Power to the People:

Comparing Power Usage for PCs and Thin Clients in an Office Network Environment

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Purpose of this Study

Over the course of this last year energy costs have been rising--not just in California, but across the United States. Some small businesses are seeing prices in excess of 20 cents per kilowatt hour (kWh), resulting in noticeably higher energy bills. Given this situation, it's natural to wonder whether using low-power devices such as thin clients[1] could reduce the power bills and, if so, by how much. However, although there is no shortage of opinions about the real power-saving capabilities of thin clients versus PCs, there *is* a serious lack of hard data readily available to back up these opinions because hardware power ratings do not reflect actual power *usage*.

To fill this information gap, we present a unique *practical study* which introduces laboratory style test equipment into a working production IT system. Using real-world measurements of PCs, thin client devices, Pentium-based servers, and, networking equipment, we have developed hard data about the power requirements of these commonly used devices. We summarize and present this data in a manner which allows the reader to easily determine how much it costs to power their existing networks, and, the cost savings that will result if they exchange PCs for thin client devices.

Since we intended this to be a practical study, we decided to use an actual operating business office to ensure that our readings would reflect real-world usage patterns. We measured computers and other equipment in combinations which reflect the way that these devices are normally used. Because the cost of electricity varies from region to region in the United States, we've included a table of actual power costs for sample areas to better illustrate the true cost/savings numbers for diverse regions within the continental U.S. A readily available, low cost and easy-to-use power meter was used for this study to provide a specific hardware recommendation for readers seeking to reproduce these tests on their own equipment. Finally, we've included additional relevant information and background in sidebars, figures and tables, and footnotes throughout the paper.

[1] A thin client is a desktop computing device that has no hard drive and no application software running on it locally. Applications are executed on servers while the thin client simply provides the screen display and a way to operate the keyboard and mouse. In contrast to older style "dumb" terminals, thin clients provide access to modern graphical PC based applications and to applications on other platforms such as UNIX™ and mainframes. In addition, thin clients can be configured and managed remotely via a network connection.

Test Environment

We selected a client of Thin Client Computing, Ameriwest Insurance, Scottsdale, AZ, as the ideal test environment. Ameriwest uses a range of insurance specific applications and standard productivity applications such as Microsoft Office and Internet Explorer. Traditional PC desktops are used alongside NCD ThinSTAR Windows Based Terminals (thin clients) to access a standard file server and two redundant Windows Terminal Servers. Remote offices, and users working at home, access the system either through a dial-up modem or via direct Internet access. The existing IT infrastructure reflects a typical real-world configuration for Thin Client/Server Based computing systems in use today.[2] This environment allowed for simultaneous testing of Thin Clients, traditional desktop PC's and Servers engaged in common tasks throughout the course of one full business week. The results, therefore, can be easily extrapolated to networks of any size.

Methodology

Our primary questions were simple:

> How much less power do thin clients use than the personal computers?
>
> What are the actual cost savings gained by using thin client devices?

To properly answer these questions it is important to take into account the servers, and other standard equipment, that are needed to support end user systems. To measure only the desktop device does not lead to meaningful data. Thin client devices shift the application processing away from the desktop and onto servers that otherwise would not exist on the network. The power consumption of these servers must be taken into account to develop an accurate picture of true costs and potential savings. We chose to attach our power meters to logical groups of equipment as follows:

Meter 1:	A pair of load balanced Windows NT terminal servers (4) modems for incoming remote Thin Client sessions (4) modems for access to dial-out insurance ratings services
Meter 2:	A Windows NT file server (1) 24-port, 10/100 Ethernet Switch (2) 8-port 10Base-T Ethernet hubs
Meter 3:	(2) NCD ThinSTAR 200 Windows Based Terminals
Meter 4:	A PC running a mix of applications both locally and server based

In addition to the week-long readings for the grouped devices, we took separate real-time power readings for each individual piece of equipment. This involved running the metered equipment for several minutes and averaging its data points to get a representative value for active power. As a result we have meaningful power usage data both for individual components, and, these common groupings of computer equipment.

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[2] The term "thin client/server based computing" is the full name for this technology. Since the applications are actually running on the server and only displayed by the client, both "thin client" and "server" are key elements of the system.

We measured the grouped devices at five-minute intervals for 5 days over a standard work week, during which time the users engaged in their normal tasks. Each logged value was an average of the power drawn over the 5-minute period. So that we could see full power usage for all device types (see Box 1), we left all metered devices powered on for the duration of the test period. Details on the make, model and specifications of each piece of equipment are listed in Appendix A.

