Virtualization as a Green IT Technology at Ohio University

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Abstract

Two Green IT initiatives that have proportionally large potentials to save energy and money are server virtualization and desktop virtualization. Server virtualization electricity savings can be estimated using a speculative methodology with server hardware specifications as input and the use of the datacenter metric of power user efficiency (PuE). VMware's Virtual Desktop Infrastructure (VDI) is examined as an example of desktop virtualization and a methodology for calculating its savings is established which includes phantom power, user awareness, desktop idle and utilization rates, and HVAC. The results show Ohio University's yearly savings due to server virtualization are over $6,500 worth of electricity. The results also show a fictional VDI instance of 2000 users saves over 1 million kWh and over $100,000 per year. Also examined in the results is the relationship between Ohio House Bill 251 (HB 251), information technology, and these virtualization technologies.

Table of Contents

1.1: Green IT Background

Over the past few years, Green IT has become a major trend lately in IT industries all across the world. The term can be defined simply as projects or initiatives within information technology that have a positive impact on the environment. These projects can have significant advantages for an organization, such as saving money, raising morale, attracting customers, and increasing efficiency. For most businesses, saving money is the top priority here; 55% of them see saving energy-related costs as their prime motivation for greening IT (Mines). Regardless of the specific motivation, more and more organizations are seeing green IT as a profitable venture.

Many organizations are seeing reasons to start Green IT projects and for good reason--there is a lot of potential improve on IT energy expenditure. According to Simon Mingay in 2008, 2% of all world-wide greenhouse gas emissions can be traced to the information and communications technology sector. The good news is that there is also a lot of room for improvement. That same study says that “by 2010, two thirds of best-practice enterprises will achieve a 25% reduction in information and communications technology-related power consumption compared with 2007 levels...” Even though IT is only a smaller part of a whole, it has a great potential to go green.

It is important for this research to define what “green” actually means. The easiest definition is simply being energy efficient--using less electricity equates to lesser fossil fuel consumption at power plants, and therefore a positive effect on the environmental. A broader definition of “green” can refer to greenhouse gas emissions, which is quite often used to judge overall environmental impact. These two ambiguous definitions of “greening” are highly related and, in fact, quite often green house gas emissions are calculated simply as a product of electricity consumption. This relationship breaks down when more specific metrics such as carbon footprints are used, which is a more holistic, complex measurement of environmental impact. In terms of Green IT, electricity consumption is almost always the factor being measured, and this research describes “green” in terms of both energy efficiency and greenhouse gas emissions interchangeably. Any discrepancy is only a matter of terminology, and not fundamental meaning.

There are a number of ways that information technology can achieve energy savings and some are more effective than others. According to the Gartner, the sources of green house gas emissions in IT are: PCs and monitor usage (39%), servers & cooling (23%), fixed line telecoms (15%), mobile telecoms (9%), LAN and office telecoms (6%), and printers (6%). A weighted list like this is extremely insightful when comparing various Green IT projects. For instance, a 50% decrease in printer power usage sounds great, but an 8% decrease in PC and monitor usage would have a larger overall greening impact. This shows where the low-hanging fruit are in the Green IT landscape and these are the areas which have the highest potential for energy savings.

Using a scale like this that is based on global averages is not always applicable to a given IT environment. An individual campus department or organization might have different needs and usages depending on the type of IT services that are offered. Because of this, the first step of a Green IT strategy is usually to analyze the environment and determine where the biggest areas of opportunity are. Once a profile is made, a plan of action can be prescribed that best takes advantage of these opportunities. A critical assumption of this research is that a large, diverse organization such as an institution of higher education has an energy expenditure profile that is roughly representative of global averages. When this research later identifies areas of potential savings in IT, these global averages from the Gartner study are used in order to rank them.

1.2: Green IT and Higher Education

Just as Green IT has been a major trend in business, it has found its way into higher education as well. Many universities have some sort of campus-wide sustainability program, but IT has taken longer to become a target for energy reduction (EDUCASE). Universities are finding that Green IT offers many advantages: cost savings through energy bills, attracting customers, and raising employee morale, to name a few. For universities located in Ohio, many are finding another reason to think about Green IT projects: law. According to Ohio House Bill 251, Revised Code 3345.69, all universities which receive state funding are required to set a plan to reduce energy consumption in all university buildings by 20% by 2014 from a 2004 benchmark. This has become a huge motivation for colleges within Ohio to further investigate projects within Green IT.

