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Section Four

IT and Facilities Initiatives for Improved Data Centre Energy Efficiency

Data centre energy use has become an important part of the economics of information technology (IT) because of the substantial costs of electricity and energy-related capital expenses for data centre facilities. This paper describes how data centre operators can reduce these costs via ten initiatives that improve data centre energy efficiency. Half of these initiatives are IT-related, while the other half relate to the data centre facility itself. Data centre operators are encouraged to pursue these initiatives, but with appropriate caution to avoid adversely impacting IT reliability or availability.

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1 BACKGROUND – WHY DATA CENTRE ENERGY CONSUMPTION AND ENERGY EFFICIENCY ARE IMPORTANT

Globally, data centre energy use is rising rapidly as the information-driven economy continues to expand. In the US alone, around 1 million new servers are installed each year (net of retirements), and two 500 MW power plants must be constructed each year to power the data centre facilities in which these new servers reside.[1,2] The growth in data centre electricity use poses challenges for global greenhouse gas reduction goals and can strain power grids in certain transmission-constrained regions.

In addition, data centre energy use is changing-even threatening-the economics of information technology (IT). The money required to pay the electricity bills and, even more importantly, the capital expenditure (CapEx) investment to construct the data centre facilities that house IT equipment create a "drag effect" on the economics of IT investment. Fifteen years ago, when energy use was relatively insignificant, IT performance (such as computations per second) per US dollar of server cost rose rapidly, as technology improved and hardware prices

[1] The EPA 2007 Report to Congress, p.7-8, estimates than an additional 5 GW of electricity (~10 power plants) will need to be added to support data centre load growth between 2006 and 2011. This works out to two 500 MW power plants per year.

[2] See EPA 2007, Report to Congress, p.28-39.

fell. White IT hardware is still getting faster and cheaper, the expense of each server is now burdened with significant additional costs for electricity and data centre facilities. For example, a single US$2,500 server that draws 300 W of power now requires spending around US$400 per year on electricity and requires US$3,600-US$7,500 of capital investment to build the data centre facility that houses it.[3,4] In many IT-intensive enterprises, facility costs are now 8% of the total IT budget, and that share is rising because facility costs are growing 3-4x faster than the IT budget overall.[5] If a company's IT budget doesn't increase, then facilities expenses may eventually begin to crowd out new application development. If the IT budget does increase, then the extra overhead cuts into corporate profit margins. Neither of these scenarios is good for a business.

2 POTENTIAL FOR IMPROVED EFFICIENCY

Luckily, there are large opportunities for data centres to improve their energy efficiency. Data centre operators can reduce the energy use of both their IT equipment and the data centre facility itself. These efficiency measures can both reduce electricity bills (operating expenditures, or OpEx) and help operators defer or avoid building new data centre facilities or expansions (CapEx). For a large organisation, these savings can amount to tens of millions of US dollars over a few years. The ten efficiency initiatives are summarised in Table 1 below.

Summary of IT and Facility Efficiency Initiatives	
IT Initiatives	**Facility Initiatives**
• Kill "comatose" servers and storage • Reduce or eliminate uneconomic demand for new applications • Implement virtualisation • Select energy efficient IT hardware • Enable power save features	• Correctly set temperature and humidity control points • Match the number of cooling units to the actual heat load • Make sure all cooling units can deliver their rated capacity • Deliver cold air where it is needed • Eliminate humidification and dehumidification

Table 1: Summary of IT and Facility Efficiency Initiatives

3 (300 W) / 10^3 x (2.0 PUE) x (8,760 hours) x (0.08 US$/kWh) = US$420. PUE stands for Power Usage Effectiveness and is an efficiency ratio defined as (total power coming into the data centre) / (power delivered to the IT equipment). See Belady 2007 for more information.

4 Data centre facility construction costs are typically US$12,000-25,000 per kW of IT equipment supported. This money pays for the uninterruptible power supply equipment, generators, cooling equipment, physical space, and other things required to keep IT equipment running reliably. See Turner 2008, p.3.

5 See McKinsey & Company 2008, slides 3 and 5.

3 FIVE IT EFFICIENCY OPPORTUNITIES

There are at least five things IT can do, starting today, to significantly reduce data centre energy consumption. These initiatives are largely self-funding.

3.1 Kill "Comatose" Servers and Storage

First, IT organisations can remove "comatose" IT equipment. Comatose devices are plugged in, turned on, and consuming power in the data centre, but are not doing any useful IT work. For example, comatose servers may be sitting idle or running applications that are obsolete and no longer used. Comatose equipment can account for as much as 15-30% of the total IT equipment in many data centres, unless the data centre operators have rigorous programmes for removing obsolete servers at the end of their lifecycle. This dead equipment should be decommissioned and removed.