BOX 1: Measuring Power Usage and Calculating Costs

It's not always easy for organizations to understand their own power requirements. Computer equipment is usually engraved with the device's voltage and current, but these values tell you very little about the actual power requirements. To get the rated power, you need to multiply voltage (V) times current (A) and the power factor (PF) (i.e., V*A*PF), yet power factor is almost never indicated on the equipment. If you *are* able to determine a rated power, this is still just the theoretical maximum amount of power that the power supply can draw, not the actual power requirement. A 1990 study in the Annual Review of Energy found that nameplate ratings on personal computers typically overstate actual measured power by factors of 2-4.[3] A more recent study of other computer devices such as switches, routers and hubs found that these types of equipment usually draw about 30% of their rated power.[4] Some manufacturers do provide a heat rating (in British Thermal Units, or Btus) from which you can calculate a more accurate value, but this rating is still higher than measured power. For the Dell PowerEdge 2400 server, for example, the equipment was engraved with a rating of 330 watts. When we contacted Dell and downloaded their rack advisor program, the Btu rating was approximately 285 watts. Under test conditions, however, the servers used approximately 141 watts. Meters like Brand Electronics' 21-1850 can enable users to measure actual power draws and estimate energy costs. In fact, Brand's meter will estimate the energy costs of each piece of equipment for you if you enter your local electricity price per kWh.

You can audit the electricity used by your computer equipment each year in several ways. The easiest is to perform the following calculation for each group of devices in your network:

*n***p***h**52 = the number of kilo-watt hours (kWh) per year for this device group

where:

n is the number of devices of that equipment type
p is the total power (in kilowatts) used by each of those devices
h is the number of hours each week that the equipment is on
52 is the number of weeks in a year

Simply add the kilowatt-hours for each type of device and then multiply the total number of kilowatt-hours times your average electricity price to estimate the cost of your computer equipment. Electricity prices are usually available on the rate tariffs section of your local utilities website. For further information on your electricity rates, contact your local utility directly.

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[3] Nordford et al, 1990.
[4] Kunz and Kistler, 1997.

Test Equipment

To take our measurements, we used a Brand Electronics Model 21-1850 CI power meter and data logger.[5] This is a sophisticated power measurement device with a user-friendly interface that displays power, energy, elapsed time and several other variables such as voltage, current, power factor, and, average cost. Accuracy of the meter is +/- 1.5% of the reading. The meter is intended to operate between 20 and 1850 watts, so readings below 20 watts were less accurate. Since pre-testing indicated that a single NCD ThinSTAR Windows Based Terminal draws less than 20 watts, two of these devices were connected to Meter 3 to ensure accuracy. The modems and hubs were similarly grouped for their individual readings. The model 21-1850 CI can store 8000 wattage data points in its internal memory, and, provides a software interface to allow unlimited data logging of all available parameters on a Windows 9X based PC. Both methods of data collection were used. While not as precise as more expensive meters on the market, we chose this meter for its advanced features and ease of use. The Brand Electronics 21-1850 CI meets the requirements of being easy to use, inexpensive, readily available, and sufficiently accurate to give a good idea of annual electricity costs. We recommend this device to anyone who wishes to apply the techniques used in this study to their own power requirements.

The NCD ThinSTAR 200

The Brand Electronics Model 21-1850 CI

[5] Additional data on power meter and data logger can be found on the Brand Electronics website, www.brandelectronics.com

Results of Data Collection

After our testing period was over, we uploaded wattage data from the power meters and ran individual measurements of each device. Figure 1 shows measured power for each individual piece of equipment.

