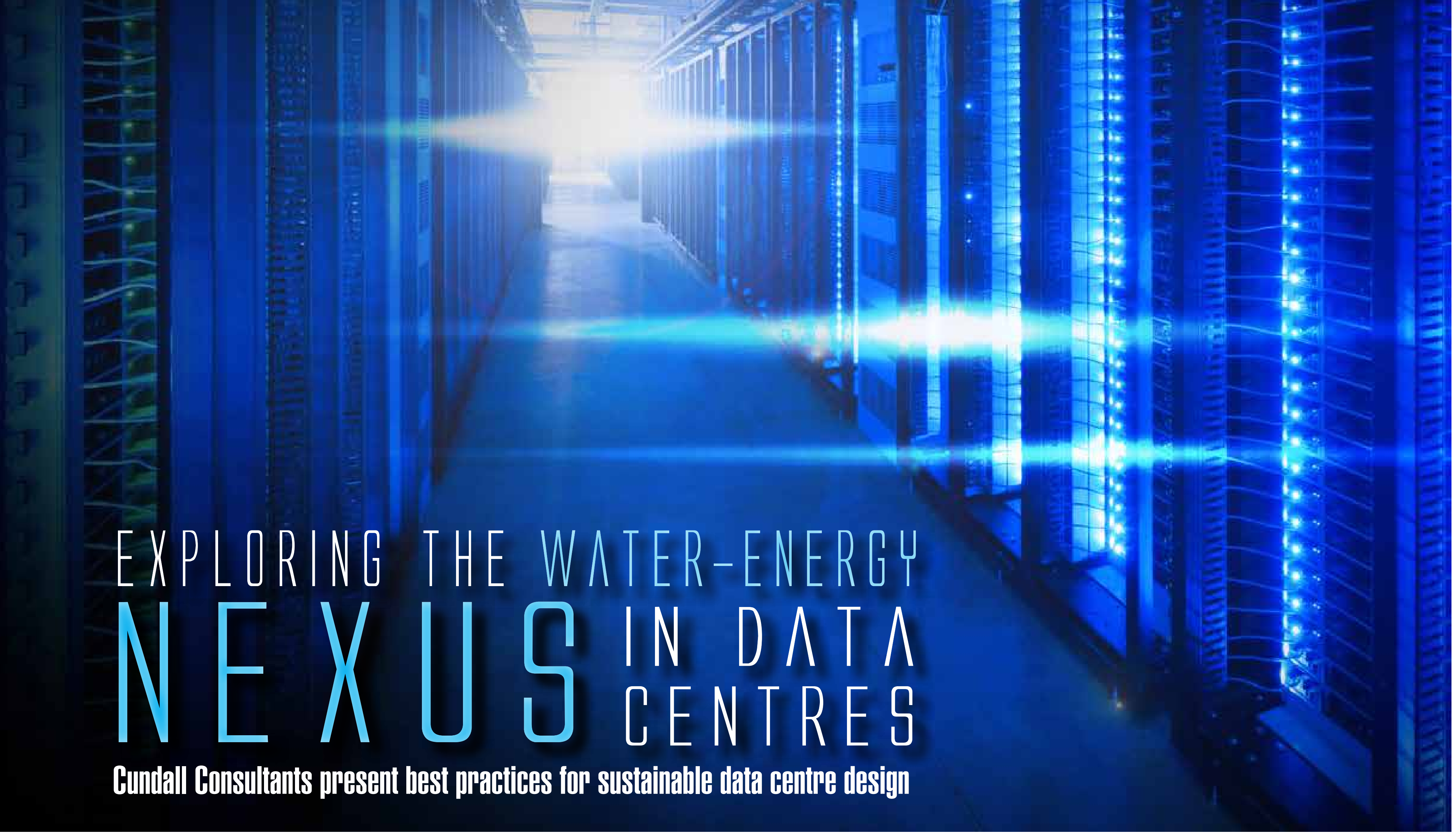

EXPLORING THE WATER-ENERGY NEXUS IN DATA CENTRES

Cundall Consultants present best practices for sustainable data centre design

As our global economies become more reliant on information and communication technologies, so increases the market for storing and processing digital data. This is demonstrated through high growth rates of data centres worldwide which are inevitably associated with increased power requirements.

