VIRTUALIZATION

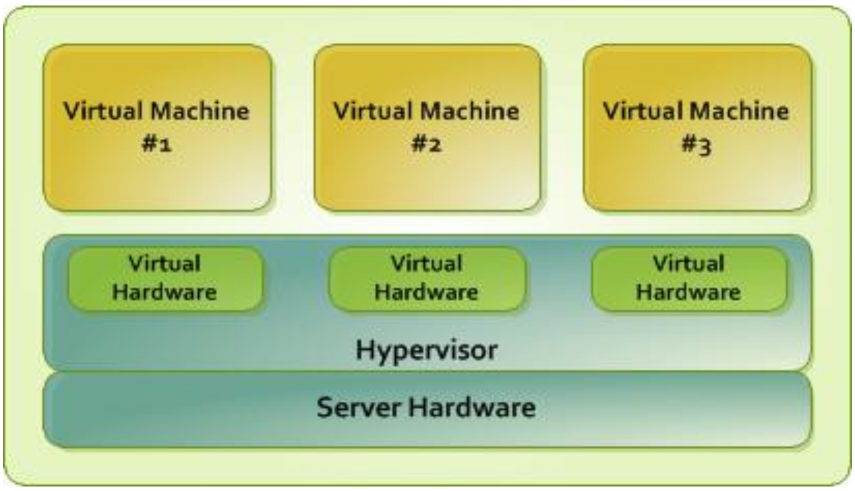
In computing, **virtualization** refers to the act of creating a virtual (rather than actual) version of something, including virtual computer hardware platforms, storage devices and computer network resources.

Virtualization began in the 1960s, as a method of logically dividing the system resources provided by mainframe computers between different applications. Since then, the meaning of the term has broadened.

Hardware virtualization

Hardware virtualization or platform virtualization refers to the creation of a virtual machine that acts like a real computer with an operating system. Software executed on these virtual machines is separated from the underlying hardware resources. For example, a computer that is running Microsoft Windows may host a virtual machine that looks like a computer with the Ubuntu Linux operating system; Ubuntu-based software can be run on the virtual machine.

In hardware virtualization, the host machine is the machine which is used by the virtualization and the *guest machine* is the virtual machine. The words *host* and *guest* are used to distinguish the software that runs on the physical machine from the software that runs on the virtual machine. The software or firmware that creates a virtual machine on the host hardware is called a hypervisor or *virtual machine monitor*.



Different types of hardware virtualization include:

- Full Virtualization – almost complete simulation of the actual hardware to allow software environments, including a guest operating system and its apps, to run unmodified.
- Para virtualization – the guest apps are executed in their own isolated domains, as if they are running on a separate system, but a hardware environment is not simulated. Guest programs need to be specifically modified to run in this environment.

Hardware-assisted Virtualization is a way of improving overall efficiency of virtualization. It involves CPUs that provide support for virtualization in hardware, and other hardware components that help improve the performance of a guest environment.

Hardware virtualization can be viewed as part of an overall trend in enterprise IT that includes autonomic virtualization, a scenario in which the IT environment will be able to manage itself based on perceived activity, and utility computing, in which computer processing power is seen as a utility that clients can pay for only as needed. The usual goal of virtualization is to centralize administrative tasks while improving scalability and overall hardware-resource utilization. With virtualization, several operating systems can be run in parallel on a single central processing unit (CPU). This parallelism tends to reduce overhead costs and differs from multitasking, which involves running several programs on the same OS. Using virtualization, an enterprise can better manage updates and rapid changes to the operating system and applications without disrupting the user. "Ultimately, virtualization dramatically improves the efficiency and availability of resources and applications in an organization. Instead of relying on the old model of “one server, one application” that leads to underutilized resources, virtual resources are dynamically applied to meet business needs without any excess fat" (Consonus Tech).

Hardware virtualization is not the same as hardware emulation. In hardware emulation, a piece of hardware imitates another, while in hardware virtualization, a hypervisor (a piece of software) imitates a particular piece of computer hardware or the entire computer. Furthermore, a hypervisor is not the same as an emulator; both are computer programs that imitate hardware, but their domain of use in language differs.

A *snapshot* is a state of a virtual machine, and generally its storage devices, at an exact point in time. A snapshot enables the virtual machine's state at the time of the snapshot to be restored later, effectively undoing any changes that occurred afterwards. This capability is useful as a backup technique, for example, prior to performing a risky operation.

Virtual machines frequently use virtual disk for their storage; in a very simple example, a 10-gigabyte hard drive disk is simulated with a 10-gigabyte flat file. Any requests by the VM for a location on its physical disk are transparently translated into an operation on the corresponding file. Once such a translation layer is present, however, it is possible to intercept the operations and send them to different files, depending on various criteria. Every time a snapshot is taken, a new file is created, and used as an overlay for its predecessors. New data is written to the topmost overlay; reading existing data, however, needs the overlay hierarchy to be scanned, resulting in accessing the most recent version. Thus, the entire stack of snapshots is virtually a single coherent disk; in that sense, creating snapshots works similarly to the incremental backup technique.

Other components of a virtual machine can also be included in a snapshot, such as the contents of its random-access memory (RAM), BIOS settings, or its configuration settings. "Save State" feature in video games console emulator is an example of such snapshots.

Restoring a snapshot consists of discarding or disregarding all overlay layers that are added after that snapshot, and directing all new changes to a new overlay.

The snapshots described above can be moved to another host machine with its own hypervisor; when the VM is temporarily stopped, snapshotted, moved, and then resumed on the new host, this is known as migration. If the older snapshots are kept in sync regularly, this operation can be quite fast, and allow the VM to provide uninterrupted service while its prior physical host is, for example, taken down for physical maintenance.

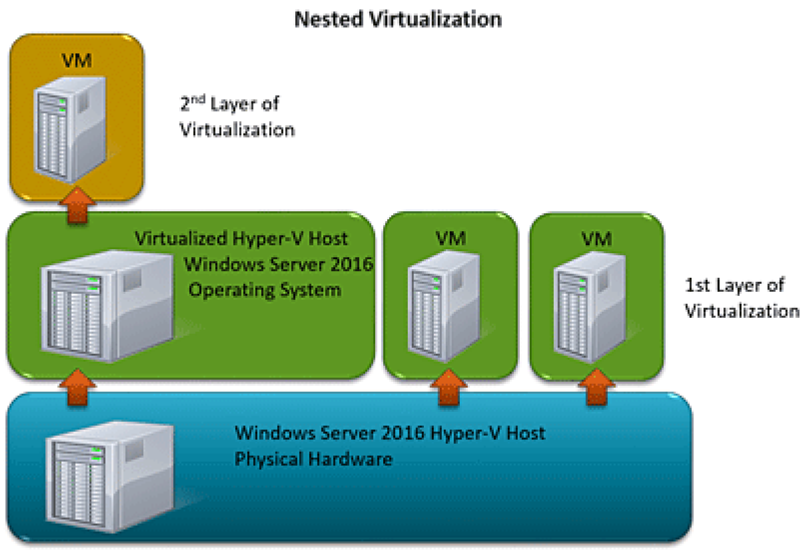
Similar to the migration mechanism described above, failover allows the VM to continue operations if the host fails. Generally it occurs if the migration has stop working. However, in this case, the VM continues operation from the *last-known* coherent state, rather than the *current* state, based on whatever materials the backup server was last provided with.

A video game console emulator is a program that allows a personal computer or video game console to emulate a different video game console's behaviour. Video game console emulators and hypervisors both perform hardware virtualization; words like "virtualization", "virtual machine", "host" and "guest" are not used in conjunction with console emulators.

Nested virtualization

Refers to the ability of running a virtual machine within another, having this general concept extendable to an arbitrary depth. In other words, nested virtualization refers to running one or more hypervisor inside another hypervisor. Nature of a nested guest virtual machine does not need not be homogeneous with its host virtual machine; for example, application virtualization can be deployed within a virtual machine created by using hardware virtualization.

Nested virtualization becomes more necessary as widespread operating systems gain built-in hypervisor functionality, which in a virtualized environment can be used only if the surrounding hypervisor supports nested virtualization; for example, Windows 7 is capable of running Windows XP applications inside a built-in virtual machine. Furthermore, moving already existing virtualized environments into a cloud, following the Infrastructure as a Service (IaaS) approach, is much more complicated if the destination IaaS platform does not support nested virtualization.



The way nested virtualization can be implemented on a particular computer architecture depends on supported hardware assisted virtualization capabilities. If a particular architecture does not provide hardware support required for nested virtualization, various software techniques are employed to enable it. Over time, more architectures gain required hardware support; for example, since the Haswell microarchitecture (announced in 2013), Intel started to include VMCS shadowing as a technology that accelerates nested virtualization.

Virtual machines running proprietary operating systems require licensing, regardless of the host machine's operating system. For example, installing Microsoft Windows into a VM guest requires its licensing requirements to be satisfied.

Desktop virtualization is the concept of separating the logical virtualization from the physical machine.

One form of desktop virtualization, virtual desktop infrastructure (VDI), can be thought of as a more advanced form of hardware virtualization. Rather than interacting with a host computer directly via a keyboard, mouse, and monitor, the user interacts with the host computer using another desktop computer or a mobile device by means of a network connection, such as a LAN, Wireless LAN or even the Internet. In addition, the host computer in this scenario becomes a server computer capable of hosting multiple virtual machines at the same time for multiple users.

As organizations continue to virtualize and converge their data center environment, client architectures also continue to evolve in order to take advantage of the predictability, continuity, and quality of service delivered by their converged infrastructure. For example, companies like HP and IBM provide a hybrid VDI model with a range of virtualization software and delivery models to improve upon the limitations of distributed client computing. Selected client environments move workloads from PCs and other devices to data center servers, creating well-managed virtual clients, with applications and client operating environments hosted on servers and storage in the data center. For users, this means they can access their desktop from any location, without being tied to a single client device. Since the resources are centralized, users moving between work locations can still access the same client environment with their applications and data. For IT administrators, this means a more centralized, efficient client environment that is easier to maintain and able to more quickly respond to the changing needs of the user and business.

Another form, session virtualization, allows multiple users to connect and log into a shared but powerful computer over the network and use it simultaneously. Each is given a desktop and a personal folder in which they store their files. With multi seat configuration, session virtualization can be accomplished using a single PC with multiple monitors, keyboards, and mice connected.

Thin clients, which are seen in desktop virtualization, are simple and/or cheap computers that are primarily designed to connect to the network. They may lack significant hard disk storage space, RAM or even processing power, but many organizations are beginning to look at the cost benefits of eliminating “thick client” desktops that are packed with software (and require software licensing fees) and making more strategic investments. Desktop virtualization simplifies software versioning and patch management, where the new image is simply updated on the server, and the desktop gets the updated version when it reboots. It also enables centralized control over what applications the user is allowed to have access to on the workstation.

Moving virtualized desktops into the cloud creates hosted virtual desktops (HVDs), in which the desktop images are centrally managed and maintained by a specialist hosting firm. Benefits include scalability and the reduction of capital expenditure, which is replaced by a monthly operational cost.

Operating-system-level virtualization, also known as containerization, refers to an operating system feature in which the kernel allows the existence of multiple isolated user-space instances. Such instances, called containers, partitions, virtual environments (VEs) or jails, may look like real computers from the point of view of programs running in them. A computer program running on an ordinary operating system can see all resources (connected devices, files and folders, network shares, CPU power, quantifiable hardware capabilities) of that computer. However, programs running inside a container can only see the container's contents and devices assigned to the container.

Containerization started gaining prominence in 2014, with the introduction of Docker.

Software

- Application Virtualization and workspace virtualization: isolating individual apps from the underlying OS and other apps; closely associated with the concept of portable applications.
- Service Virtualization: emulating the behaviour of specific components in heterogeneous component-based applications such as API-driven applications, cloud-based applications and service oriented architecture

Memory

- Memory Virtualization: aggregating random-access memory (RAM) resources from networked systems into a single memory pool
- Virtual Memory: giving an app the impression that it has contiguous working memory, isolating it from the underlying physical memory implementation

Storage

- Storage Virtualization: the process of completely abstracting logical storage from physical storage
- Distributed file: any file system that allows access to files from multiple hosts sharing via a computer network
- Virtual file system: an abstraction layer on top of a more concrete file system, allowing client applications to access different types of concrete file systems in a uniform way
- Storage hypervisor: the software that manages storage virtualization and combines physical storage resources into one or more flexible pools of logical storage
- Virtual disk: a computer program that emulates a disk drive such as a hard drive disk or optical drive disk

- Data Virtualization: the presentation of data as an abstract layer, independent of underlying database systems, structures and storage
- Database Virtualization: the decoupling of the database layer, which lies between the storage and application layers within the application stack over all

Network

- Network Virtualization: creation of a virtualized network addressing space within or across network subnets
- Virtual Private Network(VPN): a network protocol that replaces the actual wire or other physical media in a network with an abstract layer, allowing a network to be created over the Internet

Data center virtualization typically uses virtualization software along with cloud computing technology to replace traditional physical servers and other equipment housed in a physical data center.

