

# WHITE PAPER

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## How To Build A Real Green Data Centre

*Part 2: Energy Efficiency improvements that can save you money TODAY*

February 2008

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### **WHAT ARE THE SHORT TERM FIXES?**

This paper is part 2 of a series for IT and Property professionals who are concerned about energy consumption in Data Centres.

In part 1 of this series, we described the “Big Picture” view on why you should be planning to reduce your Data Centre carbon footprint, and your annual energy bill.

In this part 2, you’ll learn more about the strategies available to you through simple and sound engineering and management practices to deliver returns, with little or no additional expenditure outside your normal IT refresh cycle. How they work, and how to apply them easily to achieve energy use reductions in the order of 10% immediately, and 25% in the short to medium term.

Solutions for today include improving your management of air flow, selection of suitable room condition targets, regular re-commissioning of your plant, low power consuming processors, IT Virtualisation, and high efficiency power supplies for your IT kit.

In part 3 of this series, you’ll find out how to achieve even greater energy efficiency in your Data Centre spaces to the order of 40%, by combining these short term solutions alongside proven longer-term strategies in your next facility.



## DATA CENTRE ENERGY PERFORMANCE

### KEY ISSUES

Data Centre operations consume huge amounts of energy. To illustrate how the techniques in this White Paper series deliver reductions in that energy use, a model was selected in part 1 using high-level benchmarks.

### A DATA CENTRE ENERGY MODEL

In part 1 of this series, the concept of PUE (Power Usage Effectiveness) was described. Studies cited in part 1 demonstrated a “typical” PUE of 2 as a good basis for benchmarking.

The US EPA’s August 2007 report to congress on Server and Data Centre efficiency suggested a “best practice” benchmark that equates to a PUE of 1.5 to 1.6, relative to trends to that time.

Figure 1 shows a typical energy use break-up for comparison purposes. This model uses Chilled Water cooled close-control air conditioner scheme (often referred to as CRACs) for the air conditioning system.

For a PUE=2 Data Centre, only 50% of the energy used is powering the IT equipment.

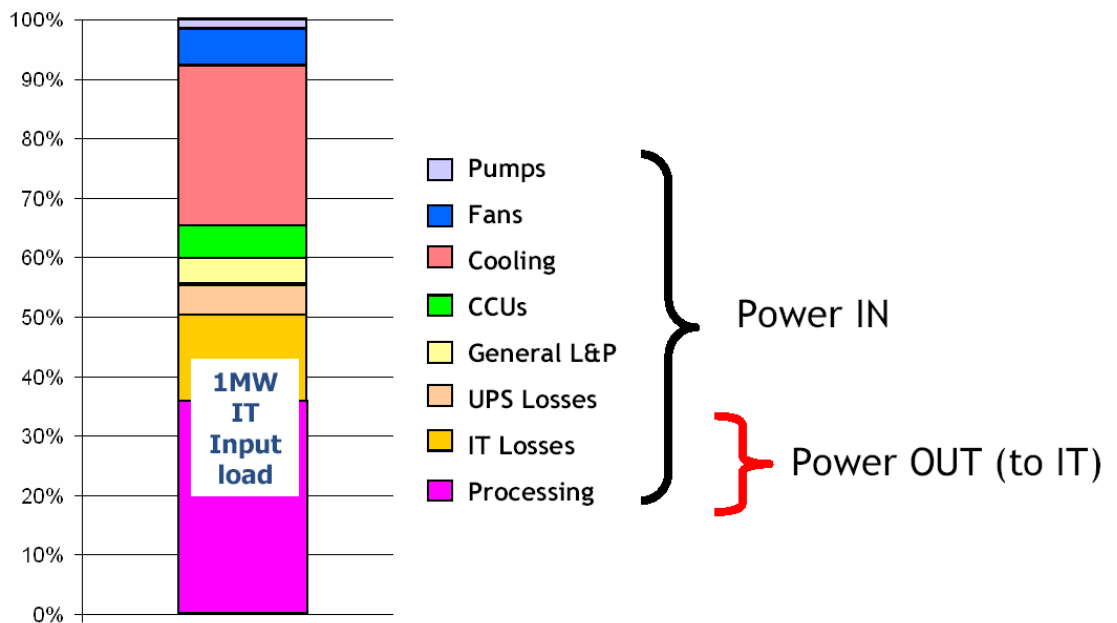


Figure 1 - Energy use in a sample Data Centre – 1MW IT load, PUE = 2



## INFRASTRUCTURE PERFORMANCE IMPROVEMENTS

### KEY ISSUES

With the infrastructure most likely in place in your Data Centre, energy efficiency improvements can be categorised in two ways:

- Using your systems to their full capability by “tightening” operations towards the intended operating modes
- Fine-tuning operating modes to reduce energy use where flexibility exists to do so.

Air flow management and re-checking that plant is operating as originally designed deliver the first of these. Extending the permitted operating bands to drive cooling systems more “softly”, and UPS systems harder, deliver the second.

