

Data Center Wastewater Discharge Trends: Crisis or Opportunity?



Introduction

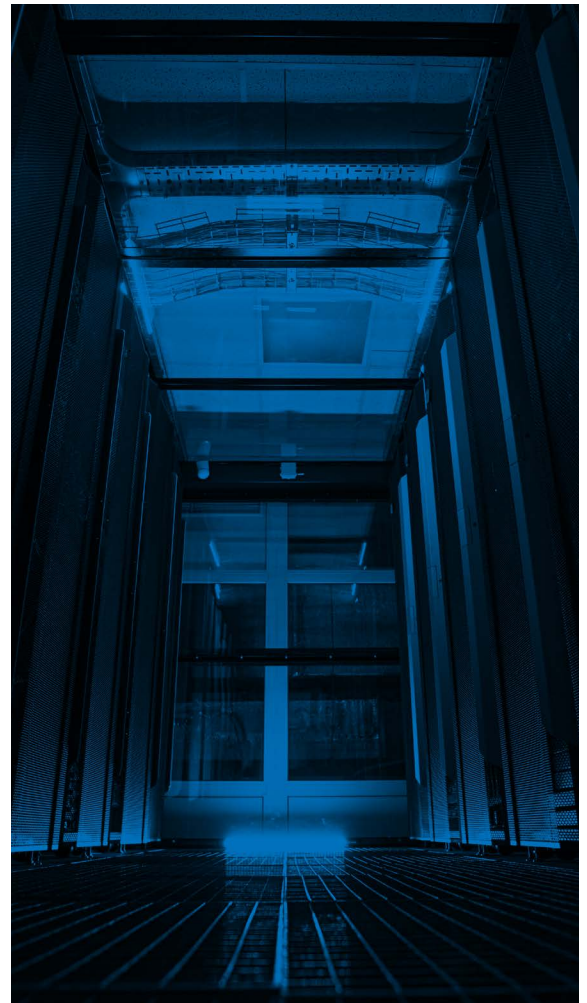
A detailed analysis of the global data center market published in 2022 expected the total number of data centers world over to grow at a Compounded Annual Growth Rate (CAGR) of about 11% [1]. This analysis, conducted before the explosion in AI applications in the second half of 2022, represents the lower limit to data center demand. More recent work on data center capacity expansion puts the net global growth in data centers worldwide in 2023-24 in the range of 20-25% [2].

The two inputs that are required in the successful, sustainable operation of data centers – power and compute equipment (CPUs, GPUs, networking equipment) – are discussed ad nauseam in the media and in the academic literature. However, one crucial input – water usage for equipment cooling – has attracted far less attention. Even less attention has been paid to the issue of data center wastewater discharge into public waters.

