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Is Cloud Computing Always Greener?

Finding the Most Energy and Carbon Efficient Information Technology Solutions for Small- and Medium-Sized Organizations

As a growing number of small- and medium-sized organizations (SMOs), such as private companies, hospitals, government agencies and educational institutions, seek to improve the energy efficiency of their Information Technology (IT) operations by moving computing applications to an Internet-based "cloud" platform, it is becoming increasingly important to understand the associated energy and climate impacts. Until now there was no independent analysis to establish whether this system of Internet-based shared servers for multiple customers is indeed the most eco-friendly choice. To uncover the major factors determining how on-premise server rooms and cloud computing stack up in carbon emissions and energy savings, the Natural Resources Defense Council and WSP Environment & Energy have partnered on groundbreaking research, examining five different scenarios with the goal of making it easier for companies to compare options and consider sustainability in their decision-making.

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Presented in our report, *The Carbon Emissions of Server Computing for Small to Medium-Sized Organizations—A Performance Study of On-Premise vs. The Cloud*,[1] our analysis focuses on SMOs because half of U.S. servers reside in smaller server rooms and closets, and are typically managed less efficiently than big data centers. The purpose of this paper is to summarize the report and the following findings from our study:

- While cloud computing is generally more energy efficient and has a smaller carbon footprint than on-premise server rooms, not all clouds are created equal: some clouds are greener than others; and
- An on-premise server room that implements energy efficiency best practices can be a greener alternative than a "brown" cloud.

Ultimately, the study revealed that various solutions exist for SMOs looking to significantly cut energy waste and emissions from both on-premise server rooms and the "cloud."

CAN CLOUD COMPUTING SAVE THE DAY?

Together, all the data centers in the United States are estimated to consume more than 75 billion kilowatt-hours of electricity annually, representing roughly 2 percent of America's total electrical energy use, and steadily growing.[2] Small server rooms and closets are responsible for more than half of that energy consumption. NRDC estimates that in many small office-based organizations with on-premise server rooms, as much as 30 percent of their total electricity use may be directed toward powering and cooling servers running 24 hours a day even when performing little or no work.[3] The energy wasted in small U.S. server rooms and closets due to poor operational practices is equivalent to the output of seven medium-sized coal-fired power plants[4] and costs U.S. businesses more than $2 billion in unnecessary electricity expenses annually.

Cloud computing—the delivery of computing services over the Internet—presents an increasingly popular alternative to on-premise server rooms for SMOs. Computing resources are shared across many organizations, enabling higher efficiency and resource utilization levels, especially in large shared facilities as opposed to small private ones.

Cloud computing providers are touting the environmental benefits of their platforms. As more IT managers move or consider moving some of their IT applications to the cloud, it is becoming increasingly important to understand cloud computing's environmental impacts and whether it is always greener than on-premise computing. The new NRDC and WSP study, *The Carbon Emissions of Server Computing for Small to Medium-Sized Organizations—A Performance Study of On-Premise vs. The Cloud*,[5] found that running a computer application in the cloud is generally more energy and carbon efficient than running it in your server room because cloud computing can serve more customers at the same time, achieving better economies of scale than SMOs.

However, the carbon footprint of cloud computing services is highly dependent on a number of important variables that were considered in our analysis:

- **Server utilization factor:** How much of the server's total processing capacity is effectively utilized.
- **Electricity carbon emissions factor:** The carbon footprint of the electricity used to power the data center.
- **Power Usage Effectiveness (PUE):** The efficiency of the facility housing the servers, including cooling, power distribution, and lighting.
- **Hardware efficiency:** The energy efficiency of the servers, data storage, and networking equipment used in the server room and data center.

The study evaluated server applications commonly used by SMOs, such as email, databases, accounting software, and file sharing, under the following five scenarios:

1. **On-premise not virtualized:** A server room or closet located on the organization's premises with one server allocated to run each application.
2. **Colocation:** A common alternative to on-premise servers, where the servers remain owned and managed by the SMO but are hosted in external facilities shared with other companies.
3. **On-premise with virtualization:** An on-premise server room where multiple applications are consolidated onto a small number of servers that run applications in virtual machines.
4. **Private cloud:** Consolidated servers and applications accessed across the SMO's intranet or a private space purchased on a public cloud.
5. **Public cloud:** Internet-based computing accessed from anywhere, with shared servers that provide computing resources to multiple customers but where the SMO pays only for the capacity it needs. Cloud computing comprises both services supporting thousands of users and hosted in large data centers, and small niche applications available over the internet, supporting only a handful of users and hosted in a colocation facility.

