



FUNDAMENTALS OF DATA CENTER POWER AND COOLING EFFICIENCY ZONES

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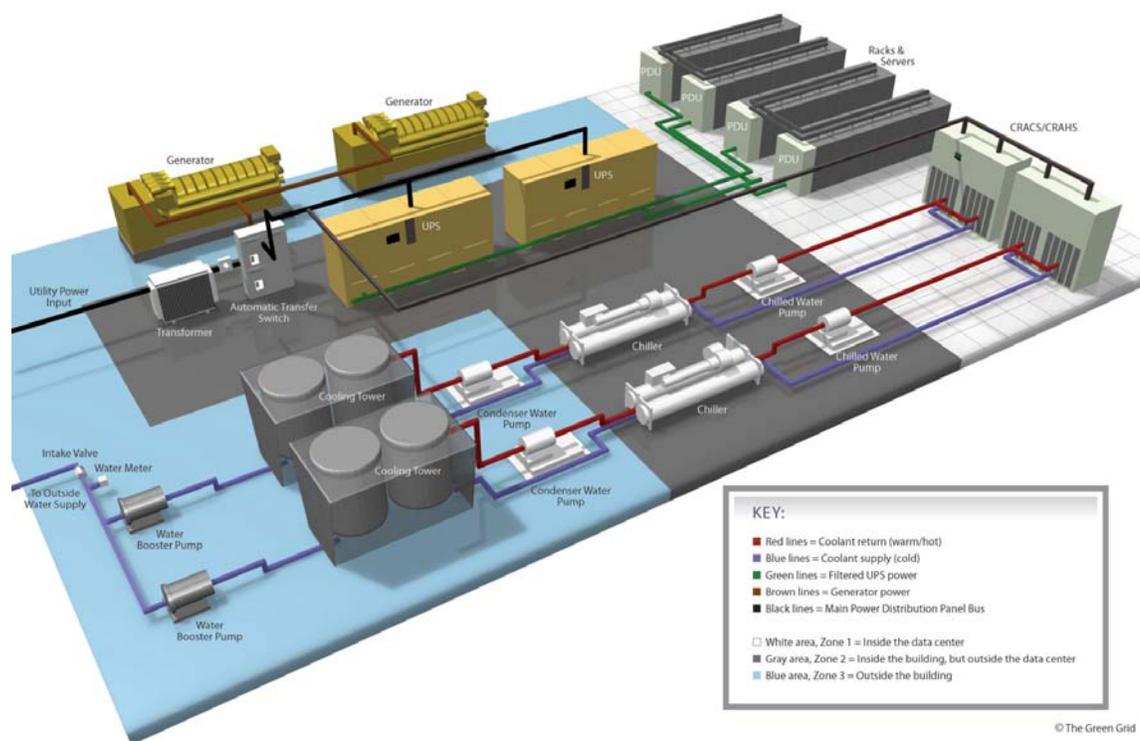
EXECUTIVE SUMMARY

Data center efficiency is impacted by physical infrastructure equipment residing both inside and outside of the physical data center. This paper provides a comprehensive overview of where the power and cooling efficiency losses are likely to occur, and offers suggestions regarding how to correct the inefficiencies.

INTRODUCTION

To understand how much energy a data center is consuming and to determine what can be done to reduce energy consumption involves several important steps. First, the existing data center energy consumption rates must be measured so that a baseline can be calculated. A standard industry metric (such as PUE) must be utilized so that the initial baseline measurement is relevant and comparable to any future measurements. See Green Grid White Paper #6, “Green Grid Data Center Power Efficiency Metrics: PUE and DCiE” for more information on this topic.

Next, the best opportunities for reductions in energy consumption need to be identified. The physical infrastructure equipment within a traditional large data center is analyzed in this paper. A graphic is provided (see Appendix A) to help identify where the energy losses are occurring. Recommendations are made on how to reduce energy costs. In addition, this paper provides a list of standard terminology (see Appendix B) to describe the key physical infrastructure components involved in the analysis. Note that the reduction of energy consumption within IT equipment is NOT within the scope of this paper. For information regarding IT power savings, please download The Green Grid White Paper #7, “Five Ways to Reduce Data Center Server Power Consumption” and #19, “Using Virtualization to Improve Data Center Productivity” from The Green Grid Web site.



SEGMENTING INTO PHYSICAL INFRASTRUCTURE ZONES

In order to simplify the analysis process, we are dividing the entity we refer to as an enterprise data center into three major interdependent physical infrastructure zones (see illustration in Appendix A). All power and cooling physical infrastructure is located in at least one of these three zones.

The zones are categorized as follows:

ZONE 1: inside the building and inside the physical data center (e.g., power distribution units)

ZONE 2: inside the building but outside of the physical data center (e.g., transformers, pumps)

ZONE 3: outside of the building (e.g., cooling towers)



In some cases power and cooling system components can reside in multiple zones. A UPS, for example, may be found inside of Zone 1 or inside of Zone 2 or in both zones simultaneously. Generators, for example, can be found in both Zone 2 and Zone 3. Other components, such as computer room air conditioners (CRACS), will most often be found inside of Zone 1 (but sometimes may be found in Zone 2). In addition some components such as cooling towers, may be part of a data center snapshot or may be excluded because of the nature of the cooling technology being deployed. In this paper, a typical, traditional large data center will be utilized as an illustrative example (see Appendix A).