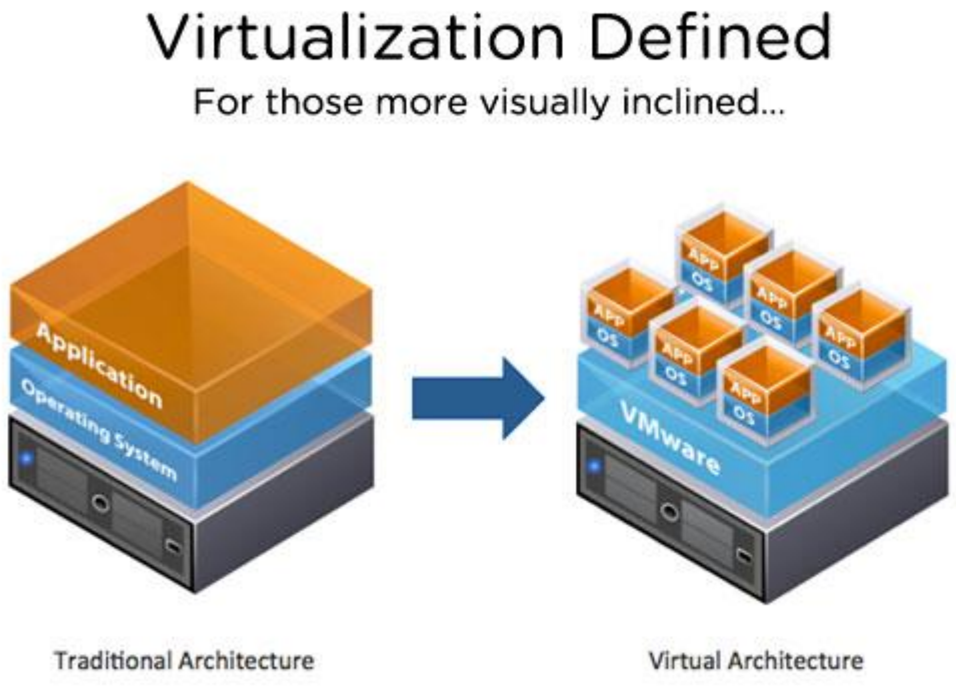
A data center that uses virtualization in data centers, sometimes referred to as a Software Defined Data Centre (SDCC), allows organizations to control their entire IT framework as a singular entity—and often from a central interface. The approach can trim capital and operational costs; improve agility, flexibility and efficiency; save IT staff time and resources; and allow businesses to focus on core business and IT issues.

Research firm MarketersMedia reports that the global data center virtualization market is projected to grow by 8 percent annually from 2017 through 2023. That would make data center virtualization a U.S. $10 billion market. Virtualization of a data center and all its hardware components—including servers, storage, and appliances—isn't a new concept (it dates back to the 1960s). But now, advances in cloud computing, software and other components have made the concept viable and even desirable.

Understanding Virtualization of the Data Center

Understanding what virtualization of a data centre means is critical to proper management of that facility. A number of related terms are used with the concept of virtualization—sometimes interchangeably. They may refer to the same thing, they sometimes overlap, and they also can mean something different. These include:

- **Server virtualization.** This approach to virtualization abstracts the physical hardware by creating a virtual server, typically running in a cloud infrastructure. This masks server resources, processors and operating systems. Server virtualization uses a hypervisor to coordinate processes and instructions with the central processing unit (CPU). A virtual server can operate on-premises or offsite in a virtual data center.



- **Big Data virtualization.** This technique of big data virtualisation produces a virtual framework for big data systems. It transforms logical data assets into virtual assets. This abstraction layer makes it easier to access data, it typically speeds data access, and it simplifies the management of data.

- **Virtualization in the data center.** This framework, as the name implies, abstracts all physical elements of a data center and creates virtual elements. It can eliminate the need for a physical space to house hardware.

- **Virtual data center.** This term refers to a pool of cloud-based servers and systems that operate as a single virtualized data center rather than a collection of physical assets.

In addition, there is sometimes confusion over other related terms, including this main term we're exploring:

- **Virtualization.** The refers to all services that are separated from the physical hardware and delivery environment through the use of a hypervisor. Virtualization allows a physical server to run multiple computing environments.

- **Private cloud.** This describes physical servers and devices that operate together within a single environment through the use of virtualization. Essentially, pooled virtualization resources create clouds.

- **Hybrid Cloud** Hybrid clouds, which may be comprised of both public and private clouds, may incorporate virtualization in different ways. As a result, changes in usage and resources may lead to performance and manageability issues.

Benefits of Virtualization

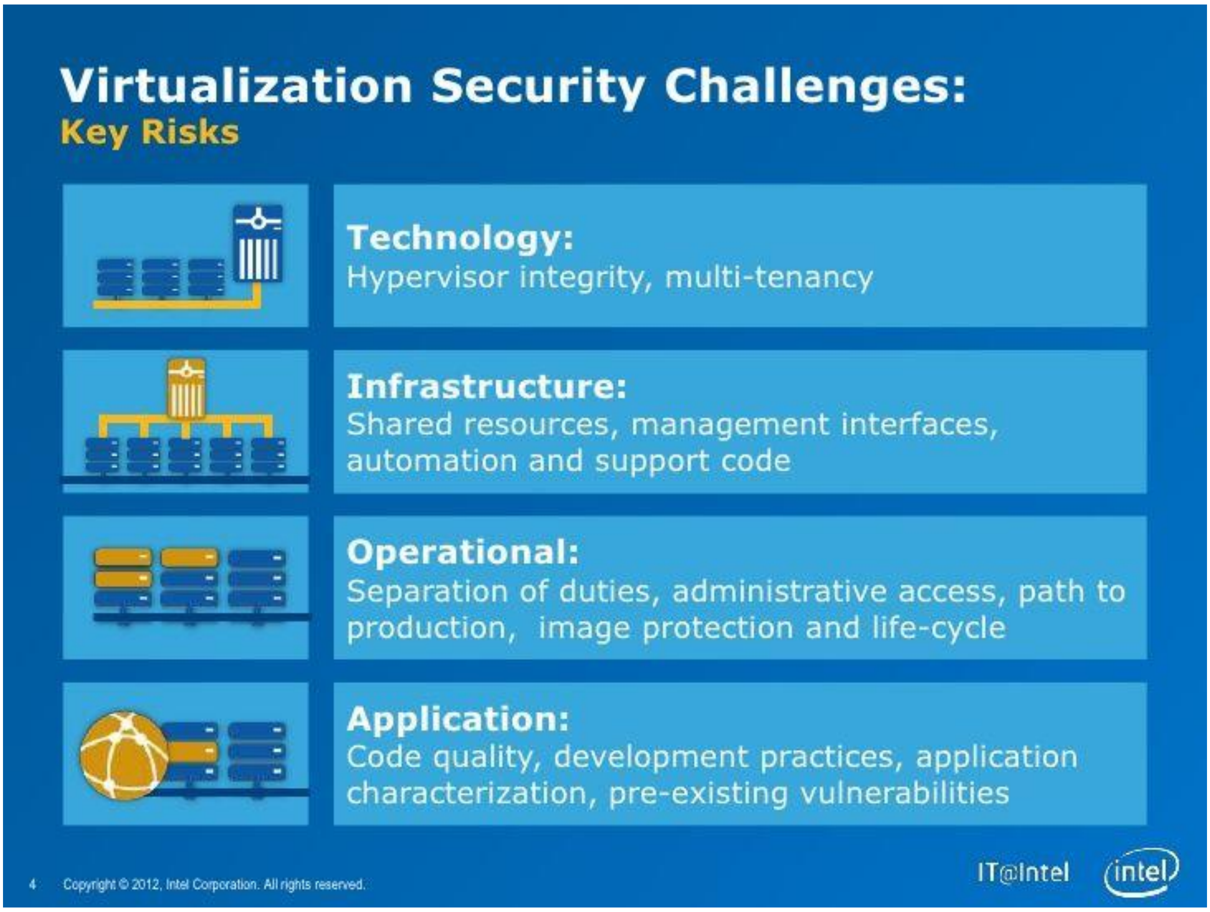
Virtualization enables virtual machines, which are a self contened of software or an OS. They introduce a number of benefits.

- **Speed and flexibility.** In many cases, virtual machines speed the delivery of services and they allow organizations to allocate computing resources more effectively.

- **Reduced capital costs.** Organizations utilize servers and computing resources more effectively. This can push utilization rates from around 60 percent to upwards of 90 percent. This reduces the need for physical hardware and devices, along with software licenses.

- **Reduce operating costs.** Fewer physical servers and devices often translates into reduce energy costs and lower heat buildup. In some cases, virtualization can help build the more efficient data centre.
- **Reduced infrastructure and real estate requirements.** Businesses that run virtualization at scale—and within large cloud frameworks—typically reduce the need for data center space or eliminate data centers altogether. In some cases, this can slash real estate and infrastructure costs to the tune of millions of dollars.

Challenges of Virtualization



Virtualization also presents a number of challenges. These include:

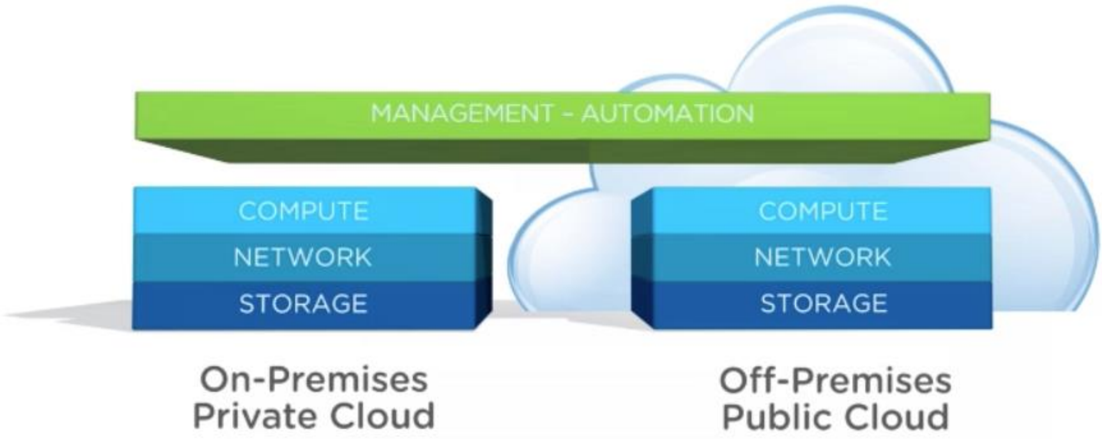
Resource management. Managing virtualized machines and the resulting IT environment can prove difficult. Although virtualization software from VMware and Microsoft is designed to simplify the task, it also introduces new complexities, including managing operating systems microservice, containers and other elements. The result can be multiple dashboards and other elements.

Infrastructure. Network connections, network storage devices and storage capacity must all be sufficient—and dynamic enough—to support a virtualized environment, particularly a virtualized data center.

Provisioning. Organizations can encounter challenges related to setting up hypervisors and provisioning virtual servers effectively and efficiently.

Managing software and other resources. Ensuring that updates and patches are applied effectively can prove difficult in a virtualized environment. There's also a need to oversee libraries of code, script and containers.

How to Manage Data Center Virtualization



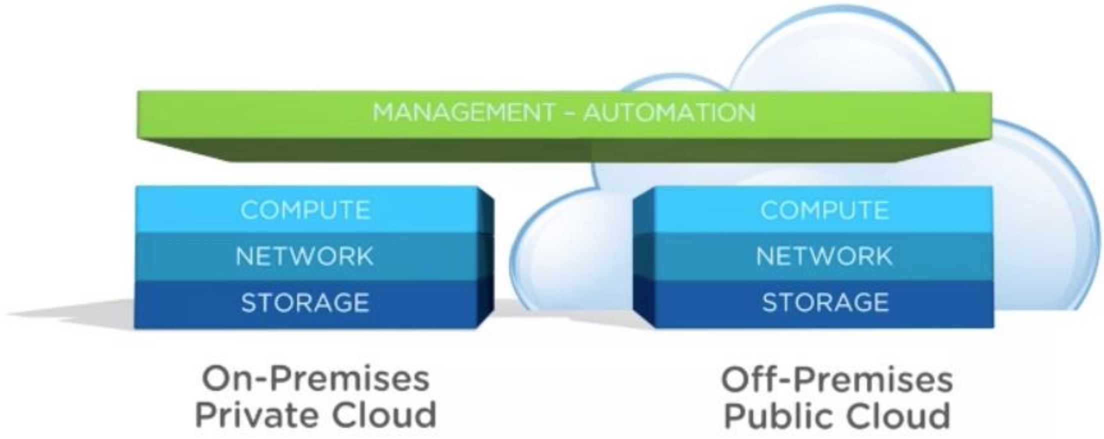
Although server virtualization is in some ways no different than overseeing physical servers, there are also some important differences. Organizations looking to maximize virtualization of a data center typically benefit by focusing on these key areas:

- **Embrace standardization.** It’s vitally important to ensure that servers run the correct software and systems and that they are updated and patched correctly. In a virtualized environment, the challenges are multiplied, and a subpar physical infrastructure will undermine the virtual framework. Consequently, it’s critical to ensure that the right configurations, templates, containers and libraries are installed and that they reach across the entire environment.

- **Address sprawl.** In many cases, the reason to adopt virtualization is to combat server sprawl. The irony is that virtualization, particularly virtualization of a data center, can create its own form of sprawl. People spin up and spin down virtual machines when they’re not actually needed. They consume resources that they don’t require. The answer is well-designed templates, auditing tools and educating teams and employees about how to use resources effectively.

