

# Microsoft's Top 10 Business Practices for Environmentally Sustainable Data Centers

## How to Reduce Energy Consumption, Waste, and Costs while Increasing Efficiency and ROI

Microsoft recognizes the tough challenges that data center managers, cloud and IT service providers face today as they struggle to support their businesses in the face of rising costs and uncertainty about how to efficiently provide web-scale cloud infrastructures. That is why we are continuing to work with our partners, customers, suppliers, governments, and leading industry and environmental organizations to apply the power of software and information technology to supporting environmental sustainability. Key areas where we collaborate to promote positive environmental outcomes include:

- Using information technology (IT) to improve energy efficiency;
- Accelerating infrastructure research to solve issues of reliability, security, connectivity, and web-scale; and
- Demonstrating responsible cloud leadership and citizenship in our own facilities, operations, and supply chain.

The fact is – being "lean and green" is good for both the business and the environment, and organizations that focus their attentions accordingly will see clear benefits. Reducing energy use and waste improves a company's bottom line, and increasing the use of recycled materials is a proven way to demonstrate good corporate citizenship to your customers, employees, and the communities you do business in.

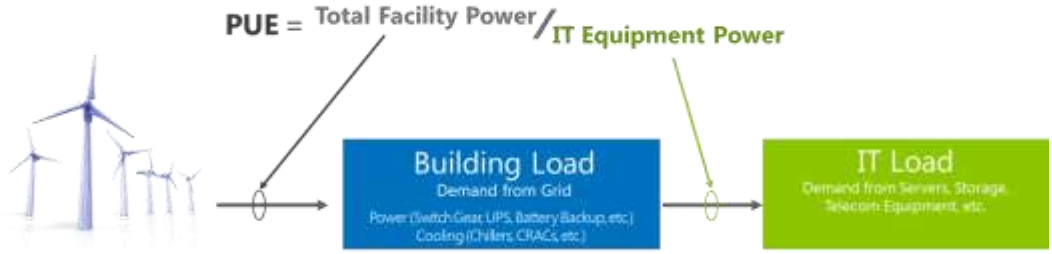
However, it isn't always easy to know where to begin in moving to greener and more efficient operations. With that in mind—along with Microsoft's commitment to share best practices with the rest of the data center industry—this paper presents the top ten best business practices for environmentally sustainable data centers. Senior members of Microsoft's Global Foundation Services (GFS) team submitted the items in this list. Their backgrounds include expertise in server and network development, data center electrical and mechanical engineering, power and cooling architecture and design, research and development, security, privacy, and compliance, and business operations and administration.

Microsoft has followed the practices below for several years now and found that in addition to helping protect the environment, they lead to optimal use of resources and help teams stay aligned with core strategies and goals.

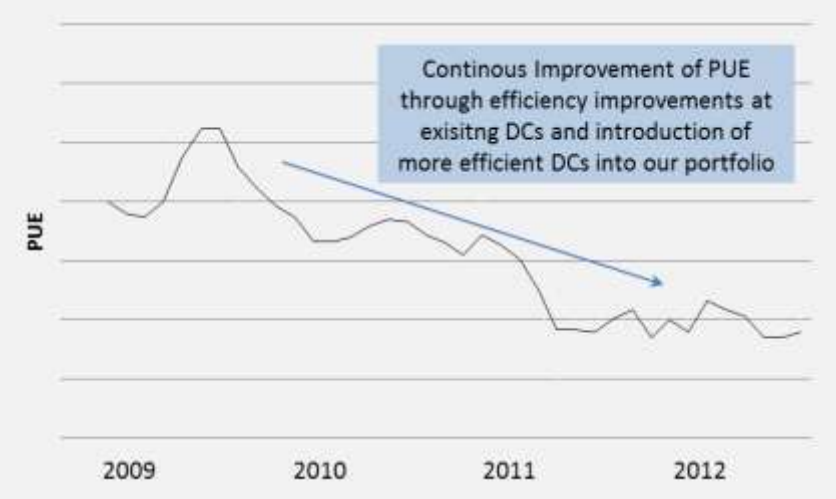
1. **Provide incentives that support your primary goals:** Incentives can help you achieve remarkable results in a relatively short period if you apply them properly. Microsoft's charge back mechanism for online services is based on energy capacity allocation and usage instead of floor space. This provides incentives for business managers to purchase lower power servers, increase utilization with virtualization, and defer purchases until they are absolutely needed.

