Cloud Computing and Sustainability:
The Environmental Benefits of Moving to the Cloud

accenture

High performance. Delivered.

In collaboration with

WSP

Executive Summary

The cloud's unprecedented economies of scale reduce overall cost and increase efficiencies, especially when replacing an organization's locally operated on-premise[1] servers. But does this advantage also translate to environmental benefits?

Cloud computing—large-scale, shared IT infrastructure available over the internet—is transforming the way corporate IT services are delivered and managed.

To assess the environmental impact of cloud computing, Microsoft engaged with Accenture—a leading technology, consulting and outsourcing company—and WSP Environment & Energy—a global consultancy dedicated to environmental and sustainability issues—to compare the energy use and carbon footprint of Microsoft cloud offerings for businesses with corresponding Microsoft on-premise deployments.

The analysis focused on three of Microsoft's mainstream business applications—Microsoft Exchange®, Microsoft SharePoint® and Microsoft Dynamics® CRM. Each application is available both as an on-premise version and as a cloud-based equivalent.[2] The team compared the environmental impact of cloud-based vs. on-premise IT delivery on a per-user basis and considered three different deployment sizes—small (100 users), medium (1,000 users) and large (10,000 users).

The study found that, for large deployments, Microsoft's cloud solutions can reduce energy use and carbon emissions by more than 30 percent when compared to their corresponding Microsoft business applications installed on-premise. The benefits are even more impressive for small deployments: Energy use and emissions can be reduced by more than 90 percent with a shared cloud service.

Several key factors enable cloud computing to lower energy use and carbon emissions from IT:

- **Dynamic Provisioning:** Reducing wasted computing resources through better matching of server capacity with actual demand.
- **Multi-Tenancy:** Flattening relative peak loads by serving large numbers of organizations and users on shared infrastructure.
- **Server Utilization:** Operating servers at higher utilization rates.
- **Data Center Efficiency:** Utilizing advanced data center infrastructure designs that reduce power loss through improved cooling, power conditioning, etc.

Though large organizations can lower energy use and emissions by addressing some of these factors in their own data centers, providers of public cloud infrastructure are best positioned to reduce the environmental impact of IT because of their scale. By moving applications to cloud services offered by Microsoft or other providers, IT decision-makers can take advantage of highly efficient cloud infrastructure, effectively "outsourcing" their IT efficiency investments while helping their company achieve its sustainability goals. Beyond the commonly cited benefits of cloud computing—such as cost savings and increased agility—cloud computing has the potential to significantly reduce the carbon footprint of many business applications.

Introduction: Is the Cloud a "Greener" Computing Alternative?

Both cloud computing and sustainability are emerging as transformative trends in business and society. Most consumers (whether they are aware of it or not) are already heavy users of cloud-enabled services, including email, social media, online gaming, and many mobile applications. The business community has begun to embrace cloud computing as a viable option to reduce costs and to improve IT and business agility.

At the same time, sustainability continues to gain importance as a performance indicator for organizations and their IT departments. Corporate sustainability officers, regulators and other stakeholders have become increasingly focused on IT's carbon footprint, and organizations are likewise placing more emphasis on developing long-term strategies to reduce their carbon footprint through more sustainable operations and products.[3]

Cloud service providers are making significant investments in data center infrastructure to provide not only raw computing power but also Software-as-a-Service (SaaS) business applications for their customers. New data centers are being built at ever-larger scales and with increased server density, resulting in greater energy consumption. The Smart 2020 report[4] "Enabling the Low Carbon Economy In the Information Age" estimates that the environmental footprint from data centers will more than triple between 2002 and 2020, making them the fastest-growing contributor to the Information and Communication Technology (ICT) sector's carbon footprint.

It stands to reason that consolidating corporate IT environments into large-scale shared infrastructure operated by specialized cloud providers would reduce the overall environmental impact and unlock new efficiencies. But does this assumption pass the test of a quantitative assessment on a per-user basis?

Considerable research has been dedicated to understanding the environmental impact of data centers and to improving their efficiency.[5] However, the aggregate sustainability impact of choosing a cloud-based application over an on-premise deployment for the same application has not been rigorously analyzed. For example, how might a CRM solution for 1,000 sales agents reduce the overall environmental footprint when it is run in the cloud versus on a company's own servers? Is there a net benefit of moving to the cloud, or are we simply "outsourcing" the environmental impact to a service provider? This Microsoft-sponsored study is targeted at answering these kinds of questions.

Note: While this research focuses on direct carbon reduction benefits of the cloud, it is also important to mention potential indirect benefits of cloud computing beyond the scope of this study. Like broadband and other technologies provided by the ICT sector, cloud computing is emerging as a viable, scalable technology that can help significantly reduce carbon emissions by enabling new solutions for smart grids, smart buildings, optimized logistics and dematerialization. The Smart 2020 report estimates the potential impact of ICT-enabled solutions to be as much as 15 percent of total global carbon emissions (or 7.8 billion tons of CO_2 equivalents per year). Broad adoption of cloud computing can stimulate innovation and accelerate the deployment of these enabled solutions. Consequently, cloud computing may have a major impact on global carbon emissions through indirect benefits in addition to the direct savings from replacement of on-premise infrastructure which are analyzed here.