KEY FINDINGS: "GREEN" CLOUDS AND "BROWN" CLOUDS

As illustrated by figure 1, the comparison between a typical server room not utilizing efficiency best-practices and a typical cloud service as defined by our study still shows large carbon efficiency gains from moving server functions to a public cloud, even in areas where electricity is generated from coal, such as in the Midwest and Mid-Atlantic regions. Even there, the cloud has a lower carbon output by a factor of two, or a 50 percent reduction, than on-premise facilities that have servers running only a single application. But when the cloud service provider is located in areas where more clean energy is used, such as the Pacific Northwest, the carbon savings increase dramatically to nearly a 48 times improvement, reducing the carbon emissions by 97 percent.

On the other hand, figure 1 also shows that an on-premise server room that implements energy efficiency best-practices can be far "greener" than a "brown" cloud that does not optimize server utilization and PUE, and is powered by high-carbon electricity.

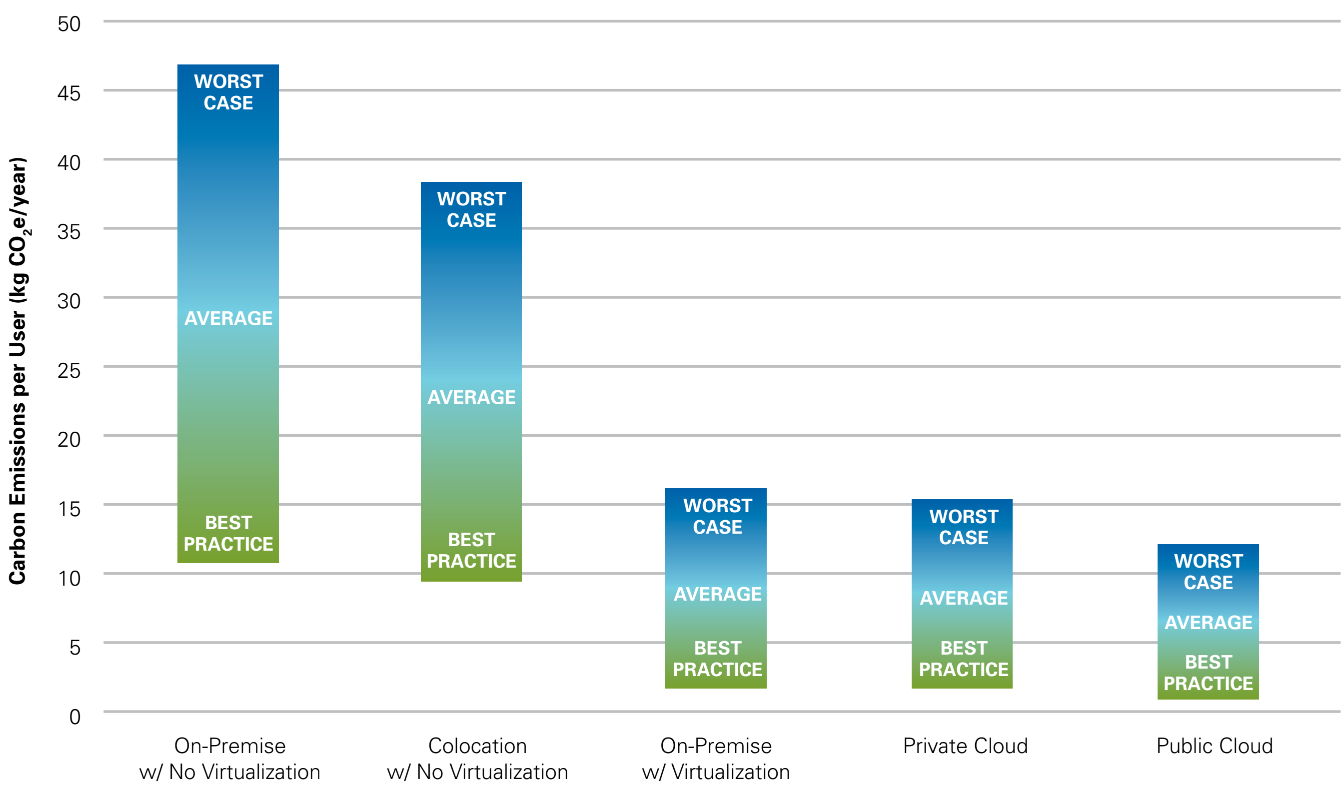
KEY FACTORS IN THE RELATIVE FOOTPRINT OF CLOUD VERSUS ON-PREMISE COMPUTING

Our analysis found that there are three factors that most influence the relative impact of cloud vs. on-premise business computing, presented here in order of importance:

1) Higher utilization of servers. The U.S. Environmental Protection Agency estimates that typical U.S. servers operate on average in a range of 5 percent to 15 percent capacity while drawing 60 percent to 90 percent of their maximum power. Sharing servers across applications, and across customers in the case of cloud computing, can increase average server utilization to 50 percent or higher.

