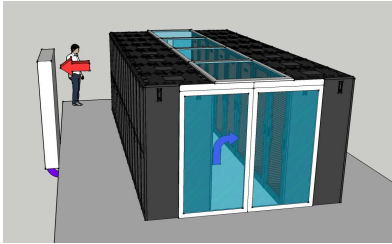
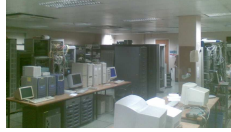


Data Centre Efficiency



How much power?!

- The US EPA found in 2006 data centres used 1.5% of total US consumption (5)
- For Bangor University data centres use approximately 5 - 10% of the total university electricity consumption.
- Load doubling every 6 years (6) - consistent with Bangor University historical data.



How much Money?!

- Assume 100kW load & poor data centre
– (Bangor University data load about 80kVA)
- Total load approx 250kW
- £260,000 per annum
– (electricity £0.117/kWh)



Carbon Reduction Commitment (CRC)

- Starts today (April)
- Includes most Universities (7) [>6000MWh]
- Approx £0.006/kWh
– But they pay some back
- Emitting less carbon:
 - Reduced Energy bills
 - Earning profit – upper part of CRC league table
 - Prestige and media coverage



Summary so far

- Data centres use a lot of power
- That costs a lot of money
- It will cost even more under CRC unless savings can be made
- CRC league table
 - Kudos + cash or shame + bill?



Data Centre Efficiency is like Onions...

- Infrastructure Efficiency (PUE / DCiE) [40% eff]
 - How many watts consumed per IT load watt
- Server “infrastructure” efficiency [70% eff]
 - How much CPU power per server watt
- Utilisation efficiency [20% eff]
 - Percentage of server time performing function
- Process efficiency [? loss]
 - Amount of processor time required to perform function



Power Usage Effectiveness (PUE) and Datacentre Infrastructure Efficiency (DCiE)

$$PUE = \frac{TotalPower}{ITEquipmentPower}$$

$$DCiE = \frac{ITEquipmentPower}{TotalPower} * 100\%$$



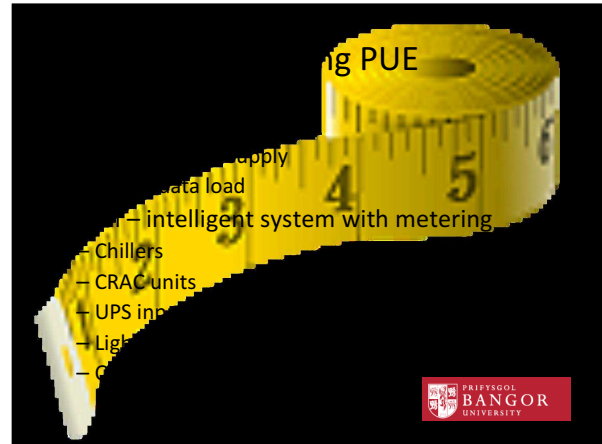
PUE – Typical Values

	PUE
Poor Data Centre (1)	3+
Typical (2)	2+
Good Data Centre (2)	1.3
State-of-the-art (2)	1.2
Free Air (3)	1.05

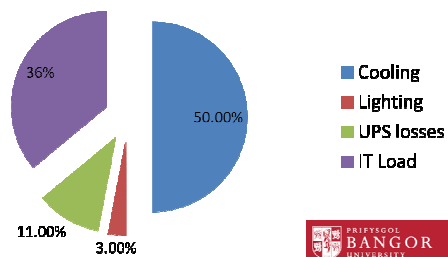


Power Usage Effectiveness (PUE)

- Advantages
 - Easy to Understand
 - Easy to calculate
 - Allows easy inter-site comparison
- Disadvantages
 - Does not measure efficiency of IT equipment
 - Does not measure utilisation of IT equipment
 - Does not allow for redundancy (tier)
 - Does not allow for local conditions
 - Does not allow for using waste heat



Where does the power go? (6)



Areas of improvement

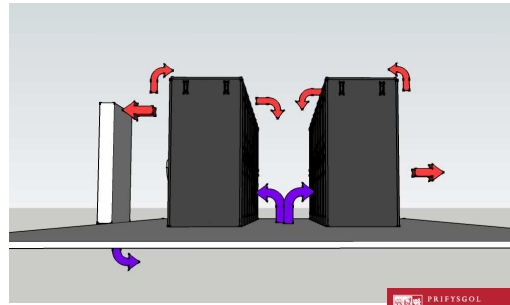
- Cooling
 - Machine room air handling
 - Much less pumping heat up hill
 - Reduced power running fans
 - “Free” cooling schemes
 - For good results do air handling first
- UPS
 - Consider replacement and operating mode
- Lighting
 - Consider replacement and operating mode