Research Approach

Building upon previous analysis work with Microsoft,[6] Accenture and WSP Environment & Energy developed a quantitative model to calculate the energy use and carbon footprint of an organization's IT applications for both cloud and on-premise deployment. This approach aligns with the assessment methodology developed by the Global e-Sustainability Initiative (GeSI),[7] the industry consortium promoting sustainability on behalf of leading ICT companies.

The model quantifies energy use and carbon emissions on a per-user basis. To account for the fact that on-premise server counts do not follow a linear scale as user counts increase, the research analyzes the impact among three different sizes of user groups: small (100 users), medium (1,000 users) and large (10,000 users).

Specific input data utilized by the research team included the following (also see the Appendix for more detailed information):

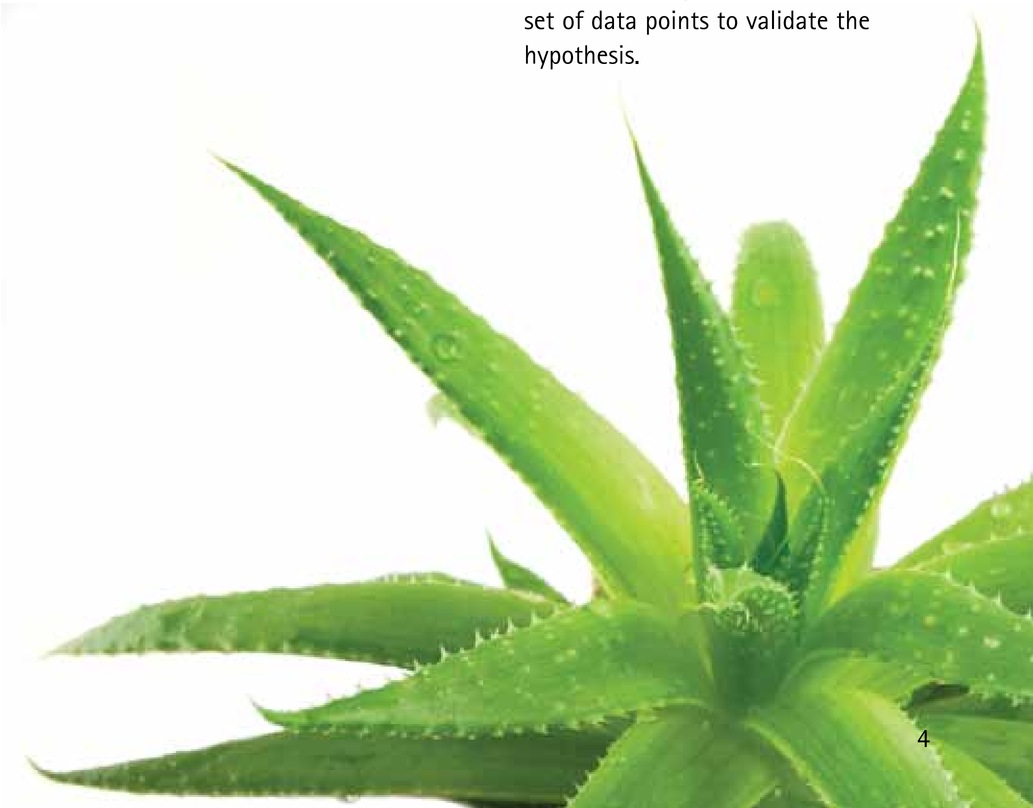
- **User Count:** Number of provisioned users for a given application.
- **Server Count:** Number of production servers to operate a given application.
- **Device Utilization:** Computational load that a device (server, network device or storage array) is handling relative to the specified peak load.
- **Power Consumption per Server:** Average power consumed by a server.
- **Power Consumption for Networking[8] and Storage:** Average power consumed for networking and storage equipment in addition to server power consumption.
- **Data Center Power Usage Effectiveness (PUE):** Data center efficiency metric which is defined as the ratio of the total data center power consumption divided by the power consumption of the IT equipment. Power usage effectiveness accounts for the power overhead from cooling, power conditioning, lighting and other components of the data center infrastructure.
- **Data Center Carbon Intensity:** Amount of carbon emitted to generate the energy consumed by a data center, depending on the mix of primary energy sources (coal, hydro, nuclear, wind, etc.) and transmission losses. The carbon emission factor is a measurement of the carbon intensity of these energy sources.

To assess the carbon footprint of cloud-based applications, the research team collected data from Microsoft's current data center operations. On-premise deployments were modeled based on Microsoft's product recommendations and input from subject-matter experts, and were validated with a case study using actual customer data.

The assessment looked at the environmental impact of three different Microsoft applications—all of them major products in Microsoft's portfolio of (server-based) business applications:[9]

- Microsoft Exchange (email, calendar and contacts)
- Microsoft SharePoint (collaboration and web publishing)
- Microsoft Dynamics CRM (customer relationship management)

These products are representative of three types of business applications that are used broadly by companies across industries. Assessing multiple applications with different usage characteristics provides a diverse set of data points to validate the hypothesis.



Summary Findings

The results of the analysis for Microsoft clearly show significant decreases in CO_2 emissions per user across the board for cloud-based versus on-premise delivery of the three applications studied (see Figure 1).

