Microsoft

Datacenter Efficiency

EXECUTIVE STRATEGY BRIEF

Operating highly-efficient datacenters is imperative as more consumers and companies move to a cloud computing environment. With high energy costs and pressure to reduce carbon emissions, datacenter operators need to accurately measure and continually innovate in order to optimize power usage and environmental sustainability.

This strategy brief discusses the factors that affect efficiency at the component, server, and system level; a holistic approach to right-sizing servers and datacenter infrastructure; and Microsoft's strategy for improving datacenter efficiency in future designs.

A DAY IN THE MICROSOFT CLOUD

THE SUSTAINABILITY IMPERATIVE

At Microsoft, we are committed to driving software and technology innovations that help people and organizations improve the environment. Our goal is to reduce the impact of our operations and products, and to be a leader in environmental responsibility. The environmental sustainability commitment for our cloud infrastructure is extensive.

- We standardize on energy-efficient servers and place a great deal of focus on configurations that use natural air flow or water economization for cooling.
- We deploy sensors throughout our facilities so we can quickly respond to changes in temperature and humidity, and we're constantly on the lookout for ways to reduce wastes and improve efficiency.
- We measure and analyze everything we do. The metric we use to track energy efficiency is Power Usage Effectiveness (PUE), a ratio of the power and cooling overhead required to support our server load, and we strive to reduce this ratio to 1.125 by 2012.
- We believe that the datacenter industry as a whole needs to share best practices around energy efficiency. That's why we helped found and actively participate in The Green Grid and Climate Savers Computing industry consortiums.

Design v. Costs

When most people think about a datacenter, they envision rows of servers mounted in racks, filling up a raised floor environment. What they often don't recognize is the vast amount of infrastructure that supports the operation of the servers—from the substation that provides primary power, to the diesel back-up generators, through the battery UPS, air handlers, cooling towers and chiller plants.

In traditional datacenter build-outs, 70 to 80 percent of the construction costs are driven by the mechanical and electrical infrastructure to operate and cool the servers. Only seven to nine percent of the cost goes to architectural systems and the building shell. Consequently, most of the cost to construct a new datacenter scales with power, not with space. Effective datacenter designs optimize for how many megawatts are in the datacenter, and how many servers this power can support. It is imperative to build enough space to ensure that it is not a constraint to utilizing all the available power.

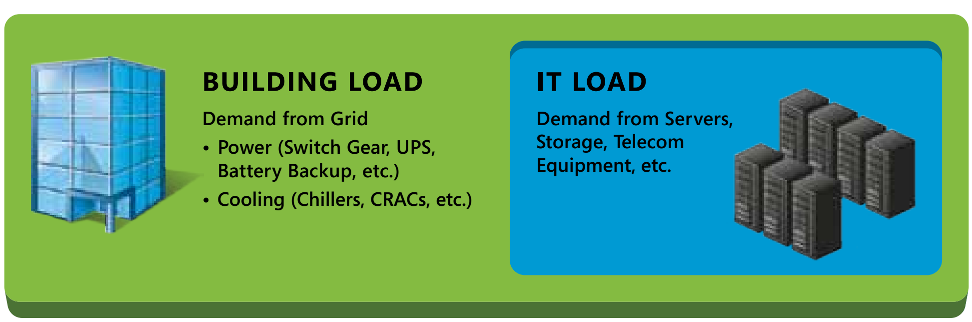
Power Usage Effectiveness

One of the metrics used for measuring datacenter efficiency is Power Usage Effectiveness, or PUE. PUE compares the power consumption for the entire facility with the power consumed by the core IT components—servers, storage and network equipment. This ratio illustrates how effectively the power being consumed translates into net compute capacity. Mathematically, the calculation is straightforward:

For example, if one watt is being consumed by the servers and one watt is being consumed for the supporting cooling, power back-up and other administrative use, the ratio would be 2.0—which is where most datacenters operate. The theoretical ideal PUE is 1.0, where the only energy consumed is for computation.

The value of this metric is that it focuses on the non-value added use of power, which in a datacenter is anything that doesn't compute or store information. Through careful design, innovative cooling strategies, and clever site selection, Microsoft has been able to reduce the PUE of our latest datacenters to a range of 1.2 to 1.5.

FIGURE 1: PUE=TOTAL FACILITY POWER / IT EQUIPMENT POWER

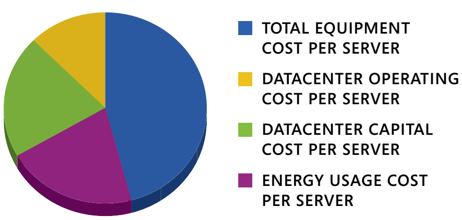


There are limitations to this metric—comparisons between companies might be misleading because of different assumptions, and some actions that reduce overall power consumption might result in a higher PUE. However, this simplicity of this metric makes it a useful tool for measuring progress over time.