EFFICIENCY GAINS INSIDE OF THE DATA CENTER (ZONE 1)

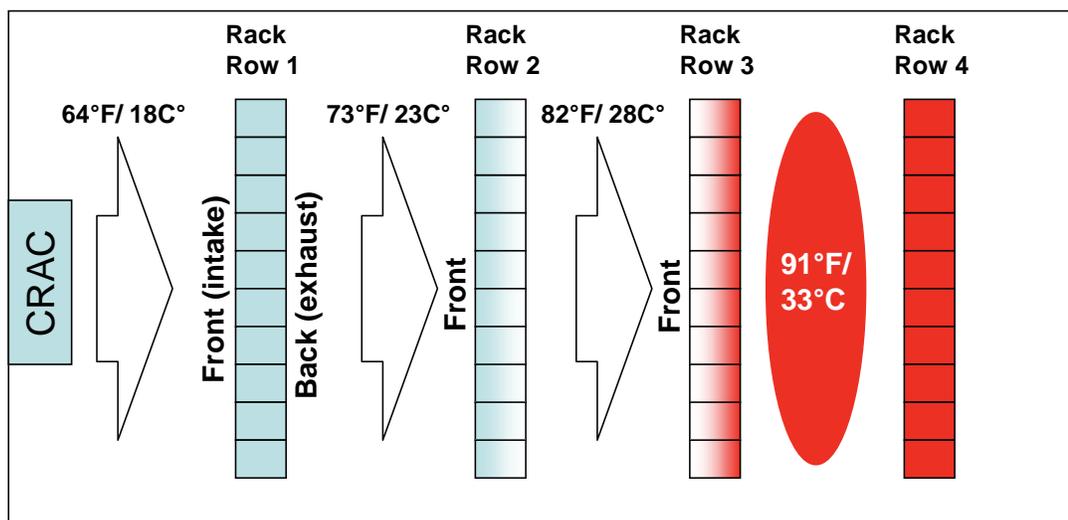
Following is list of data center (white space) characteristics that describe when, where, and why energy losses are likely to occur. Zone 1 is represented as the white area in the Appendix A illustration.

SERVER, RACK AND ROW ORIENTATION

Most modern IT equipment takes in cold air via the front and exhausts hot air out of the back. If servers, for example, are logically placed in racks with the front of the rack and the front of the server sharing the same orientation, then the user has achieved a consistent airflow direction throughout the row of racks. However, if several parallel rows of racks are set up in the same orientation, a significant efficiency problem arises. The hot exhaust air from the first row gets sucked into the “cool” air intakes of the second row of racks. With each progressive row, the air temperature gets hotter and hotter as hot air gets passed from one row of servers down to the next (see Figure 1).



FIGURE 1 – POOR RACK ORIENTATION CAN LEAD TO HOT SPOTS



To overcome this dilemma, the rows of racks should be oriented so that the fronts of the servers face each other. In addition, the backs of the rows of racks should also be facing each other. This orientation of rows creates what is known as the “hot aisle / cold aisle” approach to row layout. Such a layout, if properly organized, can greatly reduce energy losses and also prolong the life of the servers (see Figure 2).