- **Deploy the right administration and management tools.** It’s important to use the right software and tools to manage virtualization—especially when running more than a single hypervisor. Although vendors such as Microsoft and VMware offer built in tools with their virtualization software, these products may not be robust enough to tackle the intricacies of server virtualization and virtualization of a data center. Many smaller vendors address gaps and missing features by providing deeper visibility into a virtual stack and arming IT with more powerful tools for identifying problems and managing virtual servers and systems.

- **Ensure that there is adequate network storage and optimized backups.** Data storage and backups are both crucial task for any organization, but virtualization of a data center can present different challenges. Storage Area Networks (SANs) are a frequent choice for many organizations looking to tackle virtualization of a data center. But network attached storage (NAS) can work well too, and these devices are generally less expensive. Regardless of the exact approach, it's important to understand what works best and how to size storage capacity to meet the requirements of a virtualized environment. This requires visibility into where virtual machines store disc images in a SAN or other network storage framework.



Disaster recovery and business continuity are challenging issues for any business. Server virtualization and virtualization of a data center can help an enterprise navigate the task more effectively. Among the benefits:

- **Faster backups and recovery.** In many cases, it's possible to accomplish the task in hours rather than day when data is virtualized.

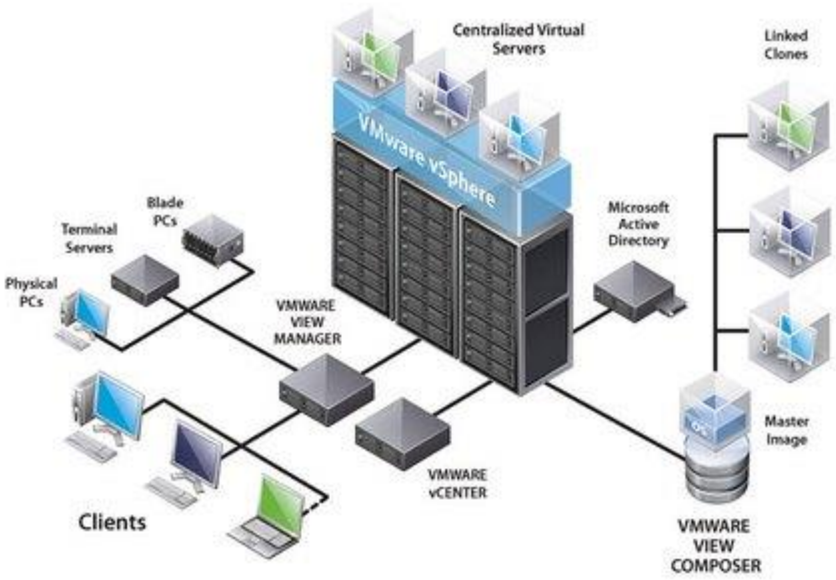
- **Better visibility into assets.** A well-designed virtualized environment with the right tools can aid in identifying and managing documents, files and other data.

- **Failover is simplified.** If it's necessary to switch to a redundant system or go back to a known working state, virtualization can help by speeding recovery time. It can also provide a platform for testing systems before moving software back into a production state.

- **The need for a smaller footprint.** Fewer servers, storage and other devices translates directly into lower costs for disaster recovery.

Data Center Virtualization Products

Numerous companies compete in the virtualization space. So how should a buyer select a data center virtualization product?



Here's the core guiding principle: By focusing on what virtualization tools make sense and where they deliver the greatest value in virtualization of a data center, an organization can improve performance, trim costs and create a more efficient computing framework.

These range from large companies like Microsoft and VMware that sell virtualization platforms and tools to best-of-breed providers that sell software and tools to manage environments and address specific tasks. These include creating and managing templates, handling disaster recovery and addressing technical tasks such as provisioning and partitioning. There are also open source tools available to address various tasks related to virtualization in a data center.

In addition to the vendors named above, here are additional choices:

- **Red Hat JBoss Enterprise Data Services:** The open source leader is a well respected name in the enterprise data center.

- **IBM InfoSphere Information Server:** Arguably the leading legacy IT name, IBM certainly knows virtualization data centers.

- **NEC Nblock:** NEC sells a solution that provides the building blocks to construct a virtual data center.

- **CDW Software Defined Data Center:** The CDW solution aims to offer flexibility and scalability that covers the complete data center.
- The introduction of virtualization software for x86 servers opened an era of server consolidation and increased operational efficiency through a reduction in the number of servers deployed and an increase in the utilization rates of servers deployed with virtualization software. Led by VMware, which delivered the first widely adopted x86 server virtualization software, this industry transition has been particularly attractive for large enterprise users.
- In the late 1990s and early 2000s, x86 servers were deployed en masse — often at excessively low levels of utilization. The hardware was growing in capacity faster than customers were able to extract value. Virtualization helped rightsize and counteract this disparity between CPU, memory capacity, and utilization. Virtualization also served as a catalyst to help larger customers contain and begin to reduce their server sprawl. Datacenter expansion was mitigated, fewer servers were deployed, and utilization rates started to increase to more acceptable levels.

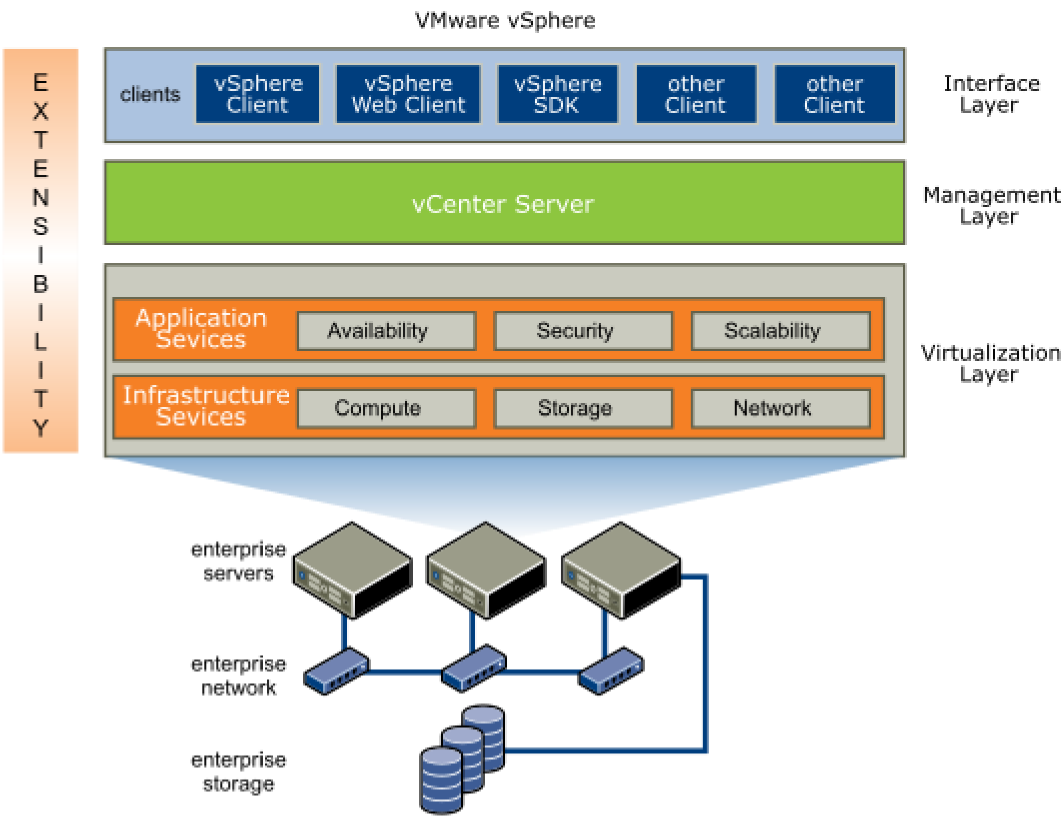
VMware virtualization

For most customers, the direct benefit of this change in trajectory was a sharply reduced spend on new servers, which was offset only modestly by the license or subscription costs for the virtualization software itself. Associated "green" benefits, which some customers cited as part of their social responsibility efforts, added to the value proposition. In reality, the green benefits, though admirable, were less likely to justify spending if there had not been an immediate and highly tangible return on the investment to virtualize the datacenter — which there was. In aggregate, virtualization software has had a dramatic effect on lowering the number of servers needed in the market. This IDC Executive Summary evaluates the impact that VMware virtualization software has made on power consumption and associated carbon dioxide (CO_2) emissions and calculates a value for the power consumption and CO_2 emissions that were avoided because of server virtualization and consolidation. Key observations include the following:
Server virtualization has positively impacted the industry by enabling customers to reduce server acquisition and life-cycle costs, reducing data center space requirements and most importantly reducing power consumption, cooling, and management demands.

..Reduction of power consumption has a direct effect on the environment, reducing the release of greenhouse gases from power generation and aiding corporate social responsibility initiatives.

..The benefits associated with server consolidation will continue to accrue for many years into the future and are augmented by reduction in cooling energy consumption and related datacenter equipment that is not needed because of a smaller server count in use. IDC used a conservative and defensible approach to calculating the power consumption avoided and associated carbon dioxide emissions that were avoided because of the industry's use of VMware virtualization software. Where possible, we used published IDC data as the basis for the secondary calculations.

IDC started with published data from IDC's Worldwide Server Tracker and IDC's Worldwide Quarterly Server Virtualization Tracker. This data was used to establish the number of physical servers, including those running without a hypervisor and those deployed with a VMware hypervisor product, for the years 2008-2015.



IDC then extended that data model back to 2003 for the purpose of establishing the number of servers deployed with VMware hypervisors during the early years of x86 virtualization adoption. By multiplying the number of servers deployed with virtualization software by the average virtual machine density, we established the number of virtual machines that were put into service each year between 2003 and 2015.

The resulting new deployment data was then aggregated using installed base calculations to determine cumulative server counts for deployments that were assumed to be avoided. The count of servers not deployed and the installed base totals derived from the count of servers not deployed were then multiplied by average power consumption rates to determine megawatt hours (MWh) avoided, which were also converted into pounds of carbon dioxide emissions avoided.

A fully detailed methodology is included in the Appendix section at the end of this document. Virtualization software makes it possible to reduce the number of physical servers used by consolidating multiple server operating system instances and their associated workloads on a smaller number of physical servers. Reducing the number of physical servers in use leads to an associated savings in data center floor space and power consumed by the server installations that have been avoided. In addition, there is often a reduction in cooling system power consumption as well, although power consumption associated with infrastructure was not considered as part of the calculation presented in this IDC Executive Summary.

Figure 1 presents IDC's calculation showing two pieces of data:

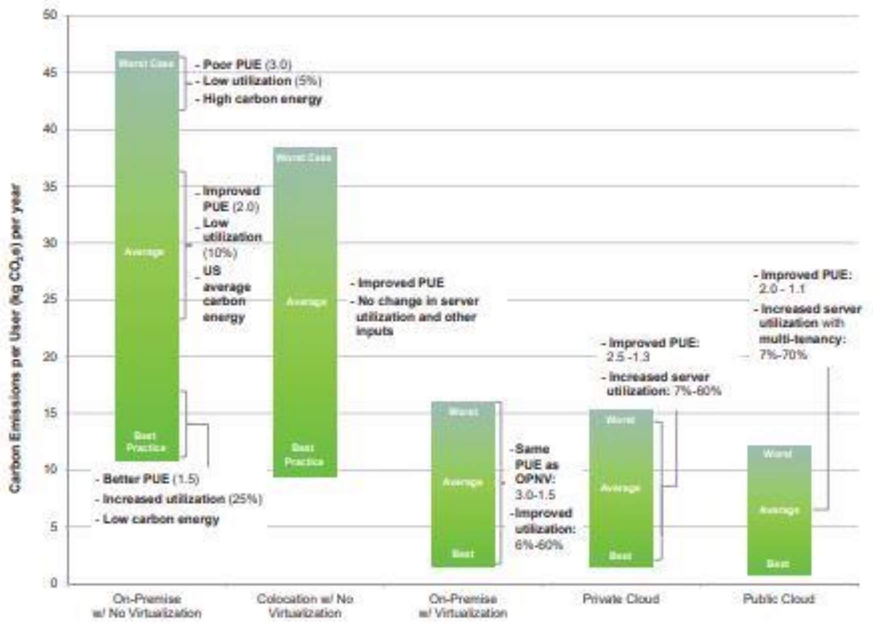
..Annual server instances worldwide avoided because of the use of new server shipments virtualized and annual existing installed servers newly redeployed with hypervisors (combined) (This constitutes the entry of new virtualized instances or, in this document, "servers avoided" each year.)

..Installed base of servers worldwide avoided annually

As indicated in Figure 1, annual servers avoided because of the use of VMware virtualization products grew from a combined total of 107,000 in 2003 to 13.8 million in 2015.

Figure 1 also shows the installed base of the server shipments avoided. That total grew from 107,000 in 2003 to 47 million in 2015. The totals shown in Figure 1 serve as the basis for calculating the amount of power and CO2 avoided because of the use of VMware virtualization products.

Figure I –
Comparison of Deployment Scenarios (Office Productivity Apps)



The Benefits of Virtualization in Reducing Power Consumption and CO2 Emissions

The notion of power consumption avoided is directly related to the avoidance of new server deployments because of the use of virtualization software. Figure 1 presents the calculated number of servers that were avoided because of the use of VMware virtualization software. By multiplying the number of servers avoided by the average power consumption and number of hours of use per day those servers would tally (if they were real servers that were placed into service in a datacenter), we can calculate the number of MWh avoided directly because of the workloads that have been consolidated on VMware virtualization products.