Why do more data centres not remove comatose equipment? One reason is that downsizing efforts to reduce labour costs can result in poor maintenance and control of asset records. Some organisations do not budget staff time to remove or re-purpose obsolete servers because they assume that servers are inexpensive, often forgetting the electricity and facility costs associated with leaving them running. In a limited survey conducted by the Green Grid, only two of thirteen companies had a rigorous de-commissioning policy.[6] Parents who are home computer users often buy a new PC but keep the old one plugged in, just in case it has necessary files or might later be passed on to a child. The same thing can happen in data centres. There will always be a push to install new equipment, but removing old equipment may be put off until "later" as new, more urgent tasks arise. Eventually, the details of which boxes are obsolete are forgotten, and it becomes a major research project to identify what equipment is safe to remove. Unless there is a strong advocate for killing comatose IT equipment (servers and storage), the inventory of dead equipment continues to increase.

Most organisations do not realise the volume of comatose equipment in their facilities until a data centre must be closed and processing migrated to a new location. This is the only time application owners must be identified for all equipment. Consistently, organisations find that they cannot identify owners for 15-30% of the installed server base. If data centre operators can identify this comatose equipment and remove it, they do not have to transport it to the new facility. Even better, turning off this equipment can free up valuable power and cooling capacity in the data centre, delaying the need to move to a new facility in the first place.

3.2 Reduce or Eliminate Uneconomic Demand for New Applications

The second thing that IT departments in data centres can do to improve energy efficiency is to throttle uneconomic demand for new applications. Obviously, a business should deploy a new application only if the benefits exceed the costs. However, many IT organisations fail to include the cost of electricity and facilities when they do cost-benefit analysis for new applications. Applications that look profitable may actually be money-losers if these extra costs are counted correctly.

[6] The Green Grid is a global consortium of IT companies and professionals seeking to improve energy efficiency in data centres and business computing environments worldwide. See http://www.thegreengrid.org

For example, a hypothetical server that costs US$2,500 to buy and generates US$2,700 worth of business value over its life may look profitable if the server acquisition cost is all the IT department considers. However, the server clearly loses money when one adds in the US$400 per year electricity bill and the amortised US$240-500 per year cost of the data centre facility to support the server.[7] In addition, software, network, and other IT costs must be added to produce a true Total Cost of Ownership. In a real-world example, one organisation's IT department made a decision to spend US$22 million on blade servers, but the department failed to consider the associated US$54 million in facility CapEx and the US$30 million in facility OpEx over three years.[8] Failure to include facilities costs when considering the cost of ownership for new IT equipment can result in uneconomic IT decisions.

3.3 Implement Virtualisation

Virtualisation can also help data centre organisations improve their energy efficiency. Many servers today are run in a one-application-per-server configuration. Historically, this was done for reliability reasons: if the operating system failed, only one application was affected. Although times have changed, the habit of running only a single application on each server persists, resulting in very low server utilisation rates-often only 5-9%. In most other business areas, a single-digit utilisation rate for an expensive asset would invite senior management consternation.

Virtualisation allows multiple applications to run reliably on a single server, greatly increasing server utilisation. One real-world data centre was able to consolidate as many as 30 separate servers onto a single more robust server with increased network storage. Even accepting increased power consumption for the remaining servers and for additional network storage, the energy savings are substantial. In one European example, 3,100 servers were reduced to 150, allowing a US$2.1 million annual reduction in electricity use and the recovery of US$14 million in facility capital. The reclaimed power and cooling capacity was so great that the company no longer needed to build a new data centre. These benefits were in addition to the IT benefits of a reduced quantity of hardware to purchase, license, and maintain, a savings in network ports and cards, a reduction in systems administrator labour, easier disaster recovery implementation, and increased speed and responsiveness to changes in user capacity demand. When the virtualisation project was first justified, the focus was on the IT benefits-no one even realised the facility benefit of avoiding construction of a new data centre.[9]

With these substantial performance and economic benefits, why is virtualisation not more widespread? Millions of virtualisation licenses are being sold, but there is increasing evidence that the licenses are not being implemented.

Virtualisation significantly increases complexity. The example above in which 3,000 servers were eliminated took three years to implement and required significant, scarce, and highly skilled technical resources. Doing virtualisation correctly requires time and resources to properly architect applications and storage, while doing it incorrectly can seriously reduce IT availability. Given this risk and lack of time, many IT professionals cannot give virtualisation the effort it requires to do well, so they end up doing nothing.