The analysis suggests that, on average across the different applications, typical carbon emission reductions by deployment size are:

- More than 90 percent for small deployments of about 100 users
- 60 to 90 percent for medium-sized deployments of about 1,000 users
- 30 to 60 percent for large deployments of about 10,000 users

As the data shows, the per-user energy use and carbon footprint is heavily dependent on the size of the deployment. The cloud advantage is particularly compelling for small deployments, because a dedicated infrastructure for small user counts—as in a small business running its own servers—typically operates at a very low utilization level and may be idle for a large part of the day. However, even large companies serving thousands of users can derive efficiencies from the cloud beyond those typically found in on-premise IT operations.

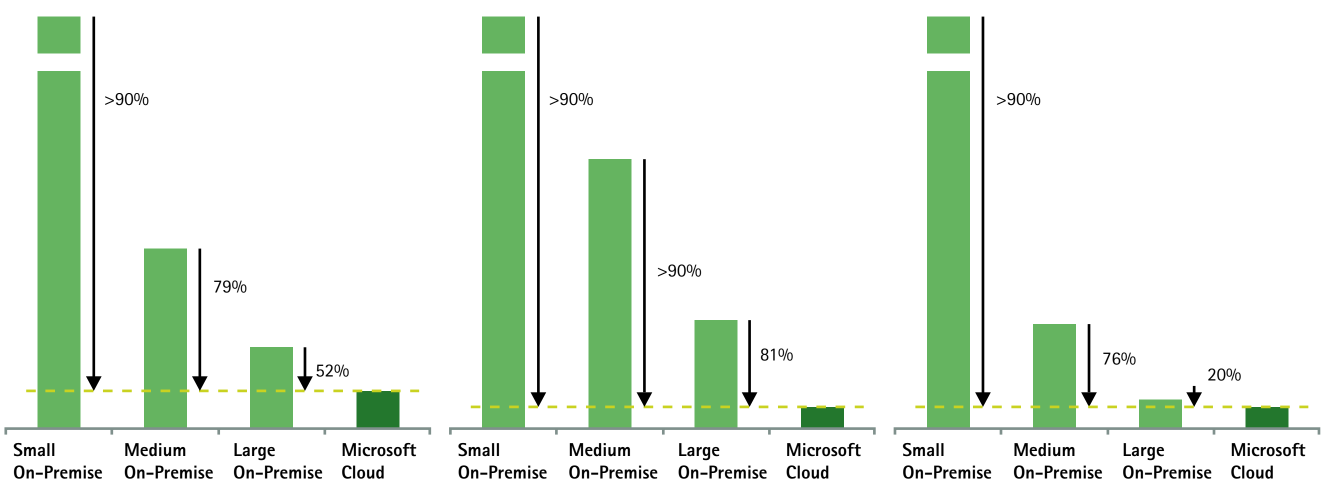
Note that, because Microsoft applications and data centers were the basis of the study, the specific carbon reductions from running other applications from other software providers on a cloud model may vary. However, the trends shown here are instructive and may be used as directional indicators for decision makers in corporate IT and sustainability leadership positions when considering a switch to cloud computing with any provider.

Figure 1: Comparison of Carbon Emissions of Cloud-Based vs. On-Premise Delivery of Three Microsoft Applications

Microsoft Exchange
On-premise vs. Cloud Comparison, CO2e per user

Microsoft Sharepoint
On-premise vs. Cloud Comparison, CO2e per user

Microsoft Dynamics CRM
On-premise vs. Cloud Comparison, CO2e per user



↓ = estimated decrease with Microsoft Cloud

How Does Cloud Computing Reduce the Environmental Impact of IT?

To understand the potential advantage of cloud computing in more detail, it is important to look at the distinct factors contributing to a lower per-user carbon footprint. These factors apply across cloud providers in general and are even relevant for many on-premise scenarios. This level of understanding can thus help IT executives target additional efficiency gains in an on-premise environment and realize additional performance advantages in the future.

Generally speaking, the comparatively smaller carbon footprint of cloud computing is a consequence of both improved infrastructure efficiency and a reduced need for IT infrastructure to support a given user base. In turn, these primary levers are heavily influenced by four key factors (see Figure 2):

- Dynamic Provisioning
- Multi-Tenancy
- Server Utilization
- Data Center Efficiency (expressed by power usage effectiveness)

