



VMware Cost-Per-Application Calculator

Methodology

TECHNICAL WHITE PAPER

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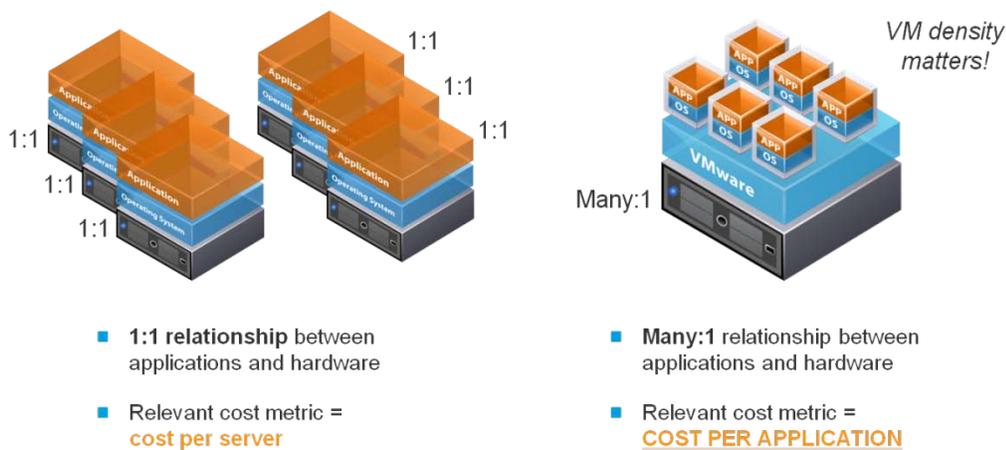
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VMware Cost-Per-Application Calculator Overview

Definitions and Objectives

Virtualization changes the way applications are deployed, making it possible to run multiple applications independently on the same server.

Figure 1. Transition from upfront licensing cost metric to cost per application metric



The number of applications that a virtualization solution can support per host has direct implications on the overall cost of its deployment. A higher number of applications per virtualization host, or virtual machine density, translates into:

- Lower infrastructure cost (less servers, networking and storage)
- Lower power and cooling costs
- Lower datacenter real estate cost

Lower guest operating systems cost (Windows Server 2012 Datacenter Edition is licensed by CPU, so fewer servers means fewer CPUs to license)

In evaluating the cost of a virtualization solution, it is essential to use a metric that not only looks at the cost of licensing the virtualization software, but also takes into account other infrastructure components such as servers, networking, storage, power, real estate and guest operating systems licensing.

In addition, because centralized management is a fundamental component of any virtualization deployment, hardware and software costs associated with related management products, such as VMware vCenter™ or Microsoft System Center need to be included, as well.

VMware defines *cost-per-application* as the sum of all these cost items divided by the number of applications virtualized:

Table 1. Cost-Per-Application Equation

	Hardware Cost (Virtualization Hosts, Management Servers, Networking, Storage)
+	Power and Cooling Cost

+	Datacenter Real Estate Cost
+	Guest Operating System Software Cost
+	Virtualization Software Cost
+	Virtualization Management Software Cost
=	Total Cost of Deployment
/	Divided by Number of Applications Virtualized
=	Cost per Application

Ultimately, companies care about how much it will cost to run the *total* set of their business applications and how well they are utilizing their infrastructure. Therefore, in a virtual IT environment, **cost-per-application** is the key metric when comparing costs.

The VMware Cost-per-Application Calculator does not provide a full total cost of ownership (TCO) analysis as it does not account for operational expense savings delivered by virtualization and it is not a multi-year analysis that accounts for depreciation of hardware equipment over its life cycle. Cost-per-application is a simple and accurate metric to estimate the **upfront capital expenditure** required for deploying a virtualization platform. For a full TCO analysis of VMware vSphere™ 5.1 that accounts for both operational savings and equipment life cycle, refer to the [VMware TCO Calculator](#).

Virtual Machine Densities of Different Virtualization Solutions

The ability to run more applications on a single host depends on several factors including hypervisor performance, resource utilization, ease of management, and overall reliability. VMware vSphere 5.1 is able to deliver higher VM densities than both Microsoft Hyper-V and Citrix XenServer because of the unique technology innovations that have been designed to maximize VM density:

- *Advanced memory management* – Memory tends to be the most highly utilized resource in a virtualized server, making memory management an integral factor for increasing VM density. VMware vSphere 5.1 makes more efficient use of available physical RAM than both Microsoft and Citrix by enabling multiple levels of memory management. While both Citrix and Microsoft have recently introduced dynamic memory capabilities, these are equivalent to the memory ballooning technique first introduced by VMware in 2002. VMware has also pioneered transparent page sharing and memory compression to further improve memory utilization with minimal impact.
- *Direct driver model* – The VMware vSphere hypervisor architecture is fundamentally different from other vendors. With VMware vSphere 5.1, VMs have direct and fast access to the hardware through validated drivers, enabling higher I/O throughput. Both Microsoft Hyper-V and Citrix XenServer rely on an “indirect” architecture where all VMs must channel I/O requests through a single partition (Parent Partition or Dom0). This creates an I/O bottleneck that is also susceptible to the problems of generic Windows device drivers – oftentimes the weakest link of Windows-based systems.
- *High performance “gang” scheduler* – VMware vSphere utilizes a purpose-built process scheduler designed specifically for highly virtualized environments. Microsoft Hyper-V and Citrix XenServer use a generic process scheduler that is part of general purpose operating systems. The problem is that these generic schedulers were not designed for virtualization and multiple virtual machines trying to access one set of resources. This limitation impacts performance at high consolidation levels.
- *Dynamic load balancing* – Virtualized applications have varying resource needs throughout the day and higher VM densities can cause resource shortages if not managed carefully. With VMware

Dynamic Resource Scheduling (DRS), VMs are load balanced across a cluster so applications get required resources when they need them – it is a “safety net” that lets administrators run individual servers at higher utilization levels while meeting service level agreements. 64% of VMware customers use DRS¹ for VM load balancing, Citrix Workload Balancing (WLB) and Microsoft Dynamic Optimization are less mature and lack the VM affinity and anti-affinity settings customers need for production environments.