[7] As mentioned earlier, data centre construction costs are typically US$12,000-25,000 per kW of IT equipment supported, so a 300 W server has associated with it US$3,600-7,500. Amortising this cost over a 15-year facility life (and assuming a discount rate of zero) yields a cost of US$240-500 per year.

[8] This example comes from proprietary data from a company in the Uptime Institute's Site Uptime Network.

[9] This example also comes from proprietary data from a company in the Uptime Institute's Site Uptime Network.

3.4 Select Energy Efficient IT Hardware

The fourth way that data centre operators can save energy is to buy energy efficient IT hardware. This may seem like an obvious strategy, but it is often neglected. Most IT hardware manufacturers offer significantly more energy efficient products, but they privately complain that the energy efficient products go unsold because data centre operators balk at the higher price tag. In most cases, the price premium is well worth it, because a more efficient server that reduces power use by 50 Watts generates a savings of US$210 in electricity bills over three years and saves a minimum of US$600 in facility CapEx.[10,11] However, IT procurement officers typically look only at performance and first cost when selecting equipment. In this way, IT energy efficiency is a management and cost-accounting problem, not a technical limitation. Bringing total cost of ownership into procurement decisions would require measuring and incentivising watt reductions much like first-cost reductions.

Data centre operators who buy large numbers of servers can hold considerable sway with manufacturers. One data centre company that buys thousands of servers annually recently held a competition in which IT equipment suppliers had to compete to see who could offer IT equipment with the greatest performance per watt. Although the company historically had a preferred supplier, another vendor stepped in an announced that their product provided the same performance at the same price, but with a 25% lower power consumption. The company promptly switched suppliers. If more buyers of IT equipment focused on performance per watt, the premium for energy efficiency would come down as suppliers innovated and competed on energy savings as a feature, and more efficient hardware would become cheaper and more widespread.

However, data centre operators looking for efficient IT equipment should remember that the power supplies in most hardware are very inefficient at low utilisation levels. Hardware vendors may advertise hardware that is "efficient" at very high utilisation (90% or higher), even though the efficiency is very poor at the low utilisation levels (5-9%) where most users actually run their hardware. All else equal, it is usually best to buy the server with the highest efficiency at low loads.

One new source of information likely to be useful to IT equipment buyers is the just-released United States Environmental Protection Agency (US EPA) ENERGY STAR standard for servers. This standard makes server energy consumption data available in a consistent format.[12]

3.5 Enable Power Save Features

Finally, data centre operators can improve efficiency by enabling the power save features in their servers and other IT equipment. Just like laptops, servers and other IT hardware come with features that reduce power consumption when there is little or no computing demand. However, most data centre operators disable power save features in their equipment because of the complexity of using the features correctly and the real or perceived

[10] Electricity savings: (50 W) / 10^3 x (2.0 PUE) x (8,760 hours/yr) x (0.08 US$/kWh) x (3 years) = US$210

[11] Again, facility savings based on facility capital costs of US$12,000-25,000 per IT kW.

[12] For more information about the US EPA's ENERGY STAR standard for servers, see Brill's Forbes article "Shaving Millions Off Data Centre Costs".

risks that IT hardware in power save mode will fail to reactivate when it's needed. Unless figuring out how power save features work is made a priority, using them will take a back seat to other tasks. As a result, a new specialty consulting field is developing around understanding how the AMD and Intel power-saving features work. This new emerging expertise may be an answer for those IT shops too busy to figure out these particular issues. Also, for data centres still wary of using power save features on critical production servers, there may at least be opportunities to enable power save on less-critical development, test, and Quality Assurance boxes.

4 FACILITY EFFICIENCY OPPORTUNITIES

In addition to improvements on the IT side, data centre operators can also improve energy efficiency by making changes to the way their facilities are run. There are five facilities initiatives that can improve reliability and reduce facilities overhead. Because they simultaneously address both reliability and energy consumption, the inherent risk associated with making facility changes is often justified.

Each of the five initiatives is associated with cooling, because the efficiency of mechanical systems is fundamentally different than that of electrical systems. Once electrical systems are installed, their efficiency cannot be greatly altered, except by changes in the actual IT load that move the system up or down on its efficiency curve. Shutting down the data centre to replace installed electrical equipment with more efficient components or systems is generally too expensive and risky to be worthwhile.