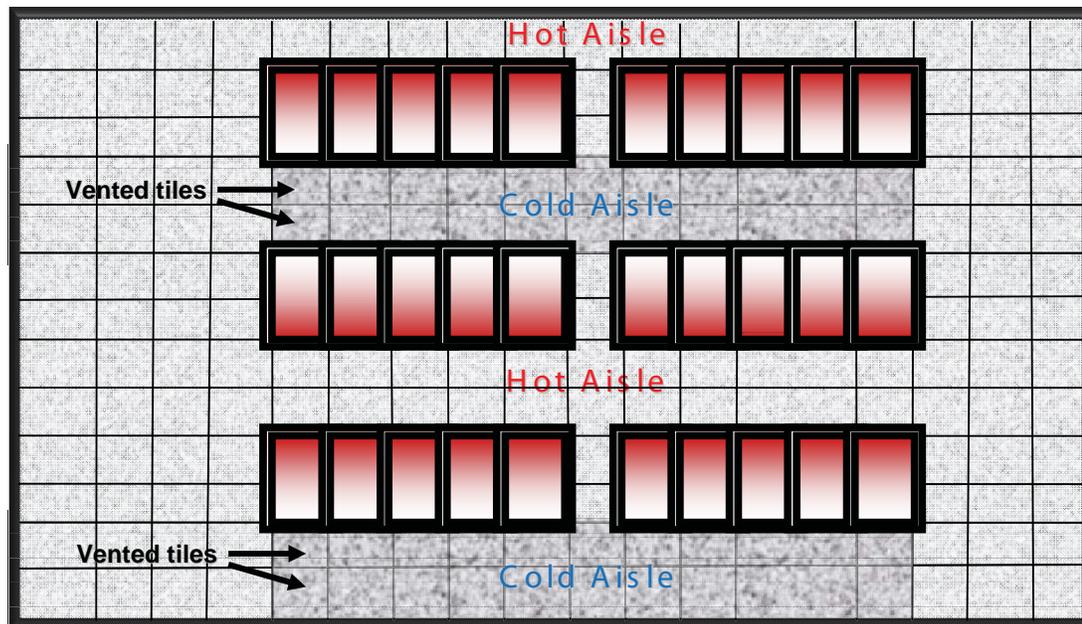


FIGURE 2 – EXAMPLE OF A BASIC HOT AISLE / COLD AISLE APPROACH

OPTIMIZED AIRFLOW WITHIN AISLES

In the data center, CRAC units may be placed outside of racks along the perimeter, mounted overhead, mounted under the raised floor or installed among the rows of IT racks. Various containment and segregation techniques can help minimize the mixing of hot and cold air. Simple devices such as blanking panels (which fill spaces between rack-mounted equipment), air dams (which seal the top, bottom, and sides of equipment), and brush grommets (which can fill open spaces around floor cable cut-outs, and barriers or cabinet chimneys to contain hot return air all can help contribute to efficiency (see Figure 3)). More advanced approaches, such as hot aisle or cold aisle containment, can also help minimize the mixing of hot and cold air. Such strategies allow airflows to be much more predictable, and, as a result, a greater portion of the CRAC capacity can be utilized. Therefore, higher power densities can be achieved.

Blanking panels



Cable cut out grommet



FIGURE 3 – SIMPLE TECHNIQUES FOR AIR FLOW EFFICIENCY IMPROVEMENT

Whenever the length of the airflow path from the CRAC to the server intakes is reduced, less fan power is required and this increases the efficiency of the cooling unit. This is a major benefit, when we consider that in many lightly loaded data centers the CRAC fan power losses alone exceed the total IT load power consumption which results in poor data center infrastructure efficiency (PUE). See the Green Grid White Paper, “Green Grid Metrics: Describing Data Center Power Efficiency” for more information on this topic.

POOR RAISED FLOOR AND RACK AIR FLOW

In many older data centers, the space beneath the raised floor has been designed to act as a plenum. However, in many cases, the space has become a dumping ground for excess cables and cords. This clutter interferes with the ability of the cooling system to force cool air under the floor, through the perforated floor tiles, and over to the server intakes. The cooling system has to work harder to achieve the same cooling result and more energy is consumed to achieve the same task.

A greener solution would be to remove cable blockage and to migrate to overhead cable distribution if possible. In addition, unused raised floor cutouts should be blocked to eliminate unwanted air leakage. Perforated tiles (with a design of about 25% open area) should be used to ensure uniform and predictable airflow distribution in lower density areas of the data center. For higher density racks, special consideration should be given to the perforated tile manufacturer’s suggested air flow rates at specified static pressure levels. In some cases where higher density racks are involved, the plenum may not be adequate to deliver the needed cubic feet per minute (CFM) through a 25% perforated tile.

Optimize air conditioner layout by placing CRACs/CRAHs across from hot aisles, make sure the first tile is at least 8 feet (2.4 meters) from CRAC/CRAH (see Figure 2) and run data cables under the hot aisle to minimize under floor airflow obstructions. In addition, air pressure sensors can be installed under the raised floor in order to slow down CRAC speeds when a constant high pressure is not needed.

DATA CENTER TEMPERATURE SET TOO LOW

Temperatures in the data center should be measured via the supply temperature at the server intake (as opposed to temperature readings at the return). Many data centers have traditionally set their temperatures as low as 55° F (13° C). However, data center equipment will safely operate at somewhat higher temperatures.

In fact, the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) specifies an allowable dry bulb temperature range of 59° to 90° F (15° to 32° C) and a new recommended range of 64.4° to 80.6° F (18° to 27° C) for environments that support critical enterprise server and storage environments (see Figure 4). Keep in mind that the humidification of the air must also be controlled. ASHRAE specifies a low-side dew point value of about 5.5° C (41.9° F) in the data center. Not only will less energy be consumed if data center temperatures are set somewhat higher, but employees working in the data center will also be more comfortable.





ASHRAE Guide	Upper Limit	Lower Limit
Temperature	27C (80.6F)	18C (64.4F)
Moisture	60% RH & 15C (59F) Dew Point	5.5C (42F) Dew Point

FIGURE 4 -- ASHRAE SPECIFICATIONS

OVERALL EQUIPMENT LAYOUT

Most users are surprised to learn that the electrical power consumption of a data center is greatly affected by the equipment layout. This is because the layout has a large impact on the effectiveness of the cooling distribution system. This is especially true for traditional perimeter cooling techniques. For a given IT load, the equipment layout can reduce the electrical power consumption of the data center significantly by affecting the efficiency of the air conditioning system.