   Microsoft has achieved significant reductions in energy consumption at its data centers by providing incentives to data center managers, not just for uptime, but also for improving energy efficiency as measured by the power usage effectiveness (PUE) of the data center. PUE is a metric that measures the ratio total data center power consumption relative to the power used by the IT infrastructure. This metric effectively determines additional power consumption over and above the power needed to run

the servers. The goal for data center operators is to eliminate as much of this additional power consumption as possible (i.e. to achieve a PUE as close to 1.0 as possible).



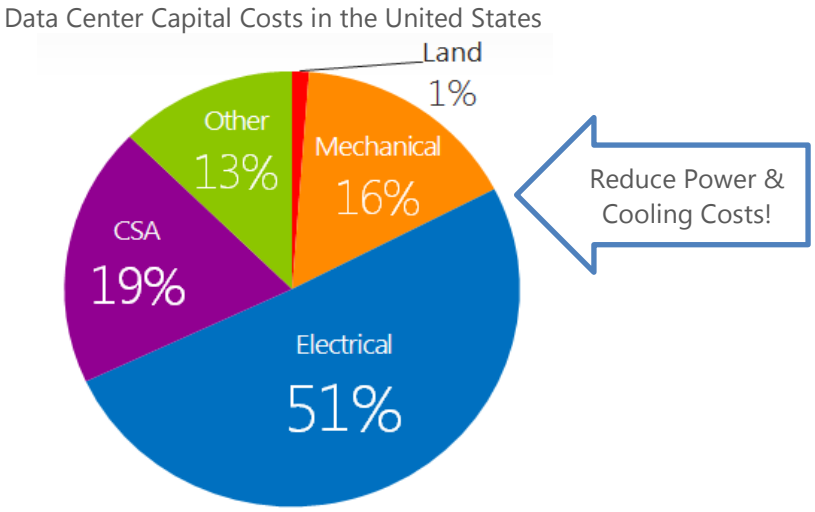

Our average Power Usage Effectiveness in 2011 was 1.40 across all of our cloud infrastructure properties, compared with an estimated industry average of 2.0. Our goal by the end of 2012 is to construct new data centers that average 1.125 PUE and use 30–50 percent less energy than traditional industry data centers. We continue to monitor our existing data center operations and tune our control systems. These efforts have resulted in some dramatic improvements, for example in our Chicago data center we are achieving an average PUE of 1.07 in our container area for the first half of 2012, compared to the initial PUE of 1.25 in 2009!




While the industry improvements in PUE are well documented, we are beginning to reach a point of diminishing returns where each dollar invested to achieve an incremental unit of PUE reduction achieves a smaller return. In order to continue to drive incentives for improvements in energy efficiency, Microsoft is one of the first data center operators to implement an internal carbon fee.

This model was announced on May 7, 2012, in conjunction with Microsoft's commitment to carbon neutrality in 2013 for all of its properties. Microsoft could have achieved carbon neutrality without the carbon fee by simply aggregating the costs at a corporate level. However, the carbon fee, which is applied to each business unit based upon energy consumption, provides both transparency and incentives to reduce energy consumption and associated carbon emissions.

**2. Focus on effective resource utilization:** Energy efficiency is an important element in Microsoft business practices, but equally important is the effective use of resources deployed. For example, if only 50 percent of a data center's power capacity is used, then highly expensive capacity is stranded in the uninterruptible power supplies (UPSs), generators, chillers, and so on. In a typical 12 Megawatt data center this could equate to $4-8 million annually in unused capital expenditure. In addition, there is embedded energy in the unused capacity since it takes energy to manufacture the UPSs, generators, chillers, and so on. Stranding capacity will also force organizations to build additional data centers sooner than necessary. This wouldn't happen had they fully utilized existing data center infrastructure first.