Figure 1. Comparison of power usage for each device

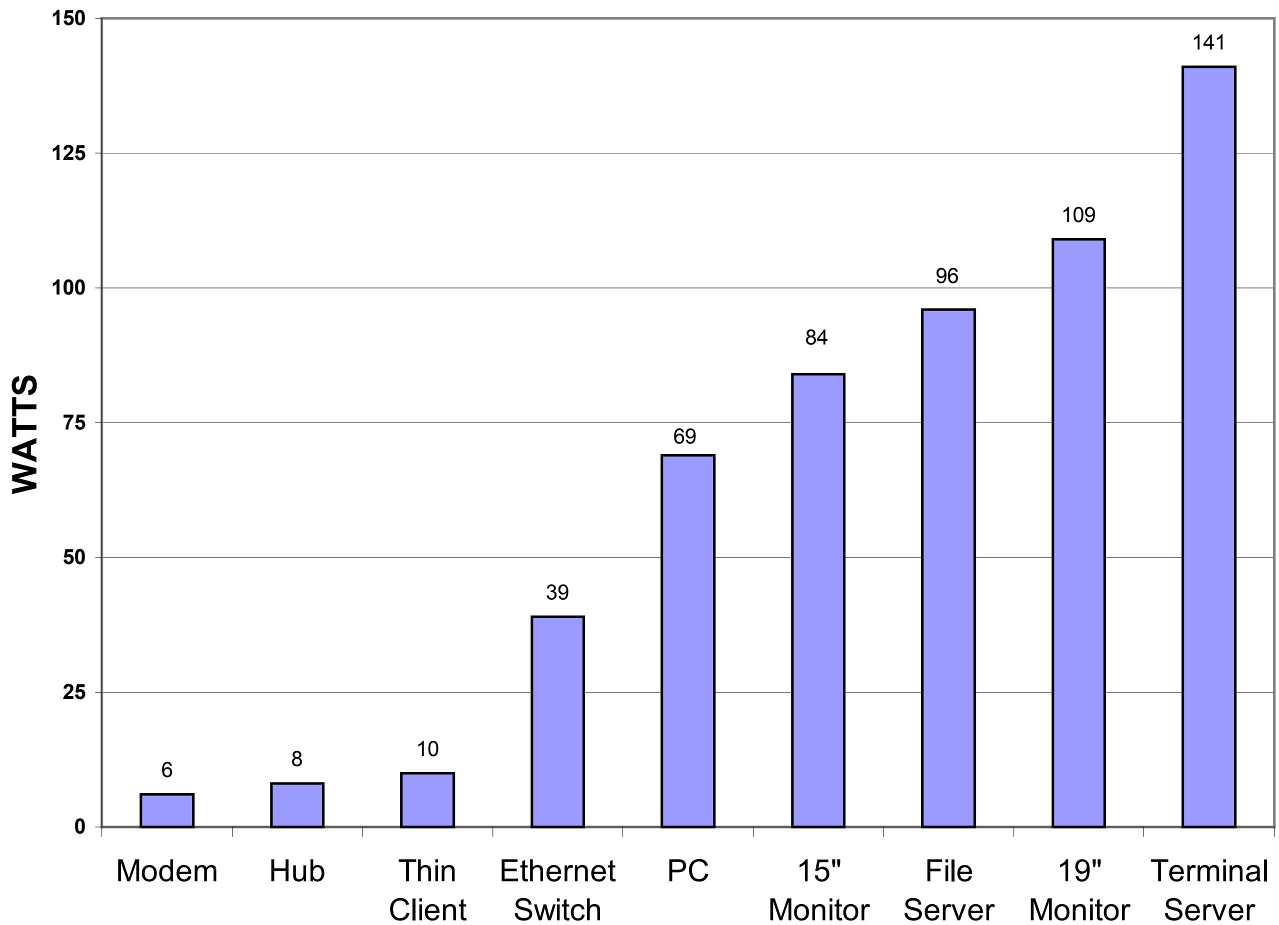
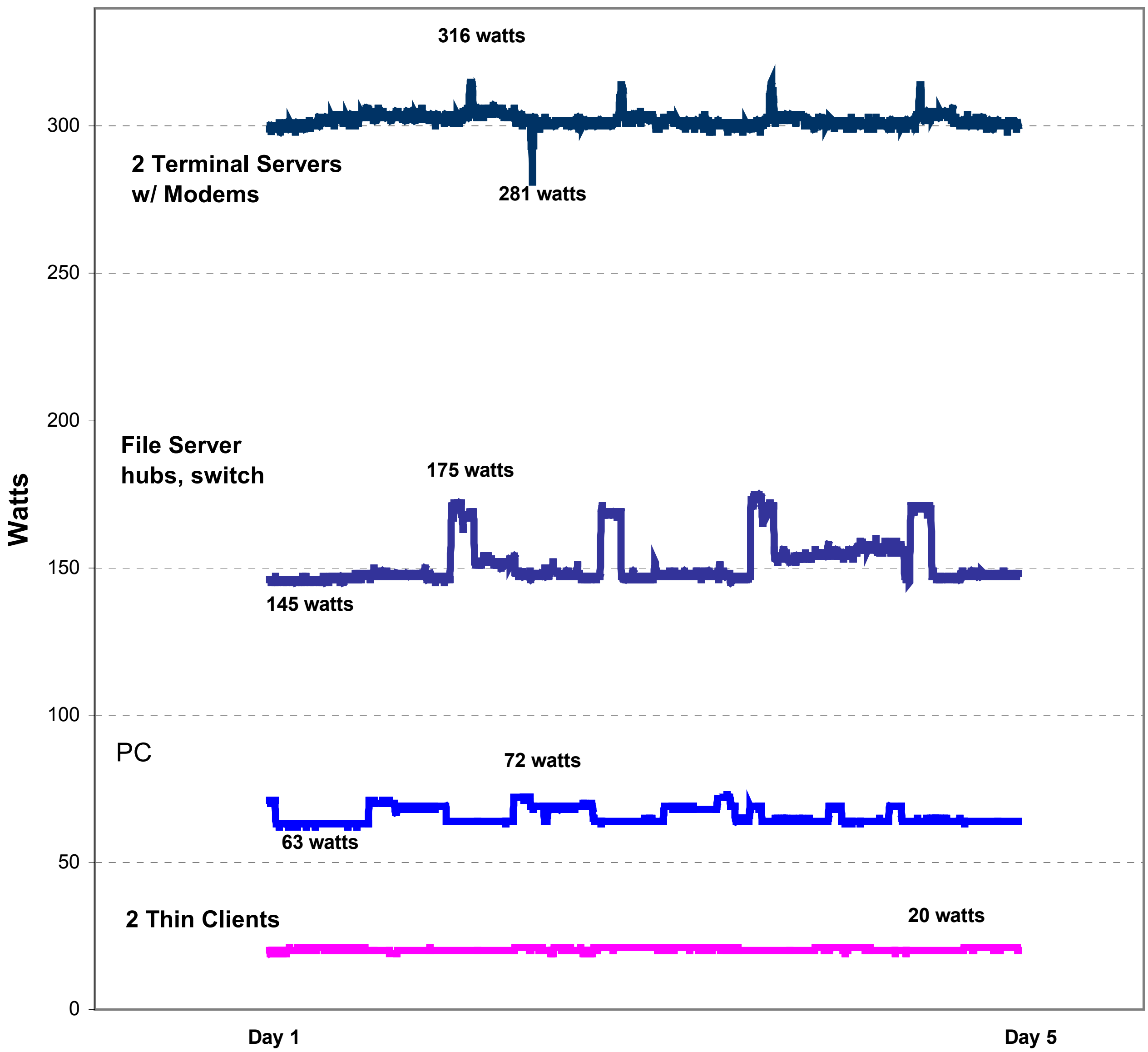