The combination of these exclusive features allows customers to confidently run up to 20% more applications per host on VMware vSphere than either Microsoft Hyper-V and Citrix XenServer can support. While both Microsoft and Citrix have added new functionality to recent releases of their virtualization software, neither vendor has all of the capabilities required to run more applications on a single host. This is supported by independent testing from the Taneja Group and Principled Technologies which demonstrated VMware vSphere’s better performance under heavy workloads. (See the full reports [here](#) and [here](#)).

Consequently VMware vSphere 5.1 can support a virtualized environment on less hardware, decreasing infrastructure costs, power and cooling costs, and datacenter real estate costs.

User Input Selection to the Calculator

Through the online interface, the user selects a number of inputs to the VMware Cost-per-Application Calculator:

Table 2. User-Selectable Inputs

Input	Description
Number of applications to virtualize	Number of applications that will be virtualized, which can be approximated by the number of virtual machines the user plans to deploy.
Virtualization host type	<p>The virtualization hosts are the servers on which the hypervisor runs virtualized applications.</p> <p>The Calculator allows the user to select among preconfigured server types:</p> <ul style="list-style-type: none"> • Server A \$5,000 – 2 socket, 2 core processors, 32GB RAM, 3 network adapters (or 5 depending on storage selection). • Server B \$6,000 – 2 socket, 4 core processors, 64GB RAM, 4 network adapters (or 6 depending on storage selection). • Server C \$12,000 – 2 socket, 6 core processors, 128GB RAM, 4 network adapters (or 6 depending on storage selection). <p>The server price does not include shared storage (HBAs, SAN switches, disk), networking infrastructure (switches), electricity, cooling or space costs.</p>

¹ Based on global survey of VMware customers (Sample size =411; Q1 2011)

Input	Description
<p>Networked storage type</p>	<p>The Calculator allows users to select among three types of networked storage:</p> <ul style="list-style-type: none"> • Fibre Channel SAN (\$5/GB disk storage cost) • iSCSI SAN (\$3/GB disk storage) • Networked Attached Storage (\$3/GB disk storage) <p>Storage costs represent industry average (source, IDC) and do not include the cost for HBAs (for FC SAN), networking cards (iSCSI SAN and NAS) and switches.</p>
<p>Compare to vendor</p>	<p>The user can create cost per application comparisons between VMware and either Citrix or Microsoft solutions. By selecting Citrix, the Calculator compares VMware vSphere (with VMware vCenter Server) to Citrix XenServer (with XenCenter). By selecting Microsoft, the Calculator will compare VMware vSphere (with VMware vCenter Server) to Windows Server 2012 (with Hyper-V and System Center 2012).</p>
<p>VMware vSphere 5.1 Edition</p>	<p>The Calculator allows the user to select the licensing kit or edition of vSphere (Essentials/Essentials Plus, Standard, Enterprise, and Enterprise Plus) that best meets his business goals. Each edition differs in features and pricing.</p> <p>Microsoft: As the higher editions of VMware vSphere 5.1 deliver much more functionality and features than Microsoft Hyper-V, a more equal comparison can be obtained by selecting vSphere Standard Edition or Essentials Plus Kit.</p> <p>Citrix: While VMware vSphere 5.1 delivers many unmatched capabilities, Citrix offers different editions of XenServer which include varying sets of features. To make a more comparable cost analysis, the calculator will match the VMware vSphere edition or kit with the most similar edition of XenServer:</p> <ul style="list-style-type: none"> • VMware vSphere Essentials and Essentials Plus → Citrix XenServer free • VMware vSphere Standard → Citrix XenServer Advanced • VMware vSphere Enterprise → Citrix XenServer Enterprise • VMware vSphere Enterprise Plus → Citrix XenServer Platinum
<p>Management deployed on physical or virtual</p>	<p>Virtualization management software (VMware vCenter and Microsoft System Center, Citrix XenCenter) can be deployed either on physical servers or in virtual machines. The Calculator allows selecting the preferred deployment strategy.</p> <p>Selecting “Physical” means that VMware vCenter and all Microsoft System Center components will be run on physical servers. Required databases will also be run on physical servers.</p> <p>Selecting “Virtual” means that VMware vCenter, all Microsoft System Center components, and Citrix XenCenter will be run in virtual machines. The System Center components will be run as virtual machines on Microsoft Hyper-V hosts and the vCenter components will run as virtual machines on VMware vSphere hosts. Required databases will also be run in virtual machines.</p>

Input	Description
Electricity	<p>Approximate cost per commercial kWh in the region where the datacenter is located. The Calculator allows the user to choose from three alternatives:</p> <ul style="list-style-type: none"> • Low – \$0.080/kWh (-20% of U.S. national average) • Average – \$0.101/kWh (U.S. average) • High – \$0.120/kWh (+20% of U.S. national average)
Real estate	<p>Approximate cost of datacenter space in the region where the datacenter is located. The Calculator allows to choose from three alternatives:</p> <ul style="list-style-type: none"> • Low – Fully burdened datacenter real estate cost of \$248/sq. ft. per year (-20% of U.S. average). • Average – Fully burdened datacenter real estate cost of \$310/sq. ft. per year (U.S. average). • High – Fully burdened datacenter real estate cost of \$372/sq. ft. per year (+20% of U.S. average). <p>“Fully burdened datacenter real estate” cost includes facilities capital cost for space build-out, power and cooling equipment capital cost, and factors in weighted depreciation.</p>

Server Cost

Server Cost represents the capital expenditure for server hardware. The model includes the following types of servers in the *Total Server Cost*:

- **Virtualization hosts** – Servers used to run virtual machines.
- **Virtualization Management servers** – Servers used to run virtualization management software (included only if the user selects “physical” as deployment option for virtualization management software – see Table 1).