*Focus on mechanical and electrical expense to reduce cost significantly.*

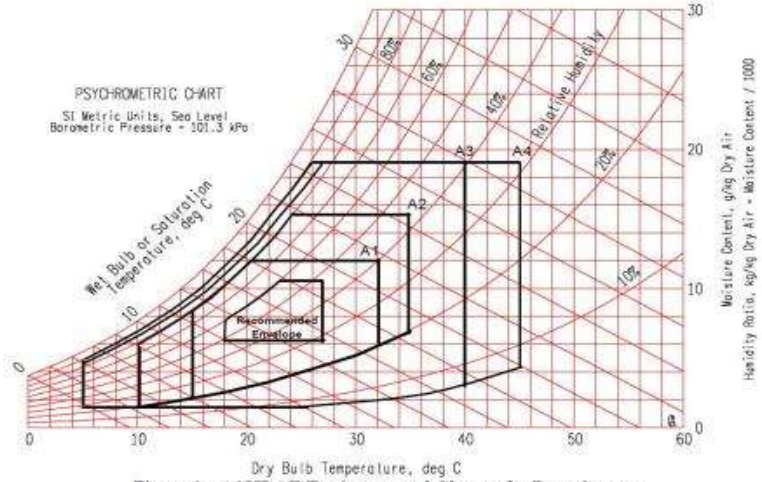


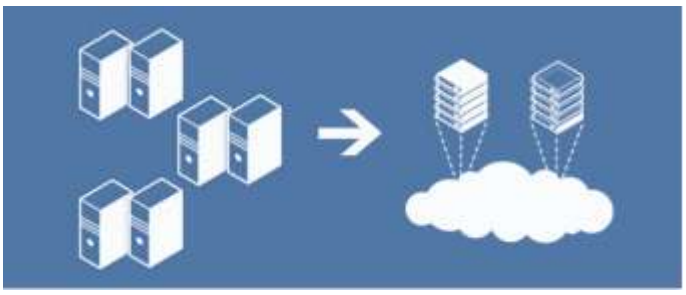

Figure 2. ASHRAE Environmental Classes for Data Centers

*Increasing the server inlet temperature can allow use of air-side economization and reduce both cooling capital and operating cost. Elimination of chillers reduces water usage by over 90 percent.*

- ASHRAE Recommended: 18 – 27°C / 40 – 60% RH
- Vendor Allowable: 10 – 35°C / 20 – 80% RH matches ASHRAE 2011 A2

**3. Use virtualization to improve server utilization and increase operational efficiency:** As noted in the point above, underutilized servers are a major problem facing many data center operators. In today's budgetary climate, IT departments are being asked to improve efficiency, not only from a capital perspective, but also with regard to operational overhead. By migrating applications from physical to virtual machines and consolidating these applications onto shared physical hardware, Microsoft data centers are increasing utilization of server resources such as central processing unit (CPU), memory, and disk input/output. It is quite common to see several instances in data centers where server resources are under-utilized. Industry analysts have reported that utilization levels are often well below 20 percent.

Microsoft is using technologies such as Hyper-V to increase virtualization and thus utilization year over year, which in turn helps increase the productivity per watt of our operations. GFS is also actively working on broad-based adoption of Microsoft's Windows Azure cloud operating system, which uses virtualization in its core. On Windows Azure, an application typically has multiple instances, each running a copy of all or part of the application's code. Each of these instances runs in its own virtual machine (VM). These VMs run 64-bit Windows Server 2008 R2, with a hypervisor specifically designed for use in the cloud.