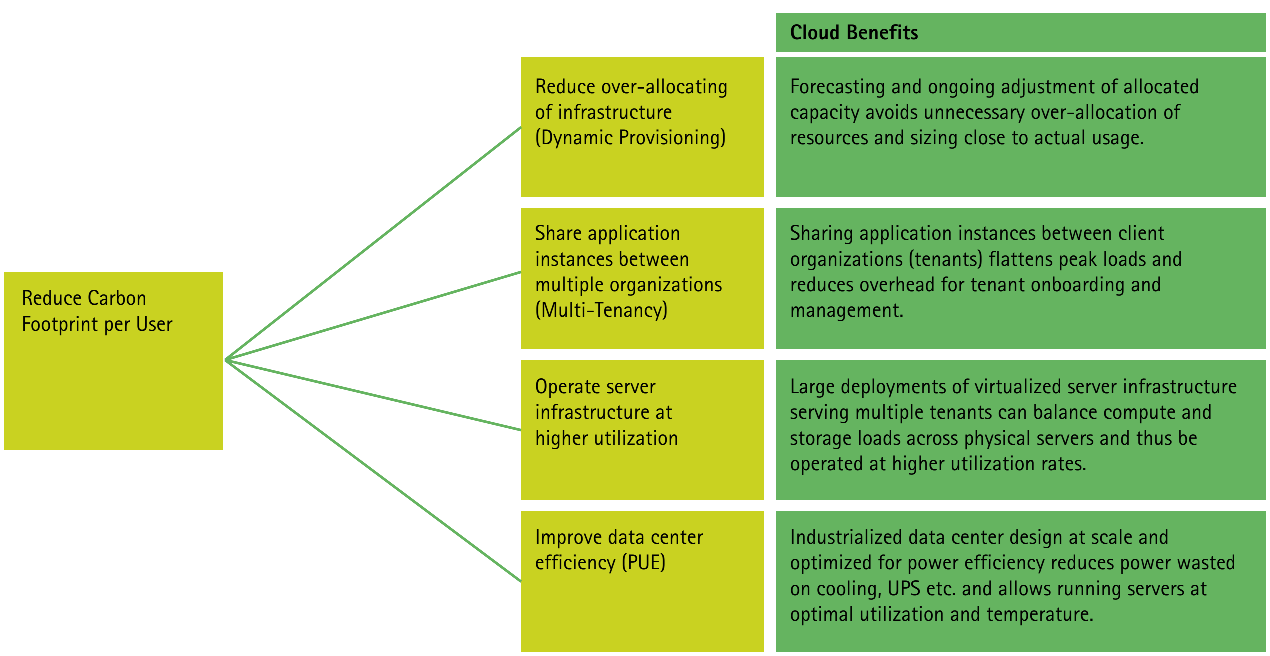
Dynamic Provisioning

IT managers typically deploy far more server, networking and storage infrastructure than is actually needed to meet application demand. This kind of over-provisioning typically results from:

- The desire to avoid ongoing capacity adjustments as demand fluctuates over time.
- Difficulty in understanding and predicting demand growth and peak loads.
- Budget policies that encourage using all available funds in a given year to avoid smaller allocations the following fiscal year.

Over-provisioning is certainly understandable. Application availability is a high priority in IT operations, because IT executives want to avoid situations in which

Figure 2: Key Drivers of Cloud Computing's Reduced Environmental Footprint



business demand for services exceeds what IT can provide. Thus infrastructure planning is typically conducted with a conservative, "just in case" mindset that results in capacity allocation that is not aligned with actual demand.

By contrast, cloud providers tend to manage capacity much more diligently, because over-provisioning at the cloud's operational scale can be very expensive. Providers typically have dedicated resources to monitor and predict demand and continually adjust capacity, and their teams have developed greater expertise in demand modeling and in the use of sophisticated tools to manage the number of running servers. Thus, cloud providers can reduce the inefficiency caused by over-provisioning by optimizing the number of active servers to support a given user base.

Multi-Tenancy

Just as multiple tenants in an apartment building use less power overall than the same number of people owning their own homes, so do the multiple tenants of a cloud-provided infrastructure reduce their overall energy use and associated carbon emissions. The cloud architecture allows providers to simultaneously serve multiple companies on the same server infrastructure. Disparate demand patterns from numerous companies flatten overall demand peaks and make fluctuations more predictable. The ratio between peak and average loads becomes smaller, and that in turn reduces the need for extra infrastructure. Major cloud providers are able to serve millions of users at thousands of companies simultaneously on one massive shared infrastructure. By operating multi-tenant environments, cloud providers can reduce overhead for on-boarding and managing individual organizations and users.

The Microsoft cloud offerings analyzed in this study are relatively new and are currently experiencing rapid growth. The more mature a given cloud service becomes, the less the demand will fluctuate, resulting in even greater energy savings in the future.

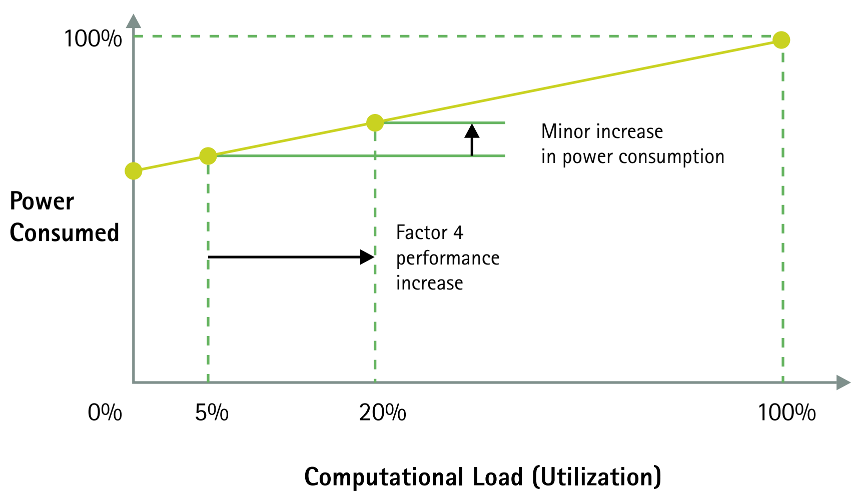
Server Utilization

Cloud computing can drive energy savings by improving server utilization (the measurement of the portion of a server's capacity that an application actively uses). As large-scale cloud providers tend to run their infrastructure at higher and more stable utilization levels than corresponding on-premise operations, the same tasks can be performed with far fewer servers. Whereas a typical on-premise application may run at 5 to 10 percent average utilization rate, the same application in the cloud may attain 40 to 70 percent utilization, thus dramatically increasing the number of users served per machine.[10]