Figure 2 shows worldwide power consumption avoidance associated with the use of VMware server virtualization products. Power avoidance grew from 191,000 MWh in 2003 to 120 million MWh in 2015. From a cumulative total, the power consumption savings grew from 191,000 MWh in 2003 to 603 million MWh in 2015. To put some perspective on that total, 603 million MWh of cumulative power consumption avoided is equivalent to the power consumed by 43% of total U.S. households for one calendar year (during 2015 per U.S. Census data). The savings from virtualization software is magnitudes of order beyond what can be delivered by incremental improvements in efficiency that come from more efficient processors, more efficient power supplies, or a move from spinning media to solid state storage.

Figure 2 –
Close-up on 3 Most Carbon Efficient Deployment Scenarios, using Utility Apps

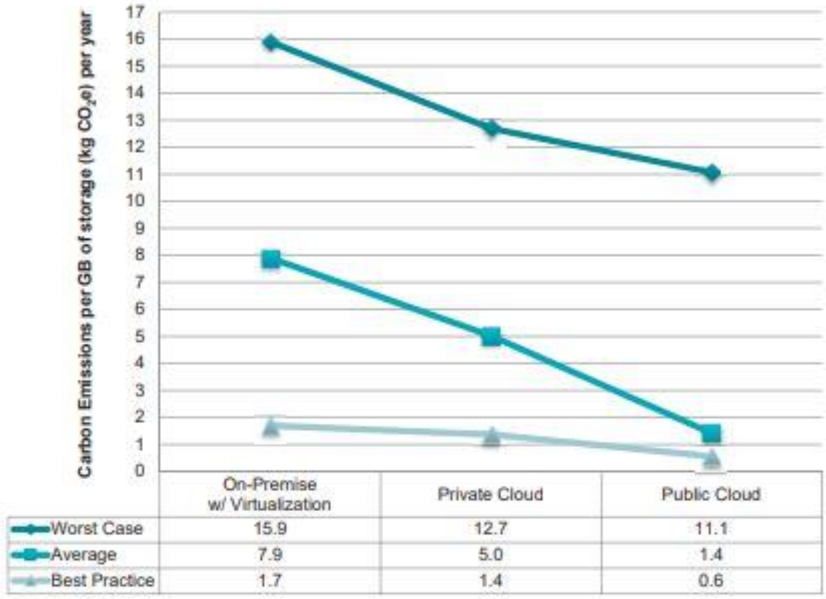
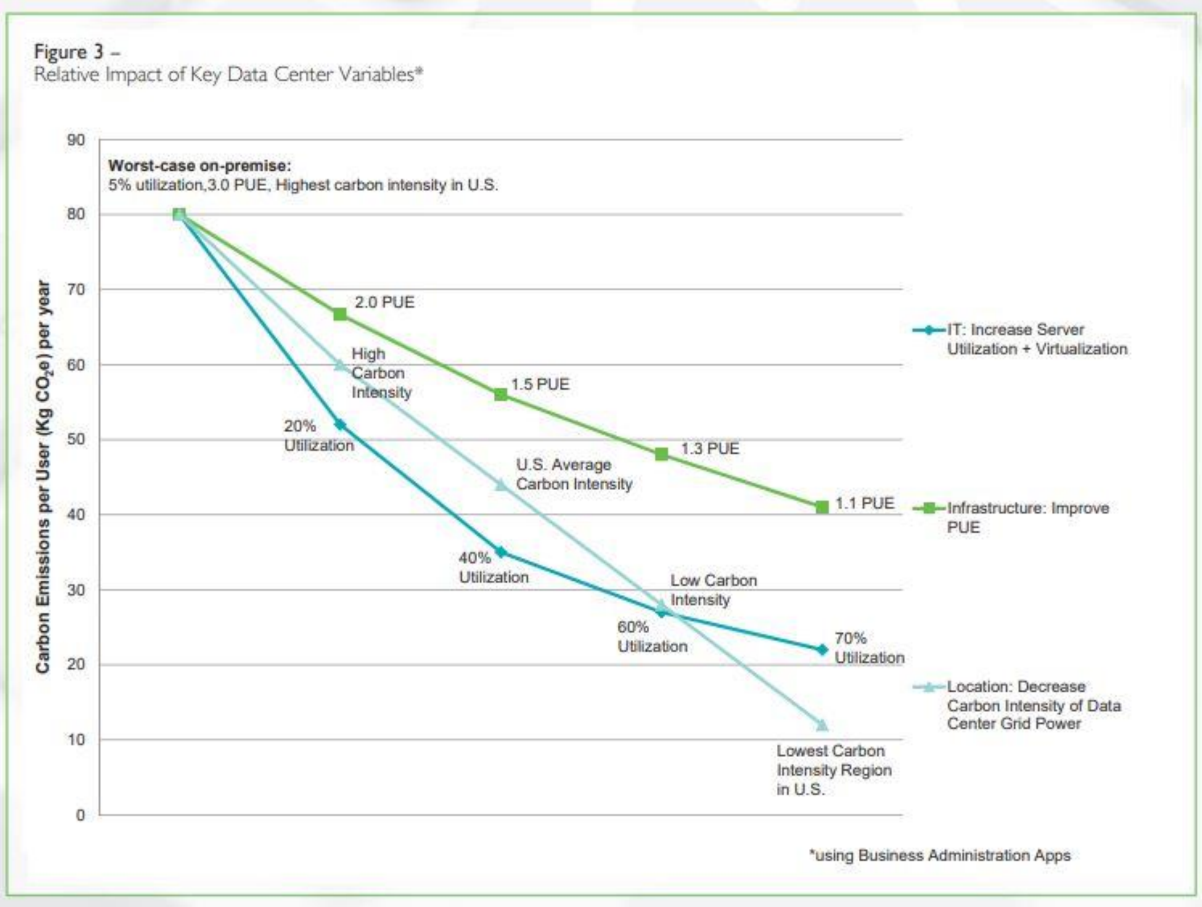


Figure 3 presents the CO2 emissions reduction related to the use of VMware server virtualization products. Figure 3 is calculated by multiplying the average number of metric tons of CO2 produced by the number of MWh produced annually and cumulatively.

As noted in Figure 3, CO2 emissions avoided related to the use of VMware server virtualization products grew from 107,000 metric tons/year in 2003 to 67 million metric tons/year in 2015. In terms of cumulative emissions, avoided emissions grew from 107,000 metric tons in 2003 to 339 million tons in 2015.

The CO2 avoidance in 2015 alone is the equivalent of removing 14 million cars from the road and the avoidance of having driven 257 million miles in 2003 and 161 billion miles in 2015. In cumulative terms, 339 million tons is the equivalent of having eliminated 812 billion automobile miles being driven over the past 13 years.



Alternatively, we could also arrive at this value using CO2 released: 148 billion pounds of CO2 released per year avoided through the use of VMware Virtualization (in 2015) divided by 14,020 pounds of CO2 released per household per year equals equivalent emissions of 10,564,839 households for one year.

Server Virtualization has been around a long time and, like many other technologies that got adopted by the business world are becoming more commonplace. In the same way the first smartphone was a flagship ground-breaking product with a prohibitive price-tag and a competitive market combined with high-demand. Which has made virtualization of your environment reliable, affordable, and a smart way to position your hardware for a longer life-span.

First, the basics:

Virtualization allows a business to have a small hardware platform that by taking advantage of powerful hardware resources, can simulate a much larger environment. With this you could have a single server that runs multiple virtual servers with the hardware investment of only one. What are the advantages?

Virtual environments scale incredibly well

it can grow with your company! Environments can be anywhere from two, ten, even ten-thousand virtualized machines. If you need more servers, you can add them easily and quickly in the virtual environment instead of waiting for hardware. It's also much more efficient to have one or more powerful servers running a large number of virtualized servers. Low on resources? You only have to purchase hardware for one more machine to be able to speed up all your virtualized machines. Resource sharing also prevents a scenario when one server is overburdened and one is underutilized. The servers can all be allotted exactly what they need, when they need it. If you need a virtual server to have more memory or drive space it can be added without turning anything off.

The burden of management for the IT environment is also reduced.

With a single place to look at all the servers, easily, preventative maintenance and day-to-day management is easier and faster than it could ever be with physical machines. Hardware maintenance is also made simpler. Less hardware means fewer worries over upgrades and warranties.

With a virtualized environment you can have additional reliability against things like failed hard-drives.

If one fails, it can be replaced without losing the environment. Most servers even have dual power-supplies so the risk of losing power is mitigated. Instead of having multiple servers that all might suffer hardware fatigue somewhere down the line, risk is consolidated to the single server. With one server to protect, a backup / disaster recovery plan and remediation strategy is vastly simplified. Business continuity is also much easier to achieve. Many business rely on ticketing systems that cost money when not operational, or have internal business or customer data that has to be available at all times. If you need redundancy to allow seamless change-over in the event of a critical hardware problem, you can add another virtualization server to fail-over to. This reduces downtime and can save your business the cost of being out of commission until hardware is replaced.

Older applications can have their life extended.

If there's something that only runs on older hardware or software you can run the 'older' software on newer hardware and not have to worry that one day the old hardware will break down, and you'll lose something critical.

Social Media Optimization

Accordingly, data center electricity consumption continues to grow and now represents roughly 2% of total electricity consumption in the US.2 Recently a number of large cloud computing providers such as Google®, Microsoft®, and Salesforce.com have demonstrated the clear energy efficiency benefits of their services, but the question of whether a typical cloud platform is significantly more energy- and carbon-efficient than an equivalent on-premise deployment remains open. More specifically, what key factors make cloud computing potentially more or less energy- and carbon-efficient than on-premise computing? Using a range of publicly available and best practice sources, NRDC and WSP completed a study to uncover the key factors that determine how on-premise and cloud computing compare from a carbon emissions perspective. The analysis focuses on the SMO: while much media attention has been dedicated to the giant internet companies and their efficient server farms, half of the servers in the United States still reside in smaller server rooms and closets which are typically managed less efficiently than large data centers.3 Furthermore, the scale of large cloud computing service providers already gives them a strong incentive to optimize energy management as energy represents a significant component of their operating expense – this is not necessarily the case with smaller cloud providers or a SMO's on-premise solution. By investigating the drivers that affect the carbon efficiency of a computing scenario, NRDC and WSP aim to enable IT managers to more easily compare the overall carbon emissions performance of some common deployment scenarios and be better equipped to integrate aspects of sustainability into their computing deployment and procurement decision making processes. Definitions In order to structure the analysis, it is important to define the different computing scenarios that are model as well as the application types.

The SMO hosts their own servers for their business applications on-site in an IT closet or server room. The business owns these servers and the software applications. The servers are often underutilized because they are provisioned to manage the highest levels of processing and for the purposes of the study; one server is allocated to run a single application and the servers only serve the SMO. The servers tend to be older and less efficient, and to be housed in facilities with sub-optimal air flow and cooling. Colocation/ Outsourcing: In some cases the SMO may choose to outsource their servers to a colocation data center, where although the infrastructure might belong to a third party, the fundamentals of how the computing works to serve the customer are the same as OPNV. In this study, the scope of the colocation scenario is limited to "unmanaged" colocation where the customer retains ownership of the equipment and responsibility for its administration. It does not include “managed” colocation which can be seen as a case of private cloud deployment. On-Premise with Virtualization (OPV): This scenario assumes the same infrastructure efficiency as OPNV, except that the SMO has employed virtualization to reduce the number of physical servers and the corresponding server power consumption. Cloud Computing Cloud computing enables the SMO access to computing and data storage capabilities without requiring they invest in their own infrastructure or train new personnel. It delivers computing services through any virtual server which is available to support a workload, rather than being limited to dedicated servers for each workload. The energy efficiency associated with cloud computing is usually attributed to the fact that the servers can potentially be more efficiently managed by a third party than they are on-premise and achieve an overall higher utilization than on-premise computing by virtue of the shared workloads. From a carbon accounting perspective, the customer must only consider their fraction of server usage in the cloud, while if they own and operate their own hardware they must take into account the entire carbon emissions associated with that server.