*Consolidating virtualized applications onto shared hardware increases the utilization of server resources.*

One immediate benefit of virtual environments is improved operational efficiency. Microsoft operations teams can deploy and manage servers in a fraction of the time it would take to deploy the equivalent physical hardware or perform a physical configuration change. In a virtual environment, managing hardware failures without disrupting service is as simple as a click of a button or automated trigger, which rolls virtual machines from the affected physical host to a healthy host.

| Performance | | | Power | |
|---|---|---|---|---|
| Target Load | Actual Load | ssj_ops | Average Active Power (W) | Performance to Power Ratio |
| 100% | 99.6% | 725,620 | 172 | 4,230 |
| 90% | 90.6% | 659,864 | 160 | 4,136 |
| 80% | 80.0% | 583,048 | 147 | 3,962 |
| 70% | 70.2% | 511,207 | 136 | 3,760 |
| 60% | 60.3% | 439,188 | 128 | 3,428 |
| 50% | 50.2% | 366,118 | 120 | 3,045 |
| 40% | 39.9% | 290,866 | 112 | 2,589 |
| 30% | 30.1% | 219,614 | 105 | 2,097 |
| 20% | 20.2% | 147,012 | 96.6 | 1,522 |
| 10% | 10.1% | 73,322 | 85.8 | 854 |
| Active Idle | | 0 | 53.6 | 0 |
| | | | ∑ssj_ops / ∑power = | 3,052 |


*Servers consume a significant amount of power when they are idle, often more than 50% of peak power. As shown above, moving from 10% load to 50% load delivers 5x the performance for 40% more power.*

A server running virtualization will often need more memory to support multiple virtual machines, and there is small software overhead for virtualization. However, the overall value proposition measured in terms of work done per cost and per watt is much better than the dedicated underutilized physical server case.

At times, one data center might have excess capacity while another has workloads reaching capacity. Microsoft has deployed a very high bandwidth data center-to-data center network that allows processing mobility to reduce the stranded capacity and wasted energy used to power idle servers.

Key benefits of virtualization include:

- Reduction in capital expenditures
- Decrease in real estate, power, and cooling costs
- Faster time to market for new products and services
- Reduction in outage and maintenance windows

**4. Drive quality up through a comprehensive compliance program:** Microsoft recognizes that comprehensive and clearly communicated security protections are essential to building the customer trust necessary for cloud computing to reach its full potential. At the Microsoft data center level, many operations technologies and processes comprise a security program and control framework that is evaluated regularly by external parties.

Microsoft holds certifications and capabilities for our data centers and operations that include:

- ISO/IEC 27001:2005
- SSAE 16/ISAE 3402 SOC 1, 2 and 3 (transitioning from SAS 70 Type I and II)
- FISMA
- HIPAA/HITECH
- PCI Data Security Standard
- Multiple U.S. State, Federal, & International Privacy Laws

Quality and compliance are tightly linked, and can be managed through a common set of processes. Effective approaches to increasing quality are almost without exception tied to observing standards and reducing variability.


*Microsoft's Online Security Compliance Process*

Microsoft utilizes a compliance framework that tracks our audit requirements and maps these obligations against our operational control activities. These mappings allow us to meet multiple obligations with a standard set of controls which helps keep our program streamlined and more effective to manage. For example, we've mapped on average 2.25 audit requirements per operational control activity.

Adopting standardized, consistent processes that address compliance has resulted in a higher quality, more efficient delivery of security capabilities. These capabilities extend across the Microsoft cloud and to Microsoft's cloud customers.

**5. Embrace change management:** Poorly planned changes to the production environment can have unexpected and sometimes disastrous results, which can spill over into the planet's environment when the impacts involve lower energy utilization and other inefficient use of resources. Changes may involve hardware, software, configuration, or process. Standardized procedures for the request, approval, coordination, and execution of changes can greatly reduce the number and severity of unplanned outages. Data center organizations should adopt and maintain repeatable, well-documented processes, where the communication of planned changes enables teams to identify risks to dependent systems and develop appropriate workarounds in advance.


*Consistent and well-documented processes help ensure smooth changes in the production environment.*