It is important to note that while servers running at higher utilization rates consume more power, the resulting increase is more than offset by the relative performance gains. As illustrated in Figure 3, increasing the utilization rate from 5 to 20 percent will allow a server to process four times the previous load, while power consumed by the server may only increase by 10 or 20 percent.[11]

Virtualization offers a strategy to improve server utilization for both cloud and on-premise scenarios by allowing applications to run in

Figure 3: Relationship between Server Utilization and Power Consumption



an environment separated from the underlying physical servers. Multiple virtual machines can share a physical server running at high utilization, which reduces the number of physical servers required to meet the same demand. IT organizations can scale individual virtual resources to fit application needs instead of allocating an entire physical system whose full capability is not utilized. In this way, virtualization provides a tool for IT departments to narrow the efficiency gap between on-premise deployment and a multi-tenant cloud service.

Data Center Efficiency

Data center design—the way facilities are physically constructed, equipped with IT and supporting infrastructure, and managed—has a major impact on the energy use for a given amount of computing power. A common measure of how efficiently a data center uses its power is called power usage effectiveness ratio (PUE).

Power usage effectiveness is defined as the ratio of overall power drawn by the data center facility to the power delivered to IT hardware.[12] For example, a power usage effectiveness of 1.5 means that for every 1 kWh of energy consumed by IT hardware, the data center must draw 1.5 kWh of energy, with 0.5 kWh used for cooling of IT equipment, transforming and conditioning the grid power, lighting and other non-IT uses. Standardizing and measuring average power usage effectiveness across companies can be difficult. However, the US Environmental Protection Agency has released an update[13] to its initial 2007 Report to Congress,[14] stating an average power usage effectiveness of 1.91 for U.S. data centers, with most businesses averaging 1.97.

Through innovation and economies of scale, cloud providers can significantly improve power usage effectiveness. Today's state-of-the-art data center designs for large cloud service providers achieve power usage effectiveness levels as low as 1.1 to 1.2.[15] This efficiency gain could reduce power consumption over traditional enterprise data centers by 40 percent through data center design alone. Innovations such as modular container design, cooling that relies on outside air or water evaporation, or advanced power management through power supply optimization, are all approaches that have significantly improved power usage effectiveness in data centers.

As cloud computing gains broader adoption and the share of data processing performed by modern data center facilities increases, the industry's PUE averages should improve. In parallel, new data center designs continue to push the envelope on driving greater efficiencies. These two trends will drive greater efficiency in data centers.

Other Important Factors

In addition to the four primary drivers of cloud computing's environmental advantage, other contributing factors are worth mentioning:

- Hardware comes with an "embodied" carbon footprint from the energy associated with producing, distributing and disposing of equipment. For the scenarios analyzed, this energy outlay adds about 10 percent to the footprint from IT operations. The total hardware impact depends heavily on the type of equipment, refresh cycles and end-of-life practices utilized. By optimizing hardware selection, management and disposal, cloud providers can outperform on-premise IT in terms of environmental impact.
- Cloud providers are more likely to take an active role in tailoring hardware components to the specific needs of the services they run. By collaborating with suppliers on specification and design of servers and other equipment for maximum efficiency, they realize benefits that are too complex for most corporate IT departments to address.
- Application code and configuration provide additional opportunities for efficiency gains—with cloud providers more likely to take advantage of them. Developers can write applications with more efficient processing, memory utilization and data fetches, ultimately resulting in additional savings of physical consumption of central processing unit (CPU), storage, memory and network. The result is that less physical infrastructure is needed to deliver a given application workload.

Generally speaking, cloud computing drives the efficiency of IT with unprecedented economies of scale, higher sophistication and strong incentives to create ongoing efficiencies and continuous improvement. Cloud providers spend a significant share of their company's operational expense on IT—much more than an average corporation with its own IT department. This circumstance leads to an increased focus on cost and efficiency improvement, driving optimization of data center and application performance beyond what many businesses can achieve on their own. Leading cloud providers will simultaneously address energy consumption in a variety of ways, whether through application code optimization, data center temperature management, server decommissioning policies or other previously described approaches.

Apart from efficiency improvements, cloud providers as well as corporate IT departments can reduce carbon emissions by powering data centers from low-carbon electricity sources, such as hydropower or wind energy. This can be accomplished by selecting a site in a utility region with a lower carbon emission factor or by actively purchasing or generating renewable electricity.

The difference in location can have a significant impact. For example, data centers in the US Northwest (where hydroelectric generation is common) run on power with roughly half the carbon intensity of the electricity that powers data centers in the Midwest (where coal power is common).[16] For a large data center with 50,000 servers, the difference can be equivalent to the carbon emissions from thousands of cars.

Managing carbon intensity through data center location and power sourcing strategies, in addition to improving energy efficiency associated with running cloud applications, gives cloud providers a powerful lever to further minimize their carbon footprint.