Private Cloud vs. Public Cloud The physical setup of “the cloud” may encompass a broad range of scenarios; the servers might be in a data center that serves multiple customers who share the same hardware, or the servers could be hosted on-site behind an organization’s firewall and work together to support multiple business units in the same organization. In this study the difference between private cloud and public cloud is defined as whether or not the cloud infrastructure serves multiple organizations or a single organization, not where the servers are physically located. Private Cloud: The term “private cloud” describes a cloud environment which serves a single organization. In some cases an SMO may consolidate their servers and applications into an organization-wide system which is maintained behind a firewall and can be accessed across an intranet. These servers may have a diversity of applications on them and serve multiple business units, but still only serve one organization. An SMO may also purchase their own portion of a public cloud; providers such as Amazon® or Rackspace® can provision a private, isolated section of a cloud platform to launch resources in a virtual network which supports a single customer. Public Cloud: In this case the SMO purchases a desired service from a cloud provider, which can be accessed from anywhere via the internet. The cloud provider may deliver their services through their own data centers, or through outsourced servers in colocation facilities or other public cloud facility. The hardware usage is shared by multiple customers and the individual customer only has to pay for the capacity they need.4 Examples of public cloud computing services may include: Google® Apps or other office applications for their business; Customer

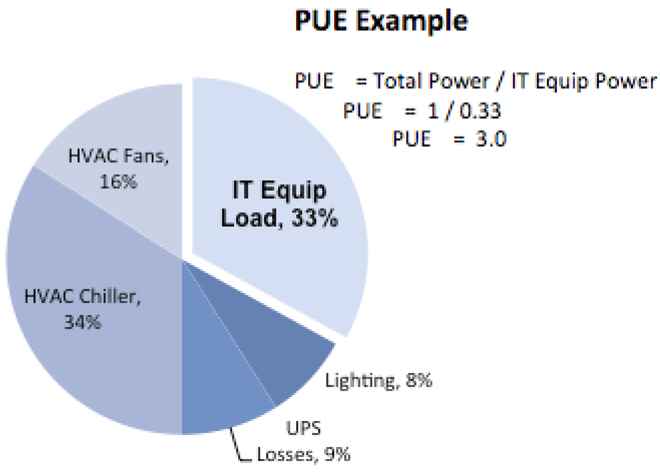
Relationship Management (CRM) web-based service such as Saleforce.com to manage its contacts and sales leads; Cloud-based business administration applications such as accounting, expense management, employee travel management, and meeting scheduling (e.g., Doodle); and

Specialized business applications delivered as cloud services to a small number of customers, for example a membership management application for a large non-profit organization. Application Types There are many factors which influence an IT manager's decision in how to deploy an application, including but not limited to, latency tolerance, scalability, growth of the organization, security, and access to hardware. While it is generally acknowledged that "transient" and "elastic" apps – those with frequent provisioning, cloning, and need for adjustment over time – may be more readily transferred to the cloud,5 NRDC and WSP selected the applications below based upon their ability to be easily deployed in either an on-premise or cloud environment, and their relevance for SMOs. Office Productivity Apps: Email is perhaps the most ubiquitous of business applications, accessed from desktops, laptops and mobile devices. It has a high data storage requirement because of fi le attachments and a high user access requirement, but given the variability across user groups, is most often licensed and managed on a per user basis. Content Management & Database Apps: CRM software and Content Management Software (CMS) are widely used application types that rely upon back-end databases to store and retrieve information. Similarly, website hosting and website development services use database layers to store content, and in the case of blogging services like Word Press, posts (articles), web pages, and visitors' comments. Each time the database is accessed or a button in a website is clicked, a "transaction" of information is processed; augmenting data to existing fields or adding new ones. These types of applications usually have low data storage requirements because large fi les are not typically uploaded or associated with a particular database, but have a high user access profile similar to email. Business Administration Apps: This type of application is used to manage information to support the backbone of an organization, no matter the industry. Human resources software, accounting software, and financial management software are common examples. These applications are categorized and assessed for performance based upon the number of transactions that are processed by the application. Utility Apps: File storage and fi le sharing software may be as critical as email, but these types of applications are not necessarily accessed as frequently. File storage and sharing software typically have a much higher storage requirement depending on the nature of the fi les (for instance, an engineering firm might store large Autocad® or Revit® fi les, while a publishing organization would have less intensive word processing documents) and are, therefore, deployed based upon the file storage and sharing requirements.

Leveraging previous studies, a quantitative analysis of the energy efficiency and carbon emissions impact by deployment and application type was developed to assess the potential impact of businesses shifting their computing requirements to a cloud service. Throughout the modeling and analysis process, NRDC and WSP used publicly available data gathered through primary and secondary research and engaged with industry experts to validate key data inputs, assumptions, and directional findings. The methodology used to develop this independent model is aligned to the assessment methodology developed by the Global e-Sustainability Initiative (GeSI) 6 and follows the process being developed by the Greenhouse Gas (GHG) Protocol's forthcoming standard for the Information

Communications & Technology (ICT) Sector Guidance for Cloud Computing and Data Center Services. The analysis represents directional performance trends and ranges that organizations can expect to realize based upon their given environment and potential constraints. The results also specify key performance indicators per application type, which are being recommended as the suggested metrics to manage by the GHG Protocol. Key Input Parameters and Variables The model uses the following key inputs and variables (Table 2) to assess performance under a variety of deployment scenarios (Table 3) for a given application type. Data sources for these inputs, definitions, and model assumptions are presented in the appendix.

Power Usage Effectiveness (PUE)



PUE has become the preferred energy efficiency metric used by the industry to measure data center infrastructure efficiency relative to the electrical load of its IT equipment. It is commonly used as an overall indicator of performance for energy consumption. As companies strive to reduce their PUE to the theoretical limit of 1.0, it forces a focus on the efficiency of the data center infrastructure. Server Utilization Rate: As the engines of the data center, servers operate in either an idle or an active mode, but even in the idle mode they are consuming a meaningful amount of electricity. As average server utilization rates hover in the 5-15% range,[7] there is a substantial amount of wasted energy in traditional operation. The underutilization of IT assets also takes an additional toll because IT manufacturing is a resource-intensive process that uses scarce materials which are damaging to the environment when extracted or processed. Server Refresh Rate: Recent research by Jonathan Koomey suggests that computing efficiency is doubling every 1.5 years, so the rate at which equipment is replaced can have an impact on overall energy consumption.[8] Most SMOs and even many data center operators are using outdated equipment which, if replaced with newer equipment, could result in reduced energy consumption. Although increasing the refresh rate contributes to the total carbon footprint of the data center due to the imbedded carbon emissions impact associated with the hardware, the emissions associated with the use phase of the server typically far outweigh the imbedded footprint for servers,[9] and the reduction in use phase emissions and the increase in imbedded emissions can be expected to be in a similar proportion. Virtualization: Virtualization and other related techniques can address the inefficiencies of low server utilization by allowing multiple applications to share a single server, thereby reducing the number of physical servers required to run workloads. Fewer servers, even when running at higher utilization levels, consume less electricity, which also reduces the need for cooling. Virtualization, if deployed effectively, is one of the key drivers of efficiency within data centers. Emission factor of server room/data center electricity source: While the other variables identified focus on the energy efficiency of a data center, the carbon emissions factor of the purchased electricity required to run a data center is one of the ultimate drivers of total carbon impact, and is dictated by the location of the data center and/or the electricity procurement decisions in markets where customers can choose between multiple providers. A carbon emission factor of purchased electricity is required to calculate the carbon footprint of a particular data center. Two identically sized and designed data centers using electricity produced by different generation means, such as renewables, hydropower, natural gas or coal, will have a potentially very different carbon footprint (factors can vary by a factor of nearly four depending on the region in the US). While an on-premise deployment does not typically have the flexibility to move to a lower carbon intensive region, an IT manager deciding between two cloud service providers can use this variable as a criterion for selection, as can cloud service providers in selecting the location of their individual data centers.

The findings of the study indicate the impacts of the previously described variables on computing performance. NRDC and WSP's model focused on those variables which contribute to the largest impact and include: Effective PUE of the server room or data centers which are hosting the servers; Effective utilization of the servers which are running a given application and corresponding number of physical servers; and Carbon emission factor of purchased electricity based on the location of the server room or data centers. Using publicly available data for the key inputs of worst case, average, and best practice, Figure 1 highlights the range of performance realized in a given deployment scenario, and the relative impacts of changing variables. P.07 The OPNV scenario is on average responsible for the most carbon emissions per user, closely followed by colocation which features improved PUE, but similar utilization and electricity source.

Application Type	Metric	Characteristics
Office Productivity (Email)	kg CO_2e per user	Typically high data storage requirements and high user access
Content Management & Database (CRM & Web)	kg CO_2e per transaction	Typically low data storage requirements and high user access
Business Administration (Finance & Accounting)	kg CO_2e per user	Typically high data storage requirements and high user access
Utility (File Storage & Sharing)	kg CO_2e per Gigabyte stored	Typically high data storage requirements and low user access

The other three scenarios all use virtualization, resulting in significantly lower emissions than non-virtualized deployments. Public cloud is on average the most efficient type of deployment, although worst-case public clouds can be responsible for much higher carbon emissions per user than best case OPV and private cloud, depending on the degree of implementation of best-practices regarding utilization levels, PUE and clean electricity procurement. The overlap across each deployment type indicates that at the margin, a deployment type that may be better on average is not necessarily so; for example, a well-managed on-premise server room with no virtualization may be equivalent to a poorly managed cloud service. Figure 2 focuses on the three most carbon efficient deployment types only and shows the average values from worst case to best case for all variables. This indicates that the average carbon efficiency gains realized by the public cloud are significant

On-Premise Not Virtualized		
Worst Case	5%	The Power of Incentives on Data Center Efficiency. Corporate Eco-Forum. March 25, 2012.
Average	10%	The Business Value of Virtualization. Forrester Research. July 2009. Best Practices Guide for Energy-Efficient Data Center Design. National Renewable Energy Laboratory. February 2010.
Best Practice	25%	Cole, Arthur. Striking the Right Balance in Server Utilization. IT Business Edge. November 16, 2009.
Colocation – Data inputs and assumptions for Colocation are the same as OPNV with an improved PUE based on scale and 3rd party financial incentives to better manage cooling loads		
On-Premise with Virtualization		
Worst Case	6%	Kaplan, Forrest, Kindler. Revolutionizing Data Center Energy Efficiency. McKinsey & CO. July 2008.
Average	30%	Best Practices for Leading Edge Data Centers. Corporate Eco-Forum. May 22, 2012.
Best Practice	60%	How VMware Virtualization Right-sizes IT Infrastructure to Reduce Power Consumption. VMware. 2008.
Private Cloud		
Worst Case	7%	Miller, Rich. "Kundra: Fed Data Centers 7 Percent Utilized". Data Center Knowledge. April 9th 2010.
Average	30%	Best Practices for Leading Edge Data Centers. Corporate Eco-Forum. May 22, 2012.
Best Practice	60%	Koomey, Jonathan. 4 reasons why cloud computing is efficient. GigaOM. July 25, 2011.
Public Cloud		
Worst Case	7%	A Measurement Study of Server Utilization in Public Clouds. 2011 IEEE Ninth International Conference on Dependable, Autonomic and Secure Computing. Huan Liu, Accenture Technology Labs. 978-0-7695-4612-4/11 © 2011 IEEE
Average	40%	Best Practices for Leading Edge Data Centers. Corporate Eco-Forum. May 22, 2012.
Best Practice	70%	Koomey, Jonathan. 4 reasons why cloud computing is efficient. GigaOM. July 25, 2011. How VMware Virtualization Right-sizes IT Infrastructure to Reduce Power Consumption. VMware. 2008.

A discussion around each variable can help IT managers better understand how and why the variables selected can impact performance so that they can prioritize their efforts at improving their organization's IT carbon efficiency. Figure 3 shows the change in carbon emissions when starting from a worst case OPNV scenario and changing each key variable in isolation. When comparing the carbon efficiency between a virtualized and a non-virtualized environment, the OPV scenario realizes improved performance as servers are consolidated and the remaining servers are more highly utilized. Since it does not take significantly more energy to run a fully-utilized server than a partially loaded one, the overall number of servers is diminished.

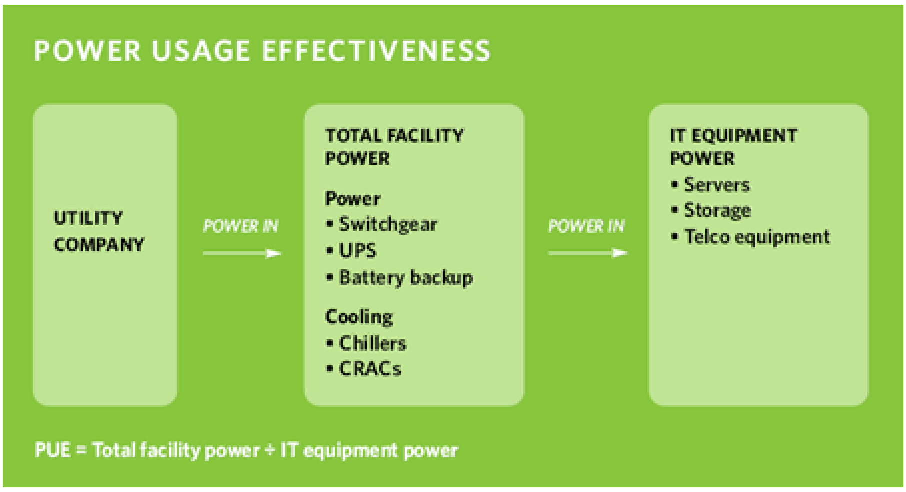
Therefore, if a SMO wants to lower its overall carbon footprint, the most efficient strategy may be to virtualize its servers and IT platform. Or as the results reinforce and other studies have shown, 10 moving to either a private cloud or a public cloud - even if the average carbon emission factor of that cloud's power source is high - would be more efficient than focusing only on reducing the PUE of the on-premise server room. Figure 3 illustrates this difference in efficiency between the three primary strategies. While a focus on utilization provides a quick reduction in emissions, those savings are diminished at high rates.

