REPORT REPRINT

The mist around datacenter water use makes for unclear views

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Introduction

Environmental sustainability will define the trajectory of the datacenter sector in the coming decade, if its expansion is to continue uninterrupted. As datacenters mushroom and the effects of climate change become amplified, operators will be pressured to demonstrate their good stewardship of natural resources. Water consumption is inevitably an area of scrutiny.

However, water consumption is different, and in some ways more complex, an issue than energy and carbon. While the total energy and related carbon footprint of a datacenter is typically dominated by its power consumption from the electrical grid, direct water consumption used for cooling is only one of the two major parts of the total water footprint. A simple reduction in direct water use without other changes will lead to an increase in total water consumption elsewhere through increased energy needs.

There is also the question of incentives: evaporating water is an inexpensive cooling method to save energy. Operators have at their disposal all the technology they need to break out of this bind, and to keep reducing their resource use across the board, but their pace will largely depend on the strength of market incentives.

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Arguably, water use in datacenters is not significant when compared to other activities. Yet direct water use by datacenters will likely be increasingly contentious, particularly in locations where it is scarce or where large datacenters concentrate. Without market price incentives, however, it will be difficult for businesses to make prudent capital or operational decisions. Accounting for the full environmental impact of a total datacenter water footprint is a nontrivial effort, but would support more informed datacenter siting and design choices that also satisfy environmental and social responsibilities.

A little water for an ocean of digital services

The concept of sustainability is not novel and some of its underlying components, such as energy efficiency, have been a key area of improvement for years. But having it take the role as a central tenet to infrastructure strategy is a more recent demand.

Media and policymakers alike have been mounting pressure on the largest IT services and datacenter operators to do much more about the environmental footprint of their infrastructures, with the implied threat of backlash in the form of bad press and more heavyhanded regulations. Enterprise customers, too, want to see their providers become efficient in their use of natural resources because that filters into their own annual sustainability reports – such reports are now expected of the world's largest corporations.

Carbon (carbon dioxide-equivalent greenhouse gas emissions to be exact) dominates the international discourse around sustainability for its global warming effect, while water consumption is a sensitive topic on a more local level. And herein lies the conflict: operators would want to optimize their use of resources holistically, but that may run counter to the interest of local communities. Datacenters use water to reduce the energy required to keep the facility cool, typically by taking advantage of the cooling effect of evaporation.

On the one hand, datacenters amount to a tiny fraction of the water consumption from households and commercial buildings, not to mention heavy industrial activity and agriculture. This is not a case of 'whataboutism' but a question of cost and benefit: datacenters deliver major social and economic value in return for a marginal increase in water use.

A more traditional datacenter design with chillers, cooling towers and a low temperature target of 20°C (68°F) may use well over 10,000 cubic meters (2.64 million gallons) of water per year to handle a megawatt of IT load. In hot climates, such a datacenter design could approach tens of thousands of cubic meters or millions of gallons a year.

In the US, a 2016 study by Lawrence Berkley National Lab (LBNL) estimated that average water consumption for purpose-built datacenters was 15,768 cubic meters (around 4.2 million gallons) per year per megawatt total datacenter load. Taking an average power usage effectiveness of 1.6 (which means there is a 60% energy overhead on top of the IT energy, in line with 451 Research studies), this yields a notch above 25,000 cubic meters or 6.67m gallons of annual water consumption for a megawatt IT load.

This is the equivalent of 60 US households' annual water demand, according to data from the US Environmental Protection Agency. No matter the assumptions around the social and economic benefits of the services underpinned by datacenters, this is marginal. A megawatt of IT load (an infrastructure of about 2,500 to 3,000 high-performance cloud servers and associated storage and networks) can support digital services for many thousands of homes, which means datacenter water consumption per household served is well under 1% of residential water needs. Arguably, this is a great tradeoff.

When a little gets far too much

On the other hand, the holistic view informs national (and international) decisionmakers. Compared to carbon emissions and climate change, availability of water tends to be a much more local concern. Datacenters and their water use are often dislocated from the population and businesses they serve by tens, if not hundreds, of miles thanks to fiber-optic networks. When large datacenters concentrate in a relatively small area, the strain on the local environment becomes considerable.

Take Northern Virginia, which is home to the largest (and growing) cluster of datacenters in the world, turbocharged by major technology and IT services companies. According to 451 Research's Datacenter Knowledgebase, by the end of 2Q 2020, there were more than 170 datacenters in the region with a combined available IT capacity of around 1.6 gigawatts. This capacity is chiefly concentrated in Loudoun County next to the Dulles Technology Corridor, serving not only the Washington DC Metropolitan Area and its immediate vicinity, but much of the Atlantic states with a combined population of over a 100 million, as well as large amounts of global internet traffic.

Many large datacenters in Loudoun make use of advanced cooling designs (such as direct and indirect air economization) that are vastly more efficient in their use of water than estimated by LBNL. Still, their combined water requirements probably amount to the equivalent of thousands of homes for a county of about 410,000 people. While there is no comprehensive data on datacenter water use in Loudoun County, it was already considerable enough for county administrators to take notice by the middle of the 2010s, and ask operators to reduce or nearly eliminate additional water consumption for their new datacenter developments – which some duly have. A low-water-use requirement has become common, enough to prompt vendors to develop cooling systems that offer low or even zero water operating modes.