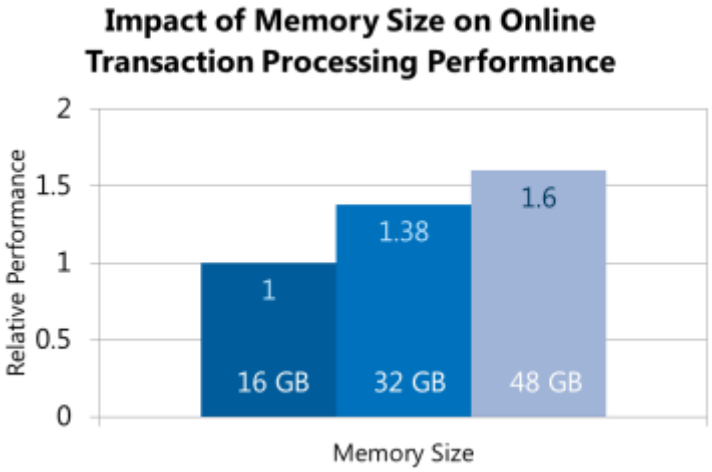
Microsoft manages changes to its data center software infrastructure through a review and planning process based on the Information Technology Infrastructure Library (ITIL) framework. Proposed changes are reviewed prior to approval to ensure that sufficient diligence has been applied. Additionally, planning for recovery in the case of unexpected results is crucial. Rollback plans must be scrutinized to ensure that all known contingencies have been considered.

When developing a change management program, it is important to consider the influences of people, processes, and technology. By employing the correct level of change management, Microsoft has increased customer satisfaction and improved service level performance without placing undue burden on its operations staff.

Other features that your change management process should include:

- Documented policies around communication and timeline requirements
- Standard templates for requesting, communicating, and reviewing changes
- Post-implementation review, including cases where things went well

**6. Invest in understanding your application workload and behavior:** The applications in your environment and the particulars of the traffic on your network are unique, and the better you understand them, the better positioned you'll be to make improvements. Moving forward in this regard requires hardware engineering and performance analysis expertise within your organization, so you should consider staffing up accordingly. Credible and competent in-house expertise is needed to properly evaluate new hardware, optimize your request for proposal (RFP) process for servers, experiment with new technologies, and provide meaningful feedback to your vendors. Once you start building this expertise, the first goal is to focus your team on understanding your environment, and then working with the vendor community. Make your needs known to them as early as possible. It's an approach that makes sense for any company in the data center industry that's working to increase efficiency. If you don't start with efficient servers, you're just going to pass inefficiencies down the line.




*In some cases, adding memory is an energy efficient way to improve performance.*

**7. Right-size your server and network platforms to meet your application requirements:** A major initiative in Microsoft data centers involves "right-sizing the platform." This can take two forms. One is where you work closely with server manufacturers to optimize their designs and remove items you don't use, such as more memory slots and input/output (I/O) slots than you need, and focus on high efficiency power supplies and advanced power management features. With the volume of servers that Microsoft purchases, most manufacturers are open to meeting these requests as well as partner with us to drive innovation into the server space to reduce resource consumption even further.

Of course, not all companies purchase servers on a scale where it makes sense for manufacturers to offer customized stock-keeping units (SKUs). That's where the second kind of right-sizing comes in. It involves being disciplined about developing the exact specifications that you need servers to meet for your needs, and then not buying machines that exceed your specifications. It's often tempting to buy the latest and greatest technology, but you should only do so after you have evaluated and quantified whether the promised gains provide an acceptable return on investment (ROI).

Remember that you may not need the latest features server vendors are selling. Understand your workload and then pick the right platform. For example, Microsoft replaced a high-end SQL four-socket SKU with a well-engineered two-socket SKU based on multi-core microprocessor technology that provided higher capacity, similar performance, and much lower power.

Similarly, by moving to commodity silicon based network switches, Microsoft has reduced typical power per 10GbE port by 70 percent.