All up, savings in energy of at least 10% are available, considering only the major opportunities. All strategies combined are capable of delivering 20% or more energy savings, depending on your starting point and your operational constraints.

### AIR MANAGEMENT - DISTRIBUTION

For Data Centres designed and built any time up to 2007 or so, air cooling is almost certainly the major mode of cooling used. Air as a cooling medium is easy to get plenty of, simple, and relatively risk-free to deliver to the equipment.

The downside with air cooling is that the ability of air to transfer heat is not very efficient; more on that aspect in part 3. What’s also a problem with air is that it is invisible and everywhere, so any “leaks” cannot be seen, and the cool and hot air flow paths are not obvious.

If your air distribution management needs work, you can expect to achieve 5-10% energy savings by adopting some or all of the strategies discussed below.

We’ll first look at some typical air flow cross sections in your Data Centre. Sections are created using Computational Fluid Dynamics (CFD) models. Warmer colours are used to represent warmer temperatures of the air at a given point.

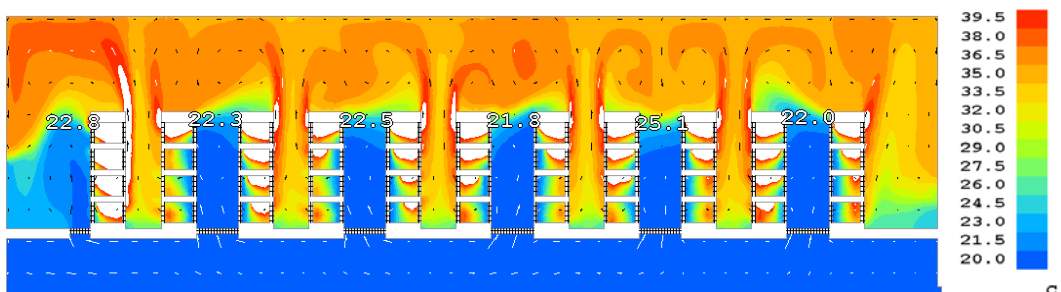


Figure 2 – Air Flow cross section for a Data Centre – 1100mm floor, 1800mm ceiling, 2.1kW/m<sup>2</sup>

Figure 2 shows a 5.8kW per rack (2100 W/m<sup>2</sup> average load density) Data Centre with a sub-floor space of 1100mm for cooling distribution and a ceiling space above the top of racks of 1800mm, arranged in a hot & cold aisle scheme. The numbers at



the top of each cold aisle are the air temperatures entering the top server of each rack.

### **Bypass Air**

The first air management problem is that of air “bypassing” the cold aisle. Bypass Air is the loss of efficiency due to air leaking from the floor, out of floor openings within racks around cables. This cooling air is NOT doing what you want, so its referred to as "bypass air". The section in Figure 2 has no bypass air; that's what you want to achieve. Cool air is flowing into the front of racks, and hot air out the back. If, for example, cooling air is entering the base of the racks or into the hot aisles, the energy used to cool that air is being wasted.

What happens if your existing Data Centre is not arranged in a hot aisle / cold aisle scheme? The principle of avoiding bypass air (and for all the air management techniques discussed in this section) is the same. Deliver the cooling to where it's needed, and not elsewhere.

### **Resistance in the air path**

In your Data Centre, the sub-floor plenum is probably used to reticulate cables, pipes, and other services. The second air management issue to avoid is “choking” the air plenum. This creates resistance which fans have to overcome, using more energy to achieve the cooling required of them. As choking the air plenum becomes worse, air cannot be delivered at all to the most affected locations, and cooling is ineffective as a result. You may have to install more air conditioning units to deal with “hot spots”. Even though there is enough cooling capacity available to deal with the load, it is unable to do the job due to restriction of air paths.

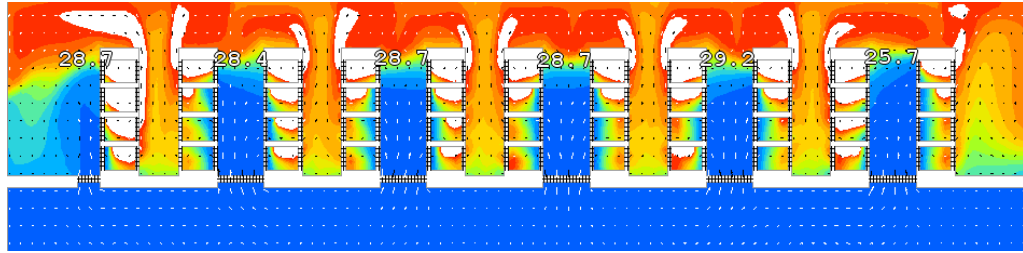
A well-managed sub-floor air plenum reduces the pressure drop in the air distribution paths. Reduced pressure drop means lower fan energy needed for cooling air flow, and fewer number of fans to achieve it.