- The layout affects the return temperature to the CRAC units, with a poor layout yielding a lower return air temperature. A lower return temperature reduces the efficiency of the CRAC units.
- The layout affects the required air delivery temperature of the CRAC units, with a poor layout requiring a colder supply for the same IT load. A lower CRAC supply temperature reduces the efficiency of the CRAC units and causes them to dehumidify the air, which in turn increases the need for energy-consuming humidification.
- The layout affects the amount of CRAC airflow that must be used in “mixing” the data center air to equalize the temperature throughout the room. A poor layout requires additional mixing fan power, which decreases efficiency and may require additional CRAC units, which draw even more electrical power.

A conservative estimate is that billions of kilowatt hours of electricity have been wasted due to poor floor plans in data centers. This loss is almost completely avoidable. For more information on data center cooling, please refer to Green Grid White Paper #10, “Seven Strategies to Improve Data Center Cooling Efficiency”.

OUT OF RACK EQUIPMENT

Out of rack equipment such as large tape libraries or mainframe computers can cause air flow inconsistencies if not properly positioned. All data center equipment capable of being mounted in racks should be installed in the racks. Equipment that does not fit into any standard rack form factor should all be placed in the same area of the data center floor in order to avoid disturbances to optimal rack airflow (see Figure 5). For optimal cooling, power densities of this equipment need to be accounted for.

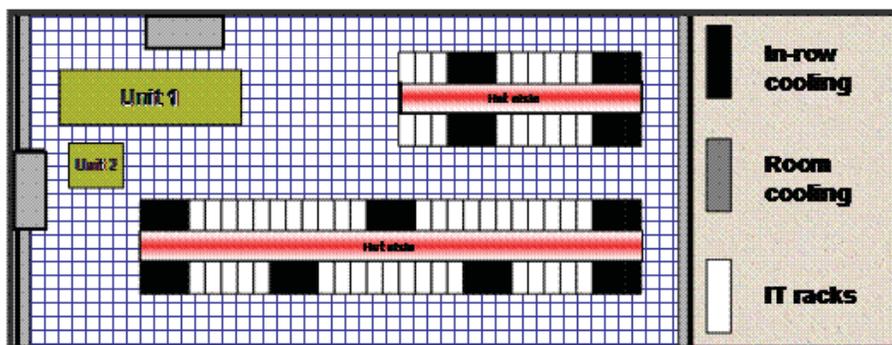


FIGURE 5 – OUT-OF-RACK EQUIPMENT CAN IMPACT AIRFLOW

RACK MOUNT PDUS

Many traditional data centers are unable to centrally monitor the flow of power to the rack and therefore to the IT equipment within each rack. They utilize “rack power strips” that cannot relay any power information. These should be replaced with intelligent rack-mount power distribution units (rPDUs). The intelligent rPDUs can provide real-time remote load monitoring of connected equipment, individual outlet power control for remote power recycling, and management of power-up or power-down sequencing of equipment. The metering of power consumption at the node level is important because it is difficult to manage what can't be measured. Metered and switched rPDUs can help to maximize energy efficiency, especially in a virtualized environment when workloads shifting from location to location. IT and Data Center Managers can also receive alarms to warn of potential power and cooling overloads.

IMPROPER HUMIDIFIER SETTINGS

Setting humidity higher than what is required by IT equipment lowers the heat removal capability of the CRAC unit and wastes electrical energy. This practice can waste thousands of gallons of water per year in a typical data center. Furthermore, steam canister and infrared humidifiers are a significant source of heat that must also be removed by the CRAC unit and therefore further detracts from its capacity. This situation is made even worse when significant hot and cold air mixing occurs in the data center because the lower temperature air returning to the CRAC unit loses more moisture in the cooling process than warmer, unmixed air would. Therefore it is essential not to operate a data center at humidity levels higher than the minimum recommended level.

Operating a data center at a minimum dewpoint of 5.5° C / 42° F (as specified by ASHRAE, which no longer bases the measurement on relative humidity) can save significant amounts of water and energy. Operation of the system within lower limits of the relative humidity design parameters should be considered for efficiency and cost savings. A slight change in set point toward the lower end of the recommended range can have a dramatic effect on the heat removal capacity and reduction in humidifier run time.

CRAC UNITS DEMAND FIGHTING

An additional problem can occur in data centers with multiple CRAC units equipped with humidifiers. It is extremely common in such cases for two CRAC units to be fighting each other to control humidity. This can occur if the return air to the two CRAC units is at slightly different temperatures, or if the calibrations of the two humidity sensors disagree, or if the CRAC units are set to different humidity settings. One CRAC unit will be dehumidifying the air while another is humidifying the air. This mode of operation is extremely wasteful,

yet is not readily apparent to the data center operators.

The problem of demand fighting can be corrected by either A) central humidity control, B) coordinated humidity control among the CRAC units, C) turning off one or more humidifiers in the CRACS, or D) by using dead band settings. Each of these techniques has advantages, which will not be discussed in detail in this paper. The best way to fix the problem is to verify that the cooling systems are set to the same settings and are properly calibrated. In addition, the dead band humidity setting should be set to +/-5%.



