Ark Continuity - Continuously Delivering high integrity data centres

# PUE Vs WUF?

## Comparative Water-usage in low PUE Data Centre Designs

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Ark Continuity delivers high integrity data centres for Government and Corporate occupiers. Ark is now building data centre campus locations at Spring Park, Wiltshire and Cody Park, Hampshire. Data Centre SQ17, module one, is now operational. All facilities are designed to be the most secure, available and sustainable in Europe.

This document is one in a series of white papers prepared by Ark Continuity. If you would like further information, please contact Ark Continuity on 0845 389 3355 or visit www.arkcontinuity.co.uk



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## Summary

At first sight the water consumption of Data Centres that utilise conditioned fresh-air as the primary source of cooling is far higher (up to 1000x) than traditional closed-circuit designs.

This paper will explore the difference between the two architectures against a UK setting and go on to demonstrate that the overall water-usage, from raw fuel extraction through fuel-processing and electrical power generation to consumption, is lower than for the fresh-air cooled solutions. The importance of room humidity set-point to limit water consumption, electrostatic discharge and rain-water harvesting is also highlighted.

## Background

The Green Grid, innovator of the PUE metric, has recently proposed the introduction of a new data-centre metric - WUF, Water Usage Factor. Data Centres in North America have traditionally had a high water usage due to their preference for water tower based heat rejection systems and, as PUE's drive lower, various 'Green Preferati' have started to target Data Centres for water consumption as well as electrical energy use.

For traditionally designed European facilities (such as the 12MVA 'SQ17' development of Ark Continuity Limited in Wiltshire) water is used for humidification, but the electrically driven chillers are air-cooled. There is a long history in the UK of a perceived link between water-towers and legionella outbreaks and the threat of having your data facility shut-down because its water-based cooling tower plant is found to (or is suspected of) contain legionella bacteria is generally regarded as an unacceptable risk. The same level of legionella cases (per capita) exists in North America but outbreaks do not automatically result in closing down local cooling-towers and good chemical water treatment routines are a highly developed activity for facility managers.

However, in pursuit of an ever lower PUE, the advent of fresh-air cooling solutions (enabled by the 2008 revision of environmental limits of ASHRAE) has brought along with it adiabatic cooling solutions, where water is used to take advantage of the wet-bulb ambient temperature and, crucially, humidification of high volumes of fresh-air. Perhaps for the first time in Europe, water consumption in Data Centres may be a growing issue.

Ark Continuity, with data centre campus sites in Corsham and Farnborough, are building alternative design solutions (aligned to different market segments) on each site and it is the difference between these two solutions that is explored in this white paper. The 12MVA Corsham facility and its counterpart development in Farnborough are both high security (IL6) Tier III or IV solutions with raised floor, chilled-water and free-cooling air-cooled chillers.

In contrast to those are a series of multiple 10MVA fresh-air solutions (IL3, Tier III) with full DX back-up, without a raised floor, has been designed by the Ark engineering team and construction has commenced. With 114MVA grid capacity available in Corsham and more than 40MVA in Farnborough, together with existing diverse fibre and planning permits, the race to populate both sites with the alternative designs, based on client demands, has started.

## Water Consumption in a Fresh- Air Based Cooling System

With an external ambient design temperature of 35°C, a typical Southern England humidity profile and a cold-aisle delivery condition of 18°C/45%RH-24°C/65%RH the 'fresh-air' data-centre design will use water for adiabatic cooling and air-humidification.

The adiabatic cooling in the air-treatment system will use approximately 100 Litres of water per year per kW of IT load. In a deployment for 1MW IT load, realistically running at 70% of full-load, this equates to 70,000 Litres/year – equivalent to flushing an average UK domestic toilet once an hour.

In common with all fresh-air based systems there is a much higher figure for water used for the humidification of the air fed to the critical space. However the consumption depends upon the external conditions and the required room conditions and can be minimised if the full extents of ASHRAE TC9.9 2008 'allowable' humidity limits are applied.

The base design in Ark's 'fresh-air' product is based on a minimum Relative Humidity of 45% and, at that condition will use approximately 970 Litres/year/kW of IT load compared to 9 Litres/year/kW in a conventional CRAC/raised-floor design. At 70% of a 1MW IT planned load capacity this is 680,000L/year, 78 Litres/hour – equivalent to flushing a toilet every 6 minutes.