Datacenter TCO

Viewed holistically, a datacenter carries a wide array of costs beyond just the servers themselves. In total, datacenters cost between $10 and $20 million per megawatt, and those costs need to be depreciated over the useful life of the datacenter, which is typically about 15 years.

FIGURE 2: BASIC 1U SERVER—5 YEAR TCO



If you look at the total cost of ownership for the servers you deploy, the acquisition cost often turns out to be less than half the overall TCO. There are other cost drivers that are equally important. For example, the cost over five years to power the server is about 20 percent. Depreciation of the electrical and mechanical construction costs also adds a significant amount.

The goal is to optimize for energy efficiency, across all components of the datacenter. PUE is a useful metric for identifying inefficiency in the supporting infrastructure, but it doesn't account for efficiency gains in the servers themselves. We look to right-size the servers to get the best performance at the lowest power.

Performance-Per-Watt-Per-Dollar

Our industry has been on a perpetual quest for ever-faster processors, with little attention spent to the tradeoffs in power and cost. In seeking out potential areas for efficiency, our team analyzed publicly-available information on processor performance, power consumption, acquisition cost. Combined, this then gave us performance per watt and performance per watt per dollar.

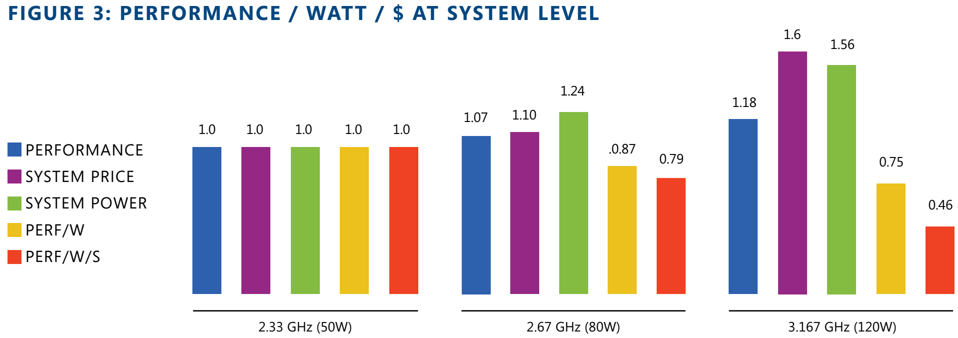
We looked at a 50 watt processor that runs at 2.33 gigahertz, an 80 watt processor that runs at 2.67 gigahertz, and the highest performer running at 3.167 gigahertz but consuming 120 watts. It was important to look at the efficiency at the server level, not just the processor level. Our assumptions were that a typical server built with these processors would cost about $2000, plus the cost of the processor themselves, and that the server power consumption aside from the processor would be 150 watts.

Following is how the analysis worked out:

We used the 50 watt processor as the baseline. The 80 watt processor gives you seven percent more performance, but it costs 10 percent more, and consumes 24 percent more power. When you calculate the ratios, the performance per watt is 13 percent lower, and the performance-per-watt-per-dollar is 21 percent lower. If you move to the highest performance processor, the numbers are even more dramatic.

The conclusion was clear—the best balance of performance, power, and price was found in the lower power processors. Since space is a minor driver of datacenter TCO, holistic optimization would suggest having more servers running lower power processors, which is the approach we take. This works well for scale out applications that can run across multiple servers.

FIGURE 3: PERFORMANCE / WATT / $ AT SYSTEM LEVEL



CARBON USAGE EFFECTIVENESS

Carbon Usage is an important consideration in the design, location, and operations of datacenter, so a Carbon Usage Effectiveness (CUE) metric is under consideration. Like PUE, CUE uses total IT equipment value as the denominator, and the same value should be used for both metrics.

For datacenters that obtain their entire power source from the energy grid and generate no local CO2, CUE is defined as follows:

CUE=Annual CO2 emissions caused by Total Datacenter Energy/IT Equipment Energy

For datacenters that emit additional CO2 emissions, such as maintenance operations of diesel generators, the actual local CO2 emission data is added to the grid-sourced energy.

Using a direct carbon emission metric will help operators identify more sustainable ways to source and deploy energy, compare the true sustainability between datacenters and over time, and highlight the importance of considering renewable sources when selecting datacenter sites.

MICROSOFT OPERATIONS CENTER (MOC)

The Microsoft Operations Center (MOC) delivers a centralized management that provides competitive advantages of speed, efficiency, trust, service reliability, and quality to Microsoft's cloud services.

The MOC is highly integrated to the core network and datacenter infrastructure to deliver comprehensive incident management and service support. It manages one of the largest Microsoft System Center implementations in the world, as well as Non-Windows environments.

As a federated operations center, it maintains a robust business continuity process—with failover capabilities in Redmond, India and California—retaining instant availability of geo-replicated service continuity in the event of a natural disaster or other calamity.