At Ohio University, a college of about twenty thousand enrollees, Green IT is being looked at as an instrument to become House Bill 251 (HB251) compliant. One of the major purposes of this research is to identify how Ohio University IT can best help to accomplish the goal set by HB251. This is done by first finding the areas of greatest potential savings by analyzing the research literature on Green IT. The goal is to maximize the amount of energy saved, so only the areas of high savings will be investigated. Projects that cost more and take up more time than they are worth in savings are not worthwhile investments. After identifying the greatest areas of potential savings, Green IT projects within those areas will be studied, and energy-savings impact of those projects will be accessed and measured.

1.3 Green IT Opportunities

According to the Gartner study mentioned earlier, the two greatest areas for IT greening are PC/monitor usage and servers/cooling, which consume nearly two-thirds of the total ICT power nation-wide. Given how broad a topic these two areas of energy consumption are, there are many ways to increase efficiency within them. Some projects are in the form of an education campaign, such as a computer usage habit that is inefficient of energy. Often times new technologies are involved, which can mean new hardware procurement or a new look at how services are delivered. The cases of desktop computing and server operation are no different, and there are many ways to increase the energy efficiencies of each. In each area, this research has identified and studied one project that has a large potential to go green.

In the case of server energy, reductions usually come in the form of either removing excessive servers or by making current servers more efficient. A popular way of achieving this is through virtualization, which replaces physical machines with virtual representations that can be consolidated onto fewer physical machines. Simon Mingay recommends, “Consolidate, Virtualize, and Decommission in the Data Center.” The Systems and Operations department at Ohio University has been working on virtualizing their central database since 2008. During the course of this virtualization, information about each and every physical server that was retired was recorded in a database. Individual records include the server hardware specifications, usage details, physical location, administrator responsible, and any other statistics deemed useful for further endeavors. This research has taken information gathered on this database and calculated an amount of energy saved due to virtualization. These savings are a significant contribution to green IT and help to reach HB 251 specifications.

The largest greening category is PC and monitor usage at over one third of IT’s total energy consumption. Thin client computing has been used in the past to alleviate desktop power consumption. This technology replaces energy-heavy personal computers with energy-efficient thin clients that have no on-board computer processing. Instead, the computational component of the thin client is located within a server, which serves many thin clients. By concentrating the computing of many machines, the result is a net savings in electricity. This research creates a method for estimating cost savings associated with thin client computing. The method will be used to estimate the savings of a virtual desktop application in a campus-environment so that the Green IT impact of the desktop virtualization technology can be determined.

This research gauges Green IT's current and potential impact by investigating two areas. Ohio University's server virtualization project has been under way for over a year now, and its results will analyzed. Desktop virtualization power savings will be estimated, and the method of its calculation will be spelled out. Between server and desktop virtualization, an overall Green IT impact will be established. This measurement of Green IT will be weighed against HB 251 requirements and its value at Ohio University will be measured.

1.4: Purpose

The first purpose of this research was to investigate Green IT and establish the greatest potential areas of savings. In sections 1.1 and 1.2, the motivation for business and higher education to adopt Green IT practices has been spelled out. Section 1.3 has identified two areas in IT which have the greatest potential for savings: servers/cooling and PCs/monitors. The remaining purposes of this research are to investigate two projects in these areas: server and desktop virtualization. In the case of server virtualization, a method of estimating server power consumption will be spelled out and the results of Ohio University's server virtualization will be quantified. Also, the method of finding desktop virtualization power consumption will be defined and the results will predict the savings of a fictional VDI application.

Research Purposes

- Establish a method for finding server virtualization power savings.
- Calculate the power savings of Ohio University's server virtualization project.
- Establish a method for finding VDI power savings.
- Estimate a fictional VDI deployment's power savings.

2: Method

The method of this research revolves around the two projects being investigated. In the case of server virtualization, the method is largely quantitative data collection and organizing. The data from the server virtualization database was sorted, filtered, and organized to ensure that the only servers being measured were decommissioned due to virtualization. The process for determining a server's power consumption is grounded in a large bed of research literature and is discussed at length in section 2.1. Section 2.2 covers virtual desktop power savings, which is a combination of fact-finding research and non-experimental quantitative research. The metered power data used for the personal computer and thin client calculations was found through a series of tests conducted at Ohio University. The specifics of each projects' method will be discussed in the following two sections.

2.1: Server Power Consumption Method

There are two important factors for measuring power consumption of a server: the power necessary for running the device itself and the power necessary for auxiliary systems such as HVAC, lighting, UPS, and AC-DC conversion. Metering the device can be done through proprietary imbedded software if available, or a wall-based plug in device. Metering the secondary power usage involves metering the entire datacenter and like many other large institutions or businesses, these metering processes are not always possible at Ohio University. Individual machines are not metered in order to avoid hard reboots, because there is no built-in power-monitoring available, or simply because there are no power meters. Rarely are individual buildings metered on a college campus, let alone a data center within a building. For these reasons, ideal power collecting methods cannot be used and an alternative method must be used to record the power usage.