### **Separation of Supply and Return air paths**

We have already “adopted” the primary means of dealing with the third air management requirement – avoiding mixing of cool supply and warm or hot return air paths, by using the hot aisle / cold aisle scheme. It is next to impossible to enhance cooling efficiency when hot and cold aisles are not used. At low load densities, the difference in energy use is minor. As load density rises, it quickly becomes significant.

Figure 3 illustrates a third air management requirement within a hot / cold aisle scheme. In this CFD section, the available ceiling height above racks has been decreased to 800mm from Figure 2. This concentrates the hot return air within the ceiling area, increasing the extent of mixing between cold aisle air and the hot return air above.





**Figure 3 – Air Flow cross section for a Data Centre – 1100mm floor, 800mm ceiling, 2.1kW/m<sup>2</sup>**

The top part of each cold aisle is much warmer, and this warmer air is what is provided to those top-shelf servers. You can also imagine how obstacles in the return air path above the racks (such as light fittings, cable supports etc) will create turbulence and further mixing of hot and cold air paths.

Clearly, it's not easy to raise the ceiling in your existing Data Centre to reduce mixing. So what CAN you do?

Research conducted in the US by Berkeley Labs confirmed what CFD models and engineering applications predicted – that separation of supply and return air paths works, and can be applied in an existing Data Centre. Strategies that can be applied to your existing Data Centre include:

- Separating the return air path using a ceiling plenum or ducted system.

A false ceiling plenum with air intakes above the hot aisles can be used where ceiling structure and dimensions permit. Refer to figure 4.

Otherwise ducted return air can be fitted. The air balance may need to be adjusted using return air fans; the energy use of these fans has to be balanced against the energy efficiency gained by ducting scheme.

Ducted return air with take-off connections to directly extract hot exhaust air from high load racks was used in a Sydney Australia Data Centre upgrade in 2005. The load density capability was doubled to 900 W/m<sup>2</sup> for this legacy Data Centre (which did not use hot and cold aisles).

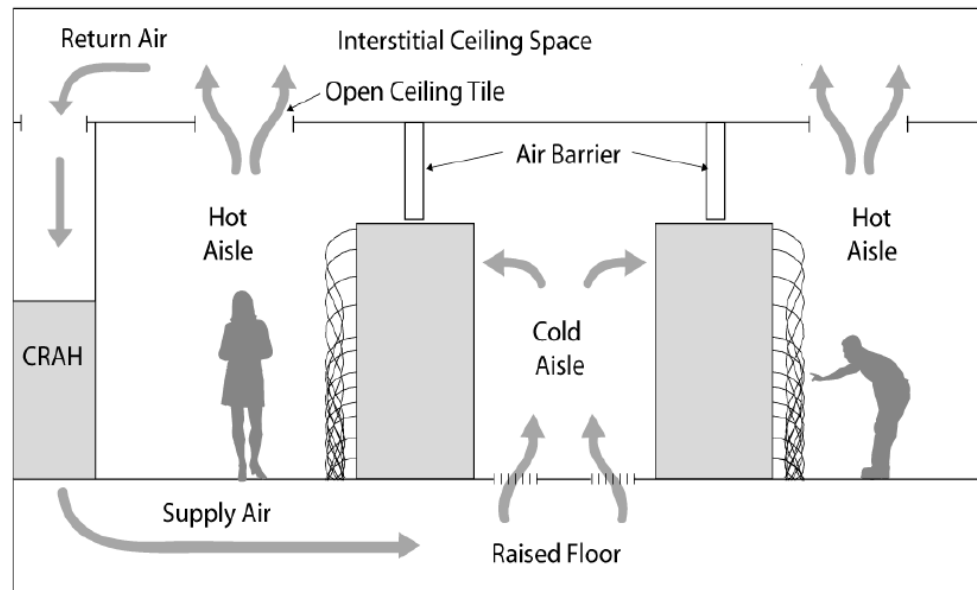
- Using air barriers to create vertical or horizontal curtains between the hot and cold air paths.

Vertical curtains between hot and cold aisles minimise the mixing of supply and return air, creating a pseudo-duct for the return air in a low ceiling environment. Refer to figure 4. A Sydney Australia Data Centre fitout within an existing building in 2008 uses this approach. CFD modelling confirmed it's validity.

It's also feasible to:

- Add Horizontal barriers ("cold caps") fitted to trap the cold air within cold aisles and prevent the return air mixing at the top shelf (such as what is occurring in Figure 3). With suitable supply air precautions (next section), you can fully enclose cold aisles with doors at the ends.
- Enclose the hot aisle with doors at the ends, with or without ceiling "hot caps", and control hot return air extraction and treatment from within the hot box this creates.





Source: *Energy Efficient Data Centres Demonstration Projects*, Berkeley Labs March 2007

**Figure 4 – Reducing Supply and Return air mixing in your Data Centre**

## AIR MANAGEMENT – AIR QUANTITY

### Variable Speed Fans

Fans operate on a cubed law relationship between power in and air moved. Using variable speed fans to run at the required speed only can deliver large energy savings with payback periods inside 12 months.

