

WHITE PAPER

How To Build A Real Green Data Centre

Part 3: Energy Efficiency strategies for your next build

February 2008

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WHAT ARE THE LONGER TERM FIXES?

This paper is part 3 of a series for IT and Property professionals who are concerned about energy consumption in Data Centres.

In parts 1 and 2 of this series, we revealed the “Big Picture” view on why you should be planning to reduce your Data Centre energy use, and how to achieve reductions of 25% in the short to medium term within an existing facility.

In this part 3, you’ll learn about the longer-term “next build” strategies available to you through simple and sound engineering practices, to deliver returns to a total of 40% energy use reductions.

Solutions for your next build include high-efficiency chiller selections, central air handling, and “free cooling” outside air systems. We’ll also look at the pros and cons of co-generation schemes for a Data Centre. You may be fortunate that your Data Centre incorporates some of these features already, and we’ll reinforce how these approaches add significant value to your Data centre for every day of operations.

As the future unfolds, strategies for energy reduction that are considered radical today will become mainstream. It’s important to build a progressive armoury of techniques to chose from, since not all of those available make sense in all applications.



DATA CENTRE ENERGY PERFORMANCE – SO FAR

KEY ISSUES

Starting in part 1 of this series, we developed a model for a sample Data Centre that used 50% of input energy for IT load. In part 2, you saw how to reduce the total energy use by about 25%, and improve the portion of energy used by the IT load to about 55% of total.

UPGRADED DATA CENTRE ENERGY MODEL

In part 2 of this series two key strategies to reduce energy usage were described:

- Infrastructure Performance improvements, including Air Management, Re-commissioning, UPS Loading, adjustments to target design conditions, and some operations management approaches (~10% energy saving).
- IT Equipment-based strategies, including the use of higher efficiency equipment, and the greater utilisation of that equipment through Virtualisation (~15% energy saving).

Starting from a Data Centre with a PUE (Power Usage Effectiveness) of 2, our sample Data Centre achieved a PUE of 1.88 over a reduced total energy usage of 25%. Of the total energy in the door, 55% is powering the IT load itself, up from 50% originally. Figure 1 shows a typical energy use break-up for the improved Data Centre model developed in part 2 of this series.

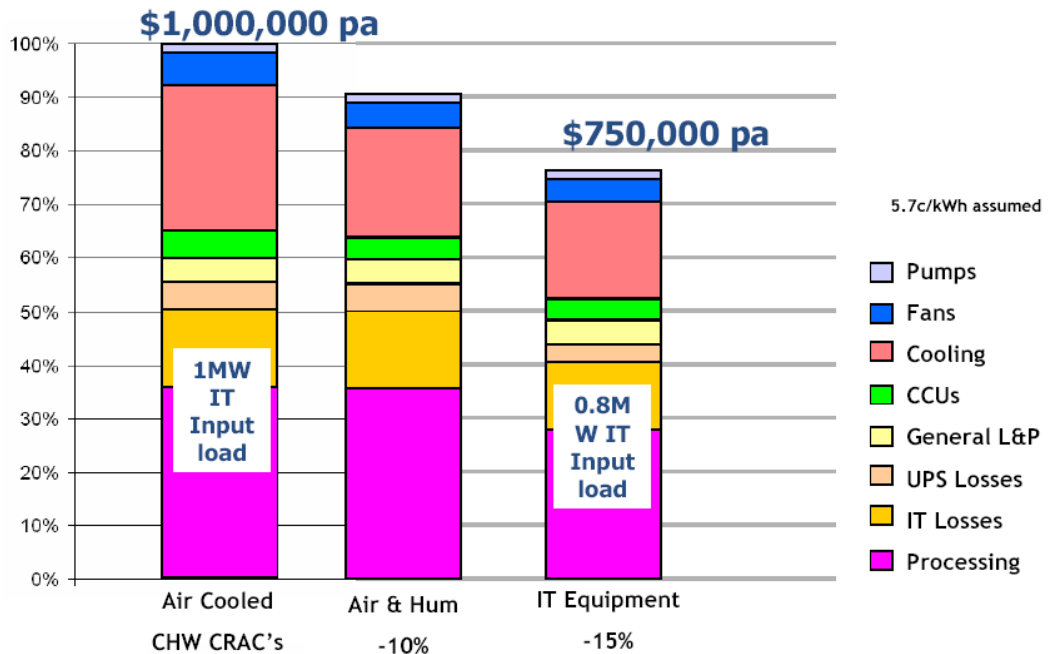


Figure 1 - Energy use in a sample “improved” Data Centre – 0.8MW IT load, PUE = 1.88



AIR CONDITIONING AND COOLING

KEY ISSUES

Cooling and related air conditioning systems remain a large part of the non-IT load within the sample Data Centre. The equipment used in your next Data Centre build can be selected for energy savings of another 15% to 20%, using:

- Higher efficiency Chillers
- Central air handling
- Free Cooling schemes, especially outside air.