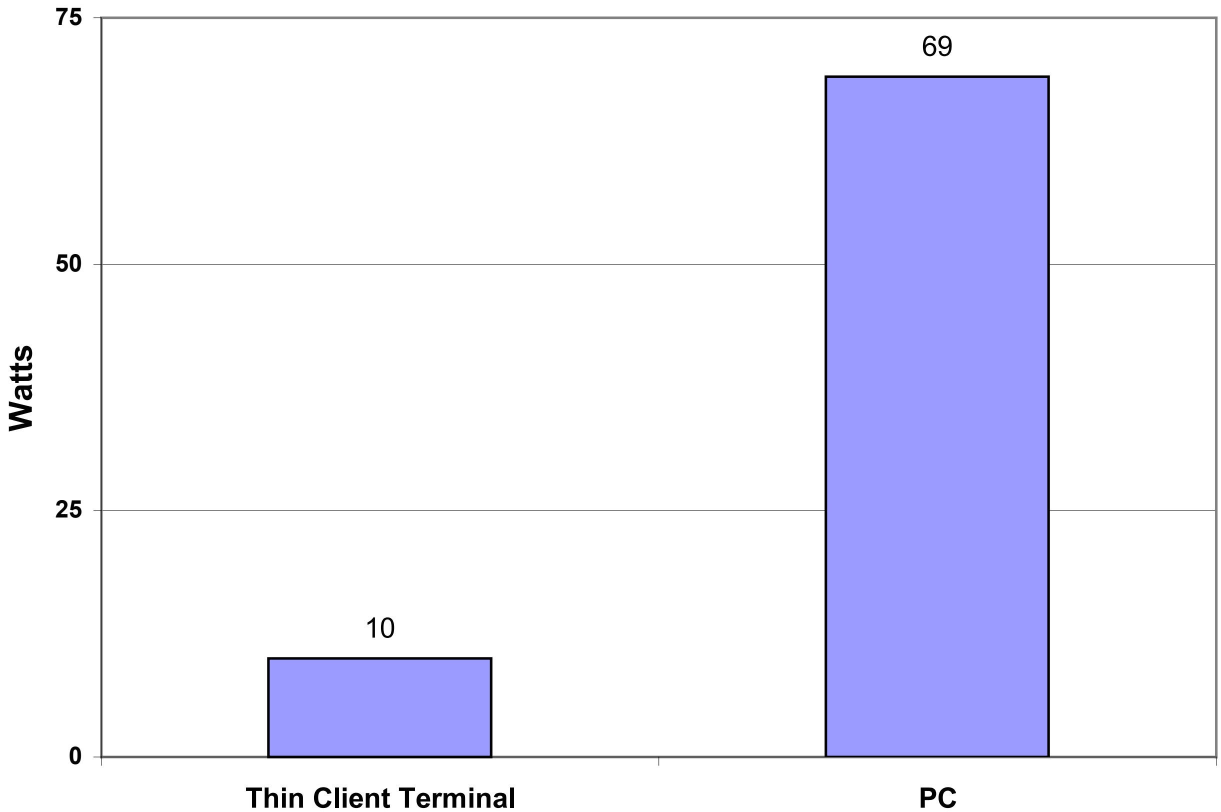
Figure 2 displays the power recordings over the 5-day period for the grouped devices. As is apparent from the graph, for most hours of the day the meters showed no large fluctuations. For the majority of the test period, recorded power for the devices on each meter fluctuated only 5 to 10 watts from the average.