The alternative solution is a speculative method that is grounded in research and requires a number of base assumptions. Instead of recording the actual power consumption, it must be estimated by taking into account a machine's model, hardware components, and utilization. The auxiliary power consumption must be adopted by observing industry averages and comparable datacenters that are found in the current research literature. Using these speculative methods, the power impact of server virtualization and consolidation can be measured.

The first step in the speculative method is to find the theoretical maximum draw of a server using an online calculator. The calculator used in this research is hosted by APC electricity and is made to calculate electrical requirements for UPS solutions. The server specification inputs include model, number and type of processors, number and type of hard disks, and the number of power supplies. It works by "drawing upon an extensive database of actual power measurements" and its results can be cross-referenced to server power studies to check for accuracy and consistency. The output of the calculator is in terms of maximum power draw, measured in Watts, and is the rate of energy consumption at full utilization.

At this point, it is important to note the difference between nameplate power ratings and the maximum power draw of the calculator. The nameplate power rating of a device is the sum of all of its power supplies' ratings, and is the maximum number of Watts that the device can handle before the power supplies fail. However, because manufacturers do not want to be held liable for power supply failures, devices are typically given more ceiling room than necessary. A server might have a 700 Watt nameplate rating, but the hardware at 100% utilization might be only capable of a 350 Watt draw. This inequality is the reason that calculator-based maximum draws are used instead of manufacturer's name plate ratings.

The online calculator output the maximum power draw of a server, but it gives no indication of average power consumption. To find the average power draw, the average server utilization must be known as well as the impact that utilization has on power consumption. A server running at low CPU utilization will typically use less power than a server running at near capacity. While the efficiency of a server depends on a multitude of software and hardware variables, there is enough data available in the research literature to estimate the impact that CPU utilization has on the average power draw of a typical industry server.

As it turns out, server utilization has little impact on the power consumption. Idle machines use a large proportion of a server's maximum energy consumption, leaving only a small portion to be decided upon by utilization. This research uses 74% of a server's maximum power draw as the idle rate of consumption. This number is a composite of four different sources[1] attempting to generalize idle power consumption of industry-generic servers. If one of the studies concluded a range of percentages (ie. between 60-80%), then the average was

[1] Sistek, Ekbote, Nordman, & Blackburn

calculated and used as a single entry (70% in the entry above) so that the four different studies could be compared. The resulting statistics showed a mean of 74% with a standard deviation of 3.1% and a range of 7.5%. These numbers are quite consistent despite the variety of hardware considered, which elevates the confidence of this research approach.

Now that maximum power draw and percentage of idle power have been determined, the average power draw should be extrapolated from the CPU utilization. However, this is not as simple as it seems. The database for retired Ohio University servers does not have CPU utilization measured consistently, and those few that do have utilization recorded are quite low (0-9%). This is backed by the research literature, which states that the average utilization of a typical server is known to be very low—less than 10% (Microsoft) and 5% (Virtualization Basics). In order to simulate CPU utilization, this research adds a 5% increase on idle power levels. Using this rate of CPU utilization, the average power draw can now be measured.

Equation 1: Average Server Power Consumption

1) $$Max\ Power = Derived\ from\ online\ Calculator$$

2) $$Idle\ Power = Max\ Power * \ Idle\%$$

3) $$Average\ Power = Idle\ Power + \ Util\% * (Max\ Power - \ Idle\ Power)$$

Idle% = 74% Util% = 5%

The resulting average server power consumption is based on two assumptions. First, that the distribution of power consumption associated with CPU utilization is linear. Assuming that it is indeed linear, at 100% utilization the server draws max power, at 0% utilization the server draws idle power, and all utilization percentages in between draw a proportional amount of power. The second assumption is that there is no inherent inaccuracy in not defining an application for a server. For example, a web server and a file server have different average idle and utilization measurements. In the case of Ohio University's server decommissioning records, the application of the server is not always known. This is not a problem because the inconsistencies of specific server applications average out over a larger number of servers on a college campus. If this method of server measurement were used in a more specific server environment, the idle and CPU utilization marks should be adjusted accordingly. The speculative method of server power consumption is not precise; it is very generalized and best applied to a very broad range of server applications.