**Table 1** (right) shows the relationship between room supply air conditions and water usage. The relaxation of the room condition to the 'allowable' humidity of ASHRAE TC9.9 reduces the local water consumption by a factor approaching 10.

**Humidification of fresh-air in the UK**

| Room supply air conditions Min | Max | | Annual water usage Litres/1MW IT Load |
|---|---|---|---|
| 18°C/45%RH | 24°C/65%RH | | 970,000 |
| 18°C/40%RH | 24°C/65%RH | | 582,000 |
| 18°C/20%RH | 24°C/80%RH | [1] | 99,000 |

Including 20% blow-down

Note [1]: Full Allowable ASHREA humidity range

**Table 1**

## Mitigation of the Water Consumption

## Water Used for Cooling

The fresh-air based adiabatic cooling system enables the Ark facility PUE to be reduced from an industry average of 2.0 to an annualised average of less than 1.2. In this way the total kWh drawn from the grid is reduced by 7MWh per year per kW of IT load.

The average UK power station 'uses' water (mainly evaporation loss in those utilising cooling towers) at a minimum rate of 0.35L/kWh and a maximum rate of around 6L/kWh, depending upon the type of fuel and cooling arrangement.[1]

[1] www.leonardo-energy.org, Article by Bruno Wachter: '*Water use in thermoelectric power stations*' created 03/04/03 and accessed 21/10/10

However the water usage in fuel extraction and subsequent processing is considerable and **Table 2** (below) combines all phases of the fuel-generation cycle with the (2008) UK fuel mix to reach an average water consumption of 1,585L/MWh.

**UK Power Generation: Estimated 'End-to-End' Water Usage**

| Fuel | UK Mix | Raw Material L/MWh | | Fuel Processing L/MWh | | Power Generation L/MWh | | Total Fuel Cycle L/MWh | |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | Min | Max | Min | Max |
| Coal | 33.3% | 20 | 270 | 504 | 792 | 1137 | 1820 | 553 | 960 |
| Oil | 1.2% | 10.8 | 25.2 | 90 | 234 | 379 | 682 | 6 | 11 |
| Natural Gas | 39.9% | 130 | 194 | 25.2 | 25.2 | 379 | 682 | 213 | 360 |
| Nuclear | 20.2% | Incl | Incl | 170 | 570 | 1516 | 1516[1] | 341 | 421 |
| Hydro | 1.9% | 0 | 0 | 0 | 0 | 5420 | 5420 | 103 | 103 |
| Wind | 0.5% | 0 | 0 | 0 | 0 | 1 | 1 | 0.01 | 0.01 |
| All other Renewables | 3.0% | 0 | 0 | 169 | 180 | 1137 | 1820 | 39 | 60 |
| Totals | 100% | | | | | | | 1255 | 1915 |

**Average Water Usage in UK Power Generation = 1585 L/MWh**

Sources:
Nuclear Energy Institute factsheet using EPRI data and other sources
US DoE, Energy Demand on Water Resources Reprt to Congress, December 2006
http://en.wikipedia.org/wiki/ Environmental_concerns_with_electricity_generation Accessed 18/11/10
Note [1]: Assumed once-through coastal cooling rather than the higher consumption of cooling towers

**Table 2**

Taking the 'average' figure we can show that the lower PUE achieved by utilising the fresh-air cooling solution uses 99,000 (20%RH) Litres of water locally but saves 11,095,000 Litres of water in the power station – a factor of over 100.

## Water Used for Humidification

The 'fresh-air' design uses approximately 100 times the amount of water locally as a conventional 'closed-circuit' data-centre. If humidity control is relaxed (to the 2008 ASHRAE allowable limits of 20-80%) then both solutions can reduce their absolute consumption but the 100:1 proportion approximately remains.

This is an apparent 'downside' of fresh-air systems. However a similar argument for the water saved in the power station (based on the enabling of low PUE) can be made. If the humidity control is relaxed then 'equivalence' can be calculated.

If this calculation is accepted it must be considered that power-stations do not use potable water – sourced from either river (with cooling towers) or sea (once-through, without cooling towers). **Table 3** (below) summarises the water usage in delivering electrical power per MW of IT load compared to the facilities' annualised PUE. Four typical PUE examples are noted in this table, from the 1.2 'fresh-air' solution to the 2.5 'legacy' data-centre of pre-2005.