To mitigate these increased power needs, efficient all-air optimisation cooling technologies have been gaining interest in the data centre community, namely Direct Air Optimisation (DAO), and Indirect Air Optimisation (IAO). The appeal of these all-air systems is reduced energy consumption. The corollary to reduced energy consumption is the increase of water usage on-site. The currently established data centre sustainability metrics – Power Usage Effectiveness (PUE), Water Usage Effectiveness (WUE), and Carbon Usage Effectiveness (CUE) - evaluate efficiency and account for the resource usage on-site only. However, water is required to generate power, and electricity is used to produce water. This is the Water-Energy Nexus. Depending on the method of production, the additional energy and water consumed off-site may be significant. Nevertheless, the currently established metrics do not consider this resource usage off-site.

In this context, the market's perception of Direct Air Optimisation (DAO) and Indirect Air Optimisation (IAO) systems may be different from the reality, depending on the characteristics of at-source water and power generation resources. To explore this idea, Cundall's Critical Systems team conducted a study investigating the theoretical resource usage of 10MW facility in three locations: San Jose, California (USA); London, UK; and Scandinavia.

Cundall's experience of modern data centre cooling systems shows that Direct Air Optimisation (DAO) and Indirect Air Optimisation (IAO) technologies reduce power consumption when compared with traditional chilled water systems. The challenge is that low energy consumption comes at a cost, typically in the form of increased water usage on-site. To better understand water usage in data centres, Cundall started by exploring the source and the quantities of the water in question.

The amount and way in which water is "used" varies markedly between power plant types and depends heavily on the specific technologies employed. It is important to make a distinction between water "withdrawal" and water "consumption". The former can be defined as "the amount of water removed from the ground or diverted from a water source for use", and the latter is the quantity "evaporated, transpired, incorporated into products or crops, or otherwise removed from the immediate water environment".

The water withdrawn but not consumed normally undergoes degradation such as thermal pollution, or chemical pollution, due to boiler blow-down, or from airborne emissions. In 2010, 583bcm (billion cubic metres) or 15% of global water withdrawals were used for energy production. Of this, 66bcm (11%) was water consumed. In industrialised countries, electricity generation is responsible for around 40% of freshwater withdrawals. For power plants where water supply downstream is a limitation, water consumption is the most important metric.

Another consideration when evaluating water and energy use is the energy expended in the generation of potable water. To collect, distribute and treat water, certain energy-intensive processes may be required. The Energy Water Intensity Factor (EWIF) is a metric designed to incorporate all the energy used for the water production and distribution to the end user. Inevitably, the EWIF is higher in arid regions where water is pumped from deep boreholes, or desalination of seawater and brackish water is required. In California for example, water is pumped across great distances and large elevation changes, so the electrical energy used to provide water is very high. Even in wetter climates, the energy expended may be high. A case in point is the water industry in the UK which contributes 0.8% of the country's annual greenhouse gas emissions.

The water can therefore have highly variable embodied energy dependent mostly on location. For example, the seawater used for cooling in nuclear plants will have a very low associated energy, whereas freshwater used by coal-fired power stations is likely to have undergone treatment prior to use.

Increasing the water usage in data centres means there is an increase in off-site power consumption to provide the additional water. On the other hand, reducing the on-site power consumption reduces the quantity of water used at the power station. Cundall analysed the extent to which each factor is variable for these three disparate locations to demonstrate this water-energy nexus:

- **San Jose, California, USA:** San Jose is a major data centre hub, since Silicon Valley is located in this area. Additionally, California is facing one of the most severe droughts on record, going through its 5th year of drought. This has significantly increased the water stress in the area, resulting in the use of desalination plants for the provision of potable water.

- **London, UK:** The UK is receiving the highest percentage of global investment in the data centre sector amongst European countries (8.4%), and it has the third largest quantity worldwide after the USA (with 24.2%) and Japan (with 10.5%). The highest data centre intensity is found in the Greater London Area. Another characteristic of the UK, is the carbon intensive power generation industry, which results in high energy related carbon emissions.

- **Scandinavia:** The Nordic area has seen the largest percentage increase in data centre industry in the Western Europe (+17%), and this is due to increased new build activity. It is anticipated that the market in third party data centres floor space will increase by 2.5 times, and the power requirements will triple between 2015 and 2017. The area is characterised by very high penetration of renewable sources of energy, the weather profile favours the use of all air optimisation systems, while the area offers very low energy prices and taxation incentives to data centre developers.