The final component to finding a server's total power consumption is the cooling, lighting, UPS, AC-DC conversion, and other auxiliary power consumers. Since we will be estimating the savings of removing a server from a datacenter, that datacenter's power draw will need to be profiled and put into a metric. The metric used by this research is called Power User Efficiency (PuE), which is defined as the "Total Facility Power/IT Equipment Power" (Belady, 2008). For example, a PuE of two would mean that for every watt used by the servers in the datacenter, another watt of electricity is used to cool, light, and provide power to those servers. Multiplying the PuE by the average server power consumption will result in the overall power impact of that server.

$$Total\ Server\ Power\ Consumption = Average\ Power * PuE$$

As mentioned earlier, the actual PuE of Ohio University's datacenter is unknown. In order to fill in the blank, this research identifies an industry standard PuE of 2.4. This is calculated by averaging the results of ten different studies[2] that either spell out a PuE case study or attempt to find an industry-standard PuE themselves. Among these ten studies, the minimum is 1.77 and the maximum is 3.57. The mean, median, and mode were 2.40, 2.36, and 2.5 respectively with a standard deviation of .52. These results are satisfactorily consistent to adopt 2.4 as an industry-standard PuE and this is the number used to find the total server power consumption.

One final consideration for finding server power consumption is the issue of blade servers versus rack servers. So far, the speculative model has been applied to rack servers only. Measuring the power consumption of blade servers must take into account the electricity expenditure of both the blade chassis and the individual blades. The method uses the IBM BladeCenter Power Configurator, available from IBM's website[3]. The average total power of a single blade is calculated by taking the max power of one blade and adding one seventh of the total chassis consumption. This is done under the assumption that each chassis has fourteen slots and that on average, one half of all slots are occupied. This is an area where the research

[2] Ten studies: Koomey, Brill, Greenberg, Ekbote, Mingay, http://www.thegreengrid.org, Sawyer, Cappuccio, Bolander, IBM Report

[3] http://www-03.ibm.com/systems/bladecenter/resources/powerconfig/index.html

literature is lacking and there is no consensus on what an average blade environment is. The numbers used for this study are estimates and if an individual blade environment's chasis utilization is known, it should be used instead. The total blade server power is then multiplied by utilization percentage and PuE to find an average consumption.

By using a speculative model, this research has identified a method of determining server power consumption without knowing any actual power readings. The inputs to the method are the server model, CPU(s) and HDD(s), and the output is an average power draw. The average power draw is then multiplied by the PuE to represent the auxiliary electricity draw of a datacenter's equipment. In the results section of this report, the speculative method of determining power consumption will be applied to a number of servers that were removed due to virtualization at Ohio University. This will be the measureable Green IT impact that server virtualization has achieved.

2.2: Method: Thin Client Computing Power

Thin client computing is a technology which has a potential to save considerable amounts of energy. These savings are realized by replacing traditional personal computers with thin clients that use less electricity. Computation that used to take place on the desktop computer now takes place on a centrally located server that serves many thin clients. The user experience is, in theory, the same for the user, and the net energy consumption is lower.

There are a few different technologies which apply thin client computing and all of them employ some sort of virtualization. One such technology is VMware's View (formerly Virtual Desktop Infrastructure), which will be referred to as VDI for the remainder of this study. The virtualization is achieved by software located on a server, which creates the illusion of many independent machines to a remote user. While there may be only one physical server, there can be many virtual machines. In the case of VDI, these virtual machines are desktop images, and users interact with them in the same way they would a normal desktop. The display information is sent to the user's thin client, which is projected onto a monitor. By using virtualization, VDI is able to condense the computational power of many users into a single, centrally located server environment, all-the-while saving electricity.

At Ohio University, Central IT is currently conducting a trial of the VDI technology. VMware back-end software was used in conjunction with Wyse brand V10L thin clients. One of the outcomes of the project was a reliable set of power consumption measurements of the thin clients and personal computers involved. The measurement equipment used was a wall-mounted Watt meter called the Kill-A-Watt, which measures the actual electricity flow to the machine to within .2%. These measurements will be used later when the total power savings of VDI is found.

The method to quantify VDI power savings includes three factors: the power of the desktops being replaced, the power of the thin clients replacing them, and the power of the server component. The savings are found by subtracting the after environment (total thin client and server power measurements) from the before environment (total desktop power measurements). Calculating VDI power savings also has an inherent time component. Over a given period of time, a computer, server, or thin client does not draw the same amount of power: sometimes they are on, sometimes they are off, etc. Not only does each device need to have a known operating power draw, but the amount of time that they are operating under that draw must be know. Because of this, each of the three indentified factors must have an average operating time as well as an average power consumption rate. The total savings will be in terms of electricity saved in a year and will be found using this equation:

Equation 2: Total VDI Power Savings

1) $VDI\ Power\ Savings = Before - After$
2) $VDI\ Power\ Savings = Desktop\ Power - (Thin\ Client\ Power + Server\ Power)$
3) $VDI\ Power\ Savings = D_P * D_T - (TC_P * TC_T + S_P * S_T)$

D = desktop, TC = thin client, S = server, P = power, and T = time.