Database servers – Servers used to run the databases required by virtualization management software (included only if the user selected “physical” as deployment option for virtualization management software – see Table 1).

Table 3. Input to Server Cost Calculation

Input	Description	Value	Source
Number of applications to virtualize	Estimated number of virtual machines that the user plans to deploy	Between 1 and 1,000	User Input

Input	Description	Value	Source
Hosts unit cost	Cost of a virtualization host inclusive of hardware support	<p>Value depends on Server Type selection:</p> <ul style="list-style-type: none"> • Server A - \$5,000 unit price, 2 socket, dual-core processors, 32GB RAM, 3 or 5 network adapters (depending on storage selection), rack 2U • Server B - \$6,000 unit price, 2 socket, quad-core processors, 64GB RAM, 4 or 6 network adapters (depending on storage selection), rack 2U • Server C - \$12,000 unit price, 2 socket, six-core processors, 128GB RAM, 4 or 6 network adapters (depending on storage selection), rack 2U <p>Cost of 3-years of hardware support is added to the unit price (assumed to be 15% of unit price for all server types).</p> <p>For more details, refer to “Appendix B” of “VMware Cost-Per-Application – Results Report”.</p> <p><i>Unit Cost of Virtualization Host = Server Price + 3 Year Support Cost</i></p>	User Input
Number of applications per host (i.e., virtual machine density)	Number of virtual machines per virtualization host	<p>Value depends on Server Type selection</p> <p>For more details refer to “VMware Cost-Per-Application – Results Report.”</p>	<p>Conditional on input selection</p> <p>Based on industry averages</p>

Input	Description	Value	Source
Management servers and DB servers unit cost	Cost of a management server and a database server inclusive of hardware support	<p>Value is fixed and the same for both management and DB servers:</p> <ul style="list-style-type: none"> \$4,000 unit price, 1 socket, dual-core processors, 8GB RAM, 2 network adapters, rack 1U. <p>Cost of 3-years of hardware support is added to the unit price (assumed to be 15% of unit price).</p> <p>For more details, refer to “Appendix B” of “VMware Cost-Per-Application – Results Report.”</p> <p><i>Unit Cost of Management Server = Server Price + 3 Year Support Cost</i></p> <p><i>Unit Cost of DB Server = Server Price + 3 Year Support Cost</i></p>	Industry average

Server Cost Calculation

- Number of Hosts = Number of Applications to Virtualize / Number of Virtual Machines per Host.
- Number of Management and DB Servers* – The value depends on the size of the environment (number of virtual machines and number of managed hosts) and on the input selection for “Management deployment”:
 - If “virtual” has been selected, the *Number of Management and DB Servers* is 0.
 - If “physical” has been selected, the *Number of Management and DB Servers* depends on the size of the deployment.
- Cost of Servers = (Number of Hosts * Host Unit Cost) + (Number of Management Servers * Management Server Unit Cost) + (Number Of DB Servers * DB Server Unit Cost).

Note: Numbers are rounded up to the closest integer number.

Assumptions

- Server price is inclusive of internal disk storage and controllers. It does not include host bus adapters cost (included in storage cost) and operating system costs (included in operating system software cost).

Storage Cost

Storage Cost represents the capital expenditure for Networked Storage hardware given the number of applications/virtual machines specified as input to the Calculator. In *Storage Cost* we included the following items:

- Host Bus Adapters (HBAs) – only for Fibre Channel SAN

- SAN switches – only for Fibre Channel SAN
- Disk storage

Table 4. Input to Storage Cost Calculation

Input	Description	Value	Source
Number of HBAs per host	Number of HBAs in each virtualization host	2	Default established to support redundancy
HBAs unit cost	Price of an HBA	\$1,250	Industry average
Number of ports per SAN switch		24	Survey of several HBAs (Fibre Channel) from CDW (www.cdw.com)
SAN switch unit cost	Price of a SAN Switch	\$6,000	Survey average of several SAN Fibre Channel switches from US online national resellers
Average disk space capacity per virtual disk per virtual machine (GB)	Disk Storage Space (GB) needed on the SAN for the number of virtual machines specified as input	100GB	Industry average and VMware experiential estimate
Cost of disk storage (\$/GB)	Cost of 1GB of disk storage space	FC = \$5/GB	Survey of storage from online national US reseller for mid range SAN, RAID DAS
		iSCSI = \$3/GB	
		NAS = \$3/GB	

Storage Cost Calculation

1. Number of HBAs = Number of Virtualization Hosts * Number of HBAs per Virtualization Host
2. Cost of HBAs = Number of HBAs * HBA Unit Cost
3. Number of SAN Switches = 2 * Number of Hosts / Number of Ports per Switch
4. Cost of SAN Switches = Number of SAN Switches * SAN Switch Unit Cost
5. SAN Disk Storage Capacity = Number of Virtual Machines * Average disk space capacity per virtual disk per Virtual Machine
6. Cost of SAN Disk Storage = SAN Disk Storage Capacity * Cost per GB of SAN Disk Storage
7. Storage Cost = Cost Of HBAs + Cost Of SAN Switches + Cost of SAN Disk Storage

Note: *Number of SAN Switches* is rounded up to the closest integer number

Assumptions

- All virtualization hosts are connected to networked storage.

- All virtual machine virtual disks are on networked storage and have the same fixed amount of disk space allocated.
- Each host has two single channel HBAs for redundancy (only for FC SAN case).
- The SAN switches are doubled for redundancy (only for FC SAN case).