Cooling systems, on the other hand, are more flexible. Computer room cooling efficiency can be dramatically improved by adjustment rather than replacement. While some risk is involved, the magnitude of this risk can be controlled or limited to certain areas. Also, because of the inherent non-linearity of temperature and relative humidity, cooling stability is actually greatly improved by increasing energy efficiency. Inefficiencies in a cooling system may not be obvious, and may result in "hot spots" where some IT equipment does not get adequate cooling. Surprisingly, adding more cooling to compensate for hot spots often worsens the problem by making the cooling system more unstable, as well as incurring costs and construction risk. Conversely, improving efficiency can reduce hot spots and improve cooling reliability.

The following five facility initiatives will increase cooling reliability and stability, reduce operating expenses, and cut capital costs by tuning up the computer room cooling investment.

4.1 Correctly Set Temperature and Humidity Control Points

The easiest efficiency initiative that data centre operators can undertake is to correctly set the temperature and relative humidity control points on the cooling units. The only environmental conditions in a computer room that count are at the air intake of the computer hardware. A good equipment intake temperature is 22˚C (72˚F).[13] At the exhaust side of the computer fans and at the return air intake of the cooling units, a hotter air temperature is expected and desirable.

[13] For reference, this is close to the middle of the temperature range for data centre equipment recommended in 2008 by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), Technical Committee 9.9. See ASHRAE 2008.

Unfortunately, many sites make the mistake of setting the cooling unit controls to keep the return air at 22˚C (72˚F) or colder. In order to maintain this condition, the cooling units must often deliver air that's colder than 15˚C (59˚F), so it is still cool after it has picked up heat from the IT hardware and made its way back to the return air intake. Delivering such cold air wastes energy and can reduce reliability by causing condensation inside the IT hardware. A common myth is that colder temperatures provide thermal ride-through in the event of a power failure, but this myth is unsupported by science. As heat densities have risen, heavily loaded computer rooms will now overheat within minutes and require uninterruptible cooling, not extremely cold temperatures. The air delivered to IT hardware should be cold, but coldest is not best.

Virtually all cooling units control temperature and relative humidity based on their return air, so the user must compensate for the difference between supply and return. The temperature of the air leaving the cooling unit should be a few degrees colder than the desired hardware air intake temperature. To get 22˚C (72˚F) air at the IT hardware intake, the air leaving the cooling unit must be around 21˚C (70˚F). This in turn means that the cooling unit should be programmed to maintain a temperature of ~28˚C (82˚F) at the cooling unit's return air intake. In other words, the cooling unit set point should be the cold aisle temperature plus the difference between the cold and hot aisles.[14]

These temperatures are illustrative only; different data centres will have different thermal requirements. However, all data centres can benefit from the practice of focusing on air temperatures at the server intake and not setting cooling units to demand excessively cold return air temperatures. Data centre operators are encouraged to record the set points of their cooling units and examine them. The further below the desired set point the actual temperatures are, the greater the opportunity for significant energy savings. However, operators should be cautious not to change set points without first doing a computer room cooling tune-up, as outlined in the next four initiatives.

4.2 Match the Number of Cooling Units to the Actual Heat Load

The second way to improve facility energy efficiency is to make sure the number of cooling units deployed is appropriately matched to the actual heat load in the data centre. Uptime Institute's research has determined that, on average, the typical computer room has three times more cooling running than is required by the actual heat load. Moreover, the computer rooms with the most excess cooling had the highest incidence of hot spots. Reducing the amount of cooling (not including redundant units) to match the heat load actually increases cooling stability and quality while saving energy.

As part of this initiative, data centre operators should also change the controls on the cooling unit so the blower turns off if cooling fails. Without this change, a failed cooling unit will continue to pump increasingly hot air into the physical space it controls. The blower must be turned off before adjacent redundant units can provide cooling. This is a basic control error in virtually every computer room.

[14] For users unfamiliar with the terms, the "aisles" here refer to the popular "hot aisle / cold aisle" configuration of server racks in a computer room. Alternate rows of racks are designated as cold aisles (being fed cold supply air) and hot aisles (where hot air from IT equipment is exhausted). The front of each row of IT equipment racks, where the air intake is located, faces toward a cold aisle.

Again, it is important to do a complete computer room tune-up before turning off any cooling units, to ensure that the data centre will not overheat.

4.3 Make Sure All Cooling Units Can Deliver Their Rated Capacity

Next, data centre operators can validate that all cooling units are capable of delivering their rated capacity. Often a cooling unit cannot deliver its rated cooling capacity because of poor installation or inadequate maintenance. Common examples include incorrect piping where supply and return have been reversed, filters that are plugged or incorrectly selected, throttling valves that are stuck, compressors that are undercharged with refrigerant, belts that are slipping, and pulley sheave sizes that were incorrectly selected.[15] It is often helpful if a third-party independent of the current contractor performs this investigation.

