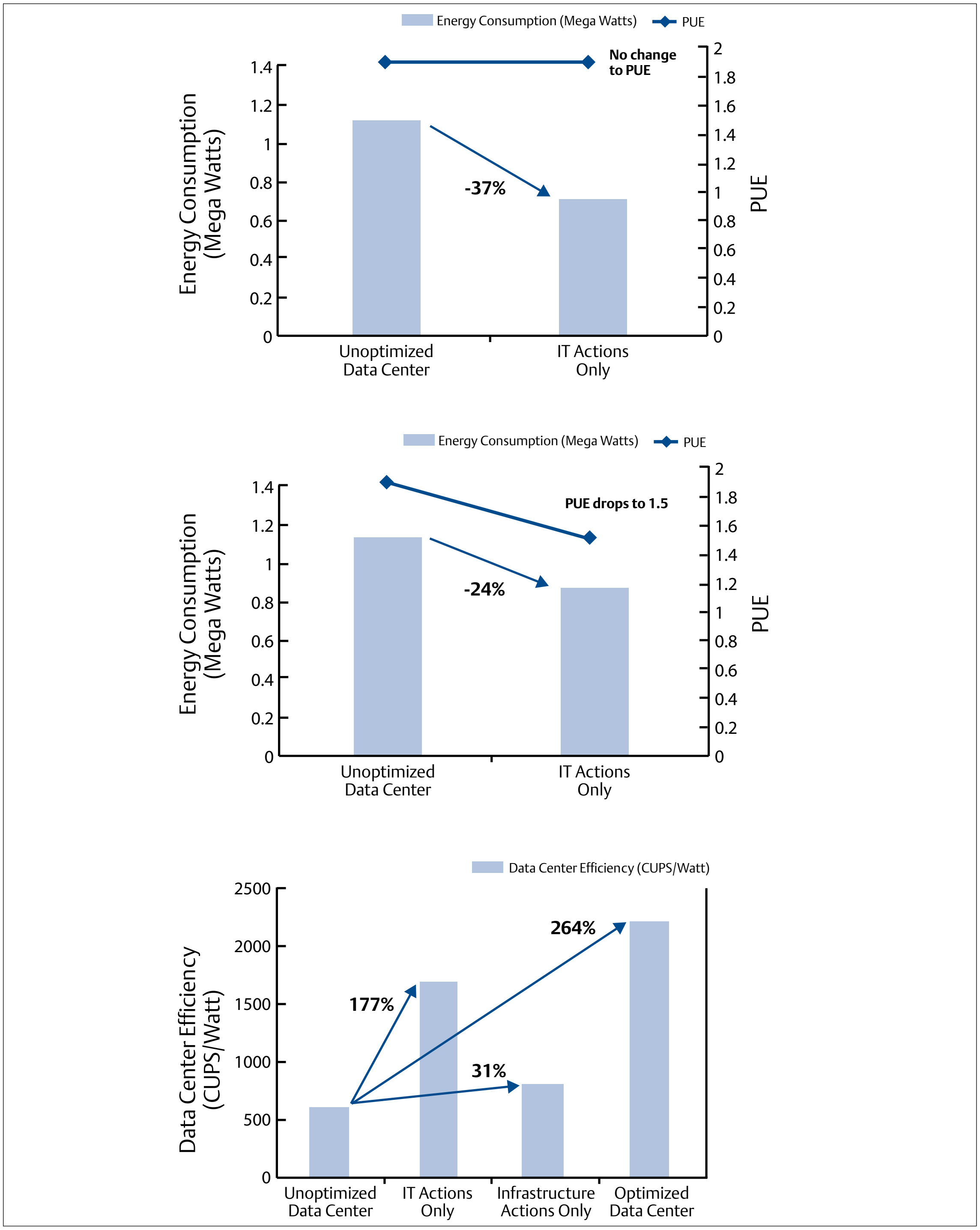


Figure 10. The five IT actions in Energy Logic produce a 37 percent reduction in energy consumption, but have no impact on PUE (top). The five infrastructure actions in Energy Logic reduce PUE from 1.9 to 1.5, but achieve a smaller reduction in energy consumption than the IT actions (middle). In addition, Energy Logic shows that a greater reduction in infrastructure energy consumption could be achieved if the IT actions are taken first. This indicates PUE is not driving the right behavior. When the CUPS metric is used (bottom), Energy Logic IT actions create a 177 percent improvement in efficiency, infrastructure actions create a 31 percent improvement, and both IT and infrastructure actions create a 264 percent improvement. The CUPS/watt metric drives the optimal behavior.

Appendix B

Simple Tool for Assessing Data Center Efficiency

To identify the data center locations that would most benefit from efficiency improvement efforts:

1. Complete the sample template below for each data center location.
   - Fill in the number of servers/blade servers purchased each year and their average utilization rate.
   - If you have implemented virtualization, increase utilization rates for physical servers hosting virtual machines appropriately.
   - Multiply columns A, B, and C together to calculate the total computing output of servers from each year of purchase.