Each component must be broken down and its method determined in order to fill the equation and calculate the total savings. Sections 2.2a and 2.2b cover the desktop’s power and time components respectively. Section 2.2c covers thin clients and 2.2d retouches on servers. 2.2e will define a few extra considerations. By the end of the VDI power savings method, all six of the power and time components in the equation will have been examined and their specific method determined.

2.2a: Desktop Power

The first component in the equation is the desktop, or personal computer. The ubiquity of cheap, fast personal computers is great for many reasons, however, it also results in a great variety in hardware components and an ambiguous definition of a "typical" computer. Since the purpose of this research is to estimate the savings of an average industry VDI application, an industry-typical workplace computer must be identified. The computer deemed to be work-place-typical in this research has the following hardware specifications detailed in Table 1.

Table 1: "Typical" Workplace Computer Specifications

- Intel P4 2.8 Ghz CPU
- 1.48 Ghz DDR memory
- 40 GB SCSI HDD
- Intel 82865G on-board Graphics Controller

To get a full energy profile for the PC, three operation states were measured for energy consumption: off, idle, and max load. To measure the off state, the device simply has to be plugged in but not switched on. The method for idle consumption was to turn the computer on, log in, and wait at least fifteen minutes. No excessive applications should be running besides what would normally be running in the background. For max load, no particular was benchmark used. The results were found simply by recording the highest wattage observed while performing complex computational tasks such as copying large spreadsheets. It was quite apparent when the computer had maxed out because the meter would read the same high value consistently. The meter used was P3 International's Kill-A-Watt meter. This is an in-expensive watt meter designed for small appliances plugged into a common 120 volt wall socket. The findings will be discussed later in the results portion of this report.

We can now extrapolate the average PC power consumption by determining an average idle time and by assuming a two-state utilization model. Like servers, desktops are idle for the majority of the time. Users might be away from their desk, using non-CPU-intense applications, or even taking a nap. "A Typical Computer Spends > 80% of Time at Less than 5% CPU Utilization." (Calwell) However, when the computer is not idle, it must be using some percentage of its computing capacity. The two-state model assumes that when it is not idle, it is at maximum utilization. Using this two-state model, the average consumption can be found:

Equation 3: Two-State Desktop Power Model

$$Average\ Consumption\ = Idle\ Power \times Idle\% \ +\ Full\ Load\ Power \times Load\%$$

Idle% = 80%   Load% = 20%

While this black & white picture of CPU usage is not actually true, it simplifies the process of calculating power consumption. CPU usage is extremely bursty in nature, which is extremely difficult to meter effectively. Even more difficult is translating the CPU % to electricity draw. The two state model is much more convenient and reliable to measure. Both idle and load can be found using reproducible techniques and the results are consistent and precise. After using this method to meter the two states of operation, PC average power consumption can be found and then filled into the equation for VDI total power savings.

2.2b: Desktop Time

The next step in the VDI power savings equation is the time component of the PC, which is measured in terms of hours-per-year. To find the total hours that a device is turned on over the course of a year, methods for calculating hours-per-day and days-per-year are necessary. User behavior is extremely important, because, for example, some office employees leave their computer switched on overnight while others do not. This research creates the concept of “user awareness” to profile user behavior into quantifiable categories. These categories are used to calculate an average hours-per-year which is in turn put into the VDI power savings equation.

User awareness is a ratio of users who practice “good” power-saving behavior to those with “bad” behavior. One of the biggest differences between the users is hours-per-day with their desktop on. An aware user turns their computer on in the morning and off after a nine hour workday, while an unaware user leaves their computer on twenty four hours a day. An aware user also powers their PC off for 104 weekend days, 10 federal holidays (U.S. Office of Personnel Management, 2009), and 8 sick days (Lyons, 2006) per year. An unaware person leaves their computer on for 365 days a year. The differences between the two user awareness models are visible in the first two columns of table 1:

Table 2: User Awareness

	Aware	Unaware	Average (36%)
Hours / Day	9	24	18.6
Days / Year	243	365	321.1
Hours / Year	2187	8760	5972.5

The third column in table 1 represents the ratio of aware users to unaware users. According to a Lawrence Berkley National Labs report, 36% of desktop computers were switched off overnight across twelve office buildings (Roberson, et al. 2004). This value of 36% is used by this research as the average awareness ratio among users. Used as a weighted average, the results can be seen in column three of table 1. 5972.5 is the average number of hours-per-year that the average workplace employee leaves their desktop device powered on. This is the number that will be used in the total VDI power savings equation for the desktop time component.