4.4 Deliver Cold Air Where it is Needed

The fourth way to improve facility energy efficiency is to make sure the data centre's cooling system delivers cold air where it is most needed. Computer room cooling typically allows uncontrolled mixing of hot and cold air. While this process can work, it is inefficient and requires the cooling units to deliver very cold air to compensate. For computer rooms with raised floors, more than 60% of the available cold air is typically wasted. There are often too many perforated floor tiles installed, perforated tiles installed in the wrong places, and unsealed cable cutouts that allow cold air to escape into the hot aisle. For maximum cooling efficiency, the hot aisle should be uncomfortably hot. A simple measurement of the hot aisle and cold aisles should reveal a temperature difference of at least 5.6˚C (10˚F). A smaller difference indicates significant air mixing, which reduces cooling capacity and efficiency. This mixing can be corrected by sealing cable cutouts and removing perforated tiles from the hot aisle. Once this is done, under-floor static pressure should go up dramatically. If it does not, the culprit is often cold air leakage through the floor or walls to surrounding spaces.

Fixing these air flow problems keeps the IT equipment cool while saving energy by eliminating wasted cooling.

4.5 Eliminate Humidification and Dehumidification

The last thing data centre operators can do to improve facility efficiency is to eliminate humidification and dehumidification.

One common problem is adjacent cooling units "fighting" each other over humidity levels. As a simple diagnostic, data centre operators can do an inventory of the de-humidification or humidification indicator lights on every cooling unit and record the physical location of each unit. This survey takes less than 30 minutes in a typical computer room, and operators often find that one cooling unit is humidifying while the unit next to it is simultaneously de-humidifying. Up to 30% of the units can be in this state, which wastes enormous amounts

[15] Some problems, such as incorrect piping, can lurk unnoticed in a facility for 10-20 years. Operators may simply notice that the cooling system mysteriously seems very inefficient.

of energy and creates significant water leakage risk.[16] Proper engineering plus calibration of cooling unit sensors can totally eliminate this problem.

Since computer rooms are machine rooms with few people (or no people), it is also often possible to severely restrict outside air coming into the computer room. If this is done, there should be little need for either de-humidification or humidification. Restricting outside air eliminates the possibility of saving energy via “free cooling” from cold outside air. However, if the energy savings from reduced humidity control are greater than the potential free cooling savings, or if reliability objectives prevent the use of free cooling anyway, then restricting outside air flow can be worthwhile.

5 CONCLUSION – PURSUE ENERGY SAVINGS AGGRESSIVELY, BUT CAREFULLY

These IT and facility initiatives are steps almost all data centres can implement to improve their energy efficiency. Improved efficiency can allow an IT-intensive organisation to achieve significant savings in electricity OpEx and facility CapEx. For large organisations, these savings can total tens of millions of US dollars over a few years. In addition, improved energy efficiency contributes to global greenhouse gas reduction goals and helps reduce strain on regional power grids where transmission constraints exist. The technology to implement these IT and facility efficiency initiatives exists today.

However, there are challenges to capturing the energy savings opportunities. In many organisations, the IT department is unaware of the energy-related costs that their decisions can impose on their colleagues responsible for data centre facilities. Even when they are aware, IT department staff often have no incentive to improve efficiency. These are management problems, not technology problems. Another barrier is the technical challenge of properly using virtualisation and hardware power save features without reducing IT availability; capturing these savings requires the appropriate expertise.

Challenges also exist on the facility-side. Changing a data centre’s cooling system is not something that should be done without serious engineering oversight. Ability to validate actual cooling unit performance is a rare skill, and many local mechanical contractors do not have the training to do this work with the necessary precision. The frequency of air turnover in a computer room is once a minute; mistakes can quickly become very serious, even catastrophic.

There are large and lucrative opportunities for improved efficiency, but the cost of one data centre failure caused by an ill-advised IT change or cooling system adjustment can wipe out a decade or more of energy savings. So, IT and facilities managers are cautioned to pursue efficiency aggressively, but carefully.

[16] Since this water is inside pipes, the magnitude of the flows is invisible without special measurement. If this water were allowed to accumulate in the computer room over the course of a year, it would often fill the computer room to the height of about eight feet.

6 AUTHORS' NOTE

The content of this article was derived primarily from three articles by Ken Brill published by Forbes magazine on Forbes.com, as well as from the Uptime Institute publication Three Imperatives for Making Data Centre Efficiency a C-suite Priority. See references section for full citations.

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