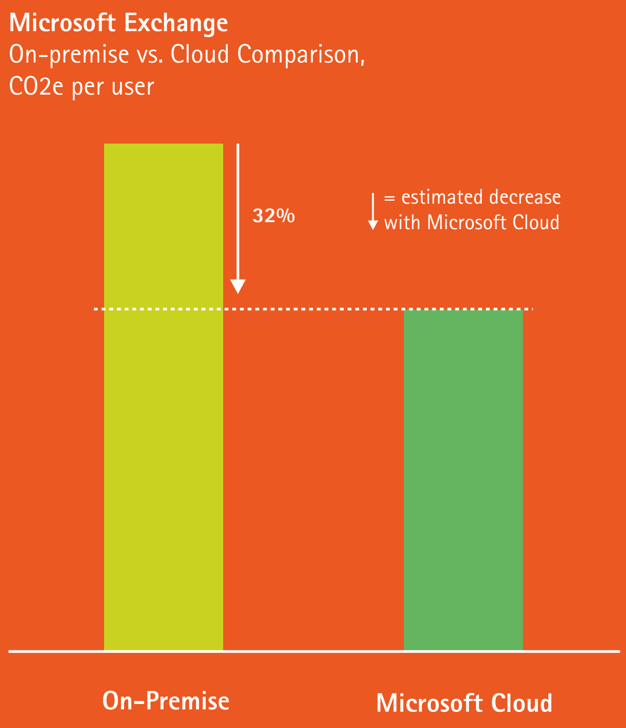
Case Study – Global Consumer Goods Company

To further validate the findings produced in this study about the reduced energy use and environmental impact of cloud computing, Accenture and WSP Environment & Energy worked with a global consumer goods company to estimate the potential for an improved carbon footprint after moving email and messaging services from its current data centers to Microsoft's cloud-based Exchange Online offering.

The analysis focused on the company's operations in North America and Europe. The current large on-premise deployment of roughly 50,000 users in North America and Europe already benefits from major economies of scale, with emissions per user far lower than any small or mid-size deployment. However, the analysis revealed that moving to a cloud solution would save energy and further reduce carbon emissions by 32 percent.

The results are in line with the predicted carbon savings for large deployments (30 to 60 percent reduction) and help confirm the findings of the primary research study. The cloud maintains a strong efficiency margin over on-premise solutions, even for efficiently operated, large-scale deployments similar to that of this global company.

Comparison of On-Premise and Cloud Deployment for a Global Consumer Goods Company



Conclusion & Outlook

Expanding the Cloud

What will be the environmental impact if cloud-based solutions are widely adopted by businesses to replace current on-premise deployments?

To illustrate the findings from this study in an example, it is possible to estimate the potential carbon savings assuming all US companies with 100 to 10,000 employees were using Microsoft Exchange and would switch from on-premise email servers to the corresponding cloud solution.[17] For this scenario, the reduction of carbon emissions would be equivalent to the emissions saved from permanently removing about 100,000 passenger cars from the road.[18]

This number represents the impact of just a single business application for a third of the total US workforce. When considered on a global scale and across an entire spectrum of business applications, the potential impact is very impressive.

These gains will be accelerated by both Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS) offerings, Microsoft's Windows Azure® services providing an example for both. As public clouds, such services allow any IT department or independent software vendor to develop cloud-based applications and run them on highly efficient infrastructures. The entire IT industry, including users and providers, will thus be able to reduce its environmental impact through cloud computing. Alternative architectures to large-scale public clouds—including private clouds, community clouds and hybrid architectures—can all be expected to yield efficiency gains of varying dimensions.

Although the carbon emissions of cloud providers will increase as they run a growing percentage of other companies' applications, overall net emissions will decrease when customers replace existing on-premise servers with cloud services. Thus, organizations that plan to reduce energy use and improve their carbon footprint can consider migrating to the cloud as an important means for improving industry-wide environmental sustainability.

Further Improvements

This study's finding that companies can reduce their carbon emissions by 30 to 90 percent by switching to a cloud infrastructure is certainly impressive. As impressive as these numbers are, the cloud's efficiency is likely to improve even more over time. Cloud computing is rapidly expanding; demand is increasing and providers are ramping up extra servers to meet predicted future capacity requirements. As more customers become cloud users, greater economies of scale will be reached and cloud providers will be able to more accurately predict capacity for computing demand.

As Microsoft and other providers build more data centers based on leading-edge designs, and retrofit older data centers, average PUE will continue to improve and per-user footprint of cloud business applications will shrink further over time.

Current technology and practices will also evolve as the data center and cloud market develops further. The following trends are likely:

- At the macro-economic level, cloud computing will help achieve economies of scale by centralizing computing power and improving access to variable capacity at a more affordable cost.
- At the corporate IT leadership level, moving to the cloud will allow a company to benefit from aggregate IT efficiency advantages in one stroke, instead of investing in gradual improvements of on-premise infrastructure over time.
- At the data center level, cloud computing's growth and drive toward consolidation and industrialization will pave the way for further scale and efficiency.
- At the application development level, software engineers will be challenged to code more efficient applications.