2.2c: Thin Clients

The next part of the VDI power savings is the thin client, which uses much of the same method as the personal computer. The power draw was metered using the same Kill-A-Watt device and the same states of operation were tested. The thin client methodology also uses the same user awareness ratios to measure the time component. Users are assumed to not change their power conservation habits after switching to a new computing technology. Thin client computing is, in theory, the exact same user experience as the personal computer, so a typical user should be nearly unaware of a change. There is no further methodology to define for the thin client because it uses the same metrics as the personal computer for both power draw calculation and hours-per-year calculation. The results, however, are quite different and will be discussed in length in the results section of this research.

2.2d: VDI Server

The reason that a thin client's electricity profile is different from PCs is because their computing is done at the VDI server. The method for calculating the power draw of a VDI server is the same speculative model used previously in this research. The time component of the server is simply twenty four hours a day, 365 days a year. Servers are designed and maintained for over 99% availability with mere minutes of downtime a year, especially when the application is as critical as desktop virtualization. Given the results of the power draw and time methods, the average consumption over a year can be found and plugged into equation 2.

Using the speculative model to calculate the power draw of the VDI server raises a number of assumptions and problem areas. One of the major problems with the speculative model is that it does not specify the application or service that the server is used for. VDI is a very specific usage and the utilization profile of a VDI server is an area where more research is needed. In a VMware environment, the virtual servers can switch to multiple physical machines to balance the workload, so utilization is both constantly changing and difficult to average. This research assumes a 50% utilization mark for a VDI server because VDI servers tend to be much more efficient of utilization than an average server. This is an area that requires more research to produce a more precise number, however, any the overall impact on the power consumption is not highly significant due to the high proportion of idle power draw.

2.2e Extra Considerations

There are a few more things to consider in the context of VDI power savings. First is the concept of phantom power—electricity that is drawn from the wall while a device is turned off. The draw is typically small, but can add up over the course of a year. Phantom power calculation has a time and power component and applies to both PCs and thin clients. The power component is recorded using the Watt-meter when the device is turned off. Both the personal computer and thin client time components are calculated by finding the inverse of the user awareness model. The total number of hours-per-year while off must be found for an average user that is weighted between aware and unaware users. Multiplying the time and power components will result in the total consumption of phantom power and can be added to the equation along with the PC and thin client consumptions respectively.

Another factor that hasn't been addressed yet is the heating, vacuuming and cooling (HVAC) associated with PCs and thin clients. Computers give off heat and the building has to spend energy to maintain the environment; the equivalent of PuE for the server method. The electricity that flows into a computer is largely converted into heat, but the actual rate of conversion suffers from a lack of research. This study assumes that for every Watt that flows into a computer, one Watt is spent by HVAC to cool it. This is based on an assumption that nearly all of the input electricity into a computer is converted to heat and that the HVAC performs at a 1:1 ratio. The efficiency of the HVAC, outside to inside temperature differential, and volume of office space are out of the scope of this research. The value of HVAC is multiplied to the total average desktop and thin client draws just like the power user efficiency is for the speculative server model.

As a VDI application begins to scale, an individual server will run out of capacity. In order to estimate larger VDI deployments, an average VDI-instance to server ratio must be established so that the number of servers can be estimated. This number depends greatly on the server specifications, and in the case of VDI, random access memory tends to be the limiting factor for the maximum number of concurrent VMs. This research uses a maximum ratio of 25 virtual machines per server, which is based on vendor information and experience from O.U.'s trial. New information from VMware suggests that 6-7 instances per core is not far from attainable, which has some large implications with high-end, multiple-processor, multiple-core servers becoming commonplace industry-wide. For this research, the ratio of 25 VMs/server is used to scale the server side power consumption.

One factor that is not mentioned in the method of this research is the power consumption of monitors. A base assumption is that an end user will use the same monitor for their thin client as they did for their PC, which eliminates the monitor usage from the equation. However, some thin client models have built-in monitors. If this is the case, then the equation needs to be modified by measuring the original monitor's consumption and adding it to the "before" segment of the equation with the PC. Otherwise, the power consumption of monitors does not need to be factored into the equation.

3.1 Results of Ohio University's Server Virtualization

Ohio University has one major datacenter administrated by the Central IT department. Over the past few years, the system operations team has been working to consolidate and virtualize the centrally located servers to be more efficient. Thirty servers have been decommissioned due to virtualization and their hardware specifications have been recorded. Using the method prescribed in this research, the energy savings associated with this effort is 138,079 kilo-watt hours per year. Using the local price of electricity, server virtualization saves Ohio University $6,549 per year in electricity alone. This is actually deceivingly small considering the low price of electricity ($.04743 / kWh) compared to the national average ($.10 / kWh). Using national average numbers, the result would be $13,808 per year.