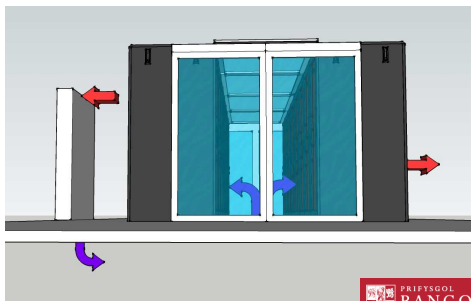
How NOT to cool your data centre



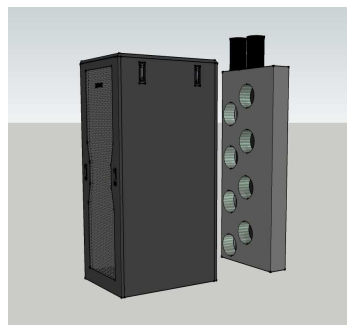
Hot and cold aisle



Aisle containment



Small scale containment



Either capture hot air with fan door or heat with water cooled door

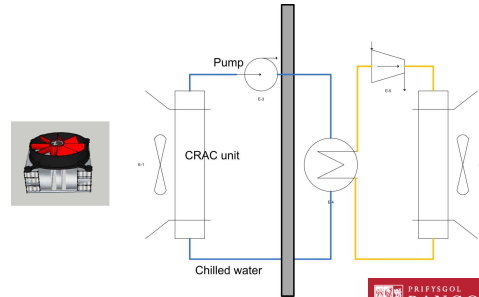


Why Containment

- Allows much better control of inlet air temperature
 - This allows much higher air inlet temperature without equipment overheating
 - Makes free cooling solutions viable
 - Makes traditional air conditioning more efficient



Standard Cooling

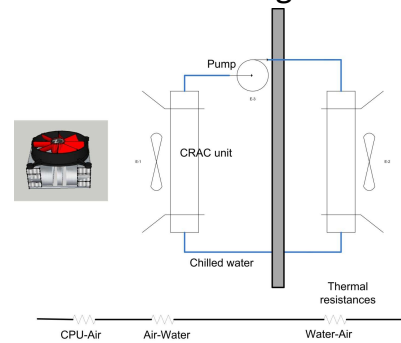


Efficiency Measures – Std Cooling

- Temperature
 - Use high air inlet temperature
 - Too high can reduce efficiency – server fan power
 - Use high chilled water temperature
- CRAC units
 - Run fans using Variable Frequency Drives
- Chillers
 - Avoid over provisioning
 - Select chillers with good part load COP



Free cooling

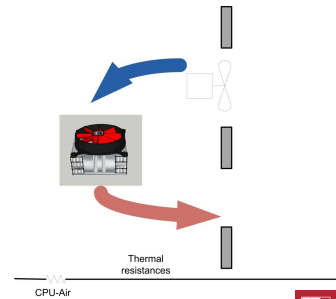


Free Cooling

- Advantages
 - Viable for most of year in UK
 - Maintains clean air in data room
 - PUE 1.2 or better achievable
- Disadvantages
 - Needs backup chilled water plant
 - “Oversized” components give more free cooling days
 - More expensive to install than traditional



Free air cooling



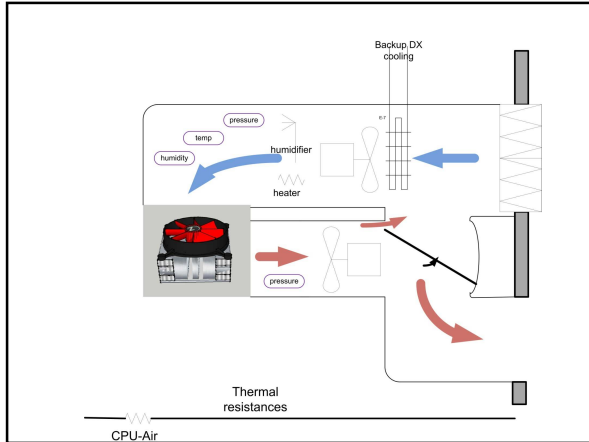
Example of Free Air Cooling



Free Air Cooling

- Advantages
 - Very Simple
 - Highly efficient – Sun demo PUE=1.05 (3)
 - Cheap
- Disadvantages
 - Limited temperature control
 - No humidity control
 - Air quality





Free air solution – Weatherite(7)



Also available from
NexusEco (8) and
IMA cooling systems (9)

IMA off adiabatic backup
Cooling



Cooling improvements summary

- Containment is vital for high efficiency
- Consider free cooling options
- Free air cooling is a commercial option