Power usage effectiveness (PUE)

PUE is a critical metric to consider in the actual delivery of computing services. According to the Uptime Institute, the average PUE across the United States data center pool is 1.8, slightly lower than the Environmental Protection Agency's (EPA's) initial survey showing 1.91 in 2009.11 This means that although data centers are slowly becoming more efficiently cooled and older facilities are taken offline, the stock of legacy data centers will continue to have an impact on national data center efficiency, even as data centers built by Google®, Microsoft®, eBay®, and Facebook® are lauded for their impressive efficiencies.12 Small SMO server rooms are often managed inefficiently and suffer from classic economies of scale issues that cloud service providers are directly incentivized to manage. Large cloud providers can rationalize investments in efficiency improvements because they can spread the costs over a larger server base and they usually own and operate the data centers – a huge overhead cost. Most SMOs are unable to achieve the low PUEs that cloud server providers are realizing in their best-in-class data centers. Regardless, the proportional contribution that PUE can have on the overall carbon emissions footprint is less than that of focusing on increasing server utilization through virtualization or the location of data centers. Server Utilization and Virtualization It is estimated that, on average, servers running a single application may be about 5% to 15% utilized,13 meaning that for most of the time the majority of the server is drawing a substantial amount of power, but performing little or no useful computing. Even when the server is idle or underutilized it may consume between 60% and 90% of its full power draw.14 This inefficiency causes tremendous energy waste, and according to recent research from Microsoft®, for every 100 watts of power consumed in a typical data center, only three watts are used for useful computing. In other words, a typical data center consumes more than 30 times the energy that it uses to perform computations.15 Virtualization and other related techniques offer a solution to address the primary challenge of hardware under-utilization and, ultimately, the inefficiencies inherent in traditional on-premise computing. Because virtualization can result in a 10 to 1 server consolidation ratio to run identical workloads, 16 its implementation can realize significant energy reductions. Virtualization effectively increases the energy efficiency of the system because that energy is actually going to computing rather than powering idle or near-idle servers. P.09 Public cloud providers can realize the potential of very high utilization rates because workloads may be transferred between servers and data centers as the hardware is accessed by multiple users at the same time, smoothing out load peaks and troughs. In this scenario, the number of servers required becomes less relevant as thousands of transactions are processed simultaneously using the same hardware.17 However, the true performance and utilization of the cloud must be determined on a case-by-case basis; despite the opportunity for this increased effi ciency, various studies have indicated that in actuality the utilization of cloud environments may be well less than perceived, with measured examples indicating utilization rates as low as 7% on average.18 Nonetheless, it's clear that in better managed public cloud environments, the aspects of diversity and aggregation where thousands of unique users in different geographies help to spread the computing loads across a provider's platform, allowing for increased utilization and lower electricity consumption.

Carbon Emission Factors of Electricity Source Despite server consolidation and virtualization trends, the physical installed server base continues to expand19 and ultimately, no matter how efficient a data center is, it still requires electricity to operate. That energy source is associated with a carbon emissions factor based upon the type of fuel used. Consequently, the power source of electricity can significantly alter the overall carbon efficiency of a data center. Corporate reporting practices dictated by the GHG Protocol require that an organization report carbon emissions associated with their operations by using EPA's eGRID emission factors, which are calculated in sub-regions across the United States, rather than using emission factors from their specific local utility. This is in some cases a burden for companies that invest in renewable energy directly to power their data centers or have access to utilities that can offer a high percentage of renewables even though the regional average is higher. While an SMO is not likely to be able to move their location solely because of carbon emission factors, cloud providers are increasingly considering this variable amongst the other key factors such as the adequate availability of reliable and affordable electricity, telecommunications infrastructure and accessibility, tax incentives, climate, and proximity to end users. Even though it may be difficult to pin down a real emissions average for any cloud provider's architecture unless they have published this data transparently and are actively engaged in tracking it, the model suggests that no matter how efficient a cloud provider's IT architecture or how effectively the hardware is utilized and cooled, the location of the data center and the composition of the fuel mix will make a significant impact on the overall carbon emissions of a scenario. This is best illustrated by removing the carbon emissions factor as a variable, which considers only energy efficiency performance of the four deployment scenarios. The results indicate that the public cloud, in either a worst or best case, significantly outperforms the other deployments types. However, when the carbon emissions factor of purchased electricity is layered over these results, the range of impact and performance is considerably increased

If your server room is a typical OPNV, with average values for PUE, utilization and carbon intensity, compares the potential for savings of common alternatives. While increasing refresh rates and improving PUE do offer savings between 10% and 30%, the percentage impact and order of magnitude that a focus on increasing server utilization and virtualization or a move to a private or public cloud deployment, is a considerable advantage for a typical on-premise deployment. Finally, it's worth comparing the carbon efficiency offered by the public cloud but with the variable of the carbon emission grid factor. In a worst case scenario, where public cloud data centers may be located in areas with high carbon emission factors, such as some Midwest US and Mid-Atlantic states, the cloud remains more carbon-efficient by a factor of 2 or a reduction in emissions of roughly 50%. But when a data center provider's public cloud is located in areas of low carbon intensity, such as in the Pacific Northwest, the savings increase dramatically to nearly a 48 times improvement. Thus, while cloud computing can generally be shown to be a more energy and carbon efficient solution when compared to on premise computing, all of the key variables identified in this paper contribute widely to the overall carbon efficiency of a given computing scenario. Each variable must be considered when making application delivery choices and vendor selection with cloud providers if environmental and/ or sustainability criteria are important performance indicators.



Model Overview The study quantified four application types against five deployment scenarios by dividing the total energy consumption and resulting carbon footprint against the number of active users, transactions, or gigabytes of delivered data (as relevant) for a given application. The model was independently developed based on ISO 14044 guidelines for Life Cycle Assessment, BSI PAS 2050 Specifications for the Assessment of GHG Emissions of Goods and Services, and the WRI/WBCSD GHG Product & Supply Chain Protocol, including the forthcoming ICT Sector Supplement. The aggregated results in this report have been calculated based on a scope limited to the United States. Organizations 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. Secondary data inputs were derived from a variety of data sources referenced throughout the paper. Time period considered: a one-year application use, licensing, or subscription agreement. GHG emissions ("carbon emissions") included are stated as carbon dioxide equivalent (CO2 e) emissions and take into account the six primary GHG gases including carbon dioxide (CO2), sulphur hexafluoride (SF6), methane (CH4), nitrous oxide (N2O), hydro fluorocarbons (HFCs), and per fluorocarbons (PFCs). 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 and allocated according to a prescribed specific scenario refresh rate. Life Cycle Inventory of a server derived from three different published studies from IBM®, Dell®, and Apple®. Process Energy for IT Infrastructure Estimated power consumption of servers is based on industry-standard figures provided by Hewlett Packard® and Dell®, and verified by experts using specific server configuration sizing calculations. A mixture of different vendors' systems was assessed, rather than any single server product. The model includes essential power for critical IT environment and utilizes publicly available data center-specific PUE ratios covering worst to best practice PUE's based upon EPA, Green Grid, Microsoft®, Salesforce.com, and Google® published reports and Jonathan Koomey research. Appropriate carbon emissions factors were applied to the energy consumption of specific data center locations from the U.S.EPA's eGRID2012 Version 1.0, May 2012. A storage consumption and network usage efficiency ratio were also applied based upon primary data provided by salesforce.com, and referenced from secondary data from the EPA, Green Grid, and research by Jonathan Koomey, PhD Research from the National Laboratory for Applied Network Research (NLANR) Project informed the path of data transfer (from a data center to a business customer). Model Data Input Exclusions Energy consumed during software development. Tertiary suppliers and process materials which are not significant (i.e., do not constitute an input to 95% of the product or process). Refrigerants (except where used in primary production of raw inputs). Embedded energy of capital equipment, transportation vehicles, buildings, and their energy use not directly related to servers and associated equipment. Maintenance of capital equipment.

Government agencies spend **more than $5 billion per year on energy**, and the cost of powering and cooling data centers is a large portion of that. As they work to lessen that demand, both to trim utility costs and minimize environmental impact, agencies are discovering the virtues of virtualization.
The centre of expertise for energy effency In data centers. recommends data center virtualization as one of its “high-level best practices,” alongside more obvious measures such as turning off unused equipment and decommissioning unused servers.
Buildings with data centers spend 25 percent to 35 percent more on electricity per square foot than those without, according to the u.s energy information administration.
The Office of Management and Budget has been pushing federal agencies to close and consolidate data centers where possible, and to optimize remaining facilities through methods such as energy metering and virtualization.

Among the agencies reaping the multiple benefits of virtualization: the state department, which had about 3,700 virtual servers in its core U.S. data centers in 2015. Today, that number is close to 6,000, the result of the agency's virtualization-first strategy that gives strong preference to virtual machines over physical servers.
“For new applications, the default is a virtual server,” says Mark stokes, chief of the department’s Enterprise Server Operations Center division. “We’re probably about 95 percent successful with that. But there are some things that you just can’t virtualize, and they stay physical.”

By using virtual machines, the State Department can reduce costs associated with capital spending for physical servers, software licensing and the labor associated with managing physical hardware. The move has also simplified reporting for software license compliance.

“But another benefit is reducing our carbon footprint and emissions,” Virtualization reduces space requirements in the data center, which leads to reduced energy consumption.

“We’ve also reduced our environmental impact when it comes to decommissioning and disposal of hardware,” he adds. “If you have five applications on one server and apps go away, you’re only disposing of one server instead of five.”

How Virtualization Yields Significant Environmental Benefits

Chris Gardner, a senior analyst for infrastructure and operations at tech research firm Forrester, says it’s typical for organizations to place more emphasis on reducing their costs than on reducing their carbon footprint, but the benefits tend to go hand in hand.

“When you’re using less energy to run fewer physical servers, you’re also lowering costs,” Gardner says. “And you get a higher amount of consolidation. Typically, you want to run systems at 80 percent capacity at all times. To do that, you need to virtualize machines.”

Interior Department officials chose virtualization to maximize environmental savings, says Ken Klinner, the agency’s director for planning and performance management.

“Along with sustainability, we chose virtualization to provision servers faster, enjoy the inherent failover and redundancy of a virtualized environment, allow for almost immediate changes and improve portability,” Klinner says. “Energy consumption is lowered in this process, supporting our sustainability goals.”

Although a number of agencies cite energy efficiency as a major benefit of data center virtualization, exact numbers can be difficult to come by.

First Virtual Envoirnment

The Federal Emergency Management Agency, which stood up its first virtual environment in the mid-2000s, hasn’t tracked energy use metrics associated with the technology. However, virtualization has allowed the agency to reduce the physical footprint of its infrastructure while supporting a maintenance and IT operations workforce that has become more mobile.

“These activities make FEMA more energy-efficient,” says Lizzie Smith, FEMA’s press secretary.

Virtualization Eases Patch to Public Cloud

Although cost and energy efficiency are top drivers of virtualization, they’re far from the only benefits. The technology also eases backups, facilitates cloud migration, simplifies deployment, helps prevent vendor lock-in and allows IT staffers to quickly create testing environments.

“There are so many benefits that I would say, ‘Give me a reason an application shouldn’t be running on a virtual machine,’” says Gardner. “Ninety-nine times out of 100, the application owner would not be able to give me a reason. There may be some reluctance on the part of operators — a fear that performance is going to suffer."

"In fact, the system is usually going to run identically, if not better, as a result of virtualization," he adds. "Everyone should apply that same test: 'Give me a reason an environment shouldn't be virtualized.' And usually, people won't be able to." For many organizations, virtualization has become something of a -stepping-stone on the path to public cloud migration. Gardner says that some organizations are now considering on-premises server virtualization where they once might have tried to push workloads to the public cloud.
"Five or so years ago, when the cloud was just starting up, people were looking at new virtualization instances almost as a negative, thinking, 'I should just use the cloud,'" he says.

"Now we're seeing, if you have legacy applications, in some cases it's not worth going through the upgrade necessary to migrate them**.** But if you virtualize them, that's a quick win until you re architect them with cloud-native technologies.**"**
Klinner says that virtualization, coupled with public cloud resources, helps Interior to better support remote work.

"The DOI's work is often remote, as employees work in the field, where the nation's resources are located," he says. "Virtualization creates increased flexibility and better utilization of our physical resources for our end users.

"By moving email and collaboration services to the cloud and reducing the footprint of physical servers**,** our remote workers benefit from increased accessibility to the resources they need, wherever they are located."
FEMA's virtualization push, Litzow says, has largely been driven by a desire to improve IT services while also decreasing the footprint of physical infrastructure.

Data Center

Requirements than a completely private Data Center, such as one built for the Pentagon that is dedicated to securely maintaining classified data. Regardless of classification, an effective Data Center operation is achieved through a balanced investment in the facility and equipment housed. The elements of a Data Center breakdown includes but not limited to the following: ⊄ Facility – the location and "white space," or usable space, that is available for IT equipment. Providing around the clock access to information makes Data Centers one of the most energy consuming facilities in the world. A high emphasis is placed on design to optimize white space and environmental control to keep equipment within manufacturer-specified temperature/humidity range. Support infrastructure –

equipment contributing to securely sustaining the highest level of availability possible. The Uptime Institute defined four tiers Data Centers can fall under with availability ranging from 99.671% - 99.995%. Some components for supporting infrastructure include:

- Uninterruptible Power Sources (UPS) – battery banks, generators, and redundant power sources.
- Environmental Control – Computer Room Air Conditioners (CRAC), Heating, Ventilation, and Air Conditioning (HVAC) systems, and exhaust systems.
- Physical security systems – biometrics and video surveillance systems.
- IT equipment – actual equipment for IT operations and storage of the organization’s data. This includes servers, storage hardware, cables, and racks, as well as a variety of information security elements such as firewalls.
- Operations staff – to monitor operations and maintain IT and infrastructural equipment around the clock. Data Centers have evolved significantly in recent years, adopting technologies such as virtualization to optimize resource utilization and increase IT flexibility.