There are some site-specific constraints on the use of the second and third of these.

REFRIGERATION

Looking back at Figure 1 above, the “Cooling” load category accounts for about 24% of the total load in our sample Data Centre.

If your next build choice is to be energy efficient, you’ll be looking at a Chilled Water cooled system, rather than an air-cooled split condenser CRAC based scheme. You will not have much need to reclaim heat losses from the chillers for heating use, so the most energy efficient Chiller available should be selected.

Figure 2 shows a collection of Chiller manufacturer data on relative efficiency of Chillers over the range of operating loads. The electrical kW (kWe) required to produce each refrigeration kW (kW_r) is plotted against the loading %. Pumps and cooling towers are included as part of the electrical load necessary (i.e. whole of system).

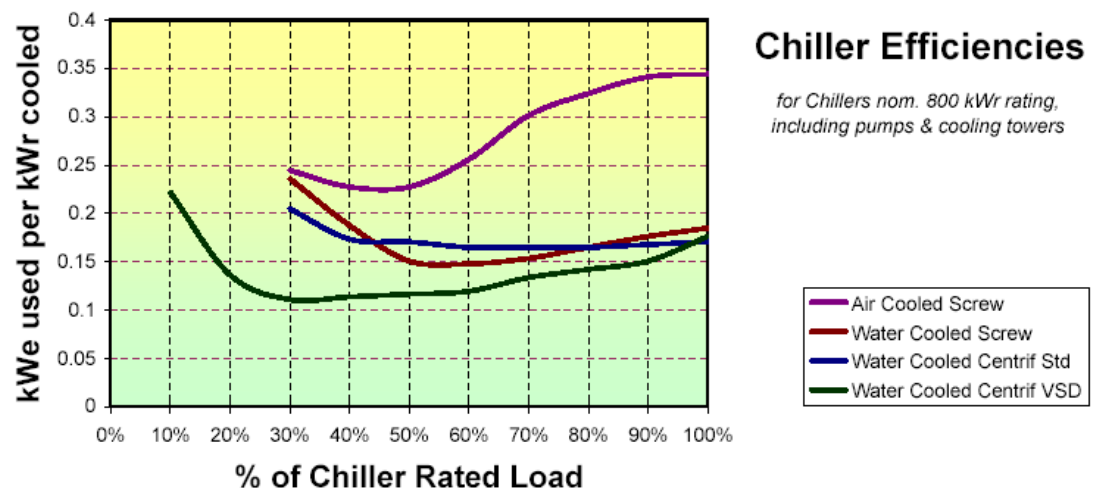


Figure 2 – Comparison of energy efficiencies of Chillers

A water-cooled variable speed drive Chiller is more energy efficient from two perspectives:

1. At a given load %, less kWe is required to create the cooling capacity, and



2. At a wide range of loads, the Chiller remains efficient

The first point is clearly desirable.

The second point is desirable where load varies. For an outside air scheme (discussed below), this is relevant. For your Data Centre today, efficiency over varying load may not be that important.

You can expect to achieve a 10% or more energy saving through optimum Chiller selection, compared to a standard water-cooled Chiller (more, when compared to an Air Cooled machine).

A brief note on using water cooled Chillers, versus Air Cooled Chillers. Water is consumed by the Cooling Tower in significant amounts depending on ambient conditions. The type of Cooling Tower selected, and the use of rainwater harvesting, can reduce this water usage.

AIR HANDLING SCHEMES

When selecting the air handling scheme for your next build, the energy savings measures discussed in Part 2 of this series need to be factored into the system design, and also drive aspects of the building design.

In part 2 we already concluded that a low ceiling, and a shallower raised floor, compromised energy efficiency. Figures 3 and 4 show two CFD sections for varying building profiles and the impact of varying ceiling height.

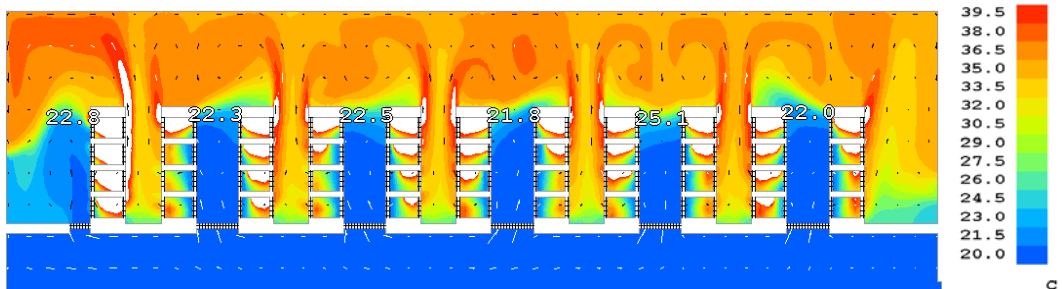


Figure 3 – Air Flow cross section for a Data Centre – 1100mm floor, 1800mm ceiling, 2.1kW/m²