Once you have managed air paths to maximise cooling system efficiency, you can now take advantage of this significant energy saving measure. Two key strategies are available to a well-managed air distribution system:

- Reduce the speed of all fans in your cooling system, so that they operate at optimum speed for the required cooling delivery, and
- Run ALL your fans (duty and standby), so that overall average fan speed is reduced even further.

HP's Dynamic Smart Cooling™ system uses this principle across multiple CRAC type air units as part of its strategy of reducing energy usage overall.

A further advantage of running all duty and standby fans at lower speed is that failure of a fan can more quickly be recovered. VSD's cost money, but payback periods of less than 1 year are not uncommon.

### Air Supply quantity to racks

As you implement improved management of the air distribution scheme, it's important to keep an eye on how MUCH air is able to get to your servers. Your equipment rack / server fans draw air from cold aisles and rely on the air



distribution scheme to provide sufficient air to the cold aisle so that this can occur freely. There must be at least as much cold air volume flowing to the aisles as is required by the various racks of equipment in them. When aisles are enclosed, this becomes critical.

If insufficient air is supplied to the front of the racks, they must draw air from elsewhere; the most likely space is the hot aisle, or the hot return air stream above the racks. Air quantity might be insufficient due to distribution blockages, in rows of equipment more remote from the air supply source, or for a number of other reasons. The effect is the same whatever the reason – air supply is warm, not cold.

Most Data Centres are not provided with any dynamic method of controlling air to individual cold aisles. In that case, sufficient supply air needs to be available to each cold aisle to match the server air quantity at any time. This air quantity changes frequently.

It is feasible to control air quantity to each row's cold aisle. Some complexity is introduced, with extra controls for air flow volume and temperature. Significant advantages in terms of efficiency of the air cooling scheme can be delivered with supply air control, to offset controls costs. Temperature control to racks is improved as well.

### DESIGN CONDITIONS

Chances are, your Data Centre was originally designed with close control of temperature and humidity as a goal. The published ASHRAE limits for Data Centres are 20 to 25°C, 40 to 55% relative humidity (RH).

If air distribution and supply are tightened as discussed above, opportunities are available to critically examine expanded control bands. The impact is twofold:

- Energy is used to maintain conditions within the control bands. In the worst case, one part of the plant is working to move conditions up, whilst another part is trying to move them down. Humidity control using multiple CRAC units is the classic example; of 10 units, you might have 3 humidifying the local air (adding steam), 3 dehumidifying the air (drying, using heaters), and 4 happy as things are.

(If you think this is your Data Centre, get your maintenance staff to switch OFF the humidity controllers in most of your CRAC units. Only leave enough running to keep your conditions where they need to be.)

- The scope to accept conditions as they are from fresh air intakes are fewer, so extra energy is used to trim conditions up or down within outside air supplies.

We examine the use of outside air “free cooling” schemes in part 3 of this series.

You should expect to be able to achieve about a 5% energy saving with wider humidity control alone. On top of a 5% or so saving from wider temperature bands and refrigeration control, 10% is a realistic target reduction in energy use through modified design conditions.

### Temperature Conditions

Temperature control is often selected at 22 +/- 1.5°C.



## How To Build A Real Green Data Centre

Part 2: Energy Efficiency improvements that can save you money TODAY

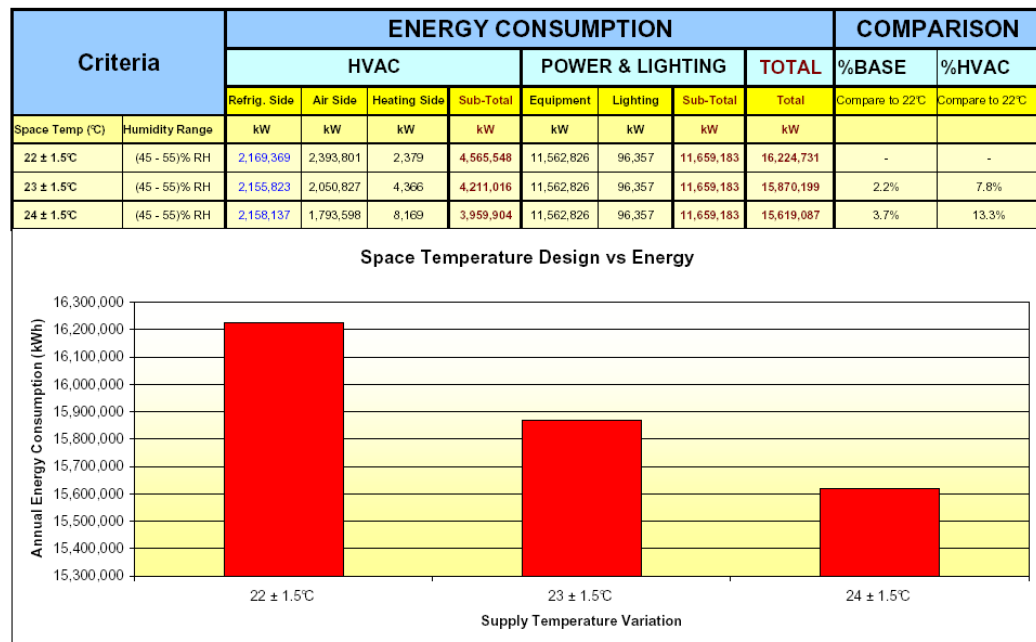
The ASHRAE allowable limits for Data Centre space temperature are 15 to 32°C. Overlaid on the recommended and allowable temperature limits is a need to control the rate of change of temperature, to avoid undesirable stress-testing of equipment. For personnel comfort, you may wish to not exceed the recommended limits of 25°C. What happens if you change your Data Centre set point up a few degrees to stay mostly within that recommended band?