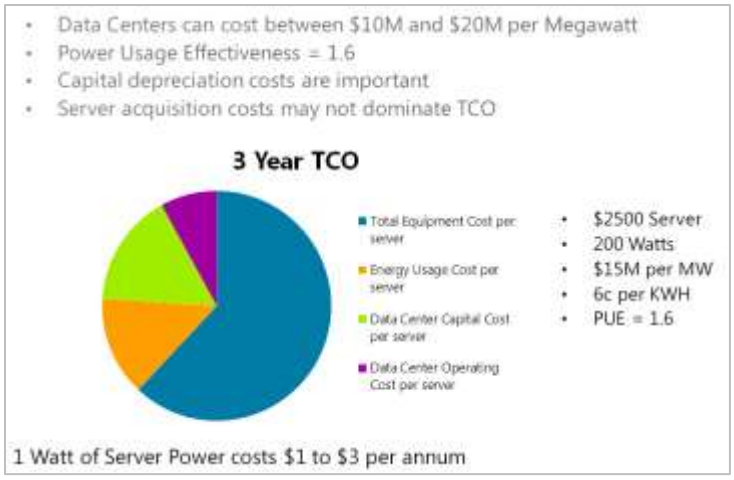
Conventional wisdom has been to buy something bigger than your current needs so you can protect your investment. But with today's rapid advances in technology, this can lead to rapid obsolescence. You may find that a better alternative is to buy for today's needs and then add more capacity as and when you need it. Also, look for opportunities to use low power dual socket servers to maximize energy efficiency. Of course, there is no single answer. Again, analyze your needs and evaluate your alternatives.

**8. Evaluate and test servers for performance, power, and total cost of ownership:** Microsoft's procurement philosophy is built around testing. Our hardware teams run power and performance tests on all "short list" candidate servers, then calculate the total cost of ownership, including energy costs. Consider using more efficient power supplies even at a small purchase price penalty to lower the energy costs over the life of the server. The focus needs to be on performance per watt per dollar, instead of just performance. The key is to bring the testing in-house so you can evaluate performance and other criteria in your specific environment and on your workload. It's important to not rely on published benchmark data, which may not be applicable to your needs and environment.

For smaller organizations that don't have resources to do their own evaluation and testing, SPECpower_ssj2008 (the industry-standard SPEC benchmark that evaluates the power and performance characteristics of volume server class computers) can be used in the absence of anything else to estimate workload power.

*In-house testing is the only way to verify how equipment will perform in your specific environment.*

In addition to doing its own tests, Microsoft requests this data from vendors in all of its RFPs. For more information, visit the Standard Performance Evaluation Corp. web site at www.spec.org/specpower.




*Total Cost of Ownership Example*

**9. Standardize the infrastructure as much as you can:** High degree of variability in the infrastructure can increase costs. Standardizing on a small set of servers, network equipment and data center technologies can drive economies of scale, and reduce support costs. Custom deployments are more error prone. At Microsoft, we use a standard network architecture and small set of server SKUs. Microsoft's server standards program encourages internal customers to choose from a consolidated catalogue of servers. Narrowing the number of SKUs allows Microsoft to make larger volume buys at lower cost and simplify the supply chain. It also helps reduce operational expenditures and complexities around installing and supporting a variety of models. Complementing this approach, Microsoft's server selection process is built around a 12- to 18-month cycle, so new models of servers are not constantly being brought on board. This increases operational consistency and results in better pricing, as long-term orders are more attractive to vendors.

**10. Take advantage of competitive bids from multiple manufacturers to foster innovation and reduce costs:** Competition between manufacturers is a good thing, which Microsoft encourages through ongoing analysis of proposals from multiple companies that puts most of the weight on price, power, and performance. Microsoft develops hardware requirements, shares them with multiple manufacturers, and then works actively to develop optimized solutions. After a preliminary analysis, detailed development work continues with the company that has the best-proposed design. Energy efficiency, power consumption, cost effectiveness and application performance per watt each play key roles in hardware selection. The competition motivates manufacturers to be price competitive, drive innovation, and provide the most energy efficient, lowest total cost of ownership (TCO) solutions. Even though performance is important, many applications can be scaled out. Server purchases should be based on the total cost of ownership that takes into account energy consumption costs and data center capital allocation costs. At Microsoft, performance per TCO$ is an important buying criterion.