DYNAMIC HOT SPOTS

Higher server densities accelerate the appearance of hot spots in the data center. Again, it is recommended that ASHRAE data center temperature guidelines are followed so that a "hot spot" can be accurately defined. Workload irregularities, consolidation, virtualization, and the removal and addition of IT equipment add complexity to the issue by constantly shifting loads from one server to another. Therefore cooling in the data center needs to be able to handle the prospect of dynamic hot spots.

As room based cooling begins to give way to row-based and rack-based cooling in high density data centers (or high density data center pods) the need to bring the cooling as close as possible to the heat source becomes imperative. Row and rack-based cooling has the advantage of allowing the heat control to be localized and targeted. The fact that the cool air has a much shorter path of distribution helps to reduce overall energy consumption.

SOLAR LOADING

Outside temperature will have an impact on temperature control within the data center. Warmer locations and warmer seasons will create extra heat that needs to be removed from the data center. Numerous techniques can be deployed in order to minimize the effect of solar heat (one example is to paint or construct the roof in such a manner that it is white in color instead of black, since a dark color absorbs more heat). A LEED accredited architect with training in the area of day lighting techniques can assist data center owners minimize the impact of solar insulation within the data center space.

INEFFICIENT FAN MOTORS

Many electric motor-driven devices operate at full speed even when the loads they are supporting require less capacity. To match the output of the fan to the load, a speed control mechanism needs to be put into place in order to maximize efficiency. Devices such as variable frequency drives (VFD) can help. If VFDs are incorporated into CRACS and CRAHS, considerable energy savings can be realized. VFDs accomplish part load control by varying electric motor speed. The energy savings with VFDs depends on the operating conditions but savings of 50 percent or more over other part load control strategies can be accomplished. Adequate controls of VFDs is important. Fan speed must be adjusted to match the IT load in real time. Both management software and wired and wireless thermal sensors can help in the regulation or control of VFD drives.

TRANSFORMERS

Many traditional data centers have installed floor-based PDUs with dry-type transformers (with typical 3-5% losses) to convert 480 Vac to 208/120 Vac to feed the IT loads. This is the case for the USA, but not for Europe where 400 Vac is a standard. In the US, these transformers may be eliminated if the UPS output is 415/240 Vac feeding equipment power supplies within the various data center IT components that are rated nominally 100-240 Vac universal input. Special consideration should be taken to ensure that 230/415 Vac rated circuit breakers and downstream plugs and receptacles are utilized.

EFFICIENCY GAINS INSIDE THE BUILDING BUT OUTSIDE OF THE DATA CENTER (ZONE 2)

Following is list of areas inside the building but outside of data centers that point out where energy losses are likely to occur (Zone 2 is represented as the gray area of the illustration in Appendix A):

PUMPING SYSTEMS

Chilled water circulating pumps provide a good opportunity for savings if variable frequency drives are deployed. In most cases the pumps run continuously and at the same speed, regardless of the demand. To achieve variable flow savings, the common valves in CRAHs can be converted from three-way to two-way valves. This will allow only the water required by current demand to circulate. This allows for lower pump speeds during lower flow demand. Pump speeds can be regulated by controls in order to maintain differential pressure across supply and return.



LEGACY VERSUS HIGH-EFFICIENCY UPS

Most UPS manufacturers quote UPS efficiency at 100% load because it represents the very best efficiency the UPS will attain. Unfortunately, very few users will ever reap the benefits of this efficiency because it is unlikely they will ever reach 100% load. Specifying a UPS based on its full load efficiency is like buying a car that gets maximum fuel efficiency on the highway and using it only for city driving. In dual corded applications, with two utility feeds (A and B), and where redundant UPS loads are typically at 30-40% of maximum to ensure adequate capacity in case of utility transfer, low load efficiency becomes a critical issue.