A thermal / energy use model of a 1000m<sup>2</sup> @ 1200 W/m<sup>2</sup> Data Centre was carried out for a Telco operator who was seeking energy savings. This Telco had trialed a facility using an occupied hours temperature set point of 22°C, and an after hours set point of 27°C. Although this demonstrated an energy saving, the shift in temperature on a regular basis was suspected of causing higher equipment failures for some kit. So energy use for a 1 or 2°C temperature shift was modelled as an alternate. The results are shown in Figure 5.

The predicted energy savings by raising ONLY the temperature set point were:

- For a 1°C rise - 2.7% overall, 7.8% within the air conditioning plant
- For a 2°C rise - 3.7% overall, 13.3% within the air conditioning plant.

Annually, the savings at a 5.7 c/kWh tariff are in the order of \$20,000 and \$35,000 respectively.



**Figure 5 – Energy Savings comparison – Temperature adjustments of 1 and 2°C**

The concept of wider temperature set points is not new. In the mid 1970's, Bell South in the USA set out to reduce their energy usage and studied opportunities across every facility, from the largest Data Centre to the smallest POP site. Key strategies adopted as a result of their review:

- design conditions were raised from 22 to 25°C (78°F) in occupied spaces, with an after-hours reset to 29°C (85°F)
- design conditions in unoccupied spaces were raised to 27°C (80°F)



- for the higher-temperature spaces, a local manual override was used to reset the design condition to 25°C (78°F) when personnel were within the area.

### Relative Humidity

Relative Humidity (RH) is difficult and energy-intensive to control to a close band. People who walk into your Data Centre past the Humidity sensors emit enough moisture to take you outside a narrow RH band.

ASHRAE's recommended limits are 40-55% RH; the allowable limits are 20-80% RH. Equipment vendors views and engineering factors mean that your "comfortable" RH limits might be set somewhere within this 20 to 80% band; quite sizeable energy savings can be achieved by adding 10% to either side of the recommended limits.

To reduce energy used for Humidity control within your existing system:

- Select the conditions that are really NEEDED, using as wide a band as you can
- Check that your humidity sensors are calibrated and suitably positioned to respond to room conditions, not transient conditions such as personnel traffic
- Switch off humidification equipment that you do not need - use the minimum quantity of separate devices you can tolerate, so that different devices do not "fight" each other.

We looked at two case studies on temperature above. The Telco for which the energy model was performed runs their facilities at about 30-70% RH band (this varies based on location due to local ambient factors). The Bell South team who did the 1970's energy review switched off their humidity control altogether, even in coastal locations.

### Chiller settings

A further opportunity exists with Chilled Water refrigeration systems that relates to both temperature and humidity set points. Two aspects should be fine-tuned:

- Chilled Water Supply temperature can be varied up and down according to the ambient RH and seasonal variations in temperature. In summer, lower chilled water supply temperature to cooling coils reduce the need for dehumidification. In cooler times, chillers can be operated at elevated temperature to reduce the energy needed for refrigeration.
- Chilled Water Return temperature is often selected as a fixed band above the supply temperature, but many chiller systems can operate at higher temperature "splits" with greater efficiency, and use less pumping energy.

Use of Chiller temperature adjustments needs to be examined according to site equipment selections; it will not work everywhere.

## RE-COMMISSIONING

When your Data Centre was handed over, a system commissioning process would have been completed that recorded the performance of the equipment as installed. Fine tuning at that time would have been required to get things working as necessary.



Once a Data Centre goes “live”, the extent of change of the load characteristics is huge. On top of that, the various components of the plant experience wear-out, collect dust in filters, “drift” in control setpoints due to component variability or planned changes at a given time. All these mean that the air conditioning plant is likely to be wasting energy, and doing its job sub-optimally.