2) Carbon emissions factor of the electricity powering the servers. Two identically sized and designed data centers using power from high-carbon sources such as coal, or from lower-carbon sources such as renewable energy, will have a very different carbon footprint (varying by a factor of nearly four depending on the region in the United States where they are located).

Figure 1: Comparison of Deployment Scenarios (Office Productivity Applications)



3) Efficiency of the server room infrastructure, including cooling and power distribution, as measured by the PUE metric. While PUE remains a key opportunity for efficiency improvements in server rooms, the potential emissions savings from improving PUE may be less than what can be achieved from increasing server utilization or using cleaner electricity.

Upgrading server equipment to newer models is another way to reduce overall energy consumption, given that computing efficiency reportedly is doubling every one and a half years.[6] Replacing or "refreshing" outdated equipment saves energy by taking advantage of higher efficiency and lower idle power consumption in the newest equipment. However, the promise of more efficient hardware is not fully realized if server utilization levels are not increased as well. For example, an application using just 5 percent of an older server may run at 1 percent utilization on a newer one, not fully using the increased performance capabilities of the new hardware.

A private cloud, which consolidates servers and applications accessed across a company's intranet, offers similar benefits and limitations to a public cloud. The main difference is potentially lower server utilization levels due to lower economies of scale and diversity of users.

Off-premise colocation facilities can provide more efficient cooling and power distribution. However, if the servers are run at low utilization levels and/or are powered by dirty electricity, colocation is only marginally better than an on-premise, non-virtualized server room when it comes to carbon emissions.