As enterprise IT needs continue to evolve toward on-demand services, many organizations are moving toward cloud-based services and infrastructure. A focus has also been placed on provisions to reduce the enormous energy consumption of Data Centers by incorporating more efficient technologies and practices in Data Center management to curtail environmental impact. Data Centers built to these standards have been coined “Green Data Centers” (GDCs). Virtualization is one the most Data Center technologies to evolve in recent years . Its benefits are easily realized in its deployment on servers, storage and I/O interconnects. Overall Data Center management is simplified from servicing new request for server resources to server provisioning tasks as a result of fewer physical servers.

Virtualization accelerates application deployment and can dynamically scale compute resources to meet increasing application demand. Virtualization lowers operation expenses (OPEX) as it reduces the hardware footprint of servers and other related hardware's which drives down requirements for power, space and cooling. Virtualization also enables high availability and disaster recovery solutions through the relative hardware of independence of virtual machines. Virtualization increases resources utilization, lowers costs, increase flexibility and provide the ability for IT to respond to an elastic demand for resources as IT transitions to a highly effective, service-oriented operation. Typically, the Data Center footprint is the actual size of the computer device or equipment it takes on the room or floor of the Data Center facility.

Usually, the Data Center footprint is used by IT capacity planners and IT administrators in evaluating the available physical space in the facility. It is known that the larger the device footprint, the more expensive its physical acquisition and maintenance. Data Center footprint is also helpful in identifying the footprint per device category. Some of the major devices / equipment that are evaluated for DataCenter footprint includes servers, routers, switches, work stations, storage devices and more. 1.1 Why Virtualization?

- Number of servers (server consolidation)
- Real Estate floor space
- Benefits including easy provisioning and cost
- Management personnel
- Quick build/destroy for test and prototypes 1.2 Objectives
- To centralize management of Data Center to improve efficiency and security
- To help in identifying footprint per device category (square feet/meters of area)

- To enhance application service delivery and responsiveness
- To realize the full benefits of data footprint reduction
- To ensure existing investments in real estate are realized because there are no scope for reconfiguring existing real estate
- To enable IT capacity planners and administrators in evaluating the available physical space in the facility 1.3 Scope of The Work Virtualization has been an integral part of IT planning for effective resource optimization, management simplification and isolation on Data Centers.

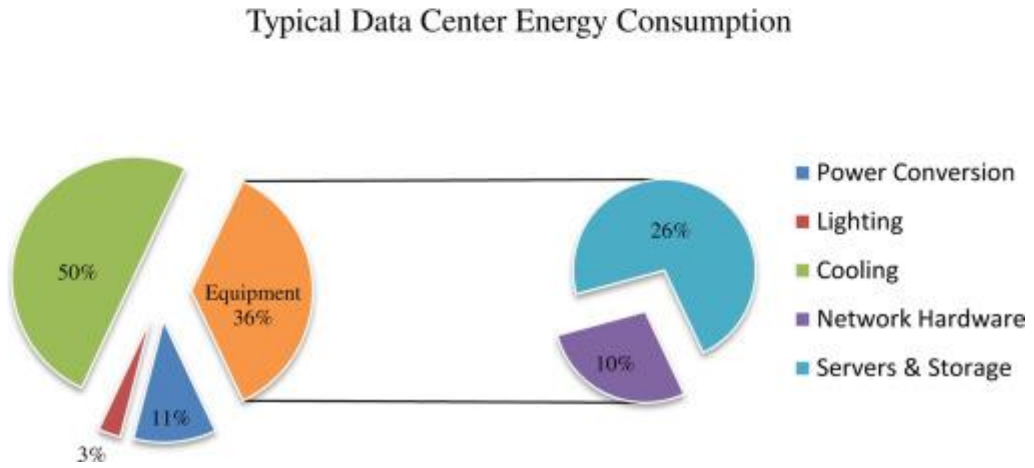
Because Virtualization touches multiple layers in the Data Center, understanding the full scope of Virtualization technologies is required for effective planning, design and deployments. The effects are applicable to Classical Ethernet, Data Center Bridging, Unified IO, Unified Computing, Servers of multiple types, Hypervisors, Virtual Machines, Virtual Switches, Virtualized Adapters, Virtual Service Nodes, Storage, Fibre-Channel, services and transport environments which taken collectively require in-depth understanding for an end-to-end strategy. This project work approaches this by simply offering the opportunity to host and run different operating systems on a single bare metal thereby reducing the Data Center footprint using Virtualization.

RELATED WORK During the course of these work the following discussed papers were reviewed for their technical importance and contributions relative to my work. I had drawn some inferences to assist in understanding the subject matter of my paper. In [1], Atefah et al observed that due to the increasing use of cloud computing services and the amount of energy used by Data Centers, there was a growing interest in reducing energy consumption and carbon footprint of Data Centers. They write that the Cloud Data Centers uses Virtualization technology to host multiple virtual machines (VMs) on a single physical server. They confirmed that by applying VM placement algorithms, cloud providers were able to enhance energy efficiency and reduce carbon footprint. Since previous works was focused on reducing the used with a single or multiple Data Centers without considering their sources and Power Usage Effectiveness (PUE). In contrast, their paper was a novel for VM placement algorithm to increasethe environmental sustainability by taking into account distributed Data Centers with different carbon footprint rates and PUEs. Their simulation results show that the proposed algorithm reduces the CO2 emission and power consumption , while it maintained the same level of quality of service (QoS) compared to their competitive algorithms.

Since there is problem in the use of VM placement to reduce cloud computing energy consumption and carbon footprint. They have propose a future work to study the impact of different user applications and VM holding times on the VM placement policies. And also to explore the effect of inter-data center network distances and data locality on the cloud computing system carbon footprint. In Stutz et al concluded from a study in the research conducted in 2011 to determine the carbon footprint of the Dell PowerEdge R710, a typical high volume , 2U rack server that is representative of a range of similar server products. The total carbon footprint of the server was approximately 6 tons CO2eq when used in the US.

The GHG emissions from use account for over 90 percent of the total life-cycle impact. They confirmed that the carbon footprint of a Data Center can be massively reduced by virtualizing under-utilized servers into only a few highly-utilized ones. They saw that two scenarios looking at different refresh cycles and their impact on the carbon footprint to support their views that, an aggressive refresh cycles makes sense if the power use decreases by at least 10 percent generation over generation. This could be even clearer if the workload can be kept constant and the increased performance level enables the number of servers to be reduced at every refresh. In Islam et al pin point that there was an increasing serious concerns about the IT carbon footprints through pushing Data Center operators to cap their energy consumption. They noted that naturally, achieving capping involves deciding on the energy usage over a long timescale (without foreseeing the far future) and hence, this calls for this process “energy budgeting”. The specific goal of their paper was to study energy budgeting for virtualized Data Centers from an algorithmic perspective to develop a provable-energy online algorithm, called eBud (energy budgeting), which determines server CPU speed and resource allocation to virtual machines for minimizing the Dtat Center operational cost while satisfying the long term energy capping constant in an online fashion. They rigorously prove that eBud achieves a close-to-minimum cost compared to the optional offline algorithm with future information, while bounding the potential violation of energy budget constant, in an almost arbitrarily random environment.

They also perform a trace-based simulation study to complement the analysis. The simulation results were consistent with their theoretical analysis and show that eBud reduces the cost by more than 60 percent (compared to state-of-the-art prediction-based algorithm) while resulting in a zero energy budget deficit. In [4], Larm confirms that Information technology (IT) is at the heart of every successful modern business. He mentioned that It is so pervasive and that energy efficiency through the implementation of green IT has moved to a centre stage for many companies in their pursuit of helping make a difference for the environment. His paper provides an overview on the importance of implementing green IT, the significance and growing role of IT and Data Centers in the world's consumption of electric energy and carbon footprint, and the significance of using “lessons learned” and best practice approaches for implementing green IT.



He maintained that Green IT was an ideal way for most companies to make a significant step in the green direction. The paper further discuss power issues at Data Centers in South Africa based on his recent experience. The solutions to these power issues include virtualization of servers and data storage. He concluded that cloud computing has become the ultimate way to virtualize IT resources and to save energy. In these paper explores the effectiveness of content deduplication in a large (typically 100s of DB) host-sidecaches. They observed that previous deduplication studies focused on data mostly at rest in the backup and archive applications. Their study actually focused on cached data and dynamic workloads within the shared VM infrastructure. They analyse the I/O traces from six virtual desktop infrastructure (VDI) I/O storms and two long-term Common Internet File System (CIFS) studies and show that deduplication can reduce the data footprint inside host-side caches by as much as 67%. In [6], the paper proposes a Greenhead, a holistic resource management framework for embedding Virtual Data Centers (VDC) across geographically distributed Data Center connected through a backbone network. The goal of Greenhead was to maximize the cloud provider's revenue while ensuring that the infrastructure is as environment-friendly as possible. To evaluate the effectiveness of their proposal, they conducted an extensive simulation of four Data Centers connected through the National Science Foundation Network (NSFNet) topology.

Their results showed that Greenhead improves a requests' acceptance ratio and revenue by up to 40% while ensuring high usage of renewable energy and minimal carbon footprint. In [7], Azun upholds that testing cloud -based software systems needs techniques and tools to deal with infrastructure-based quality concerns of clouds. These tools can be built on the cloud platform to take advantage of virtualized platforms and services as well as substantial resources and parallelized execution. He explores the concept of cloud computing, surveys various modelling and simulation techniques and introduces cloud testing.

The paper provides a review on cloud testing by discussing new requirements, issues, and challenges as well as conducting a survey of new benchmarks uniquely created for cloud computing. In [8], Prof. Ranbhise et al writes that there are different resources in cloud environment like Virtual Machines, CPU resources, Memory, Hard Disk space of server machines located in Data Centers. They said that the server machines are consuming energy to provide services to users in cloud computing. And so to analyzing the resources allocation in cloud computing environment which are scalable to some number of servers we will require Cloud simulation and modelling tool which will take care of the cloud as per requirements. They analysed the simulation of cloud on CloudSim and Cloud report for better analysis of cloud environment. They concluded that CloudSim is a perfect solution for modelling the cloud against scaling in and scaling out of the infrastructure requirements and that Clouds reports is the perfect solution for costing of the infrastructure, resources utilization, power consumption of the customized environment. In [9], Michael et al observed that computing today is shifting from hosting services in servers owned by organizations to Data Centers providing resources to a number of other organizations on a shared infrastructure.

They maintained that managing such Data Center will present a unique set of goals and challenges. Their paper suggested that through the use of virtualization, multiple users can run isolated virtual machines on a single physical bare metal, allowing for a higher server utilization. They also believed that by consolidating virtual machines onto fewer physical hosts, infrastructure costs can be reduced in terms of the number of servers required, power consumption, and maintenance. They saw that to meet constantly changing workloads levels , running virtual machines may need to be migrated (moved) to another physical host. They mentioned that algorithms to perform dynamic virtual machine reallocation, as well as dynamic resource provisioning on a single a single host, are open research problems.

Experimenting with such algorithms on the Data Center scale is impractical. Thus, there is a need for simulation tools to allow rapid development and evaluation of Data Center management techniques. They presented DCSim, an extensible simulation framework for simulating a Data Center hosting an

Infrastructure as a Service (IaaS) cloud. They went ahead to evaluate the scalability of DCSim, and demonstrated its usefulness in evaluating virtual machine management techniques. This was shown through an experimental results which shows that DCSim is scalable to some large simulations (featuring 10000 bare metals and 40000 virtual machines), and allowing evaluation of techniques at a speed and scale not possible with a traditional implementation. In savvy industry veteran Greg Schulz provides real-world insight, addressing best practices, server, software, storage. Networking, and facilities issues concerning any current or next-generation virtual Data Center that relies on the underlying physical infrastructures. He pointed out that many current and emerging technologies can enable a green and efficient virtual Data Center to support and sustain business growth with a reasonable return on investment. These books present virtually all critical IT technologies and techniques to discuss the interdependencies that need to be supported to enable a dynamic, energy-efficient, economical, and environmentally-friendly green IT Data Center. This is a path that every organization must ultimately follow.

METHODOLOGY

When developing a comprehensive cloud strategy to safely and effectively leverage these new platforms and capabilities, taking stock of internal resources and organizational design is paramount. The classic mantra of "People, Process, and Technology" fully applies to this cloud strategy and is an essential first step in the transformational process.

A solid cloud methodology includes four core phases:

1. Organizational Readiness Assessment
    1. Staff competencies
    2. Organization structure
    3. Cultural considerations
2. Architecture review
    1. Complete inventory of all storage, network, computing components
    2. Assessment of monitoring and management capabilities
3. Cloud computing planning
    1. On-premise
    2. Hybrid
    3. Off-premise
4. Cloud transformation
    1. Implementation of migration plans
    2. Identify early successes and value capture

We focus on several critical success factors regarding the planning and execution of the transformational process. These are not listed in order or priority and are prevalent throughout the engagement process.

- Cloud transition can fit into current OPEX and CAPEX budgets
- Organization modeling is critical for effective collaboration
- Setting the “Pace of Change” to match business needs
- Implementation enables strategic IT alignment with the business
- Planning can produce early program ROI
- Results deliver real competitive differentiation

Designing and deploying such a cloud-based infrastructure requires a new approach within IT: the traditional technical disciplines must be broken down in favor of seamless cross-functional teams focused on Architecture, Engineering, and Operations. Traditionally these teams frequently operate in technical silos rather than by a collaborative team approach. Placing these functions into cross functional teams allow for a deeper collaboration across disciplines.   Collaboration across these three IT teams enables essential sharing of knowledge of long-term strategies, current implementations and day-to-day operational results.