**Conclusion:** Beyond the business practices listed above, Microsoft's Global Foundation Services' team is taking significant steps in four areas important to environmental sustainability:

- **Using recycled resources whenever practical:** The Microsoft data center in San Antonio, Texas, for example, uses approximately eight million gallons of recycled water a month from the city's waste water system during peak cooling months. Our Quincy, Des Moines, and Boydton data

centers' building shells are made from recycled steel. They are also twice as efficient and use only one percent of the water consumed by more traditional, water-cooled data centers that are still the industry standard. We also use recycled fiber cement in our new construction projects to help improve air quality and reduce carbon. For example, one of our data centers realized a savings of over 198 tons of $CO_2$, the equivalent of taking 90 cars off the road a year. Additionally, as part of our community commitment to Quincy, Microsoft entered a public-private partnership with the municipality that enables the reuse of water from local food processing plants to meet the cooling needs of our data center. This eliminated our need for potable resources while also significantly recharging the supply returned to ground water with approximately 80 percent of the treated water now going back to the community aquifer. In October 2011, we transferred the plant to the city to extend these sustainability benefits to other industries in the region. This was the first known transfer of a water treatment plant to a municipality and is valued at tens of millions of dollars.

- **Using renewable resources to power our data centers:** Microsoft's commitment to carbon neutrality means that for every unit of energy that is not already provided by a renewable generation resource (hydro, wind, solar), Microsoft will purchase renewable energy to insure that 100 percent of our data center energy consumption is carbon-free. In addition, we are actively working on projects that will demonstrate the ability of Microsoft data centers to run directly on renewable power resources. Today, our facility in Quincy, Washington, uses 100 percent renewable hydropower from the Columbia River Basin, and our data center in Dublin, Ireland, uses outside air for cooling.

- **Reducing waste in operations:** There is opportunity to optimizing supply chain logistics by not shipping full-assembled racks, which reduces packing materials, transportation, and shipping wastes and costs, and allows for simplifying the rack design and manufacturing. In some cases the engineering to protect fully loaded racks in shipping can add up to 2x the rack cost and adds considerable weight. Further, we have found efficiencies in retaining the electrical and mechanical rack infrastructure when decommissioning the servers themselves, saving the obvious costs and accelerating the deployment schedule. Additionally, we decided to avoid raised floors and chillers to significantly reduce water usage to approximately one percent in our newer facilities. In several locations, we have eliminated the use of Direct Expansion (DX) air-handlers for back-up cooling. For example, DX units were installed in the first phase of our Dublin data center in 2009, but were hardly used. The warmest average high temperature in Dublin is 19 °C (66 °F) in July and August, and hasn't exceeded a maximum of 82°F between 1971 and 2000. The DX units were also left out of earlier capacity expansions at the existing site in 2011.

- **Recycling all our servers and electronic equipment:** we send 100 percent of our equipment to a third-party vendor that recycles and/or resells it.

- **Taking part in industry environmental groups:** Microsoft is a co-founder and active participant in the Climate Savers Computing Initiative and The Green Grid—industry organizations focused on improving computer systems and data center efficiency, and establishing a firm methodology for measuring CUE, PUE, and WUE accurately and consistently (metrics co-developed by Microsoft's Christian Belady). We also participate in the European Code of Conduct for Data Centre's and are one of their first Sustainability Best Practice honorees. The U.S. Environmental

Protection Agency also recently recognized Microsoft as the third largest purchaser of green power in the U.S., purchasing more than 1.1 billion kilowatt-hours (kWh) of green power annually. In part, through these groups Microsoft is advocating that the industry move to a broader range of operating environments that will enable data centers to run without chillers in many parts of the globe, thereby saving large amounts of power and capital expense.

Microsoft has also implemented a number of best practices and policy guidelines that drive its construction and facility operations worldwide. Examples include benchmarks for the design, construction, and operation of high performance green buildings, high efficiency electric motors for pumps and fans, electronic variable speed drives, electronic ballasts for fluorescent lamps, and occupancy dimmers. In short, GFS leaves no stone unturned in optimizing its use of power and natural resources.

Global Foundations Services' focus on the environment is consistent with Microsoft's commitments in this area. Most recently, we announced in May 2012 that Microsoft is instituting a companywide commitment to achieve carbon neutrality beginning in July 2012, and will institute an internal carbon price, which will make the company's business divisions financially responsible for the cost of offsetting their carbon emissions. Because data centers are a significant component of Microsoft's carbon footprint, GFS will play a vital role in Microsoft's efforts to meet this corporate goal.

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