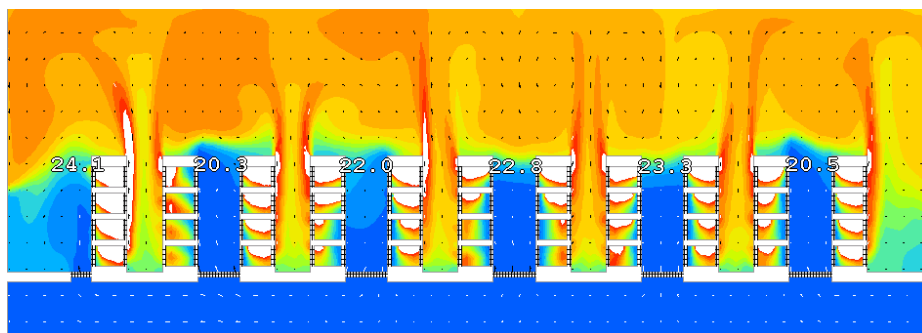


Figure 4 – Air Flow cross section for a Data Centre – 1100mm floor, 2800mm ceiling, 2.1kW/m²

Figure 3 shows a 5.8kW per rack (2100 W/m² 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.

Figure 4 shows the same scheme with an extra 1000mm ceiling above the racks. It's clear that using this higher ceiling creates less constriction in the return air path. This means less resistance, and less tendency for cold supply and hot return air to mix; that means less overall energy.

An important part of your next build is aligning the building profile with low energy usage objectives.

There is a good chance that your current Data Centre uses CRAC-type distributed air conditioning units, blowing into the floor plenum and arranged around the floor space. It's certainly possible to run these systems efficiently from an energy perspective.

However, you'll usually be able to squeeze a few more kW from your Data Centre's energy consumption by the use of a Central Air Handling scheme. This involves the use of large fans and ducts located in a central plant area, with return air ducted back to the equipment. The cost is comparable to a CRAC solution, assuming that you plan to build out capacity at the time of construction.

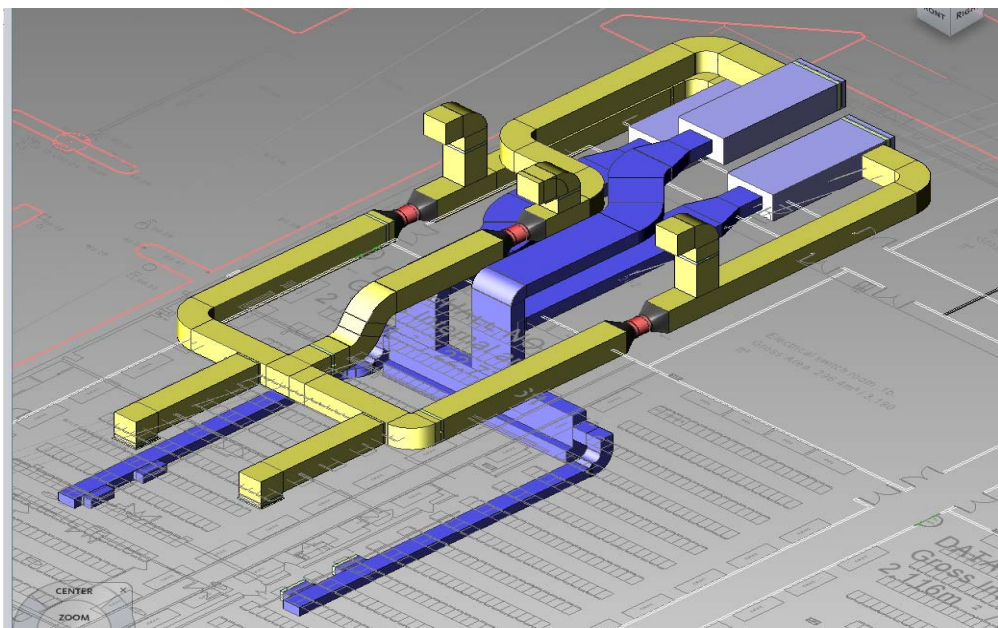


Figure 5 – Central Air Handling Scheme –ducted supply (blue) and return (yellow) air paths

An example is shown in Figure 5 above. Central Air Handling:

- Simplifies & reduces maintenance requirements, using more robust equipment.
- Reduces overall Fan energy required. Fans operate on a cubed law relationship between power in and air moved. Larger fans move air more efficiently per unit of kW used and permit greater scope for speed turn-down.
- Facilitates the use of redundant capacity to save more fan energy by turning down all fans on variable speed drives.