Networking Cost

Networking Cost represents the capital expenditure for network switches given the number of applications/virtual machines specified as input to the Calculator. In *Networking Cost*, we included the following items:

- Networking switches

Table 5. Input to Networking Cost Calculation

Input	Description	Value	Source
Number of NICs per virtualization host		Value depends on Server Type selection: <ul style="list-style-type: none"> • For Server Type A, 3 NICs per host if connected to FC SAN, 5 if connected to iSCSI SAN or NAS • For Server Type B, 4 NICs per host if connected to FC SAN, 6 if connected to iSCSI SAN or NAS • For Server Type C, 4 NICs per host if connected to FC SAN, 6 if connected to iSCSI SAN or NAS 	Industry average for workload production servers and VMware experiential estimate
Number of NICs Per mgmt. and DB servers		2	Industry average for low-end for non- production workload servers and VMware experiential estimate
Number of ports per NIC		2	Industry average

Input	Description	Value	Source
Number of ports per networking switch		24	Average from VMware customers survey
Networking switch unit cost	Price Of a Networking Switch	\$4,000	Surveyed customers and various switches at large online US reseller.

Networking Cost Calculation

1. Total Number of NICs = (Number of NICs per Virtualization Host * Number of Virtualization Hosts) + (Number of NICs per Management and DB Server * Number of Management and DB Servers)
2. Number of Networking Switches = Total Number of NICs * Number of Ports per NIC / Number Of Ports per Networking Switch
3. Networking Cost = Number of Networking Switches * Networking Switch Unit Cost

Note: *Number of Networking Switches* is rounded up to the closest integer number

Assumptions

- Other networking costs such as cabling are omitted for simplicity.

Power and Cooling Cost

Power consumption in the datacenter can be divided into three main categories:

- Operating power for the computing Infrastructure (IT loads): Server hardware, network switches, SAN components, etc.
- Network critical physical infrastructure or NCPI (non-IT loads): Transformers, uninterruptible power supplies (UPS), power wiring, fans and lighting.
- Cooling power for air conditioners, pumps and humidifiers.

Virtualization drives the need for less physical servers and related networking, storage and datacenter infrastructure, meaning less power consumption for operations and cooling. This typically drives substantial reductions in annual power service costs, as well as important “green” savings in carbon emissions. A complete model would account for each asset consuming power as listed above, but for simplicity, the methodology focuses only on the power saved from reduction in server hardware with regard to direct operating and cooling power, leaving out potential power and cooling savings for networking, storage and other datacenter infrastructure.

The operating power consumed by server hardware can be calculated by adding up the power ratings of each server in the datacenter. Because this number represents the maximum power used, it should be derated to achieve steady-state power consumption. The steady-state constant was determined empirically. According to the American Power Conversion Corporation “...the nameplate rating of most IT devices is well in excess of the actual running load by a factor of at least 33 percent.”² Forrester Research, Inc. corroborates this idea, indicating that idle x86 servers consume between 30-40 percent of maximum (rated)

² Sawyer, Richard, “Calculating Total Power Requirements for Data Centers”, American Power Conversion, 2004

power.³

As well as operating power, servers produce heat and require substantial cooling to keep them running at prescribed temperatures. According to experiments completed in the HP Laboratories, 0.8W of power is consumed by the cooling equipment for every 1W of heat dissipation in the datacenter (designated in this document as the Load Factor, L). This figure is confirmed by Forrester Research, Inc., which estimates that 0.5W to 1.0W of power is required to dissipate 1W of heat.

Energy costs will vary by worldwide region and state / province. IT equipment energy costs need to reflect cooling costs that can be as much as twice those of the actual IT equipment, depending on the PUE (power usage effectiveness) of the datacenter.

Besides the annual operating and cooling power costs, many organizations are becoming more conscious as to the environmental impact of datacenter power consumption. According to an enterprise storage forum article, the U.S. national average CO₂ emission for electrical power is 1.341lbs per kWh.⁴ For comparison, a typical gallon of gasoline (octane level will vary) will on average generate about 20 lbs of CO₂. Virtualization can help to not only reduce operating and cooling but stop the costly rise in carbon emissions, estimated such that 100 servers retired is equivalent to taking 122 cars off the road per year.

Table 6. Input to Power and Cooling Cost Calculation

Input	Description	Value	Source
Server nameplate operating power	Sum of the nameplate power ratings of all computing infrastructure in the datacenter in kW	2 CPU: 550W	Available from manufacturer's web site (server specs). Averages used for each of three major providers.
Electricity price per hour	Price per hour of 1 kW of electricity.	<ul style="list-style-type: none"> • Low – \$0.080/kWh (-20% of U.S. national average) • Average – \$0.101/kWh (U.S. average) • High – \$0.120/kWh (+20% of U.S. national average) 	Energy Information Administration ⁵
Nameplate to steady state power conversion	The steady state constant used to convert nameplate power consumption to steady state	0.67	American Power Conversion ⁶ . On average, nameplate ratings are 33% higher than steady state load
Cooling load factor	Estimated cooling load factor (Watts of cooling electricity needed to dissipate 1W of heat)	0.8	Empirically determined in HP Laboratories

³ Fichera, Richard, "Power And Cooling Heat Up The Data Center", Forrester Research, Inc. March 8, 2006

⁴ Shulz, Gary, "Storage Power and Cooling Issues Heat Up", May 21, 2007 <http://www.enterprisestorageforum.com/>

⁵ Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

⁶ Sawyer, Richard, "Calculating Total Power Requirements for Data Centers", American Power Conversion, 2004

Airflow redundancy	The airflow redundancy required to cool the datacenter	125%	A 25% increment over current airflow needed to support proper cooling. SearchDataCenter.com ⁷
Airflow de-rating	The percentage of airflow that is available for cooling server heat	80%	SearchDataCenter.com (see above)
Datacenter operating hours	The product of hours per day, days per week and weeks per year that the datacenter is operational (server on hours per year)	8736 hours on average (24x7x52) per year	Annual operating hours for typical 24x7x52 operation

Power and Cooling Cost Calculation

- Actual Op. Power = Name Plate Power * Name Plate to Steady State Conversion Factor
- Actual Cooling Power = Actual Op. Power * Cooling Load Factor * (1 + Air Flow Redundancy Required in DC) / Air Flow De-rating
- Power and Cooling Cost = (Number Of Virtualization Hosts + Number Of Management and DB Servers) * (Actual Op Power + Actual Cooling Power) * Electricity Price per Hour / 1000 * Datacenter Operating Hours

Assumptions

- This calculation is for operating power consumed during the first year of operation only and does not include the costs or savings (amortization and maintenance costs) of the power delivery and cooling systems.