Loudoun County is a special case, but nonetheless makes an important point – the growing awareness of water availability is far from unique. Shifting rain patterns together with a rise in average temperatures will result in reduced supply in a high number of areas in the US, according the US Forest Service. At the same time, population is set to increase in many of the same locations, driving water demand up.

The European Union, too, warns that parts of Europe have seen a reduction in rainfall that has already led to water stress in some member states such as Belgium, Spain and Italy. Cape Town in South Africa experienced near catastrophic water shortages in 2017. The list goes on. A study by the World Resource Institute, a Washington-based independent think tank, warns that nearly one quarter of the world's population live in areas with severe water stress where demand is exceeding 80% of supply.

Treading carefully

The mandate to drastically reduce or eliminate datacenter water consumption is clear, but it comes with caveats. A side effect of water reduction (all things being equal) is an increase in energy consumption and related carbon emissions, which frustrates energy efficiency targets and climate change goals. It is also likely to increase energy bills more than it offsets water cost reductions – undermining economic incentives because evaporating water is a simple and inexpensive way to cool datacenters (or any heat-generating systems).

There is a gaping discrepancy between market prices and perceived value by society. Trucost (part of S&P Global Market Intelligence) argues that water is massively underpriced when accounting for environmental externalities. Worse still, in specific cases, chasing on-site water can be counterproductive for water policy too, because electrical power typically has a considerable water footprint due to cooling needs and evaporation from reservoirs, depending on how it's generated.

A 2017 study by Argonne National Laboratory (ANL) of Department of Energy estimated that the average water consumption factor for electricity in the US is 2.18 liters (0.576 gallon) per kilowatt-hour. For the area represented by ReliabilityFirst (a regional electric reliability organization, to which Virginia belongs), this value is 1.43 l/kWh (0.378 gal). Taking this number, a megawatt total load would indirectly consume 12,527 cubic meters (3.3 million gallons) of water a year. Every percentage point change to the PUE (0.01) results in 125.3 cubic meters (33,092 gallons) of change to indirect water consumption.

Based on the ANL study and performance data from various cooling system vendors, the marginal tradeoff potential in Northern Virginia between on-site and off-site water appears to be favorable on balance, in the view of 451 Research. On average, less water is needed to generate the additional electrical power than is saved by reducing evaporative cooling.

Datacenter operators have the opportunity to reconfigure existing systems (making fans work harder, switching on compressors sooner) or make design changes (opting for cooling systems that use less or no water for similar cooling performance) for upcoming development to reduce both on-site water and total water footprint at the same time.

Yet the fact remains that this will inevitably lead to some relative increase in carbon emissions in a location where the electrical grid is largely fossil-fuel powered, and a shift of some water consumption from where the datacenter is located to the source of power generation, which might unintentionally contribute to water stress elsewhere.

Consumption (water that's lost for further use) is not the only measure for environmental impact, since large amounts of water withdrawals, even if returned for use with little to no loss, for thermoelectric power plants adversely impact the natural environment. A datacenter operator may improve its own water balance at the expense of the hidden cost of massive water withdrawal at power stations.

Trucost calculates that if water were fully costed for environmental value, its use, including the side effects of withdrawals, would amount to about 40% of revenue of the prime electrical utility in Northern Virginia, Dominion Energy, with a mix of coal, gas, oil, nuclear and hydroelectric plants powering the grid in the area.

A bigger point is that there is no general guidance or recommendation, this water and carbon balance will change considerably site by site. In locations less favorable for such tradeoffs due to climatic conditions and electricity generation mix, such as Dallas or Chicago, most or all on-site water savings may be offset by an increase in indirect water consumption via drawing more electrical power.

Tradeoffs will not be enough

Most of the datacenter sector has plenty of optimization headroom to simultaneously reduce both water consumption and energy use by addressing various points of inefficiencies in airflow, cooling system controls and set points. Detailed engineering simulations help make informed decisions in facility design and equipment choices.

Even better, past 451 Research analyses indicate that taking advantage of the full width of allowed temperature bands, per guidance from de facto standard-setting body ASHRAE, would allow for further steep reductions in energy and water use without increasing IT component failure rates.

The challenge for web services and technology companies is that they've already implemented most, if not all, these techniques. Cloud datacenters already operate near the physical limits of air cooling and electrical distribution, using very little energy and water to run their facilities compared to the rest of the sector.

But relentless growth in their footprint invites public and regulatory scrutiny on local, national and global stages. Any increase in global emissions to satisfy local water concerns is unlikely to be good enough for the hyperscale companies – the prime target of policymakers.

It will take sweeping infrastructure design changes, such as the adoption of direct contact cooling (e.g., solid state or liquid to chip, total immersion) to break this conundrum, presuming it does not result in disproportionate environmental costs throughout the supply chain. Quantifying the full price of externalities in monetary terms would help make the ESG (environmental, social and corporate governance) case for complex infrastructure redesign programs and energy-sourcing decisions.