- Can be sized from day 1 to cater for future load increases with only fine tuning required to realise the cooling required for these increases.

Central Air Handling has been used successfully in many Data Centres worldwide. Before CRAC units became readily available, it was the norm. For example, in the case study of Bell South's operations in the 1970's quoted in Part 2, all large facilities used central air handling.

One of the key collateral benefits of using a central air handling plant is that it permits the easy use of Outside Air free cooling – more on that below. The overall energy balance needs to be analysed; if outside air free cooling is not used, CRACs may be, overall, more energy efficient depending on site conditions.

Ductwork schemes need to be carefully designed to reduce pressure drop (i.e. resistance), so that most advantage is taken of the energy saving opportunities.

Motors selected (for any fan) should be high efficiency, high quality type. The energy savings alone will offset any cost differential within a few years.

In areas of peak load density, it may be more efficient to introduce specific localised cooling schemes rather than size the central cooling system to handle very high loads across the whole Data Centre. A Central Air Handling plant should be capable of dealing with 1500-2000W/m² without difficulty. Higher densities become a balance between fan energy centrally versus locally.

For our overall model, we're going to assume that use of central air handling can deliver savings in energy use of 3%. The actual figure can be higher, but this value has been achieved on a number of different designs and is considered a realistic benchmark.

FREE COOLING SCHEMES

There are a number of potential "free cooling" schemes available for your next build, including:

- An Outside Air Cycle to cool using the ambient air available outside the building.
- Geo-exchange or Ground source cooling, using multiple deep bores to exchange heat with the ground.
- Water side economisers, using low ambient air temperature to delivery cool chilled water circuits.

If you have a need for heating of an office or other space attached to your Data Centre, you can recover heat from the condenser water system to do this.

A Geo-exchange system is feasible in lieu of Cooling Towers, and an excellent means of saving water consumption. However the system requires a lot of land that is, preferably, not below the Data Centre building. For the high loads involved, it becomes quite expensive. It's worth a look early in project evaluations, but we will not rely on it for this discussion.

Water side economisers are frequently used in cool climates as an option on Air Cooled Chillers which provide for direct heat transfer between chilled water return and ambient air. This arrangement is not normally viable in warm climates.



However, in the situation where elevated chilled water temperature is required, water side economisers offer substantial energy savings even in warm climates.

Normally the most attractive free cooling system in a warmer climate is an Outside Air Cycle or “air side” economiser. The air and water side economiser are not used together.

In the right climate, and with the selection of internal design temperature and humidity conditions to suit, an outside air cycle can deliver significant energy savings in cooling. Engineering is needed to:

- Analyse local climate dependencies
- Design air paths for low resistance
- Select suitable filters to scrub external air clean
- Control humidification efficiently - central, wider bands are preferred.

We’ll discuss the latter two in more detail in the next section.

A key operational advantage of outside air cycles are that they provide an emergency backup mode of ventilation if the refrigeration plant fails or requires maintenance shutdown. Air can still be circulated through the facility. At least one Telco with whom we’re familiar have taken advantage of this aspect in many of their larger sites.

On outside air cycle makes most sense with central air handling; it is difficult to engineer an energy efficient system using CRACs with outside air.

The sample UK design above shown in Figure 5 enabled a 25% saving in predicted energy use through the combination of central and outside air systems. In less favourable climate conditions, savings in the order of 10% should be achievable.

OUTSIDE AIR IN OPERATION

Firstly it should be noted that although the outside (fresh) air requirements for a Data Centre are not high, they remain a requirement. Whether a full outside air free cooling scheme is used or not, outside air has to be dealt with.

“Dealing” with outside air that is introduced into your Data Centre requires two views:

- Air temperature - the outside air has to be cooled if above the desired supply temperature, or mixed with return air if below it.
- Relative Humidity (RH) - outside air will often contain more moisture than you wish to introduce into your Data Centre (depending on your selected RH band).

If you are NOT using an outside air free cooling cycle, it’s desirable to not have to operate all of your plant to handle these issues. A separate outside air pre-conditioning plant will save energy by enabling the rest of the plant to operate at a higher chilled water temperature, reducing chiller energy use (assuming that your site’s ambient conditions don’t require you to do so anyway).

When you are using free outside air cooling, we noted above that the system needs to be engineered to:



- Select suitable filters to scrub external air clean
- Control humidification efficiently - central, wider bands are preferred.

Filtering the air is normally not a significantly different problem from what you would require without the outside air cycle, but it does need to be examined. In some locations, airborne particulates or pollutants need to be trapped as they are drawn inside.