UPS efficiency

- Old UPSs typically 85-88%
 - Bangor Uni UPS 90% at 50% load – 6 years old
- Current best of breed examples
 - 96% (Riello MP120)
 - 94% (Chloride 80-Net)
- Electricity cost (100kW load /annum)
 - 85% £18,000
 - 90% £11,500
 - 96% £4,500



UPS efficiency

- UPS load typically 20 – 30% dual redundant
 - Even lower efficiencies for old UPS
- Consider using “eco” settings (line interactive) not dual conversion.
- Consider modular UPS
 - No need for excess capacity as installed
 - Decreased initial investment
 - Increased efficiency



Gamatronic
Power+ Mega
25kW/module
(10)



Lighting efficiency

- LED racks – resist the temptation!
- CFL ballasts in modern fittings
- Incandescent (100W) – 2%
- Compact fluorescent, magnetic – 9%
- Compact fluorescent, electronic – 20%
- LED – 30%
- Motion sensor lights



Other Measures

- Supply IT load with DC
- Fit batteries in servers, eliminate UPS
- Eliminate server fans
- Tri-generation
- Waste heat re-use
- Biomass



Summary - Infrastructure

- Cooling
 - Sort out machine room air handling
 - Consider chiller replacement
- UPS
 - Consider management and economic UPS replacement
- Lighting
 - Consider lighting control and economics lighting replacement
- Funding
 - Tricky when IT Services pay for the upgrades but Estates pays the electricity bill



Better Measures of Efficiency

$$DCeP = \frac{\text{UsefulWork}}{\text{EnergyCons}} \cdot \frac{(\text{SumTasks} * \text{ValueTasks}) * \text{Utility} * \text{AbsTime}}{\text{EnergyCons}}$$

SumTasks – Number of tasks performed, e.g. web pages served

ValueTasks – Weight tasks according to corporate aims

Utility – Weighting tasks for meeting SLA

AbsTime – Time interval, at least twenty times mean run time



DCeP

- Advantages
 - Measures actual productivity
- Disadvantages
 - Site Specific
 - No PR value
 - Difficult to measure relative success
 - May be difficult to measure



Proxies for Data Centre Efficiency (4)

- Approximate efficiency spanning more layers of the onion
- Avoid limitations of DCeP

Useful work and self-assessment	DCeP subset by productivity
DCeP by sample workload	Bits per kWh
Weighted CPU utilisation SPECint_rate	Weighted CPU utilisation SPECpower
Compute units/second trend curve	Operating system workload efficiency



Data Centre Efficiency is like Onions...

- Infrastructure Efficiency (PUE / DCIE) [50% loss]
 - How many watts consumed per IT load watt
- Server “infrastructure” efficiency [30% loss]
 - How much CPU power per server watt
- Utilisation efficiency [80% loss]
 - Percentage of server time performing function
- Process efficiency [? loss]
 - Amount of processor time required to perform function



Proxies for Data Centre Efficiency (4)

- Weighted CPU Utilisation

$$\text{Proxy}_{\text{SPECint}} = \frac{T * \sum_{i=1}^n \left(U_{\text{AVG}} * B_i * \left(\frac{\text{Clk}_i}{\text{Clk} - B_i} \right) \right)}{E_{\text{DC}}}$$

T=time window
U_{AVG}=Average CPU utilisation
B_i=Server benchmark (SPECint_rate2000 or SPECint_rate2006)

Improving Proxy_SPECint

- Select efficient servers (typ 25% saving(5))
- Minimise idle time (typ 85% idle (5))
 - Server virtualisation
 - Resist over-provisioning
 - Switch off or virtualise legacy machines
- Minimise part load power consumption
 - Look at SPECpower & compare at part load (typ idle power >60% full load power (5))



Proxies for Data Centre Efficiency (4)

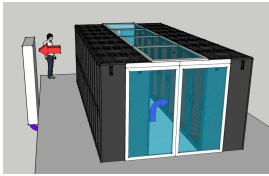
- Weighted CPU Utilisation
 - No software modifications required
 - Site to site comparisons possible
 - No weighting of time criticality or utility
 - OS overhead counted as useful work



Data Centre Efficiency not new to



Questions?



References

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- (3) Sun – Free Air Cooling Proof of Concept - <http://wikis.sun.com/display/freeaircooling/Free+Air+Cooling+Proof+of+Concept>
- (4) The Green Grid - <http://www.thegreengrid.org/~media/WhitePapers/White Paper 17 - Proxies Proposals for Measuring Data Center Efficiencyv2.ashx?lang=en>

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- (7) Weatherite – <http://www.weatherite-group.com>

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