When plant is re-commissioned, the recommended process is:

1. Re-seal air paths. Check that air is going where it is supposed to be, not going where it is of no use.
2. Re-tune the air and water flows, using the last known good set of data available for your Data Centre.
3. Fine-tune air and water flows to serve the load you have TODAY. This is probably not the same as the load that was installed when the plant was last commissioned to support that load.
4. Check that the logic of the control scheme, and the set points, remains optimal. Check that the Design Conditions (previous section) are the best choice to serve the load, and adjust set points where this is not the case.
5. Plan when the NEXT re-commissioning will occur. At first this should be a seasonal choice, since differing outside conditions create varying plant performance. As regular re-commissioning is completed, previous seasonal data adjustments may be able to applied without the need to go through the “full” process.

You may feel the benefits are only be marginal, but consider this:

- A 2500m<sup>2</sup> Data Centre facility in southern Australia had been operating for about 8 years. In that time, additional former warehouse space was converted to create over 150% of the original space. Equipment refresh and a number of other factors had varied the performance of the air conditioning scheme to the point where the intended outside air “free cooling” cycle was no longer able to maintain conditions. The plant was re-commissioned and returned to its intended operating parameters. The PUE changed from 2.2 to 1.9, reducing energy consumption by about 15%!

## UPS LOADING

The majority of UPS equipment works most efficiently when it is more heavily loaded. Rotary and delta-conversion systems are in general better than double-conversion (traditional Static) UPS plant. Assuming you have static UPS installed, you might expect efficiency at varying load of:

90% in the range from 100% to about 60% loaded;

85% in the range from 40% to 60% loaded;

< 85% below 40% loaded.

If you run a redundant UPS module somewhere, it’s likely that your modules are operating in the 40% to 60% range much of the time. If your plant itself is lightly loaded, you’re probably doing worse than that.

To make matters worse, IT load power factors near 1 don’t match the rating details of many UPS, which are selected for 0.8 power factor. (Power factor is a measure of



how much “real” work is done as a ratio of the total power used to do it; nearer to 1 is better.) The impact of this is that your UPS may be really only 80% loaded when it’s operating as much load as it is capable of, so backing off the load with redundant plant could have you operating well below 50% of “real” load.

So when you are analysing UPS loadings, it becomes important to check more than just the “% load” display provided by some manufacturers. All load parameters need to be factored in.

Ideally, UPS loading should be as high as possible whilst still retaining your desired redundancy. A change from 50% to 65% loading can translate into an improvement (i.e. reduction) in energy losses of 5%.

### OPERATIONS MANAGEMENT

Outside the big-ticket energy savings of the cooling and UPS plants, simple operational issues can deliver relatively small, but still important, savings.

How often are you the only person in your Data Centre’s central technical area? How often is no-one there at all? The fact is, Data Centres have little need for people-friendly features like lighting, much of the time. The “lights out” Data Centre has been a topic of discussion since at least the 1980’s. Have you implemented:

- Low energy lighting types?
- Automated, or semi-automated, switching schemes that keep lights off if no-one is there to see them?
- Task lighting at specific locations where it’s needed, rather than everywhere?

The Data Centre energy model in Figure 5 uses over \$5,000 in energy every year for lighting the technical area alone. It’s easy to save some of this, even though the impact is probably less than 1% of your energy usage.

An area of increasing sophistication in your Data Centre is “power management”. Tools are available to you that can monitor power usage, power-off equipment that is not being used for extended periods, or report on which racks are the thirstiest. Knowing where your energy is being used arms you with data to do something about it. The chairman of the US-based Rocky Mountain Institute (RMI) has noted that IT load varies by a factor of 3 or more, yet power load hardly changes at all. Since the IT load generates heat, the energy wastage is translated in yet more energy to cool that heat off. RMI consider that savings of energy of about 20% ought to be attainable. What can be achieved will depend on your IT usage profile and applications. But even if only 2% is achieved, the savings matter.

These operational aspects seem obvious opportunities. But are they being done?



## IT STRATEGIES

### KEY ISSUES

The Infrastructure discussed in the previous chapter exists to serve the IT equipment, and infrastructure energy use is highly dependant on IT equipment load.

Now we'll look at the bigger opportunities to reduce the power losses and power used for processing, at the IT racks. These are short to medium term for your Data Centre. Processing power can be reduced through application virtualisation, and selection of the processors themselves. Combined together, the processing aspects alone can deliver 15% energy reductions or more.

Reducing losses in the power supplies at IT equipment can deliver another swathe of energy savings. Equipment power supplies running at 70-75% efficiency over their typical operating range are one of the most inefficient parts of many Data Centres.

The incentive for change within IT will be enhanced if the power bills (which are typically paid by someone other than IT) are linked to IT strategy decisions.

### PROCESSORS

In the early 2000's, a step change in processor power consumption occurred – both in attitude and quantum.

Equipment is now shipped with processors on board that use in the order of half or less of the power of their predecessors of equal throughput. The Intel Xeon 5100 achieved double throughput at 60% of the power usage of its predecessor. The AMD Opteron delivers the same processing for 380 watts of power that consumed 740 watts in previous x86 series processors.