The specification of an acceptable level of air pollutants for a Data Centre was studied by Berkeley Labs in 2006-2007, during a review of outside air cycle system performance. The US EPA annual health level was found to be typical of the standard of air quality required. That means there is no special level of filtering required for most locations.

Humidity control with outside air cycles is a more complex problem. The operating hours of an outside air system are driven largely by a choice between:

- When the external ambient conditions are within internal design conditions (temperature and relative humidity bands), and
- Otherwise, when it's still economical on an energy balance to adjust the outside air humidity levels to within the design conditions.

Both are local climate dependent. The first determines the portion of the base time that your outside air system can operate and deliver free cooling. The second determines whether it remains viable to use the outside air cycle outside this base time. The need for humidity control reduces the energy savings achieved with an outside air cycle.

The wider the humidity band accepted, the less of an energy penalty is imposed to stay within that band.

In part 1, we referred to a study across an Australian client's facilities into PUE. 11 of 12 facilities, are equipped with outside air cycles. In part 2, we cited one example where the correct functioning of the outside air cycle in a 2500m² Data Centre facility in southern Australia reduced energy usage by 15%. Another example of the energy savings gained from the same study:

- An 800m² Telco facility in Brisbane equipped with outside air cycle demonstrated a PUE of 1.75 with outside air operating, during the cooler months, and a PUE of 2.03 during warmer months when it was inactive due to unsuitable external conditions.



POWER SYSTEMS

KEY ISSUES

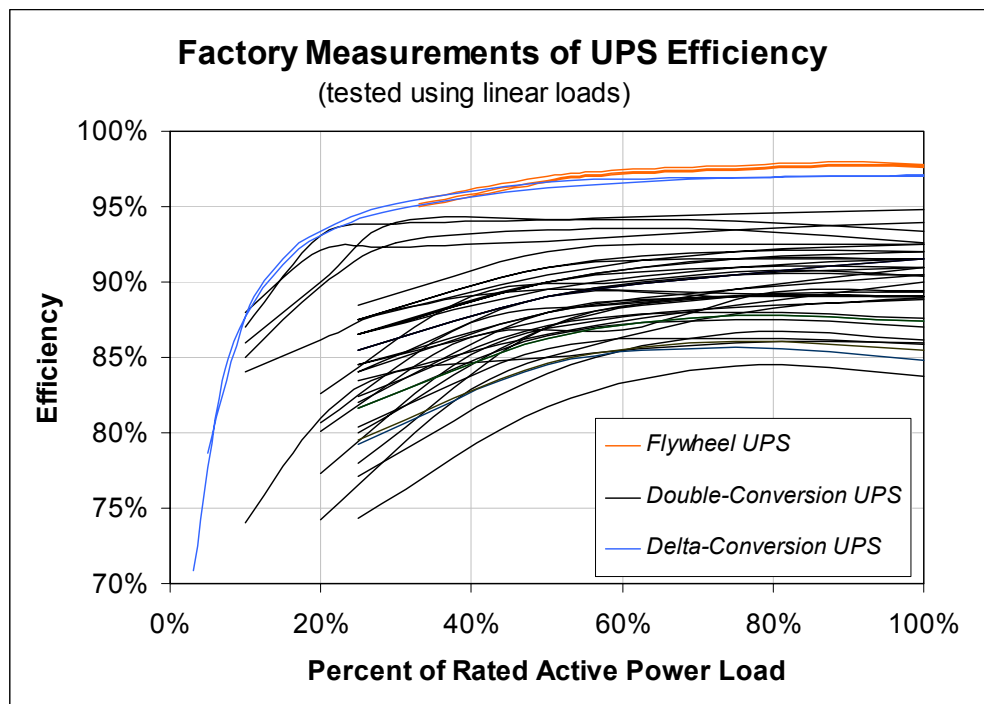
There are energy savings opportunities on the Power system side as well. The conventional aspects relate to selecting low-loss components, cables, and equipment, thereby reducing overall heat that must be cooled as well as the direct losses themselves. The UPS is a primary target for energy savings.

On the more pro-active side, a Co-Generation plant offers the ability to enhance the overall efficiency of the grid to chip power cycle that we analysed in part 1 of this series. Whereas the conventional grid system delivers power to your Data Centre from its primary energy source at an efficiency of about 30%, a Co-Generation plant can achieve a 70% or better overall efficiency.

UPS CONFIGURATION

In part 2 of this series we examined the impact of energy conversions within the UPS, and the relative efficiency of UPS as load varies. We aimed to select our UPS to maximise their loading, thereby raising their overall efficiency. That might not be feasible in an existing site in your case, but for a “new build” the UPS configuration can be selected specifically for higher plant utilisation.

Figure 6 presents a plot of factory measurements of UPS Efficiency.