As the efficiency of cloud computing increases, more services will develop and while each service or transaction will continue to use less energy, there is a strong possibility that, in aggregate, computing will use more energy over time. The challenge is to ensure that the services provided in the cloud actually replace current activities of higher carbon intensity. As an analogy, a study on music distribution shifting to an online model demonstrated significant carbon savings—as long as consumers do not also burn the downloaded music onto CDs.[19]

Cloud computing has enormous potential to transform the world of IT—reducing costs, improving efficiency and business agility, and contributing to a more sustainable world. This study confirms that cloud computing can reduce carbon emissions by 30 to 90 percent for major business applications today and that future energy savings are likely as cloud computing continues to evolve. Companies who adopt cloud computing will accrue the inherent business benefits of this technology, and will also play a crucial role in making IT more sustainable by significantly reducing energy consumption.

Appendix

Model Overview

- The study quantified Microsoft Exchange, Microsoft SharePoint and Microsoft Dynamics CRM application fulfillment activities for both cloud and on-premise scenarios by dividing the total energy consumption and resulting carbon footprint against the number of active users for a given application.
- The Microsoft Dynamics CRM results in Figure 1 are based on the planned cloud installation operating at target capacity.
- The model was independently developed based on ISO 14044 guidelines for Life Cycle Assessment, BSI PAS 2050 Specifications for the Assessment of Greenhouse gas (GHG) Emissions of Goods and Services, and the WRI/WBCSD GHG Protocol.
- The study and related analytical modeling builds upon the work previously completed by Accenture and WSP Environment & Energy to assess the carbon impacts of Digital Distribution for Microsoft Volume Licensing of Microsoft Office.
- The aggregated results in this report have been calculated based on a scope limited to North American and European regions. Customers operating in different regions will be subject to different carbon emission factors and specific data center utilization rates that could affect the findings of a similar study.
- Primary data was provided by Microsoft, Accenture and Avanade (using actual measurements or conservative estimates) for cloud and on-premise scenarios.
- Secondary data for materials was derived from the EcoInvent database and other publicly available databases collated in SimaPro.
- Secondary server consumption data was derived from industry averages based on J. G. Koomey, "Estimating Total Power Consumption by Servers in the U.S. and the World" – February 15, 2007; and GreenGrid.
- Time period considered: a one-year application licensing or subscription agreement.
- GHG emissions ("carbon emissions") included are stated as carbon dioxide equivalent (CO_2e) emissions and take into account the six primary GHG gases including, CO_2 (carbon dioxide), SF_6 (sulphur hexafluoride), CH_4 (methane), N_2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons).
- The study includes the use phase of the product by the customer. While use is assumed to be the same rate for cloud and on-premise, the efficiency and energy consumption associated with the two scenarios are different.

Materials

- Primary materials included in the study consisted of servers and related network equipment used to host an application. Embodied emissions from physical hardware were estimated based on the weight and composition of each component.
- Embodied emissions from physical infrastructure included servers, but not facilities and other equipment.
- Emissions related to the material manufacture, assembly and recovery of servers and networking equipment are based on a 3.5-year refresh rate for data center hardware. Life Cycle Inventory of a server derived from Masanet E., et al. 'Optimization of Product Life Cycles to Reduce Greenhouse Gas Emissions in California.' California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-110-F. August 5, 2005. And from Christopher R. Hannemann, Van P. Carey, Amip J. Shah, Chandrakant Patel, "Lifetime energy consumption of an enterprise server," ISEE, pp.1-5, 2008 IEEE International Symposium on Electronics and the Environment, 2008.

Process Energy for IT Infrastructure

- Power consumption of Microsoft's servers was based on direct power measurement of application-specific server racks from Microsoft data centers.
- Estimated power consumption of servers within the on-premise environment was based on industry-standard figures provided by Hewlett Packard and verified by Accenture and Avanade using specific server configuration sizing calculations. A mixture of different vendors' on-premise systems was assessed, rather than any single server product.
- The model includes essential power for critical IT environment and utilizes a Microsoft data center-specific power usage effectiveness (PUE) ratio and an organization-type specific on-premise PUE ratio based upon EPA, Green Grid and J.G. Koomey research.
- A storage consumption and network usage efficiency ratio was also used, based upon Microsoft data and EPA, Green Grid and J. G. Koomey research, validated by Accenture and Avanade.
- For on-premise scenarios, a server redundancy factor of 2X was assumed. For cloud, the model relies on Microsoft's actual server counts which include redundancies to meet corresponding service levels.

Supply Chain Logistics & Distribution

- Emission factors for transportation were derived from the WRI/WBCSD GHG Protocol CO_2 emissions from Mobile Sources.
- Emissions were calculated based on frequency, modes, distance and weight (ton-kilometers) of the hardware.
- Servers are assumed to be manufactured in Asia and transported by marine freight to North America or Europe.

End-of-Life (EoL) Processes

- End-of-life calculations include the emissions associated with recycling and land filling IT equipment amortized over the useful life of the equipment.
- The study used a conservative assumption of 20 percent recycling and recovery for servers and network equipment.

Model Exclusions

The model used in the research study excluded the following factors:

- Energy consumed during software development.
- Tertiary suppliers and process materials that are not significant (i.e., that do not constitute an input to 95 percent of the product or process).
- Offsetting of emissions from any other part of the supply chain.
- Embodied energy of capital equipment, transportation vehicles, buildings and their energy use not directly related to servers and associated equipment.
- Maintenance of capital equipment.
- Refrigerants (except where used in the primary production of raw inputs).