Table 3: O.U. Server Virtualization Savings

Num.	Server Draw	Whole Datacenter[1]	kWh / Year	Savings / Year[2]
30	6,751 W	16,202 W	138,079 kWh	$6,549

1) Includes PuE
2) O.U. electricity cost: $0.04743 / kWh.

A full list of all the virtualized servers including specifications and estimated max power draw is available in appendix 1.

3.2 Results of Virtual Desktop

The method outlined in this research is designed to predict the savings of a VDI application. In higher education, possible VDI deployments might be 50 desktops in a department, 400 workstations in a library, or 2000 office/lab/work computers campus-wide. The savings results of each of these cases will be looked at using the method described in this research. Table 4 shows the Watt-meter results for the PC and thin clients, as well as the server power draw using the server speculative power model. Table 5 shows the before, after, and savings of the fictional campus applications. Table 6 shows the dollar savings attached to these electricity savings.

Table 4: Individual Power Draws

	1 PC	1 Thin Client	1 VDI Server[1]
Draw (Idle)	65.0 W	13.0 W	267 W
Draw (Max)	120.0 W	13.0 W	359 W
Draw (Off)	3.0 W	3.0 W	-
Draw (Avg)[2]	76.0 W	13.0 W	313 W
kWh /Year[3]	932 kWh	171 kWh	6585 kWh

1) Uses speculative model for a HP ProLiant DL360 G4, 2 x Intel Xeon 5400, 2 x SCSI HDD.

2) Weighted for 80% desktop idle time and 50% server utilization.

3) Includes phantom power for all off-time, HVAC/PuE, and user awareness.

Table 5: Kilo-Watt-Hour Savings per Year

	PCs	Thin Clients	Servers	Savings
50 users	46,618 kWh	8,530 kWh	13,170 kWh	25,176 kWh
400 users	372,945 kWh	68,239 kWh	105,364 kWh	201,442 kWh
2000 users	1,864,723 kWh	341,196 kWh	526,823 kWh	1,007,230 kWh

Table 6: Dollar Savings per Year

	O.U. ($.0474/kWh)	National ($.10/kWh)
50 users	$1,194	$2,518
400 users	$9,554	$20,144
2000 users	$47,773	$100,723

4) Discussion

The dollar savings results of both server and desktop virtualization appear at first to be moderately low when judged on a university campus scale. Projects in Green IT tend to not boast massive savings and the general attitude is that any savings are good savings and worth considering. The two Green IT project discussed in this research are no different. In the case of server virtualization, the power savings they've produced are not incredibly massive, but are still an improvement on the campus energy bill. The VDI results are more variable because of the three different examples used, but the scale of $2,512 to $100,723 yearly savings is still relatively small for a college campus. however, they are money savings none-the-less.

Money is not the only motivation for Green IT projects and for higher education in the state of Ohio, House Bill 251 compliance is a major factor. This means establishing a plan to reduce energy consumption in buildings by 20%. The energy savings results of OU's server virtualization project totaled .11% of OU's entire electricity draw from 2008. This does not seem to be a large portion, but for an individual project within the IT department, it is a step in the right direction. Universities are struggling to meet HB 251 and campus sustainability requirements and anything that IT can contribute via. Green IT is something out of nothing.

The results of a virtual desktop installation show the potential to save even more energy than Ohio University's server virtualization project. 2000 personal computers replaced by a virtual desktop technology result in savings of over one million kilo-watt hours per year. This amounts to .89% of OU's campus-wide 2008 power. Nearly 1/20th of OU's HB251 compliance could be satisfied by this Green IT technology, while saving $100,723 in energy costs per year. It is important to note that this is a best-case scenario where there are no extraneous scaling issues and there are no negative performance issues associated with VDI. There are positive and negative side effects of VDI technology that make it not applicable to every computing scenario, however, they are out of the scope of this paper. Only power consumption considerations are taken into account and this is not to be taken as a positive or negative endorsement of the virtual desktop technology.

The acceptance of Green IT is increasing year by and year and its presence at Ohio University is starting to bolster. The Central IT department's server virtualization project currently saves over $6,500 in electricity every year and more are virtualized every year. It has become less of a specific project and more of an organizational creed since its inception. Plans to implement virtual desktop have started with a proof-of-concept trial and the incentives of HB 251 might make it a lofty power-saving project. This research only studied these two areas of savings, but there are many more in the vast gamut of Green IT projects. The potential for power and money savings in Green IT are large, and each year more projects tap into this potential for the benefit of the organization, its employees, its customers, and the environment as a whole.