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

Figure 6 – UPS efficiency at varying loads

A common approach to UPS redundancy is to parallel multiple modules together to create a plant of the required sized, with one module a “standby” (i.e. n+1). You



might then take two of these plants and configure them in an “A and B” power path scheme.

That means that your UPS modules are operating at or below 40 to 50% utilisation.

You can see in Figure 6 that Delta Conversion and Rotary / Flywheel systems are more energy efficient than conventional double-conversion systems (static UPS). An improvement in losses from 85% to 95% is significant, because over 50% of your total load is your IT load, which is being powered through the UPS.

ELECTRICAL EQUIPMENT SELECTIONS

Assuming that the UPS is at optimum already for your “new build” site, and within the system dependability constraints you have decided upon, what other opportunities are there in electrical equipment selections?

ALL electrical equipment has inherent losses. In part 1 of this series we mapped the losses from Grid to Chip, and showed the impact of major electrical components as part of that plot. The major non-IT losses beyond the UPS and outside the IT equipment that are still costing you energy (and money) are:

- Transformer efficiency
- Low loss cables
- Low power lighting
- Occupancy-based lighting

Selecting each of these for lowest practical energy loss should enable you to squeeze a few more % energy efficiency from your new build Data Centre.

CO-GENERATION

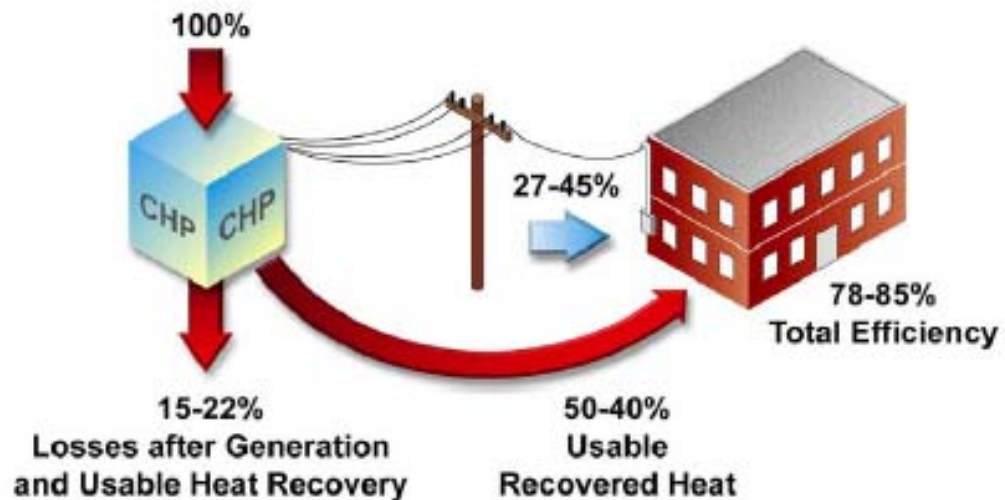
Co-Generation may mean different schemes in different contexts. A fuel is used to generate power, and heat is recovered and used for a process. This is a Combined Heat and Power (CHP) plant. In the context of a Data Centre, we are talking about using an incoming fuel supply to generate POWER and COOLING. We’re generally not interested in the recovered heat as an output (but we do make use of it for cooling).

The first thing to recognise about Co-Generation in a Data Centre is that it can be a replacement or supplement to an incoming grid-powered supply. It is NOT a standby power supply, unless you decide to use two different fuel sources for your generators. You would still expect to have a diesel or other fuel driven standby power plant, as well as the Co-Generation plant. It may of course be feasible to recover heat from the standby plant as well as the Co-Generation plant. Electric driven backup Chillers need to be considered as part of the standby plant solution.

Recovered heat is used in Absorption Chillers to generate cooling. The ratio of power to cooling generated varies according to technology selection. You can expect a ratio that suits most Data Centre applications reasonably well. One service provider in Australia quotes approximately 1.4 to 1.5 Power to Cooling from a gas-fired Co-Generation plant.



Figure 7 illustrates one view of the overall process efficiency. Other accounting or process details give overall efficiencies that vary from about 70% upwards.



Source: Caterpillar & US Midwest CHP Centre

Figure 7 – Co-generation - typical overall process efficiency

Reliability and availability of a fuel supply are required, of course. Considering Co-Generation opens the availability of gas INSTEAD of utility power as a site criteria. Whilst a Co-Generation plant may be expensive, reticulating high voltage cabling to a specific location or having to augment existing utility network capacity can also be expensive. The economics of one choice against another has to be considered in conjunction with the overall energy situation.

Gas is the first fuel considered in many applications. There are also a number of viable renewable fuels such as bio-diesel or bio-gas from waste management streams. Environmentally, the emissions from a co-generation plant operated on gas are generally an improvement on central generation using conventional coal. Using renewable fuels offers an added benefit.