How does that impact energy efficiency for a given throughput of processing? In a 1000kW load including 500 servers, if all the servers use a chip such as the AMD Opteron, you'll save 180 kW (18%) of the load that's doing useful work. With 75% efficient power supplies, that's magnified to a 240kW (24%) saving in energy use at the equipment level. Including the cooling and UPS systems to support it, you have a total saving in the order of 20% in energy use in total for your Data Centre (at a PUE of 2).

Savings in processor energy use are predicted to flatten by major vendors, so we cannot expect to keep reducing energy at this level.

### VIRTUALISATION

We'll assume that your IT team have already taken up most of what they can in consolidation of IT equipment into blade servers and other high density gear, or are on the way.

"Phase 2" of this theme is Virtualisation, the multiplexing of applications running on your consolidated kit. Virtualisation makes better use of what's on your floor. Re-jigging equipment and applications to more heavily utilise the available processing means less floor space used, less power used, and less cooling required.



The statistics on exact performance of virtualisation schemes are highly variable, being application, network, and technology dependent (amongst other factors). Various vendors indicate factors of 3 to 10 improvement in utilisation of kit. Figure 6 below illustrates several vendors view of the virtualisation opportunity. Power use reductions at the server of the order of 50% are predicted when the utilisation indicated in Figure 6 are realised. Major energy savings are in the offing.

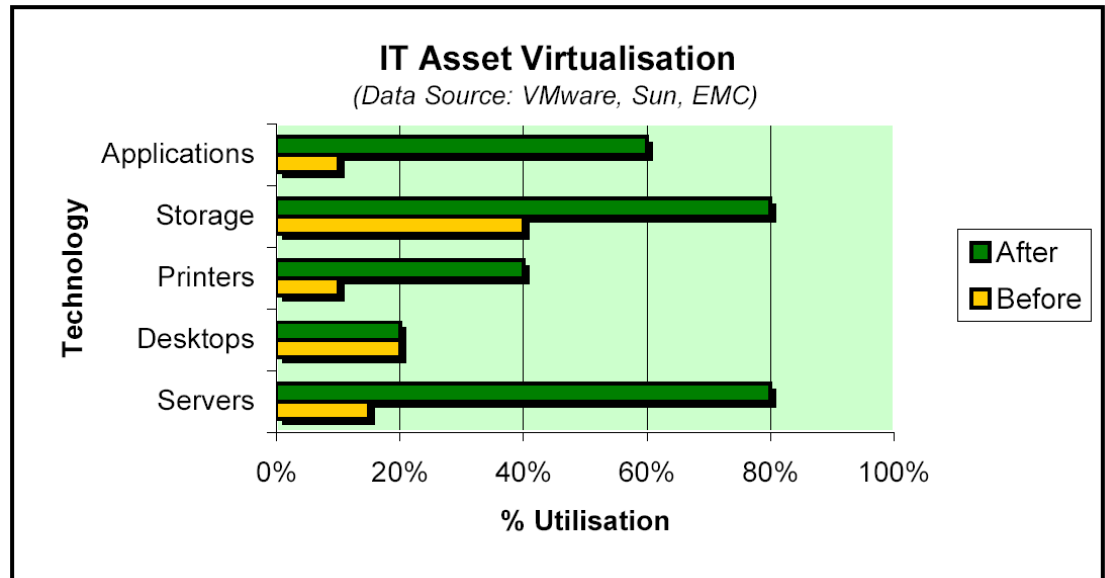


Figure 4 – IT Equipment & Virtualisation – improvements in utilisation

### EQUIPMENT POWER SUPPLIES

Rack power supplies are one of the least efficient pieces of kit in your inventory.

In 2003, an analysis of ours on dual power supply blade server equipment measured the full load of a fully populated server rack. With both power supplies active, the total power used was 110% of that required with only one power supply active. That's 5% extra power per supply path just to keep things ticking and warm.

Typical power supply performance is:

70-75% efficient in the range from 100% to about 40% loaded

65% at 20% loaded

55% at 10% loaded.

Suppose all your IT kit was operating with power supplies that were 70% efficient. For a 1000kW processor load, you would be using 1300kW of load from your UPS. UPS is expensive, and so is the energy it's consuming. If you upgraded to 90% efficient power supplies, you would reduce your total load to 1100kW and have capacity in your UPS for about another 18% of equipment load. You could reduce your overall Data Centre energy use by about 300kW through knock-on savings in UPS losses and cooling plant.



## ENERGY PERFORMANCE IMPROVEMENTS TODAY

### KEY ISSUES

Not all of the energy saving measures we've discussed can be implemented everywhere. Some are already in place, whilst others may not suit the IT or plant systems you've already got operating.

What's clear is that today, in your Data Centre, you can slice a large piece off the energy usage with relatively little outlay. Maybe enough to defer some planned capital expenditure for space expansion or capacity upgrade that you thought you had to do. Certainly enough to make energy savings add value.