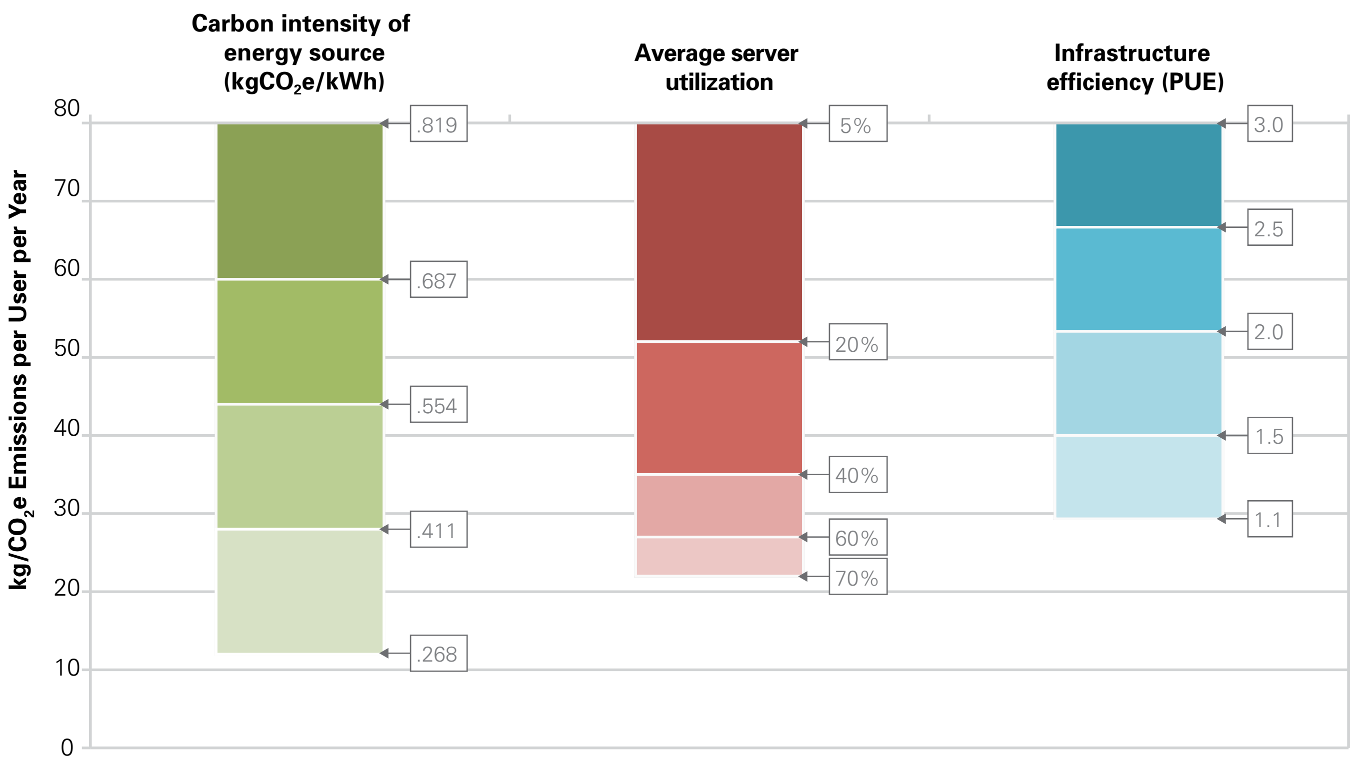
RECOMMENDATIONS: HOW SMALL- AND MEDIUM-SIZED ORGANIZATIONS CAN ACHIEVE HIGHER EFFICIENCY AND A SMALLER CARBON FOOTPRINT

Based on the above findings, NRDC offers the following recommendations to help SMOs reduce the energy use and carbon footprint from their computer applications. These recommendations address all stakeholders in the smaller server room environment, from the IT and facilities staff who manage them, to company employees, cloud service providers, utilities, and policymakers.

Server Room Managers:

- Consider moving your existing computing applications, and deploying new applications, to efficient and low-carbon cloud services. To make the right decision, ask cloud service providers to disclose not just their PUE, but also their average server utilization rate and the carbon emissions factor of their electricity source. You may not have the flexibility to move your own data center to a less carbon-intensive region, but you can consider these factors in choosing a cloud provider.
- For those applications that cannot be migrated to the cloud, apply energy and carbon efficiency best practices to your on-premise servers. The easiest way to lower your carbon footprint may be to virtualize your servers. Consolidation can yield overall energy savings of 50 percent or higher, and is one of the key drivers of data center efficiency.[7] Also, upgrade outdated equipment, switch off unused servers, and set others to go into low-power mode when inactive.

Figure 2: Comparison of Deployment Scenarios (Office Productivity Applications)



Company Executives and Employees:

- Work with your IT and facilities managers to make the assessment and improvement of the energy and carbon efficiency of your server rooms a priority in the organization's sustainability and cost-efficiency strategies.

Cloud Service Providers:

- Disclose all carbon efficiency parameters of your services, including not just PUE, but also average server utilization and your electricity source's carbon emissions factor.
- Implement energy efficiency best-practices in your data centers.
- Consider data center site location for availability of low-carbon energy resources.
- Encourage your energy suppliers to invest in energy efficiency and other clean energy resources.