The dependability of a Co-Generation plant involves both electrical and cooling plant aspects. The Mueller Energy Centre in Austin, Texas USA serves a critical hospital load and solved these concerns by:

- Using N+2 redundancy on the primary generating sets, with diesel backup sets and an incoming utility supply
- Using N+2 Chilled water cooling comprising a heat recovery Chiller, an electric Chiller, and Chilled water storage to retain the ability to deliver Chilled Water during handover between primary and standby sources.



GREEN DATA CENTRE PERFORMANCE – NEXT BUILD

KEY ISSUES

With your next build, you have access to energy saving in cooling plant and power plant. The total of those discussed in this White Paper are capable of delivering in over 20% on the cooling side, and about 10% on the power side within the Data Centre.

Co-Generation provides a further opportunity for overall grid efficiency and other environmental benefits.

A GREEN DATA CENTRE ENERGY MODEL

From our improvements in Part 2 of this series, we took up a 25% energy reduction. We reduced a \$1,000,000 pa energy bill to \$750,000pa.

From that point on in this Part 3, you've seen where further energy savings of 10% using energy-efficient Chillers, 10% on outside air free cooling, and about 3% on central air handling can further improve your energy bottom line.

You've also got a suite of power-related improvements in UPS and low loss electrical equipment that are capable of 10% more savings relative to the part of the Data Centre load that they make up.

If we now take on the more significant cooling energy savings, our energy model for a green Data Centre is shown in Figure 8.

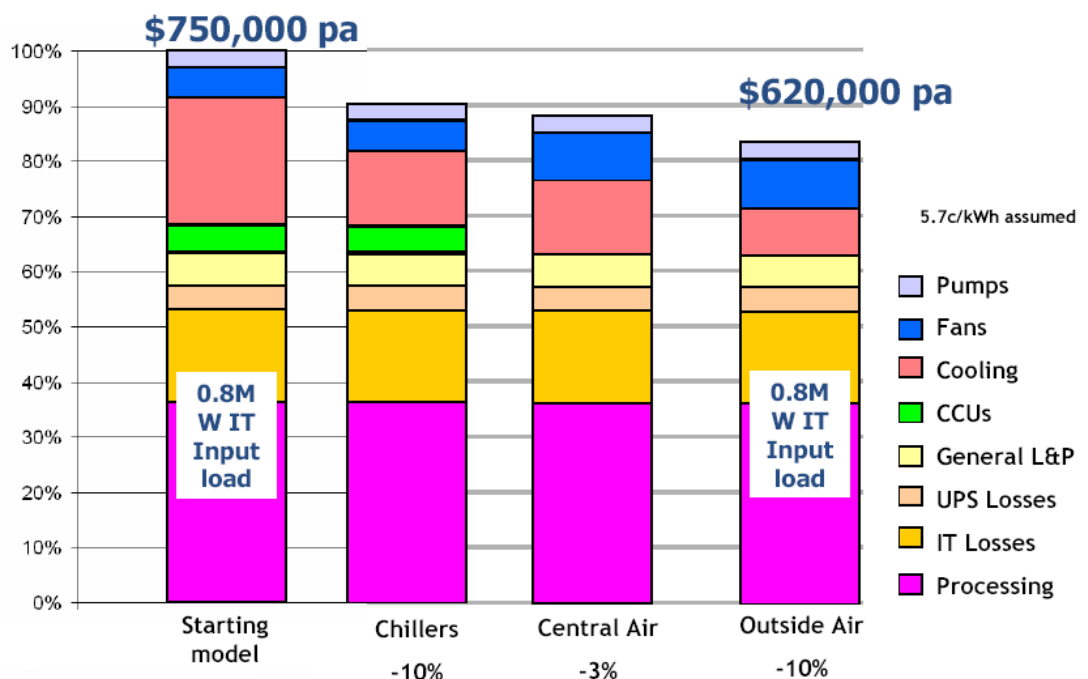


Figure 8 - Energy use in a sample Green Data Centre – 0.8MW IT load, PUE = 1.55



From the starting point of Part 1 and a PUE of 2, your Data Centre is saving about 40% of its original energy usage, and your energy bill has reduced by \$380,000 per annum.

Co-Generation provides opportunity to resolve incoming site power availability obstacles for your next build, whilst also having an overall positive impact on the energy big picture, from the Grid to your IT Chip.

DIRECT COOLING SYSTEMS

Although we have not taken up any energy savings from direct cooling systems in our model, it's worth considering what the opportunities are. We still have about 10% of total energy use in our model above being consumed by fans.