A logical first step for both people and process may be the establishment of a private cloud within the IT infrastructure. Creating a version of a public cloud infrastructure residing within the organization allows for culture change, the accumulation of technological proficiency, and if done correctly, provides a clear pathway for eventual migration to the public cloud.

On-premises infrastructure is in decline in many places (and for good economic reasons!), but these datacenters will remain in service for many years to come in one capacity or another. That drives a need to optimize the current assets and procedures in the existing datacenter. Building on-premises efficiently and leveraging modern platforms requires the same insights that preparing for cloud requires:

Designing and deploying such a platform requires a new approach within IT: the traditional technical disciplines must be broken down in favor of cross-functional teams focused on Architecture, Engineering, and Operations.

Architecture:
Translating a business need into technical requirements requires a unique understanding: one that is analytical, technical, outcome oriented, and forward looking. No matter where or how applications will be run, Architects are critical to defining the future and ensuring fundamental alignment between business needs and the technical platforms that support them. Architects are inherently visionary, naturally curious, and driven by rational analysis. They design the consumable platform of resources with knowledge across every technical discipline with a heavy emphasis on software-defined solutions that allow a broad range of capabilities on standard, ubiquitous hardware. The real value of Architectural resources is realized by IT infrastructure's ability to adapt to changing business conditions without the need for "forklift" technology investments.
Engineering:
While Architects are defining the longer-term design characteristics of the IT infrastructure, Engineers are focused on implementing current solutions that are consistent with the Architectural design. They implement the scalable platforms that provide the business with IT solutions that are agile, scalable, timely, and cost effective to meet current and changing business needs. Implementing new or transitional products into the IT infrastructure in a seamless manner with a keen eye on minimizing any negative business impacts is the ultimate goal of an Engineer.
Operations:
As long as there are applications under business control, there will be operators needed to maintain and monitor them. Operations "runs the railroad" ensuring that all of the IT infrastructure components are operating at optimized service levels. Setting critical service level metrics on all IT components is key to successfully monitoring all operational components. Operations resources are focused on identifying any alerts or trends that may represent IT service disruptions resulting in business services impacts.
Collaboration across these three IT teams enables essential sharing of knowledge of long-term strategies, current implementations and day-to-day operational results. All three teams working together ensure optimal alignment with business stakeholders. In addition to optimizing IT/Business results, increased

collaboration across teams results in a higher engagement level of all resources leading to lower turn-over of critical staff.

The only “cloud” Sid Caesar ever saw was the one surrounding Imogene Coca’s head, but there’s truth in his words when it comes to developing a cloud strategy for businesses and healthcare organizations. Don’t reinvent the wheel. Model your environment after the guys who did it first, and adapt it to make it work for you.

CONCLUSION

It is clear that virtualization software has had a significant, positive effect on lowering the number of servers used in the market.

- The data presented in this IDC Executive Summary presents the reductions in power consumption and related CO_2 emissions directly attributed to VMware products in use around the world. VMware is a market leader in server virtualization software, and its products have been and continue to be a major driving force in helping customers realize higher levels of operational efficiencies in their datacenters — resulting in a positive benefit to the planet through reducing CO_2 emissions.

- IDC used a conservative and defensible approach to calculating the power consumption avoided and associated carbon dioxide emissions that were avoided because of the industry's use of VMware virtualization software. Where possible, we used published IDC data as the basis for the secondary calculations.
- IDC based this model on syndicated (published) IDC data including the following dimensions:
- IDC's Worldwide Server Tracker data provided the basis for total worldwide server shipments. We used data from calendar years 2003 through 2015 as a starting point for this model.
- ..IDC's Worldwide Quarterly Server Virtualization Tracker was the basis for new server shipments virtualized using VMware virtualization. We included all VMware virtualization products including VMware GSX, VMware ESX, VMware Server, and VMware vSphere. IDC's Worldwide Quarterly Server Virtualization Software Tracker provides data from 2008 through 2015. Servers running competitive hypervisors from Microsoft, Red Hat, Citrix, and others were specifically excluded from this analysis.
- To bridge earlier historical years that predate IDC's Worldwide Quarterly Server Virtualization Tracker, IDC applied assumptions to solve for a complete historical view for the use of VMware hypervisor products on new server shipments virtualized (new servers shipped with a hypervisor

installed before shipment, during shipment, or immediately after delivery). Assumptions applied for the period from 2007 back to 2003 were as follows:

6. At this point in the model, IDC applied a "discount" to reduce instances from the installed base that may have been the result of virtualization sprawl.

..The discount applied ranged from 6% of instances in 2003 to 25% in 2015. The presumption is that virtualization software, in conjunction with today's datacenter-oriented virtualization-friendly licensing, makes it easy (and affordable) to spin up more instances than would have happened if a hardware and software purchase was necessary for each individual instance to be created.

7. Installed base of total server instances in use each year was determined by an installed base calculation on the discounted instance total, using a mathematical formula that replicates the calculations for physical server installed base totals produced in IDC's Worldwide Server Tracker database. This calculation is done individually for new server shipment virtualized instances and separately for instances aboard installed base servers that have had hypervisors installed, and varied by form factor. Overall, the average life expectancy for servers included in this study was about 4.5 years.

..The presumption is that virtualized operating system/workload instances on a server newly deployed will have a life cycle much like that of an existing server installation (because the alternative would have been to install that instance on a dedicated server).

..Separately, we calculated the life expectancy/installed base for instances aboard installed servers that received a hypervisor through a redeployment midlife; instances running on these servers were assumed to have a considerably shorter life cycle than instances running on brand-new servers.

..These two separate installed base calculations were combined to produce a total number of server instances that were avoided because of the use of VMware virtualization solutions.

8. The overall total installed base of servers in use were then multiplied by power consumption estimates for each server product type (blade, density optimized, rack optimized, and tower), and by socket count.

We used U.S. Department of Energy estimates to help shape the actual power consumed by servers, which tends to be roughly 70% of the rating of the power supply included with the server itself.

Power consumption was assumed to be higher in early product years, with efficiency improving each year up to 2015. 9. The results of step 8 were then multiplied by the number of hours of utilization per day those servers experienced.

Commercial servers commonly used in large-scale datacenters and cloud environments, including blade, density-optimized, and rack-optimized form factors, were assumed to have a high level of "on time" — between 20 hours and 24 hours — because the result of shutting down servers during low-use periods can be detrimental to the balancing of cooling systems counteracting the heat exhausted from datacenter infrastructure.

Density-optimized form factors, commonly used in hyperscale datacenters, were assumed to have the highest uptimes. However, density-optimized servers are not heavily used with VMware hypervisor products because most density-optimized servers tend to run bare metal workloads.

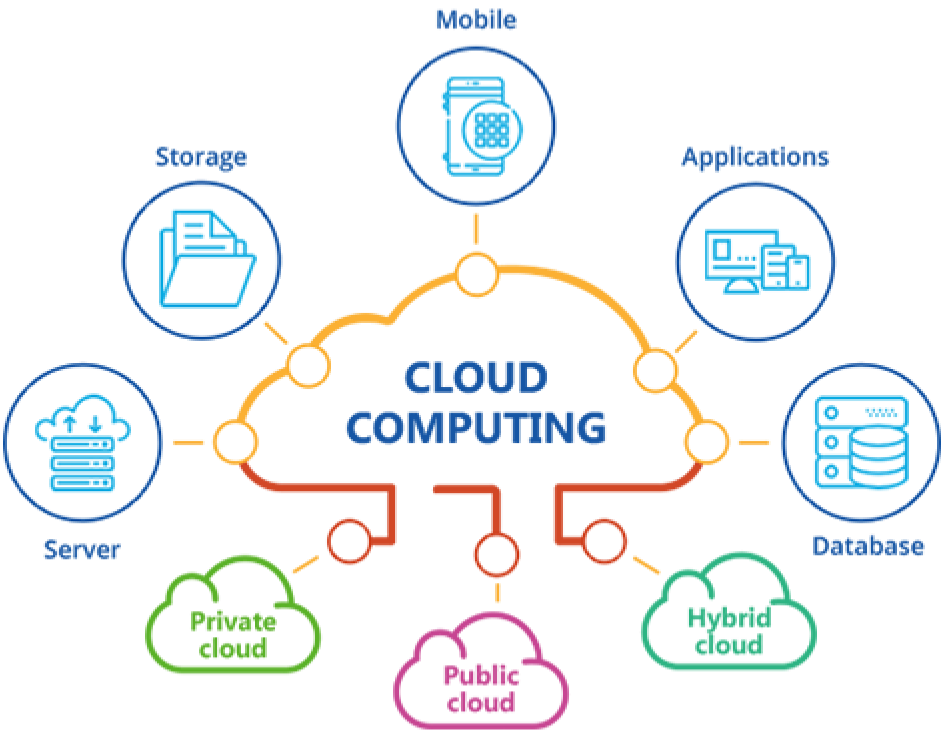
..However, form factors more likely to have non-datacenter deployments were treated uniquely. Tower form factors are commonly used in small and medium-sized businesses (SMBs) and branch offices and were assumed to have a comparatively short daily "on time" of 12 hours per day. (Source: IDC estimates)

- The resulting data produced watt hours of power consumed per day and per year.
- In 2003, the assumption applied is that VMware was the only viable x86 server virtualization technology in (relative) widespread use. We scaled the overall worldwide penetration of virtualization deployments on new server shipments from 18% in 2008 (reported in IDC's Worldwide Quarterly Server Virtualization Tracker) to 2% in 2003.
- We scaled VMware's overall share of the worldwide total of new server shipments virtualized from 61% in 2008 to 100% in 2003. (In other words, VMware captured 100% of the 2% of new server shipments that were virtualized in 2003). In 2003, VMware was the only viable virtualization technology on x86 hardware.
- IDC's working models behind the top-level conclusions produced here were built using detailed dimensions including product type (blade, density optimized, rack optimized, and tower) and socket count (1 socket, 2 sockets, and 4+ sockets).
- IDC applied the same assumption to bridge from 2007 back to 2003 to develop a complete historical view for the use of VMware hypervisor products on existing installed servers.
- Virtual machine density (VM density), as reported in IDC's Worldwide Quarterly Server Virtualization Tracker for 2008 to 2015, was scaled back linearly to solve for historical data: The starting point for this model — 2003 — assumes two VMs/new server shipments virtualized.
- Total instances were calculated by multiplying VM density for new server shipments virtualized and installed base deployments (individually) by their respective unit volume to come up with total instances placed into service each given year.

- We converted annual power consumption to megawatt hours annually and in turn converted MWh to equivalent CO_2 emissions associated with that power consumption.
- CO_2 generation rate used is for the overall United States, or 1,238.516lb of CO_2 per MWh of power generated. IDC recognizes that there are differences in global emissions factors and this would be an area for further study.
- Our assumption is that emerging geographies have higher CO_2 emission rates and mature geographies (such as Western Europe) have lower CO_2 emission rates.
- The United States accounted for about 34% of new server shipments in 2015, while Western Europe accounted for 19% of new server shipments. Asia/Pacific outside of Japan accounted for 31% of new server shipments in 2015. We used the average U.S. CO_2 emission rate/MWh for the overall worldwide calculation, assuming that higher emission rates (because of the use of inexpensive, high-emission fuels) in the fast-growing emerging market segments will more than offset the lower emission rates of Western Europe.
- 747 billion pounds CO_2 (cumulative) divided by 14,020 pounds CO_2 emission from electric utilization per year per household equals 53,299,638 households' emission for one year.
- 53,299,638 divided by 124,587,000 households total (per U.S. Census data) equals 43%.
- The calculation for annual CO_2 avoidance per household is as follows:

Using MWh: 119,593,970 MWh per year (in 2015) avoided through the use of VMware Virtualization divided by 11.320 MWh per year per household (note that we divide KWh by 1,000 to get to MWh) equals equivalent emissions of 10,564,838 households for one year.

Cloud-based computing is now developing very fast and it drastically changes the classical way of computation. Email, movies, music, television and telephone services increasingly rely on cloud computing to serve, store and transmit data. As these technologies develop and mature, efficient hardware, software, and server provisioning will continue to make the cloud the most energy efficient platform for delivering computing. Green Cloud Computing is still in its initial stage and it still we have to explore lot of things which are still not known or not explored. Cloud computing need not just remain confined to e-mail servers and private organizational clouds. It can be expanded to be used in e-commerce, storing medical reports, fingerprint, DNA and other essential details of people, providing study materials for education, and so on. Many organizations, including Greenpeace International, claim that cloud computing does more harm than good but we have seen that with proper usage of cloud services a large amount of energy savings and reduction of carbon footprint can be achieved.



We have looked into the clouds of Google Inc. and Green cloud and found them to be quite green as compared to other clouds, like those maintained by Apple or Microsoft. Still, there is huge room for improvement and further research in this field, especially in areas like development of more efficient data servers, cooling systems, and so on. Also, efforts have to be made to shift as many users as possible to using all the varied cloud services so as to maximize the gains available from cloud computing. Thus, we conclude by saying that cloud computing is not a farce but if used efficiently can go a long way in helping to reduce carbon footprint of the ICT sector.