Datacenter Real Estate Cost

Savings in datacenter real estate are achieved by reducing the number of physical servers consuming valuable datacenter space. Reducing the number of physical servers enables reclaiming of current datacenter space so future datacenter facilities build-out can be avoided or deferred.

Due to the special infrastructure (racks, cooling, power systems, acoustics and disaster resilience) required in datacenters, datacenters are often significantly more expensive to build than standard commercial properties. According to industry research, a datacenter rated at 40W per square foot costs approximately \$400 per square foot.⁸ As datacenters today consume at least 270W per square foot, current datacenters are costing on average of \$2,700 per square foot. At the Computerworld 2009 projection of 500W per square foot, the same datacenter would cost \$5,000 per square foot to build.

VMware can reduce a company’s physical server count and datacenter footprint today, and reduce the need for future construction of new datacenters. The Cost Per Application calculation accounts for the total yearly datacenter carrying costs, accounting for the monthly real-estate rental cost, plus amortizing the cost of datacenter facilities, power and cooling build-out.

⁷ McFarlane, Robert, “Let’s Add an Air Conditioner,” SearchDataCenter news article, published November 30, 2005. http://searchdatacenter.techtarget.com/columnItem/0,294698,sid80_gci1148906,00.html

⁸ Anthes, Gary, “Data Centers Get a Makeover”, Computerworld news article, published November 1, 2005. <http://www.computerworld.com/databasetopics/data/datacenter/story/0,10801,97021,00.html?SKC=home97021>

Table 6. Input to Datacenter Real Estate Calculation

Input	Description	Value	Source
Rack size consumed per server	Average rack size for current server hardware (in number of U per server)	1 CPU = 1U 2 CPU = 2U	Typical server configurations from manufacturer web sites.
Unit Space per rack	Average units which can be installed in a rack	Set to 24 by default	Typical usable datacenter rack space, accounting for a 42U rack, but 43% consumed with needed power distribution, cable management, keyboard / display and spacing (source: VMware).
Space per rack	Square feet / square meters per rack	7 Square Feet (approx)	Typical rack size including space for the rack (VMware estimates).
Capital cost for facilities datacenter space build-out (per square foot)	Capital cost for facilities datacenter space build-out	<ul style="list-style-type: none"> • Low – \$1,200 per Sq Foot • Average – \$1,500 per Sq Foot • High – \$1,800 per Sq Foot 	According to Computerworld (see reference above), a datacenter rated at 40W per square foot costs approximately \$400 per square foot. At the 2009 projection of 500W per square foot, the same datacenter would cost \$5,000 per square foot to build. Using these data points, estimates are that today, datacenter space costs at least \$2,700 per square foot to construct. Accounting for the infrastructure only here, nets an estimated \$1,200 per square foot for build-out.
Years to Amortize Build-out Costs	Average weighted depreciation to use for build-out and equipment (in years)	10 years	Estimates on useful life for typical datacenter build-out.

Input	Description	Value	Source
Capital cost for power and cooling equipment (per square foot)	Capital cost for power and cooling equipment per server	<ul style="list-style-type: none"> • Low – \$960 per Sq Foot • Average – \$1,200 per Sq Foot • High – \$1,440 per Sq Foot 	Per server, additional cost is needed for power and cooling equipment, estimated to be \$1,500 per server, of a total of \$2,700 per square foot.
Cost for the space (lease, rent, mortgage) in square foot per year	Cost for the space (lease, rent, mortgage) in square feet per year	\$40.00 per square foot per year	Average space for datacenter lease space in US (may vary based on datacenter location and region).

Datacenter Real Estate Calculation

1. Total Number of Racks = Round Up (Number of Servers (by type)* Rack Size Consumed per Server / Unit Space per Rack)
2. Total Area Consumed By Servers = Number of Racks * Sq. Ft. of Single Rack
3. Average Fully Burdened Datacenter Cost Per Square Foot Per Year = (Cost to Build Datacenter Facilities + Cost for Datacenter Power and Cooling Infrastructure) / Years to Amortize Build-out Costs + Annual Space Lease or Allocated Annual Real Estate Cost per Square Foot
4. Datacenter Real Estate Cost = Total Area Consumed by Servers * Average Fully Burdened Datacenter cost

Assumptions

This calculation is for year 1 capital expenses related to datacenter space consumed by servers only.

Guest Operating System Licenses and Support Cost

A guest operating system (OS) is the OS that runs in a virtual machine. The cost of guest OSs includes the cost of both licensing and support. Pricing and packaging for licensing and support depend on vendor of choice.