Data Center Efficiency Tracking -Sample Template

Data Center Name: ______________________________ Date: ______________

Year of Server Purchase	Estimated MCUPS per Server*	Number of Servers	Server Utilization (%)	Total Output (MCUPS)
	A	B	C	D = A x B x C
2000	0.50			
2001	0.75			
2002	1.00			
2003	1.50			
2004	2.25			
2005	3.25			
2006	4.75			
2007	7.00			
2008	10.25			
2009	15.25			
2010	22.50			

* Estimated MCUPS per Server numbers are based on “Creating a Meaningful Measure” section of this paper and have been extrapolated as a basis for discussion.

2. Add up the Total Output of each row and enter the total into the Total Data Center Output field.
3. Enter the Total Energy Consumption (Mega Watts) for the data center into Field E below.
4. Calculate Data Center Efficiency as shown and enter the result into the table below.

Total Data Center Output (MCUPS)	Sum of D from each row above	
Total Energy Consumption (Mega Watts)	E	
Data Center Efficiency (CUPS/Watt)	= Sum(D) / E	

5. Select data center locations on which to focus efforts using Data Center Efficiency and Total Energy Consumption measures. Focus resources on high energy consumption and low efficiency locations. This simple tool is useful for comparing data centers that consist of a similar mix of servers (i.e., number of processors per server). If data centers consist of vastly different server mixes, the Data Center Efficiency (CUPS/Data Center Watt) results provided in Figure 6 can be used to conduct a similar analysis.
6. For the selected data center, fill out the sample template using “before and after” project information to show a comparison of efficiencies that can be used to justify project selection to management. To estimate energy consumption for the ‘after’ scenario, calculate energy savings of new servers, and apply estimated cascade effect multiplier for your facility. If you want to be conservative, you can use a cascade effect multiplier of 1, though a multiplier of up to 1.8 will not be unreasonable.
7. Track Data Center Efficiency and Total Energy Consumption over time for each location.

Note that this is a simple calculation of efficiency that only takes into account servers. It does not take into account non-server IT equipment.

Appendix C

Existing Equipment and Data Center Metrics

Figure 11 shows various metrics that have been developed to quantify IT performance on the device level. Several of the server metrics meet the requirements for an effective data center metric, but have not been widely adopted.

Metric	Pros	Cons	Scalable to Data Center?
Server			
MIPS (Million Instructions per Second)	Easy to measure Good performance measure for compute intensive number-crunching operations	Not suitable for heavy 'transaction- intensive' processing such as serving Web pages which requires bandwidth and input-output speeds. Not a good measure for storage hungry applications such as video services.	Yes. Add up all MIPS or FLOPS.
FLOPS (Floating Point Operations per Second)			
SPEC benchmark (Suite of benchmarks to compare performance)	Choose benchmark most relevant to load	Not easy to calculate. SPEC scores are not backward compatible and cannot be compared across time. Does not account for non-server IT equipment.	No. CPU and Server only.
Storage			
Storage Capacity (Terabytes of capacity)	Easy to measure	Weak correlation with data center energy consumption. Does not provide efficiency guidance for server procurement. Capacity based. Does not vary based on load.	Yes –add up all the Terabytes at the data center level.
Storage Used (Terabytes used)	Easy to measure	Weak correlation with data center energy consumption. Does not provide efficiency guidance for procurement.	Yes –add up all the Terabytes at the data center level.
Network			
Terabits/second	Easy to measure. Alternate performance measure	Does not provide efficiency guidance for server procurement. All work done in the data center does not pass through the network switch.	Yes.

Figure 11. Various metrics have been developed to measure IT performance. In most cases, server performance will most directly correlate with data center performance.

There has also been a significant amount of work done on the data center metric itself (Figure 12). Each of these metrics is being developed to meet specific needs, but each, for various reasons, appears inadequate for the purpose of benchmarking data center efficiency.

Metric	Pros	Cons	Scalable to Data Center?
SPEC Score (SPEC score/power draw	Can be customized to mimic true load	Currently available only for Java	No. Server only.
Power Usage Efficiency (PUE)	Easy to understand/apply	Does not consider IT performance	Yes.
Space, Watts and Power (SWAP)	Takes space into account	Not a pure efficiency measure	No. Does not benchmark performance.
Corporate Average Data Efficiency (CADE)	Good theoretical performance	Does not define compute performance	Not known until measure is known.

Figure 12. A number of metrics have been proposed for data center efficiency, but because of limitations none have emerged as a useful industry standard.

References

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Note: Energy Logic is an approach developed by Emerson Network Power to provide organizations with the information they need to more effectively reduce data center energy consumption. It is not directly tied to a particular Emerson Network Power product or service. We encourage use of the Energy Logic approach in industry discussions on energy efficiency and will permit use of the Energy Logic graphics with the following attribution:

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