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Appendix 1: Decommissioned Servers due to Virtualization at Ohio University

OS	Model	Hardware Category	# CPUS	CPU Type	CPU Speed	# SCSI HDDs	Estimated Max Draw	Notes
Windows 2003	IBM xSeries 345	Rack Server	2	Intel Xeon	2.8 Ghz	1	244 W	[2]
Windows 2000	IBM 8670 xSeries 345	Rack Server	2	Intel Xeon	1.9 Mhz	2	266 W	[2]
Windows 2003	Gateway E-9220T	Desktop					434 W	[2,3]Measured for 1 Intel Pendium D and 2 SCSI HDD
Windows 2003	Gateway 955 Series	Desktop	1	Intel Xeon	2.4 GHz	1	141 W	[2]
Windows 2003	Data General AV3704	Data General Server	3	Intel Pentium III	500 MHz	5	370 W	[2]
Windows 2003	Gateway 9315	Gateway Server	4	Intel Xeon	3.6 Ghz	1	340 W	[2]
	Dell PowerEdge 2850	Rack Server	2	Intel Xeon	2.8 GHz	1	244 W	[2]
Windows 2003	Dell PowerEdge 4600	Rack Server	4	Intel Xeon	2 Ghz	3	572 W	[2]
Windows 2000	Gateway 975 Series	Rack Server	4	Intel Xeon	2.4 GHz	1	385 W	[2]
Windows 2000	Gateway 975 Series	Rack Server	4	Intel Xeon	2.4 GHZ	1	385 W	[2]
Windows 2000	IBM xSeries 345	Rack Server		Intel Xeon	2.8 Ghz	1	174 W	[2,3]Measured for 1 IINTEL Xeon
Windows 2003	Dell PowerEdge 4600	Rack Server	4	Intel Xeon	2 Ghz	4	596 W	[2]
Windows 2003	Gateway 955 Series	Rack Server	1	Intel Xeon	2.4 Ghz	1	141 W	[2]
Windows 2003	IBM xServer 340	Rack Server	1	Intel Pentium III	1 Ghz	2	202 W	[2]
Windows 2003	Gateway 9315	Gateway Server					130 W	[2,3]Measured for 1 INTEL Xeon and 1 SCSI HDD
Windows 2000	Dell PowerEdge 6400	Unknown	1			3	316 W	[2,3]Measured for 1 INTEL Xeon P3
Windows 2003	Gateway 9315	Gateway Server	1	Intel Xeon	2.8 Ghz	1	130 W	[2]
Windows 2000	Dell PowerEdge 4400	Rack Server					331 W	[2,3]Measured for 2 INTEL Xeon P3s and 1 SCSI HDD
Windows 2000	Dell PowerEdge 6350	Rack Server					334 W	[2,3]Measured for 2 INTEL Xeon P3s and 1 SCSI HDD
Windows 2000	Dell PowerEdge 6350	Rack Server					334 W	[2,3]Measured for 2 INTEL Xeon P3s and 1 SCSI HDD
Windows 2003	IBM Blade 867851X	Blade Server	2	Intel Xeon	2.8 Ghz	2	221 W	[1]
Windows 2003	IBM Blade 8843J1U	Blade Server	2	Intel Xeon	2.8 Ghz	2	221 W	[1]
Windows 2003	IBM Blade 883221X	Blade Server	2	Intel Xeon	2.8 Ghz	2	221 W	[1]
Windows 2003	IBM 8836-4SU	Rack Server	1	Intel Pentium 4	3.2 Ghz	1	150 W	[1]
Windows 2003	IBM 8836-4SU	Rack Server	1			1	150 W	[2,3]Measured for 1 INTEL Pentium 4
Redhat	Dell PowerEdge 6850	Rack Server	4		3.1GHz	4	828 W	[2,3]Measure for 4 INTEL Pentium Xeon 7100 and 4 SCSI HDD
Redhat	IBM	Blade Server	2	Intel Xeon	2.8GHz	1	221 W	[1]
Redhat	IBM	Blade Server	2	Intel Xeon	2.8GHz	2	221 W	[1]
Redhat	IBM	Blade Server	2	Intel Xeon	2.8GHz	2	221 W	[1]
Redhat	IBM	Blade Server	2	Intel Xeon	2.8GHz	1	221 W	[1]
Redhat	IBM	Blade Server	2	Intel Xeon	2.8GHz	2	221 W	[1]

[1] Calculated using IBM Blade Center Power Calculator as Specified in Methodology

[2] Calculated using APC Online UPS Selector Calculator as Specified in Methodology

[3] Some or All of the Hardware Specifications Were Estimated Due to Lack of Information