Figure 2: Comparison of power levels used by Equipment Groups



The NCD Thin Star 200 terminals drew approximately 10 watts each. There was almost no variation in recorded power over the 5-day period. The desktop PC that we measured at the Ameriwest site drew nearly 7 times the active power of a Thin Client terminal—69 watts versus 10 watts. (See Figure 3.)

Figure 3. Power usage of Thin Client versus PC



The weekly data for the PC also displayed very little variation. The power requirements ranged from 62 to 73 watts over the course of the week, with an average power draw of 66 watts. Active power was approximately 69 watts, and the PC idled at 63 or 64 watts.[6] Since we did not ask users to keep active logs of their daily activities, it is not clear what specific activities caused these fluctuations. However, because PC power usage fluctuates little once it's turned on, these devices are often considered a constant load.[7] Because a PC's power is relatively constant, we were able to spot check additional PCs to see how power requirements for differently configured PCs compared.[8] We measured a Pentium 4/1.5 GHz with 384 MB of memory and found that the active power over a normal workday was approximately

[6] For a description of various power modes see Appendix B, "Understanding Power Levels"
[7] This is consistent with the findings in Nordford et. al, 1990 and Nordman, 2000. This does not include PCs with power management. Power management modes are beyond the scope of this study. For information on how low-power settings affect electricity use, see Nordman et al., 1997
[8] Supported by Nordford et al., 1990 and Nordman, 2000.

85 watts. A 1 GHz PC with 256MB of RAM used 66 watts when running applications from a terminal server, but 85 watts when running a compute-intensive application locally.

The largest fluctuations in our metered readings occurred on the servers, during weekday evenings. The timing of these peaks suggests that the increased power usage occurred when the servers were executing their nightly scheduled backups. The meter with the terminal servers peaked at a max power 14 watts higher than the average power over a roughly 30 minute interval beginning at midnight each weekday night. The meter with the file server recorded peaks as high as 24 watts above the average power. This peak period lasted for approximately 5 hours each weekday evening. This result is understandable given that the file server contains the internal tape drive that is used for the nightly backups, and, the complete backup process takes several hours to complete. This was a fortunate result of doing our study using an actual operating business- we captured additional data that would not have been included in a lab-only test environment.

The only other notable deviation occurred on Meter 1, for only one 5-minute interval during the test period. Since each reading is the average power of the 5-minute period, it seems likely that one of the pieces of equipment was rebooted during this time period. This too reflects typical usage patterns- it is very common for Windows NT based servers to be rebooted on a weekly basis.

Notes on Computer Monitors and Power Usage

Because computer monitors are used by both thin clients and PCs we chose to meter them separately and include the results in the consolidated cost/savings figures. We based our estimates of power requirements for monitors on the average of measurements recorded over several minutes while the computer was active. Three CRT monitors proved to have power draws ranging from 84 to 109 watts, which corresponds with LBNL's assumed active power use of 85 watts for an average monitor.[9]

Based on the spot checks that we performed, power usage did not appear to perfectly correspond to the size of the monitor. This may be because the displays were configured at different resolutions. Our findings indicate that higher resolution settings increase power usage, as does color. White screens are the most power intensive, while black backgrounds draw the least amount of power. As an additional point of comparison we also tested a thin client device with an integrated 15" LCD display. See Table 1.