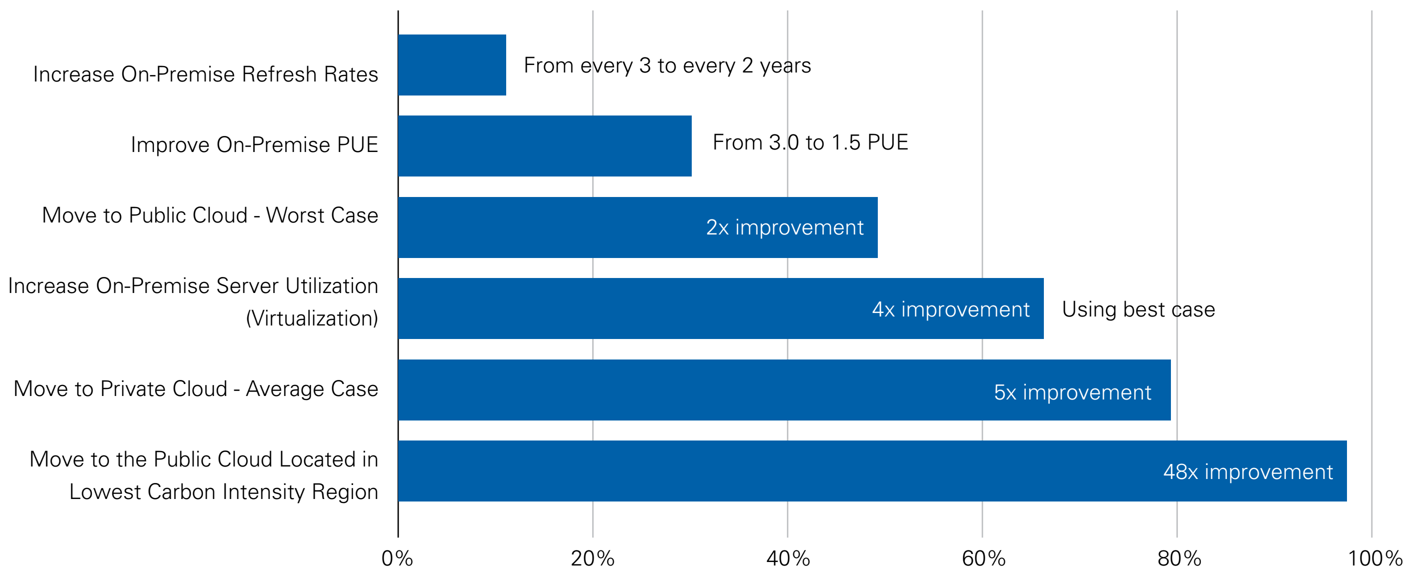
Energy Utility Program Managers and Policymakers:

- Encourage and incentivize best-practice energy and carbon efficiency measures, especially for smaller server rooms and closets that house approximately half of U.S. servers and tend to be managed less efficiently than larger data centers.

CONCLUSION

SMOs looking to improve the environmental sustainability of their operations should ask cloud service providers for full disclosure of the carbon-efficiency of the services they offer, and consider all the key variables that contribute to the energy savings and carbon impact of computing options for SMOs.

Figure 3: Potential for Carbon Reduction from On-Premise Not Virtualized



	Baseline: On-Premise Not Virtualized	Variable Scenario
Increase On-Premise Refresh Rate	Average Case On-Premise	Best Case On-Premise
Improve On-Premise PUE	Average Case On-Premise	Best Case On-Premise
Move to Public Cloud – Worst Case	Average Case On-Premise	Worst Case Public Cloud
Increase On-Premise Server Utilization (Virtualization)	Average Case On-Premise	Best Case On-Premise with Virtualization
Move to Private Cloud	Average Case On-Premise	Average Case Private Cloud
Move to the Public Cloud – Best Case Low Carbon	U.S. Average	Best Case Low Carbon (Public Cloud)

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Endnotes

1 To access the full report, please see www.wspenvironmental.com/sustain.

2 Data Center Trends Report. InformationWeek Analytics. 2010.

3 Ibid.

4 Pierre Delforge, *Are There Ghosts in Your Closet? Saving Wasted Energy in Computer Server Rooms*, February 2012. http://www.nrdc.org/energy/files/Saving-Energy-Server-Rooms-FS.pdf.

5 To access the full report, please see www.wspenvironmental.com/sustain.

6 Jonathan G., Koomey, Stephen Berard, Marla Sanchez, and Henry Wong. "Implications of Historical Trends in The Electrical Efficiency of Computing," *IEEE Annals of the History of Computing*. vol. 33, no. 3. July-September, 2011, pp. 46-54. http://doi.ieeecomputersociety.org/10.1109/MAHC.2010.28

7 Pierre Delforge, *Are There Ghosts in Your Closet? Saving Wasted Energy in Computer Server Rooms*, February 2012. http://www.nrdc.org/energy/files/Saving-Energy-Server-Rooms-FS.pdf.

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