Reducing Infrastructure Costs

To help reduce infrastructure costs, we are actively pursuing a number of strategies in our datacenters:

- Analyze actual workloads—we measure and analyze our key applications and then model those characteristic against final server options. Industry standard benchmark data, while helpful, doesn't provide the most accurate comparison between component and configuration choices. We make our final server selection based on a holistic assessment of performance against our planned workloads.
- Eliminate unnecessary components—there are some obvious opportunities here, such as eliminating DVD drives, since applications and updates are all distributed over the network. Plus, in many cases the number of input and output (I/O) expansion slots exceeds what is needed for our workloads.
- Operate servers at higher temperatures—the ASHRAE standard suggests a narrow range of operating temperature and humidity, yet server manufacturers warrant operation in a much wider band.
- Use higher efficiency power and cooling—we use high efficiency power supplies and voltage regulators and size them to match our power usage requirements. In addition, using rack level power supplies and fans results in higher efficiency.
- Chiller-less designs—our latest datacenter designs use fresh air and adiabatic cooling, which adds a small amount of moisture to the air. Both are far more efficient than traditional chillers.
- Optimize for performance/watt/$—as mentioned earlier, choosing the right processor strategy can result in marked efficiency gains across the datacenter.
- Drive server consolidation with virtualization—Windows Server and Windows Azure have virtualization built in; by driving higher utilization rates, a given set of workloads can operate on fewer servers, meaning lower hardware, power and cooling costs.
- Leverage advanced power management technology—Windows Server allows automated management of power settings; this helps with the goal to not strand power anywhere in the datacenter. Power capping is another technique that can be used to smooth out infrequent peaks.

Microsoft's Datacenter Strategy

Today we are building new datacenters that will radically change the traditional thinking and help improve efficiency. We are pursuing a shift away from traditional, monolithic, raised floor mega datacenters towards new modular pre-manufactured components that will help reduce costs, increase scalability, and improve time-to-market.

Our Chicago datacenter was a step in this direction, where we essentially have two datacenter designs in one—the top floor is a traditional high-reliability colocation space; the lower level optimizes for cost and uses an array of shipping containers, each containing approximately 2000 servers. Deploying 2000 servers at a time was a valuable learning exercise; as well the concept of containment and modularity showed great promise.

The most valuable learning from the Chicago build-out was that the concept of "containment," where we specified standard interfaces and let our partners innovate within broad parameters, proved beneficial. The initial designs were housed in ISO standard containers, but we quickly realized that we could get more efficient designs by relaxing some of the ISO compliance constraints.

Our latest datacenter designs build on these key learnings and move further towards standardized and commoditized components for IT compute and supporting equipment:

- ITPACs (IT Pre-Assembled Component) used in our latest generation of datacenters combine compute, power, cooling, and networking in self-contained modules that are pre-manufactured before delivery to the site.
- Supporting equipment is designed to be installed on indoor skids or outdoor packs, and the datacenter structure serves as the shell to house these modular components.
- ITPACs use free air for primary cooling, with secondary cooling provided by air-cooled or water-cooled chillers in locations where the weather conditions do not allow for year-round free air cooling. Adiabatic cooling, which adds a small amount of moisture to the air, offers an extremely efficient way to expand the range of temperatures that can be supported with free air cooling.

Server Platform Design Goals

In the rack-optimized servers that we're now deploying, we use shared cooling and shared power to reduce cost and improve efficiency. When these same racks go into our ITPACs, we can remove the fans from the servers, and let the ITPAC provide the airflow needed for cooling. We strive to use common components so that our supply chain issues are minimized, and we select components to optimize for the best performance-per-dollar-per-watt at the individual ITPAC and full datacenter level.

Lower Capital Expenses—we optimize these servers for some of our large services like Bing and Azure, removing any components that don't provide value to these workloads. We engage our design partners early in the process so they understand our requirements—both what is necessary and unnecessary—so they can provide solutions optimized for the lowest capital expense for the planned workloads.

Lower Operating Expenses—we reduce ongoing operating expenses by right-sizing the servers for power, memory, and disc capacity, and ensure they are matched to the application. For instance, where we will be virtualizing we need a larger memory footprint. We also specify high efficiency components such as the power supplies, and recently discovered we could save 12 watts per server just by using low power memory DIMMs—a significant savings when multiplied by tens of thousands of servers.

Building a More Efficient Datacenter

Our recent experience in datacenter designs have taught us that a holistic approach that looks at both the component and the system level is necessary to yield maximum efficiency gains. Standardization and commoditization leads to dramatic improvements in costs, scalability and efficiency, and is the foundation of our future datacenter strategy. Most important, we will continue to measure every aspect of the operations to ensure that we right-size the infrastructure for the workload running on it, we don't strand power by over-provisioning against the total balance of requirements, and we optimize for total cost over the expected life of the datacenter.

Microsoft has extensive experience operating cloud services' infrastructures, with a history of innovation, operational excellence and industry leadership. As Microsoft's cloud services portfolio and infrastructure continues to grow with new services and applications launching on a rapid basis, the Global Foundation Services team is making thoughtful investments to answer our customer's needs for greater availability, lower latency, increased security, and lower costs.

Please visit www.globalfoundationservices.com for more information.

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