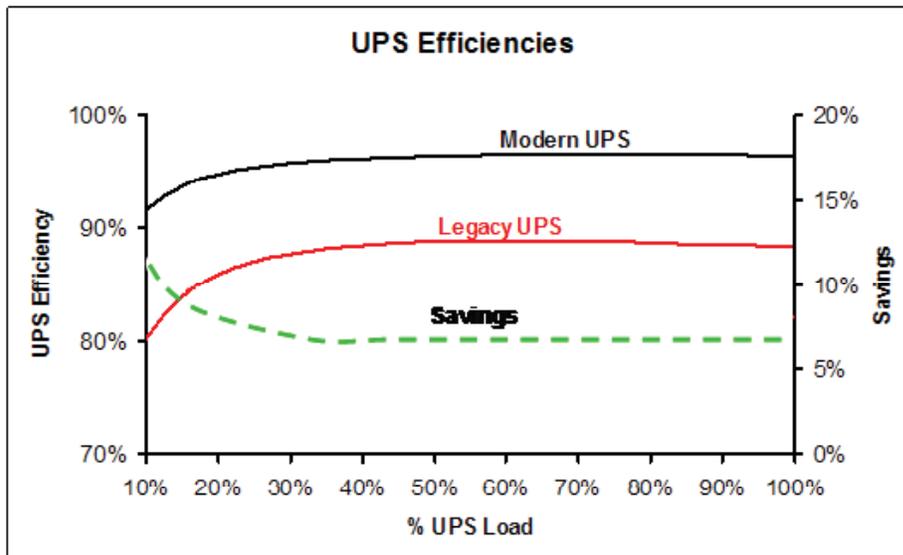


FIGURE 6 – UPS EFFICIENCY AS A FUNCTION OF LOAD COMPARING LATEST GENERATION UPS TO HISTORIC PUBLISHED DATA

At loads of 50% or lower, both modern and legacy UPS systems begin to run less efficiently than at higher loads, with significant dips occurring at loads below 20 % (see Figure 6). However, the efficiency of the modern high-efficiency UPS systems is significantly higher than legacy UPSs regardless of load. When UPS losses (heat) are reduced, this also reduces the air conditioning load, freeing up additional capacity and leading to further downstream efficiency gains. A best practice is to match UPS loads as closely as possible to data center IT loads. Scalable UPSs are available that allow for a coordinated growth path of UPS capacity and IT load. For more detailed efficiency information regarding modern data center components and configurations, see the Green Grid White Paper #4, “Quantitative Efficiency Analysis of Power Distribution Configurations for Data Centers”.



“FREE” COOLING FROM OUTSIDE AIR

Many data center owners are beginning to consider “free” outside air to supplement the cooling of their data centers. Both water-side and air-side economizers are available in the marketplace and can provide an alternative for supplemental cooling of a data center. Geographic location and climactic conditions have a major impact on the magnitude of payback that can result from deploying such systems. Data centers can also deploy thermal storage solutions that make ice at night for use during the day to provide supplemental cooling so that less chiller plant operation is required.

HOT GAS BYPASS

When diminishing loads force a refrigeration system to operate at unstable conditions, a hot gas bypass is utilized to simulate load in order to keep all equipment operating. Hot gas bypass is sometimes used to supply the compressor with a continuous full load while the chiller is catering to partial load conditions. One of the drawbacks of the hot gas bypass is that since it creates a false load to run the compressor all of the time, energy is being wasted. If the data center chiller operates at 10 to 20% load most of the time, the inefficiencies are quite evident. The recommendation is to install smaller chillers and to remove the hot gas bypass.

INTERIOR LIGHTING AND SENSORS

Standard interior lighting will usually consume 3 to 5 watts per square foot. High efficiency interior lighting can cut consumption in this area by almost 50% (1.5 to 3 watts per square foot). Occupancy sensors can increase savings by turning on lights only when the physical space is occupied. These sensors have been refined and enhanced to control lighting and HVAC in commercial office spaces. Where utility rebates are available, sensors can pay for themselves in less than one year, but most pay for themselves in two to three years without rebates. Savings will vary depending on the area size, type of lighting and occupancy pattern. The California Energy Commission estimates that typical savings range from 35% to 45%.

EFFICIENCY GAINS OUTSIDE OF THE BUILDING (ZONE 3)

Following is list of areas outside of the building where energy losses are likely to occur (Zone 3 is represented as the blue area in the Appendix A illustration):

INEFFICIENT MOTORS IN COOLING TOWERS

Cooling towers can be a good application for variable frequency drives in motors. The savings for cooling towers are generated by operating the fan(s) at lower speeds for longer periods of time as opposed to cycling the fans on and off at full speed. This reduces the energy consumption and in some periods may reduce billed demand.



Some chilled water applications that use a cooling tower may have condenser water temperature reset where the condenser water temperature is lowered during periods of low wet bulb temperature (or dew point). This saves chiller energy and although the tower fan will have to run faster to achieve lower condenser water temperature, the chiller savings more than offset the extra tower fan energy.

OVERSIZED GENERATORS

Generators are frequently oversized because they are utilized to support the entire building (including the data center portion). However, if more generator power is installed, more energy will have to be consumed in order to keep all of the block heaters running. Block heaters run 24 hours a day, 7 days a week and are deployed to increase the likelihood that the generator will actually start when needed.

Over the years, most generator plants continue to grow. These generators may be underutilized if the business changes (downsizes) or if certain applications or loads are considered non critical. Rightsizing the generator plant can save significant amounts of money in the areas of maintenance costs and energy costs. However, if the consumer goes too far undersizing the generators, the standby power generated might not be able to support each and every load when the facility is on generator power.

INEFFICIENT HOT WATER HEATER OPERATION

Generators require heaters to keep their engine blocks warm. A warm engine block increases the chances that the generator will start when required during a power outage. Most generators come equipped with standard resistance heaters. The design of these devices has not changed much in 50 years. The coefficient of performance (COP) for resistance heaters was, and is, 1 to 1: meaning that for every watt of energy used, 1 watt of heat is produced. Newer technologies, such as heat pumps have emerged over the last few years. Heat pumps have a COP of 4.2 to 1, delivering over four units of heat for each unit of electricity used. Therefore, for every \$1 of energy consumed by the heat pump, \$4.20 worth of heat is generated.