**Water Usage in grid power Vs Facilty PUE for 1MW IT Load**

Average Water Usage in UK Power Generation = 1585 L/MWh

1 MW = 8760 MWh/annum

| PUE | MWh/annum | | Metric Tons of Water/annum |
|---|---|---|---|
| 1.1 | 9,636 | | 15,272 |
| 1.2 | 10,512 | Architecture #1 | 16,660 |
| 1.3 | 11,388 | | 18,048 |
| 1.4 | 12,264 | | 19,437 |
| 1.5 | 13,140 | Architecture #2 | 20,825 |
| 1.6 | 14,016 | | 22,213 |
| 1.7 | 14,892 | | 23,602 |
| 1.8 | 15,768 | | 24,990 |
| 1.9 | 16,644 | | 26,378 |
| 2 | 17,520 | Industry Average | 27,766 |
| 2.1 | 18,396 | | 29,155 |
| 2.2 | 19,272 | | 30,543 |
| 2.3 | 20,148 | | 31,931 |
| 2.4 | 21,024 | | 33,320 |
| 2.5 | 21,900 | Legacy Average | 34,708 |

| | |
|---|---|
| Architecture #1 | Fresh-Air Cooling with full EU CoC Best Practice compliance |
| Architecture #2 | Free-Cooling Chillers with most of EU CoC Best Practice |
| Industry Average | Chilled water, raised floor, no containment |
| Legacy Average | Pre 2005 designs running at <60% load |

**Table 3**

In **Table 4** (right) the ‘end-to-end’ water usage is estimated for the various data-centre cooling designs and room conditions.

Ideally any ‘fresh-air’ data-centre design and its operation must have rain-water harvesting as part of its infrastructure as the power & resources used in the production and distribution of potable water have not been taken into account in this paper.

**End-to-End Data-Centre Water Usage, Tons/annum for 1MW IT Load**

| Data-Centre Topology | Room RH% | Grid | Adiabatic Cooling | Humidification | Total |
|---|---|---|---|---|---|
| Architecture #1 | 45%-65% | 16,660 | 100 | 970 | 17,730 |
| Architecture #1 | 40%-65% | 16,660 | 100 | 582 | 17,342 |
| Architecture #1 | 20%-80% | 16,660 | 100 | 99 | 16,859 |
| Architecture #2 | 55%±5% | 20,825 | - | 9 | 20,834 |
| Industry Average | 55%±5% | 27,766 | - | 9 | 27,775 |
| Legacy Average | 55%±5% | 34,708 | - | 9 | 34,717 |

Note that in Architecture #1 there is no appreciable advantage in allowing 80%RH

**Table 4**

## Static- Electricity & Electrostatic Discharge (ESD)

With the lower humidity limits allowed by ASHRAE it is clear that IT personnel working inside the data-rooms will have to pay closer attention to static-electricity control (wrist-bands etc). However, ASHRAE found that ESD is related to dew point (absolute humidity) rather than Relative Humidity. To cover for this condition the lower operating points for humidity in ASHRAE are now based on dew-point rather than RH. The 2008 dew-point limits are 5.5°C to 15°C – which corresponds to 44%RH/18°C and 25%RH/27°C, hence the adoption by Ark of 45%RH/18°C as our lower environmental set-point condition.

## Upper Temperature Limits

ASHRAE allowable upper temperature is 27°C. However, as pointed out in ANSI/TIA-942-2 (March 2010), operating higher than 25°C (with the current generation of Class 1 servers) can have a detrimental effect on server-fan power/noise. It is recommended that the IT OEMs should be consulted when considering ambient inlet temperatures near to 27°C, hence the adoption by engineers at Ark of 24°C/65%RH as the upper environmental set-point condition.

## Conclusions

In all cases it can be seen that Data Centres with fresh-air designs use less water (and less power) overall than traditional closed-circuit designs.

If the 20%RH lower limit of humidity is allowed under the guidelines set out in ASHRAE TC9.9 2008 then the overall water-usage is 40% less than the current industry average data-centre facility, although the dew-point must be controlled at all times.

The Ark 'fresh-air' design uses water in its adiabatic cooling and humidification systems to achieve an industry benchmarked annualised $PUE_3$ of 1.16. The additional local water consumption over-and-above a traditional closed-circuit design is sourced from rain-water harvesting and, in any case, offset by substantial water savings in the power generation supply chain.

## End

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