In the 1980's and early 1990's, large mainframe computers cooled by direct chilled water (such as the IBM 3090 series machines) were common sights in Data Centres. Higher speed and lower power mainframes like the CMOS mainframes replaced these, and the lower heat output meant a return to air cooled equipment (which is simpler).

Since the internet and server-based processing expanded, larger machines have become less common, but we have stayed with the air cooled model by and large. As load density rises, however, the attractive features of air cooling are overtaken by it's limitations.

There are a number of products that deliver air to equipment using less fan energy, by having the cooling equipment right at the rack or even being the rack itself. These strategies are usually worth a good look for dealing with high density loads that cannot be served by a "base system" such as a sub-floor plenum air cooling scheme. Many use gas refrigerant (including typical Chiller-type gasses, as well as CO₂). They serve equipment that wants its cooling delivered through an air stream.

The relative inefficiency of air remains a limitation, so a number of major equipment vendors are moving back towards direct cooling of their devices. From an energy point of view, potential savings are significant and include:

- Lower pumping energy use (fan vs. refrigerant pump)
- Cooling delivered at the heat source, minimising the heat transfer loops that are otherwise required (from five to two). Every transfer loop has losses. Eliminating these losses improves efficiency overall.
- Where used within an otherwise air-cooled environment, reduced mixing of heating loads into the "general space" enables the air cooling systems to operate at their optimum efficiency.

The use of direct cooled equipment can deliver significant energy savings. Use of direct cooled equipment provides an opportunity to reduce the 10% energy bill for fans to a few % only, depending on the mix of equipment being deployed.



CONCLUSION

The US EPA's August 2007 highlighted the impact of trends in Data Centre energy usage and was a call to action for the industry. In this 3 part series of White Papers, you've seen how to get to the "Best Practice" point indicated in Figure 9, by taking on only a part of the potential energy savings available.

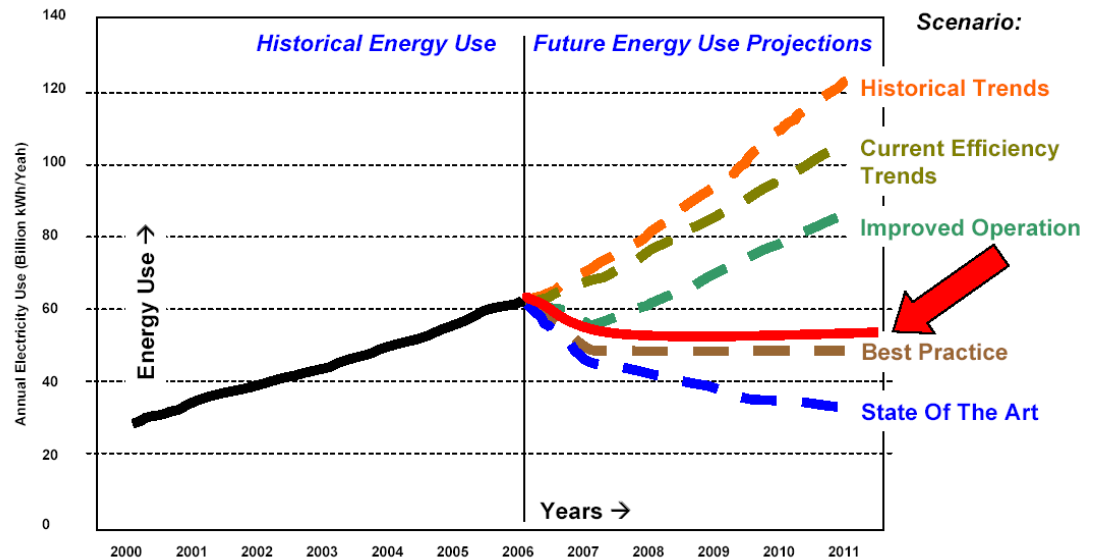


Figure 9 – Environmental scorecard so far – Improvements to Best Practice

The US EPA benchmarks for future Data Centres have been shown to be achievable, affordable, and worthwhile.

You've seen that we can go further. We are still using about 25% of the power coming into the door just to keep the IT kit warm and ticking (not doing any useful work).

We have not discussed opportunities that are not commercially "mainstream" in 2007/2008. But the drive for change is increasingly making these a reality. For more information on these aspects, [click here to find out more about these future trends](#).

The risks involved in Green Data Centre can also be great opportunities. It is important that change leadership for energy usage in Data Centres comes from within the industry, so that the directions adopted can be considered in an operational and practical context before they are imposed by regulatory authorities.

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



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Since 1995, Rowan has been a key contributor within NDY's Data Centre design teams, with over 125,000m² 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.



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Patrick leads NDY's UK operations and is a prominent figure in Data Centre projects across Europe, with experience in over 150,000m² 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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This White Paper is for information only. Before adopting any strategies described, professional advice should be sought related to your specific situation.