Table 1: Power usage for tested monitor types

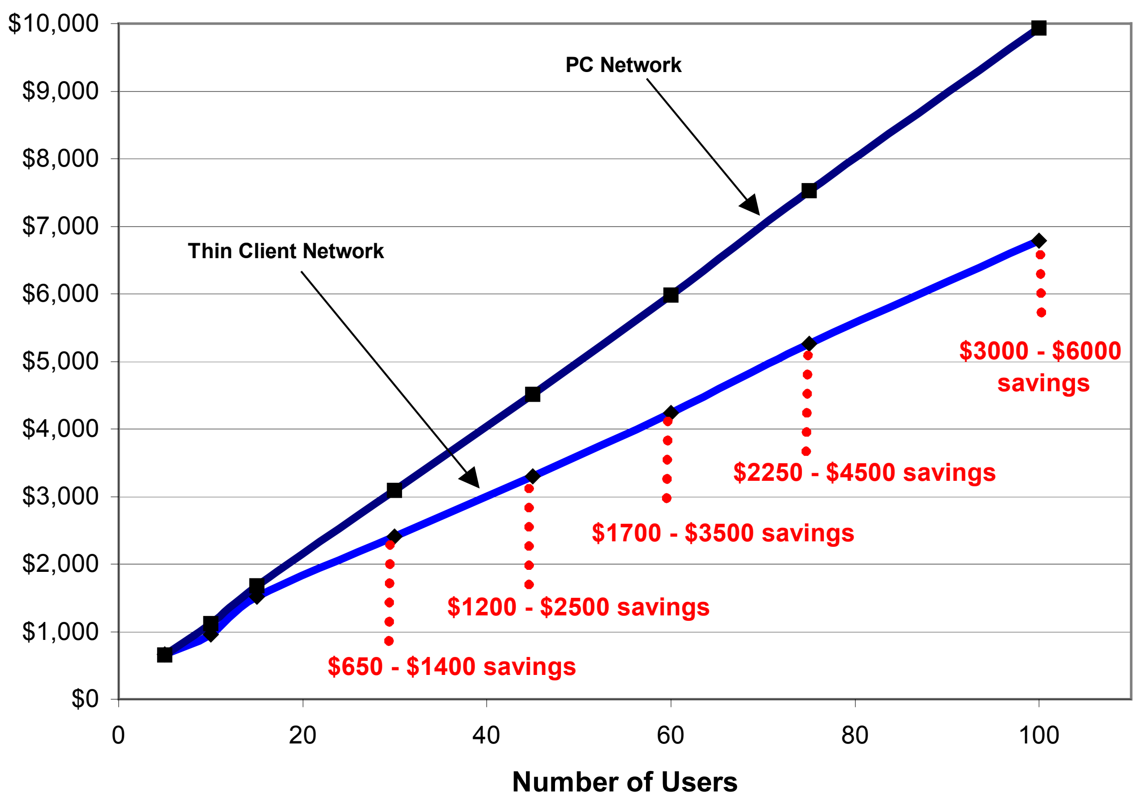
Monitor type and size	Power Usage (Watts)
15" CRT	84
19" CRT	109
21" CRT	106
15" LCD (w/ integrated thin client)	29
Resolution For 21" Monitor	**Power Usage (Watts)**
1600 x 1200	106
800 x 600	95
640 x 480	91

[9] Kawamoto et al., February 2001. We used this value of 85 for the average monitor wattage in our cost calculations

Summary of Cost Savings

Given the nature of the test environment, the methodology used, and, the data collected we were able to accurately model the total power usage costs for both PC and thin client networks of various sizes from 5 to 100 users. The annual kilowatt hour usage of each device was calculated.[10] Each network size was analyzed for the correct number of PC's or thin clients, monitors, file servers, hubs/switches, modems and terminal servers. The cost of powering each type of network is the sum of the annual kilowatt hours for all devices in that network, times the average cost per kilowatt hour. Since computers and related devices generate heat from the power consumed, there is an additional factor to consider- the cost of cooling. Although the amount of power required for cooling is site specific, it usually takes approximately 1 unit of electricity to move 2 units of heat.[11] This premium was also included in our calculations. The savings gained by replacing PC's with Thin Clients is found by subtracting the difference between the total network costs respectively. The network cost curve was calculated at ~$.10 per kWh which is at the low end of current energy rates. Savings are shown for both ~$.10 and ~$.20 per kWh to represent the fuller range of energy rates currently in effect nationwide. See Figure 4.