It takes less energy to move heat than it does to produce it through the direct conversion of electrical power. Heat pump technology takes heat out of ambient air and efficiently transfers it to the engine coolant system by using refrigerant under pressure. If it is not possible to migrate to heat pumps, insulation of existing enclosures can help the efficiency of the resistance heaters.

EXTERIOR LIGHTING

High Intensity Discharge (HID) lighting technology replaces the filament of the light bulb with a capsule of gas. The light bulbs operate at 3 to 5 times the efficiency of a typical halogen light bulb. The HID lamp's lumens per watt (LPW) efficiency is roughly six to eight times higher than that of an incandescent lamp. An HID lamp

will last, on the average, 3 to 5 times as long as a halogen bulb.

HIGH UTILITY CHARGES

In order to recoup the cost of the infrastructure to serve the annual peak load of data centers, most utilities charge commercial buildings additional fees that may have significant financial impact on the data center's total cost of energy. These include time-of-use rates, demand charges, annual ratchet clauses, cost-of-fuel adjustments, power factor penalties, and others including federal, state, and local taxes. Utility companies are not obligated to offer any company the lowest rates available. Most businesses are not aware of all the rules, riders, tariffs, tax exemptions and credits that apply to their utility bills. Data center and facilities personnel should consider the following options to help reduce their energy bills:



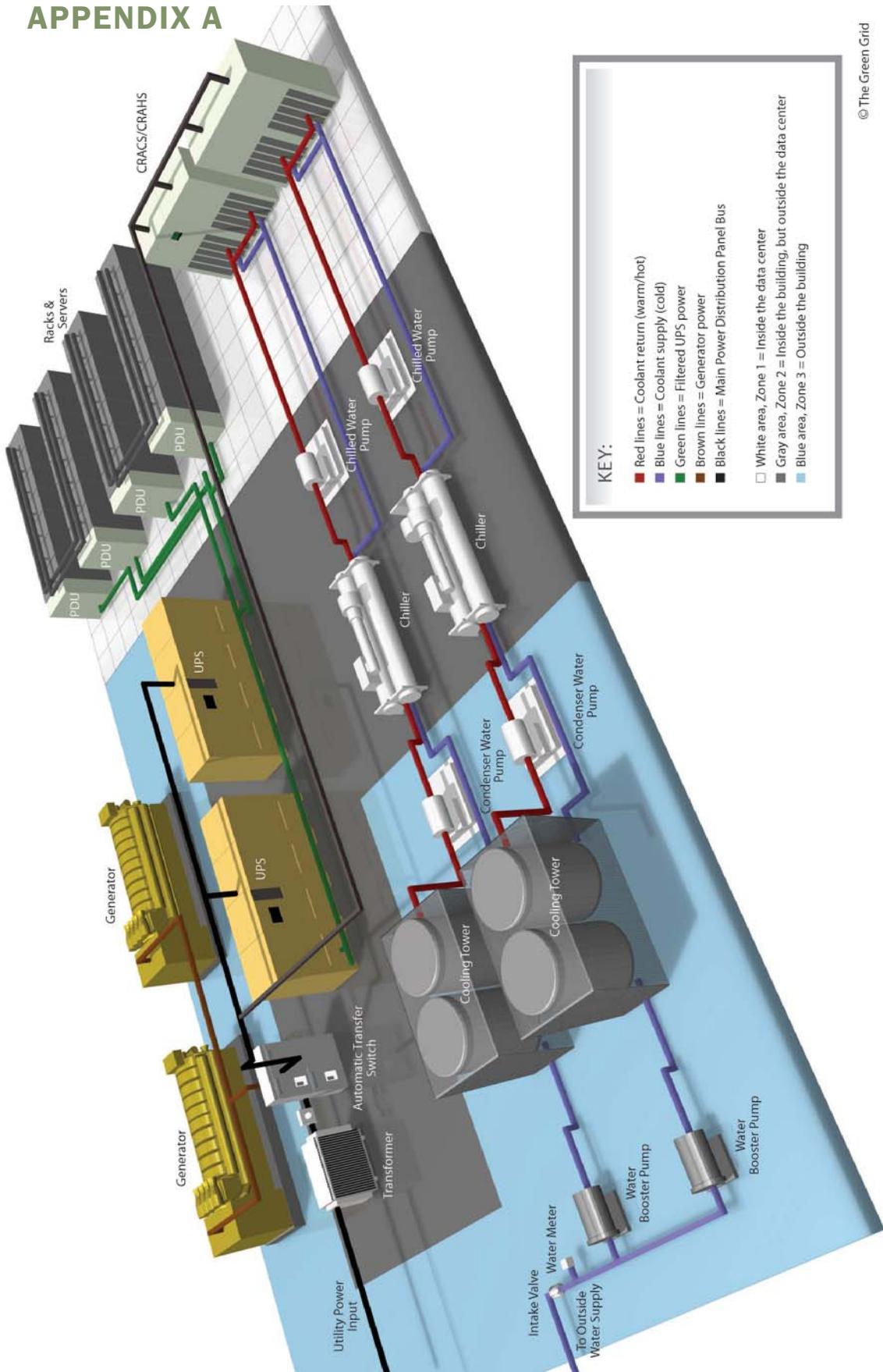
- Analyze the bill to understand how rates are being charged
- Negotiate better utility rates
- If applicable, aggregate loads for bulk utility purchasing opportunities of geographically dispersed facilities
- Allocate costs and identify energy inefficiencies by department, product or cost center
- Drive accountability throughout entire organization
- Avoid unnecessary peak demands and penalties through utility pre-notification practices