The data centre considered is a 10MW facility, based on 1,400 W/m^2 power density. The supply air temperature set point is 25ºC, and the return temperature is 37ºC. The cooling technologies investigated for their performance include the IAO power saving mode, IAO water saving mode and DAO system.

To perform the analysis, a series of data was required to evaluate both the on-site and off-site water consumption, power consumption, and carbon emissions.

To calculate the water and energy consumed off-site at the power and water plant respectively, detailed data was required. The acquisition of this data and validation of their credibility proved to be an onerous task since these figures are not readily available or centrally provided by professional associations. Similarly, obtaining carbon emission figures for different water production methods in the various countries was complicated as the data in many cases is not available online, or required purchasing.

In the following table, the data obtained and used in this exercise is summarised. It is noted that not all data was available for all locations, therefore some adjustments were made (e.g. use the average USA figures for California, etc.)

These figures show us some interesting trends. Firstly, the high carbon intensity of the UK is highlighted, as it is 1200% higher than Sweden. Additionally, the power intensity of water production in California is 570% higher than the UK. This is due to the use of fresh water which is pumped from deep boreholes, and the use of desalination plants to convert seawater to potable fresh water.

Looking at the figures for energy consumption off-site for the 10MW data centre facility, the additional energy consumed at the water plant in San Jose is equal to 270,000 kWh/year.

To put this number in context, this is the annual electricity consumption of 80 households in the UK. These findings highlight that although the percentage increase in the PUE may be small, the actual impact of this additional energy consumption from the off-site source is significant.

In London, the additional amount of water consumed at the power plant for a 10MW data centre corresponds to 1,180,000 m^3/yr and it is significantly higher than the San Jose figures.

Water intensity, power intensity and carbon intensity figures of the power and water generation facilities across San Jose, London, and Scandinavia.

	San Jose, CA, U.S.A	London, UK	Scandinavia
Carbon emissions for electricity generation, $kgCO_2/kWh$	0.169 (av. for CA)	0.51 (av. for UK)	0.0399 (av. for Sweden)
Carbon emissions for water generation $kgCO_2/litre$	0.0013 (av. for CA)	0.0005 (av. for GLA)	0.0001632 (av. for Norway)
Utility water plant energy consumption, kWh/litre	0.0034 (av. for CA)	0.0006 (av. for UK)	0.0018 (av. for Norway)
Utility power plant water consumption, litres/Kwh	7.60 (av. for USA)	12.29 (av. for UK)	*7.50

** Calculated based on the Swedish Energy mix (nuclear=38%, hydro=45.5%, other renewables=11.7%, thermal conventional=4.8%) (Energy mix, based on data provided by World Energy Council: Energy Trilemma)*

To get an estimation of the magnitude of this volume of water, it should be noted that it is enough to cover the potable water needs of all households in Stratford-upon-Avon, UK.

The figures for Scandinavia are the lowest recorded among the three locations, and this is explained by the weather profile of Sweden which favours the use of all-air optimisation systems. Looking at the absolute figures of the additional energy consumed at the water plant for a 10MW data centre facility, this is equal to 51,000 kWh/yr. To put this number in context, this is the annual electricity consumed of 15 UK households.

In conclusion, when off-site metrics are included in the assessment of water and power usage for data centres, the source of the water and the energy expended in using that water through the process of Direct Air Optimisation (DAO) and Indirect Air Optimisation (IAO) systems will significantly impact the sustainability metrics of Power Usage Effectiveness (PUE), Water Usage Effectiveness (WUE), and Carbon Usage Effectiveness (CUE).

The carbon emissions related to the water and power use, along with the embodied energy of water and the embodied water of electricity, are location specific and dependent on the energy mix of each country. Therefore, when a new data centre facility is to be constructed, the special characteristics of the locality should be considered.

Key to the calculation of the at-source metrics is to obtain credible and location specific figures for the energy, water and carbon emissions at the production stages. This exercise has revealed that currently there are no central and credible data sources available providing this information. Cundall undertook extensive research to obtain these figures and calculate the at-source sustainability metrics. If the industry is to establish the use of the revised at-source metrics, then special focus should be given to creating accessible and accredited data sources.

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