Virtualization solutions do not support the same number of guest OSs and can offer different levels of support for the same guest OS (capabilities of a virtualization platform can be different depending on the guest OS.) Before determining the cost associated with licenses and support of the guest OS of choice, it is fundamental to verify that such OS is included in support list of the virtualization vendor. VMware offers the broadest support for guest OS; more details can be found at

<http://www.vmware.com/technology/whyvmware/guest-os.html>

For simplicity, this model assumes that all hosts run Microsoft Windows Server 2012 Datacenter Edition, which is priced by CPU and includes rights to run an unlimited number of Windows Server 2012 virtual machines. Pricing details can be found at <http://www.microsoft.com/en-us/server-cloud/windows-server/buy.aspx>. The model also accounts for the cost of two years of support that Microsoft offers through the [Software Assurance Program](#). Microsoft’s SA is billed at 25% of license price and does not include “MS Support”. Customers either purchase “Support” separately from Microsoft [at \$200+ per hour] or use 3rd party services. VMware’s SNS entitles a customer to not only all software releases and updates but also

VMware's Technical Support.

Calculations

1. Number of Windows Server 2012 Datacenter Licenses = Number of Virtualization Hosts * Number of CPUs per Host
2. Total Cost of Guest OS License and Support = Number Of Windows Server 2012 Datacenter Licenses * (Windows Server 2012 Datacenter Ed. Unit License Cost + Software Assurance Unit Cost)

Assumptions

- Two years of software assurance costs roughly 50 percent of the license price.
- Microsoft has not yet released Full Packaged Prices (FPP) for Windows Server 2012, so FPP for Windows Server 2008 are used.
- Software prices are list and do not include discounts.

VMware Software Cost

VMware vSphere 5.1 Licenses and Support Cost

VMware vSphere 5.1 is the sixth generation of the industry-leading virtualization platform for building cloud infrastructures. vSphere enables users to run business critical applications with confidence and respond faster to their business.

The vSphere 5.1 licensing model is per processor (CPU). The calculator derives the number of required licenses by adding the total number of processors for all virtualization hosts.

The model also takes into account the cost of two years of "Production" support. Pricing details can be found at http://www.vmware.com/files/pdf/vsphere_pricing.pdf or in Appendix A of the "VMware Cost-Per-Application Calculator – Results Report"

When there are a total of 6 CPUs to virtualize the model automatically applies the Acceleration Kit pricing that corresponds to the vSphere Kit or Edition specified by the user.

Calculations

1. Number of VMware vSphere 5.1 Licenses = (Number of Virtualization Hosts * Number of CPUs per Host)
2. Total Cost of VMware vSphere 5.1 License and Support = Number of VMware vSphere 5.1 Licenses * (VMware vSphere 5.1 Unit License Cost + 2 Years Production SnS Unit Cost)

Assumptions

- Software prices are list and do not include discounts.

VMware vCenter Server Licenses and Support Cost

VMware vCenter Server is a centralized management solution for vSphere hosts. Although it isn't a mandatory component to run VMware ESXi hosts, this model includes it in the VMware solution as market research shows that centralized management is a component of the majority of server virtualization deployments. Unlike vSphere, VMware vCenter Server is priced by server. Pricing details can be found at http://www.vmware.com/files/pdf/vsphere_pricing.pdf or in Appendix A of the "VMware Cost-Per-Application Calculator – Results Report".

One instance of VMware vCenter Server manages up to 1,000 hosts and 10,000 virtual machines⁹. The calculator conservatively assumes 200 vSphere hosts per vCenter Server.

Calculations

1. Number of VMware vCenter Server Licenses = Roundup (Number of Virtualization Hosts / 200)
2. Total Cost of VMware vCenter Server License and Support = Number of VMware vCenter Server Licenses * (VMware vCenter Server Unit License Cost + 2 Years Production SnS Unit Cost)

VMware Acceleration Kits and VMware vSphere Essentials Plus include VMware vCenter Server and therefore do not require additional licensing for VMware vCenter Server.

Assumptions

- Software prices are list and do not include discounts.

Microsoft Software Cost

Microsoft Hyper-V Licenses and Support Cost

Microsoft Hyper-V is Microsoft's server virtualization hypervisor. Hyper-V is bundled with Windows Server 2012 and does not require additional licensing.

As described previously, the model assumes Windows Server 2012 Datacenter Edition with Hyper-V is licensed on all virtualization hosts. Consequently, there are no additional costs required to license Hyper-V.

Microsoft System Center Licenses and Support Cost

System Center is Microsoft's system management software suite. It includes: System Center Virtual Machine Manager (SCVMM), System Center Operations Manager (SCOM), System Center Configuration Manager (SCCM), System Center Data Protection Manager (SCDPM), System Center Service Manager (SCSM), Orchestrator, Endpoint Protection and App Controller. Each System Center module provides a subset of the functionalities and features required to manage a virtual infrastructure. For more details, refer to <http://www.microsoft.com/systemcenter/en/us/default.aspx>

Like VMware vCenter Server, System Center is not strictly required to run Hyper-V, but because centralized virtualization management is part of the majority of today's deployment of server virtualization this model only provides cost comparisons that include management software and its required infrastructure.

Although cost comparisons should be made between solutions with the same features set, there isn't a System Center setup that perfectly matches VMware vCenter Server capabilities. To get as close as possible to an apples-to-apples comparison, three components of the Microsoft System Center suite are required when comparing with VMware vCenter: System Center Virtual Machine Manager, System Center Operations Manager, and System Center Configuration Manager. For more details on feature comparison between VMware vCenter Server and Microsoft System Center, refer to <http://vmware.com/technology/whyvmware/virtual-management.html>.

System Center 2012 Licenses are processor-based, with each license covering up to two physical processors. Server Management Licenses are required for managed devices that run server Operating System Environments (OSEs). The number of Server MLs required for each managed server is determined by the number of physical processor in the server for Datacenter Edition and either number of physical processors in the server or number of OSEs being managed for Standard Edition (whichever is greater). For the purposes of this calculator, System Center 2012 Datacenter Server Licenses are used for environments with greater than 50 virtual machines, and System Center Essentials edition is used for environments with

⁹ Source: VMware – Configuration Maximums for VMware vSphere 5.1 (<https://www.vmware.com/support/pubs/>)

less than 50 virtual machines. For more details, refer to this Microsoft [website](#).