### AMENDED DATA CENTRE ENERGY MODEL

We saw above how energy reductions of at least 10% are achievable through improved infrastructure operations. The actual number will depend on what can be implemented in your Data Centre, and what you might have already implemented. Over 20% energy reduction is an achievable target, but not for everyone. So we'll assume that you can achieve at the bottom end of this range, 10%. Using IT strategies for selection of more energy efficient processors, we can save, conservatively, another 15% including flow-on to upstream plant savings.

The combination of all of the energy savings we've looked at can deliver much more than this; we have taken up nothing for Virtualisation nor for more efficient power supplies, and have neglected lighting and power management on the infrastructure savings.

We've saved at least 25% total of our starting energy usage (and bill).

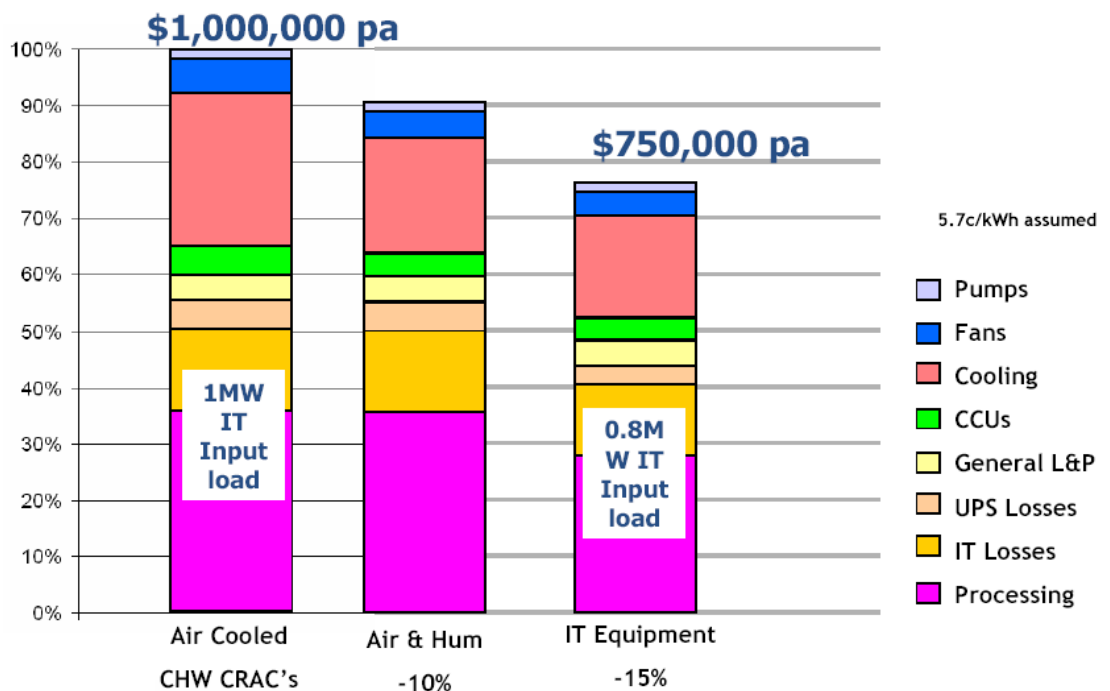


Figure 5 - Energy use in a sample "improved" Data Centre – 0.8MW IT load, PUE = 1.88



### CONCLUSION

In part 1 of this series, we described the “Big Picture” view on why you should be planning to reduce your Data Centre carbon footprint, and your annual energy bill.

In this part 2, we’ve seen how, today, you can reduce your energy usage by about 25% using only some of the strategies described, including:

- Air distribution management
- Air supply quantity
- Adjustment of design conditions
- Tuning the loading of your UPS
- Low power consumption processors

Starting with a \$1,000,000 pa energy bill, we’ve cut \$250,000 off operating expenses.

We’ve not taken up savings in a range of other areas that can deliver big savings by themselves in the right circumstances, including:

- Operational issues like lighting and power management.
- Re-commissioning of your plant
- Virtualisation
- Equipment power supply efficiency

We’re sure you’ll agree that energy savings can add value to your bottom line, as well as reducing your environmental impact.

### FURTHER READING

The authors recommend:

- Lawrence Berkeley Laboratories resource centre at <http://hightech.lbl.gov/datacenters.html>
- *High Performance Data Centers – A Design Guideline Sourcebook*, January 2006, Pacific Gas & Electric Company



### CONTRIBUTORS



**Rowan Peck** – Director

Since 1995, Rowan has been a key contributor within NDY's Data Centre design teams, with over 125,000m<sup>2</sup> of new or upgraded Data Centre space to his credit across primarily Australia and New Zealand locations. Prior to his Data Centre design days, Rowan was Data Centre Facilities and Operations Manager for a multi-national firm's facility in Australia for 4 years.



**Patrick Fogarty** – Director

Patrick leads NDY's UK operations and is a prominent figure in Data Centre projects across Europe, with experience in over 150,000m<sup>2</sup> of new or upgraded Data Centre space. His application of ESD design principles has seen Patrick drive the debate on the realistic applications of technology to the "greening" of Data Centres.

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