Figure 4. Annual Electricity Costs and Savings for 5-100 Users



To further assist the reader in establishing more specific potential costs saving based on their geographic location and network size we have included energy rates from several major cities in the continental U.S. and extended the calculations to include networks of 1000 and 2500 users. See Table 3.

[10] Assumes that desktop devices are powered on for 80 hours per week. See Nordman et al, January 1997.
[11] Takes into consideration the seasonal and geographic variations associated with heating as well as cooling. Based on assumptions in Koomey et al., December 9, 1999.

Table 3: Electricity Costs and Savings for various U.S. Cities

city	provider	season	$/kWh	# months seasonal rate	Annual Average $/kWh	Annual Savings for 30 Users	Annual Savings for 100 Users	Annual Savings for 1000 Users	Annual Savings for 2500 Users
Phoenix/ Scottsdale	Arizona Public Service	summer winter	$0.11 $0.10	5 7	$0.10	$683	$3,145	$31,450	$78,627
Chicago	Commonwealth Edison Co.	summer winter	$0.11 $0.09	3.5 8.5	$0.10	$683	$3,145	$31,450	$78,627
Boston	NStar	summer winter	$0.21 $0.14	8 4	$0.19	$1,298	$5,976	$59,760	$149,391
San Francisco	PGE	summer winter	$0.21 $0.13	6 6	$0.17	$1,161	$5,347	$53,470	$133,665
Pasadena	SCE	summer winter	$0.21 $0.15	5 7	$0.17	$1,161	$5,347	$53,470	$133,665
San Diego	SDG&E	summer winter	$0.14 $0.13	5 6	$0.14	$956	$4,403	$44,030	$110,077
Charlotte	Duke	summer winter	$0.09 $0.09	8 4	$0.09	$615	$2,831	$28,310	$70,764

General service for small commercial business rates as of July 27, 2001.
Does not include customer or demand charges, only energy charges. Total energy charges includes transmission, distribution, transition, decommissioning and public purpose funds when they vary with total kWh consumed.
Arizona: rates based on electricity consumption less than 2,500 kWh per month. If electricity consumption increases but demand does not, then rates would fall to approximately 7.3 cents/kWh. From http://www.aps.com/aps_services/business/rateplans/busrateplans_1.html.
Chicago: this includes "in lieu of demand" charges for customers < 10 kW, energy costs would be $0.04247 if > 10kW. Does not include decommissioning adjustment, franchise costs or state taxes as these numbers were not available without an address. These are bundled rates if you purchase from Commonwealth Edison, from http://www.ceco.com//comed/main.asp

Boston: G-1, small commercial without a demand meter, 6 month fixed rate from supplier, from http://www.ceco.com//comed/business/display.asp?id=623.
Pasedena: from personal communication with SCE's customer service for small businesses, GS-1 rates, July 27, 2001.
San Francisco: includes A-1 rates plus the recent energy surcharge. From www.pge.com.
San Diego: no demand charge, from http://www.sdge.com/business/ratesrules/index.html#.
Charlotte: from personal communication with Duke Energy's customer service for small businesses, July 27, 2001.

Conclusions and Recommendations

Thin Clients are far more power-efficient than PCs

Our results show that PC's use nearly 7 times the power when compared to thin clients- 69 watts versus 10 watts. Thin client devices not only use less power, they also generate less heat. When you add this additional factor of cooling the total power usage is equal to 103.5 watts for PCs versus 15 watts for thin clients. Some people use older PC's as a thin client display devices to extend the useful life of the hardware. While this may defer the up front cost of newer hardware, it brings with it the disadvantage of paying more for power to accomplish the same task. We recommend using thin client devices wherever possible.

Thin Client networks cost less to power than PC networks

To develop an accurate picture of the true cost savings that results from using thin clients, it was important to take into account all of the devices that comprise a network. This included the servers that host the applications which the thin client displays, and, the devices which are common to both types of networks. These factors were expected to diminish the overall savings resulting from the use of thin clients. Yet, even with these factors taken into account, we found that thin client networks cost from 30-60% less to power. For example, a small business with 100 users can save as much as $6,000 per year.