The number of System Center management servers depends on the size of the managed environment (number of managed servers and virtual machines). For more details, refer to the [Microsoft TechNet Deployment Guide](#).

The model determines the cost of System Center server licenses based on the following tables:

Table 7. System Center 2012 Server Licensing

Number of Virtual Machines or Hosts	SC Essentials Server License	SC 2012 Datacenter Server License
Up to 50 virtual machines	<ul style="list-style-type: none"> 1 SC Essentials or Essentials Plus (with SQL) 	-
Over 50 virtual machines	-	<ul style="list-style-type: none"> 1 SC 2012 Datacenter license per CPU of managed host

Notes: (1) with SMSD no server license is required for SCVMM (2) SC Essentials can manage up to 50 OSEs

The model also accounts for the cost of 2 years of support that Microsoft offers through the [Software Assurance Program](#).

Calculations

1. Cost of System Center Server Licenses and SA according to table above
2. Number of System Center Management Licenses for Managed Hosts = (Total Number of CPUs of Virtualization Hosts)/2
3. Total Cost of System Center License and Support = Cost of System Center Server Licenses and SA + System Center Management Licenses for Managed Hosts * (System Center Management Licenses Unit Cost + Software Assurance Unit Cost¹⁰)

Assumptions

- 2-years Software Assurance costs, roughly 50% of the license price.
- Software prices are list and do not include discounts.

Citrix Software Cost

Citrix XenServer Licenses and Subscription Cost

Citrix bundles its server virtualization hypervisor with varying capabilities of its management solution in four different editions: Free, Advanced, Enterprise, and Platinum.

<http://www.citrix.com/English/ps2/products/subfeature.asp?contentID=2300456>

¹⁰ If not already bundled in licensing package

There isn't a Citrix edition that perfectly matches VMware capabilities. To get as close as possible to an apples-to-apples comparison, this model compares VMware Essentials and Essentials Plus kits with the XenServer Free Edition, VMware Standard edition with the XenServer Advanced Edition, VMware Enterprise edition with the XenServer Enterprise Edition, and VMware Enterprise Plus with the XenServer Platinum Edition. For more details on feature comparison between VMware vCenter Server and Citrix XenServer, refer to <http://vmware.com/technology/whyvmware/virtual-management.html>

Citrix XenServer is licensed per managed server and includes one year of Subscription Advantage (SA) which provides access to platform and feature releases. To match VMware's 2 years of Production SnS, the model adds one year of SA renewal for each managed server. <http://www.citrix.com/site/SS/supportSecond.asp?sIID=3682>

Calculations

1. Number of Licenses of Citrix XenServer for Managed Hosts = Total Number Of XenServer Virtualization Hosts
2. Total Cost of Citrix XenServer and Support = Number of Licenses Citrix XenServer for Managed Hosts * (Citrix XenServer Licenses Unit Cost + Citrix XenServer SA Renewal Unit Cost)

Assumptions

Software prices are list and do not include discounts

Citrix XenServer Support Cost

Citrix charges for support, separate from the server virtualization hypervisor, on a per instance basis, sold in bundles of 5. Citrix offers multiple support editions with different service level options. To match VMware Production support levels, the model assumes "Preferred Extend Hours Support for XenServer and Citrix Essentials". <http://www.citrix.com/English/SS/supportSecond.asp?sIID=25635#programs>

The overall cost for Citrix support is a function of the number of support instances that a user will open. The model assumes that over the course of two years one package of Citrix Preferred Extend Support, which includes five support instances, will cover the needs of three XenServer hosts. In comparison, VMware Support and Subscription (SnS) places no limits on support incidents.

Calculations

1. Total Cost of XenServer License and Support = Citrix Preferred Extended Support Unit Cost * Roundup(Number of Citrix XenServer Hosts / 3)

Assumptions

- Five support instances of Citrix Preferred Extended Support for every three XenServer hosts, for two years.
- Support prices are list and do not include discounts.

Infrastructure Cost for Virtualization Management Solution

In addition to licenses and support of each virtualization management solution, the model accounts for the cost of the hardware and software infrastructure (operating systems and databases) necessary to deploy each management solution.

The model offers the possibility to choose between two deployment scenarios of the virtualization

management solution:

1. **Physical** – In this scenario, the model estimates infrastructure costs as if management and database software are deployed on dedicated physical servers, different from the virtualization hosts. The number of management and database servers depends on the management solution and on the number of managed virtualization hosts and virtual machines. The model assumes that each management and database server runs on a Windows Server 2012 Standard Edition and that the database software is Microsoft SQL Server. Since hardware requirements for management solutions are in general less demanding than those for production servers of virtualized applications, the model assumes that management and database servers will be deployed on low-end servers, less expensive than the virtualization host options. For more details about the specs of management and database servers, refer to *Appendix B of “VMware Cost-Per-Application Calculator – Results Report.”*
2. **Virtual** – In this scenario, the model estimates infrastructure costs as if management and database software are deployed in virtual machines. Such virtual machines will run on the virtualization hosts in addition to the applications. Each management and database virtual machine can be thought as the physical-to-virtual conversion of a corresponding management or database server. Consequently, the number of management and database virtual machines is the same as the number of management and database physical servers in the “Physical” deployment scenario. Because the model assumes that all virtualization hosts are licensed with Windows Server 2012 Datacenter Edition, unlike in the “physical” deployment scenario there is no additional operating system cost for management and database servers. The cost for Microsoft SQL Server licenses and support is instead still present.

Cost of Hardware and Databases for VMware vCenter Server

The number of VMware vCenter management servers depends on the size of the managed environment (number of managed servers and virtual machines). For more details refer to the ESXi and vCenter Server Setup Guide in [VMware vSphere 5.1 Documentation](#).