In addition, a company's generators might be used to shave off peaks of demand on hot days thereby avoiding surcharges. Monitoring utility energy pricing on a day-ahead basis can also help to cut down on energy costs. If the utility price is above what it costs to generate power via generators, decisions can be made regarding whether to generate power and for how long.

CONCLUSION

No new bold corporate initiative needs to be launched in order for a data center to begin reducing energy costs. A simple inspection of existing data center physical infrastructure will reveal a considerable amount of "low hanging fruit" when it comes to energy conservation.

This paper provides a roadmap for tracing the key elements of both the data center power and cooling systems and reveals those pockets where most of the energy is being wasted. In most cases, the fixes are not major and can be executed one step at a time with minimal interruption to day-to-day data center operations.



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APPENDIX B – DEFINITION OF TERMS

Air intake - Device that allows fresh air to enter into the building.

Blanking panels - Panels typically placed in unallocated portions of enclosed IT equipment racks to prevent internal recirculation of air from the rear to the front of the rack.



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Bus, power (or electrical bus) - A physical electrical interface where many devices share the same electric connection, which allows signals to be transferred between devices, allowing information or power to be shared

Chiller - A heat exchanger using air, refrigerant, water and evaporation to transfer heat to produce air conditioning. A chiller is comprised of an evaporator, condenser and compressor system.

Cooling tower - Heat-transfer device, often tower-like, in which atmospheric air cools warm water, generally by direct contact (heat transfer and evaporation).

CRAC (Computer Room Air Conditioner) - A modular packaged environmental control unit designed specifically to maintain the ambient air temperature and/or humidity of spaces that typically contain data center equipment. These products can typically perform all (or a subset) of the following functions: cool, reheat, humidify, dehumidify.

Dehumidifier - A device that removes moisture from air.

Economizer, air – A ducting arrangement and automatic control system that allow a cooling supply fan system to supply outdoor (outside) air to reduce or eliminate the need for mechanical refrigeration during mild or cold weather

Economizer, water - A system by which the supply air of a cooling system is cooled directly or indirectly or both by evaporation of water or by other appropriate fluid (in order to reduce or eliminate the need for mechanical refrigeration)

Efficiency - The ratio of the output to the input of any system. Typically used in relation to energy; smaller amounts of wasted energy denote high efficiencies.

Free standing equipment - Equipment that resides outside of data center racks.

Generator - A machine, often powered by natural gas or diesel fuel, in which mechanical energy is converted to electrical energy

Hot aisle/cold aisle - A common means to optimize cooling in IT equipment rooms by arranging IT equipment in back-to-back rows. Cold supply air from the cold aisle is pulled through the inlets of the IT equipment, and exhausted to a hot aisle to minimize recirculation

Humidifier - A device which adds moisture to the air.

Load - In data centers, load represents the total power requirement of all data center equipment (typically servers and storage devices, and physical infrastructure).

PDU (Power Distribution Unit) – A floor or rack mounted enclosure for distributing branch circuit electrical power via cables, either overhead or under a raised floor, to multiple racks or enclosures of IT equipment. The main function of a PDU is to house circuit breakers that are used to create multiple branch circuits from a single feeder circuit. A secondary function of some PDUs is to convert voltage. A data center typically has multiple PDUs.

Pump - Machine for imparting energy to a fluid, causing it to do work.

Rack - Structure for housing electronic equipment.

Raised floor - Raised floors are a building system that utilizes pedestals and floor panels to create a cavity between the building floor slab and the finished floor where equipment and furnishings are located. The cavity can be used as an air distribution plenum to provide conditioned air throughout the raised floor area. When used as an access floor, the cavity can also be used to rout power/data cabling infrastructure and/or water or coolant piping.

rPDU – (Rack-mount Power Distribution Unit) – A device designed to mount in IT equipment racks or cabinets, into which units in the rack are plugged to receive electrical power

Transformer - A device used to transfer an alternating current or voltage from one circuit to another by means of electromagnetic induction.

UPS (Uninterruptible Power Supply) fixed - Typically uses batteries as an emergency power source to provide power to data center facilities until emergency generators come on line. Fixed implies a standalone unit hard wired to the building.

UPS (Uninterruptible Power Supply) modular/scalable - Typically uses batteries as an emergency power source to provide power to data center facilities until emergency generators come on line. Modular/scalable implies units installed in racks with factory-installed whips allowing for physical mobility and flexibility.