Power savings increase as the size of the network increases

The most obvious factor here is the increased number of low power devices found in larger networks. For each PC that is replaced by a thin client there will be an additional power savings. However, the number of terminal servers required to support thin clients does not increase in a linear pattern: twice as many clients does not mean twice as many terminal servers. As clusters of servers are built to support thin client sessions, greater economies of scale are quickly realized. Departmental servers, and servers in remote offices, becoming increasingly unnecessary. There is no need for remote servers to store files, forward email, or host databases, when all the applications and data are stored centrally. Our findings suggests savings of $59,760 for a 1000 users and $149,391 for 2500 users. However, we suspect that actual measurements of large scale networks could show even greater savings.

Power costs should be included as part of Total Cost of Ownership (TCO)

Historically, the reason for using thin clients to replace PCs has been the reduced Total Cost of Ownership (TCO) gained through centralized administration and reduced desktop maintenance costs. Additional benefits include improved security, reduced down-time, and, more productive remote access. The results of this study suggest that power savings should be considered another measurable component of reduced TCO, and, one more reason to choose thin clients over PCs when possible.

Organizations can become more aware of power usage

We recommend that organizations engage in projects to measure actual power usage to calculate the cost of powering their IT infrastructures. The best way to lower these costs is to become aware of current usage patterns. Once the precise factors behind power costs are well understand for a particular environment, the direct impact of cost savings options such as thin clients can be easily measured.

For more detailed studies of your power costs, contact Thin Client Computing at info@thinclient.net

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Sources of additional information

Thin Client Computing, Scottsdale, AZ (602) 432-8649 www.thinclient.net

Network Computing Devices Inc., Mountain View, CA (800) 800-9599 www.ncd.com

Brand Electronics, Whitefield, ME (207) 549-3401 www.brandelectronics.com.

Appendix A: **Detailed Specifications of tested equipment**

Thin Client Devices	Specifications	Power Usage (Watts)
NCD ThinSTAR 200	100 Mhz RISC 8MB RAM, 8MB Flash ROM	10
NCD ThinSTAR 450	Intel Pentium 266 32 RAM, 16 MB Flash ROM	13
Servers	**Specifications**	**Power Usage (Watts)**
Dell PowerEdge 2400 (Terminal Server)	Dual P3 533,512MB RAM PERC SCSI RAID, (2) 9GB Windows NT 4.0 Terminal Server Edition SP5	141
Dell PowerEdge 2400 (File Server)	Single P3 533, 256 MB, PERC RAID (3) 18GB Windows NT Server 4.0 SP6 Internal Tape Backup Drive	96
Dell PowerEdge 1400 (Lab test)	Single P3 800, 512MB, (2) 9GB SCSI, Windows 2000 Server with Terminal Services	72
Various PC Configurations	**Specifications**	**Power Usage (Watts)**
Desktop PC #1 (AmeriWest)	Pentium Pro 200 64 MB RAM 2GB IDE	69
Desktop PC #2 (Lab test)	Celeron 300MHz 128 MB RAM 4 GB IDE hard drive Wireless Network Card	41
Desktop PC #3 (Lab test)	Pentium 1 GHz 128 MB RAM	83
Desktop PC #4 (Lab test)	Pentium 1.5 GHz 384 MB RAM 30 GB IDE Drive	85
Other Devices	**Specifications**	**Power Usage (Watts)**
3Com SuperStack model 3C16464A	24 port 10/100 Ethernet Switch	39
Pure Data Hub	8 port 10Base-T Hub	8
Multi Tech Multi Modem Model MT5600ZDX	56k Data Fax Modem	6

Appendix B. **Understanding Power Levels**

While our study focused mainly on active power, computer equipment may have several power modes, as stated in Koomey, J.G.; Cramer M.; Piette M.A., and Eto J.H, “Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties,” Lawrence Berkeley National Laboratory, LBNL Publication 37383, December 1995:

Active mode: This is the power of the device when in operation. For PC CPUs, active power can vary somewhat when different peripherals are in operation. Monitor power can also vary depending on the image being shown.

Standby mode: This mode represents an intermediate state which attempts to conserve power with instant recovery. The system is idle. If the device has no standby mode, this power level is equivalent to that of the active mode.

Suspend/Power Saving mode: This mode has the lowest power level (without being off) but has a longer recovery time than for standby.

Off mode: The power that is drawn when the device is switched off.

Note that our study did not attempt to measure Power Saving or Off modes, although we intend to cover these modes in future work. For more information on how power saving modes can affect electricity use, see Nordman, B; Piette M.A.; Kinney K. and Webber C. User Guide to Power Management in PCs and Monitors. Lawrence Berkeley National Laboratory, LBNL Publication 39466. January 1997.

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