The model determines the cost of infrastructure hardware and software necessary for deploying VMware vCenter based on the following table:

Table 8. VMware vCenter Deployment Requirements

Number of VMs or Hosts	Number of Servers for Physical Deployment of VMware vCenter Server		Additional Infrastructure Software	
	VMware vCenter Servers	Database Servers ¹¹	Windows Server 2012 Std. Ed.	Microsoft SQL Servers Licenses
Up to 50 VMs	1	-	1	¹²
Above 50 VMs	1 for every additional 200 VM's	1 for every additional 200 VM's	2 for every additional 200 VM's	1 for every additional 200 VM's

The cost of two years of support through the [Software Assurance Program](#) is added when not already part of the licensing package to all Microsoft's elements.

¹¹ If separate from management servers

¹² Assumes SQL 2005 Express, supported for small deployments of up to 5 hosts and 50 virtual machine (see <https://www.vmware.com/support/pubs/vsphere-esxi-vcenter-server-pubs.html> for more information)

Assumptions

- Two years of software assurance costs roughly 50 percent of the license price.
- Software prices are list and do not include discounts.

Cost of Hardware and Databases for Microsoft System Center

The number of System Center management servers depends on the size of the managed environment (number of managed servers and virtual machines). For more details, refer to [Microsoft TechNet Deployment Guide](#).

The model determines the cost of infrastructure hardware and software necessary for deploying System Center based on the following tables.

Table 9. System Center Essentials Deployment (for environments up to 50 virtual machines)

Number of Virtual Machines or Hosts	Number of Servers for Physical Deployment of Microsoft System Center		Additional Infrastructure Software	
	SC Essentials Servers	Database Servers ¹³	Windows Server 2012 Std. Ed.	Microsoft SQL Server Licenses
Up to 15 virtual machines	1 ¹⁴	-	1	0
From 16 to 30 virtual machines	1 ¹⁵	-	1	0
From 31 to 50 virtual machines	1 ²¹	1	2	0

Table 10. System Center Operations Manager Deployment (more than 50 virtual machines)

Number of Virtual Machines or Hosts	Number of Servers for Physical Deployment of Microsoft System Center		Additional Infrastructure Software	
	SCOM Servers	Database Servers ¹⁹	Windows Server 2012 Std. Ed.	Microsoft SQL Server Licenses
51 to 75 virtual machines	2 ¹⁶	2 ¹⁷	4	0

¹³ If separate from management servers

¹⁴ SC Essentials without SQL

¹⁵ SC Essentials with SQL

¹⁶ SCOM Remote Management Server, SCOM Management Server

¹⁷ SCOM Database Server, SCOM Data Warehouse Server

From 76 to 300 virtual machines	2 ²²	3 ¹⁸	5	1
From 301 to 600 virtual machines	3 ¹⁹	3 ²⁴	6	0
For each add'l 300 virtual machines	Add 1	3 ²⁴	Add 1	0

System Center Configuration Manager and its accompanying database can be installed on the same server. For the purposes of this model, they are always co-located on the same server.

Table 11. System Center Configuration Manager Deployment (more than 50 virtual machines)

Number of virtual machines or hosts	Number of Servers for Physical Deployment of Microsoft System Center		Additional Infrastructure Software	
	SCCM Servers	Database Servers ¹⁹	Windows Server 2012 Std. Ed.	Microsoft SQL Server Licenses
Any	1 ²⁰	-	1	-

Table 12. System Center Virtual Machine Manager Deployment (more than 50 virtual machines)

Number of virtual machines or hosts	Number of Servers for Physical Deployment of Microsoft System Center		Additional Infrastructure Software	
	SCVMM Servers	Database Servers ¹⁹	Windows Server 2012 Std. Ed.	Microsoft SQL Server Licenses
Up to 20 hosts	1	-	1	-
21-150 hosts	1	1 ²¹	2	1
Above 150 hosts	2 ²²	1 ²⁷	3	1

The cost of two years of support through the [Software Assurance Program](#) is added when not already part of the licensing package.

For more details on Windows SQL Server licensing and pricing, refer to <http://www.microsoft.com/sqlserver/en/us/get-sql-server/how-to-buy.aspx>.

Assumptions

¹⁸ SCOM Database Server, SCOM Data Warehouse Server, SCOM Reporting Server

¹⁹ SCOM Remote Management Server, two SCOM Management Servers

²⁰ SCCM requires a database server, but can be co-located with SCCM Management Server

²¹ SCVMM Database Server

²² SCVMM Management Server, SCVMM Library Server

- Two years of software assurance costs, or roughly 50 percent of the license price.
- Software prices are list and do not include discounts.

Cost of Hardware and Database for Citrix XenServer

The number of Citrix management servers is a function of the size of the managed environment (number of managed servers and virtual machines).

The model determines the cost of infrastructure hardware and software necessary for deploying Citrix XenServer based on Table 14.

Table 13. Citrix XenServer Management Hardware Deployment

Number of hosts	Number of Servers for Physical Deployment of Citrix XenServer		Additional infrastructure software	
	Data Collector servers	Database Servers	Windows Server 2012 Std. Ed.	Microsoft SQL Server Licenses
Up to 6	1	-	1	<ul style="list-style-type: none"> • 0 (up to 50 VMs – SQL express) • 1 (over 50VMs)
Up to 12	2	1	3	1
Up to 18	3	1	4	1

Beyond 18 hosts, the model adds one Data Collector server and Windows Server 2008 Std. for every 6 hosts.

The cost of two years of support through the [Software Assurance Program](#) is added when not already part of the licensing package.

For more details on Windows SQL Server licensing and pricing, refer to <http://www.microsoft.com/sqlserver/en/us/get-sql-server/how-to-buy.aspx>.

Assumptions

- Two years of software assurance costs roughly 50 percent of the license price.
- Software prices are list and do not include discounts.



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