Microsoft Project Sponsorship:

Rob Bernard, Chief Environmental Strategist

Francois Ajenstat, Senior Director Environmental Sustainability

Mark Aggar, Environmental Technologist

Accenture Authors and Key Contributors:

Dave Abood, Managing Director, Sustainability Services NA

Robin Murdoch, Senior Executive, Cloud Strategy

Stephane N'Diaye, Senior Manager, Sustainability Services NA

David Albano, Manager, Management Consulting, Sustainability

Andri Kofmehl, Manager, Management Consulting, Sustainability

Teresa Tung, Manager, Accenture Technology Labs

Ari van Schilfgaarde, Consultant, Management Consulting, Sustainability

WSP Environment & Energy Authors and Key Contributors:

Andrew Armstrong, Vice President

Josh Whitney, Senior Project Director

1 "On-premise" refers to running an IT application on an organization's own servers, either in an office space or a corporate data center rather than on a shared cloud or hosting infrastructure provided by another company.

2 Microsoft's cloud-based Exchange and SharePoint offerings (Exchange Online and SharePoint Online) are both a part of the Business Productivity Online Standard Suite (BPOS) and are sold either as a bundled business solution or individually, depending on customer preference. Specific on-premise versions analyzed were Microsoft Exchange 2007, Microsoft SharePoint 2007, and Microsoft Dynamics CRM 4.0.

3 Accenture and UN Global Compact. A New Era of Sustainability. 2010.

4 Global e-Sustainability Initiative (GeSI). SMART 2020: Enabling the Low Carbon Economy in the Information Age. 2008.

5 Microsoft Global Foundation Services. A Holistic Approach to Energy Efficiency in Data Centers. 2010.

6 Accenture and WSP. Demonstrating the Benefits of Electronic Software Distribution. 2009.

7 Gloabal e-Sustainability Initiative (GeSI). An Assessment Methodology. 2010.

8 Energy use to transmit data between users and servers was not modeled in detail. For the type of applications analyzed in this study, network equipment typically consumes around ten times less energy than servers and is thus not considered a very significant factor. The greater distances data travels in a cloud scenario may be more than offset by low utilization of corporate network equipment or employees accessing corporate servers remotely. However, when analyzing the environmental footprint of data-intensive (consumer) applications, such as music download or video streaming, data transfer contributes a significant share to the overall footprint and requires more in-depth analysis.

9 Microsoft's cloud-based Exchange and SharePoint offerings (Exchange Online and SharePoint Online) are both a part of the Business Productivity Online Standard Suite (BPOS) and are sold either as a bundled business solution or individually, depending on customer preference. Specific on-premise versions analyzed were Microsoft Exchange 2007, Microsoft SharePoint 2007, and Microsoft Dynamics CRM 4.0.

10 Silicon Valley Leadership Group. Data Center Energy Forecast. 2008.
IDC. The Economics of Virtualization: Moving Toward an Application-Based Cost Model. 2009." –

11 The Green Grid. Five Ways to Reduce Data Center Server Power Consumption. 2008.

12 The Green Grid. Green Grid Data Center Power Efficiency Metrics: PUE and DCiE. 2008.

13 US Environmental Protection Agency (EPA). ENERGY STAR Data Center Infrastructure Rating Development Update. 2009.

14 US Environmental Protection Agency (EPA). Report to Congress on Server and Data Center Energy Efficiency. 2007.

15 Microsoft. Microsoft's Top 10 Business Practices for Environmentally Sustainable Data Centers. 2009.

16 eGrid. GHG Annual Output Emission Rates. 2008.

17 Assuming that the number of email accounts is roughly the same as the number of employees and that companies either retire or re-allocate the on-premise server capacity that was dedicated to email, calendar and contacts. Using employee numbers from US Census data.

18 According to the US EPA Greenhouse Gas Equivalencies Calculator.

19 Weber, Koomey, Matthews. The Energy and Climate Change Impacts of Different Music Delivery Methods. 2009.

About Accenture

Accenture is a global management consulting, technology services and outsourcing company, with approximately 204,000 employees serving clients in more than 120 countries. Combining unparalleled experience, comprehensive capabilities across all industries and business functions, and extensive research on the world's most successful companies, Accenture collaborates with clients to help them become high-performance businesses and governments. The company generated net revenues of US$21.6 billion for the fiscal year ended Aug. 31, 2010. Its home page is www.accenture.com.

About WSP Environment & Energy

WSP Environment & Energy is one of the world's leading global consultancies, delivering solutions to environmental, energy, and sustainability issues. With over 1,000 people across 65 offices globally, WSP Environment & Energy offers a full-service consulting practice to a range of commercial and industrial clients, many of whom are Fortune 500 and FTSE 250 companies. WSP helps its clients increase business performance through process improvement, risk mitigation, and design and implementation of sustainable business practices. WSP Environment & Energy is part of WSP Group plc. Its home page is www.wspenvironmental.com/usa.

About Microsoft

Founded in 1975, Microsoft is the worldwide leader in software, services and solutions that help people and businesses realize their full potential. With 89,000 employees across its business divisions and global subsidiaries, the company generated revenues of US$ 62.5 billion in fiscal year 2010. Its home page is www.microsoft.com.