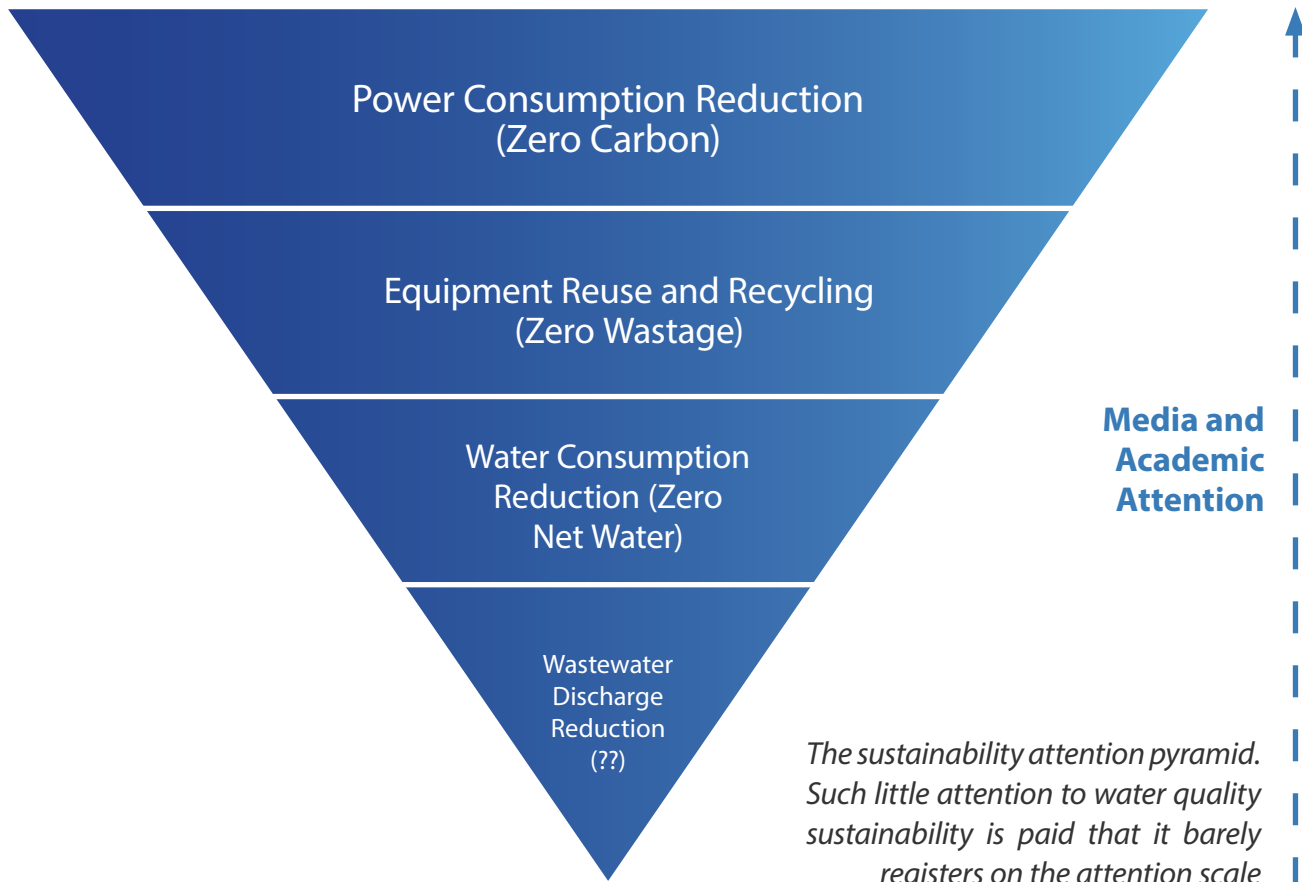
The resultant sustainability attention pyramid has direct impact on corporate spending on sustainability efforts and, in turn, has a direct real-world impact on actual sustainability achievements.

While corporate pledges to ensure Zero Carbon, Zero Waste, and Zero Water Consumption must be encouraged and adopted by the data center industry, it's worth noting that these pledges do not (and structurally cannot) account for Zero Wastewater Discharge into public waters.

Given that global data center demand continues to accelerate exponentially, it should be anticipated that data center wastewater discharge into public waters will also continue unabated. If current trends are extrapolated, this could have serious consequences for the quality of public water.



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AT KETOS, we believe that “you cannot manage what you do not measure.” In this spirit, we feel that it is important to have a baseline understanding of data center wastewater issues before beginning to plan what can be done about them.

The rest of this white paper is organized as follows: First, we give a brief description of why wastewater discharge is generated naturally in the course of normal data center cooling operations. Next, we investigate the wastewater footprint of a typical data center, followed by an estimation of a typical wastewater contaminant profile. Finally, we estimate how data center growth trends affect total annual wastewater discharge into public waters.

This whitepaper ends by offering helpful suggestions to data center operators on monitoring and managing their wastewater footprint.

Why is Wastewater Generated in Data Centers?

Data centers require substantial water for cooling to maintain operational efficiency and protect critical computing hardware from overheating.

The schematic below illustrates cooling systems in typical data centers. In most water-based cooling systems, the cooling element is chilled water that exchanges energy directly with the hot air exhaust from compute units or is part of a heat exchanger that reduces hot air temperature.

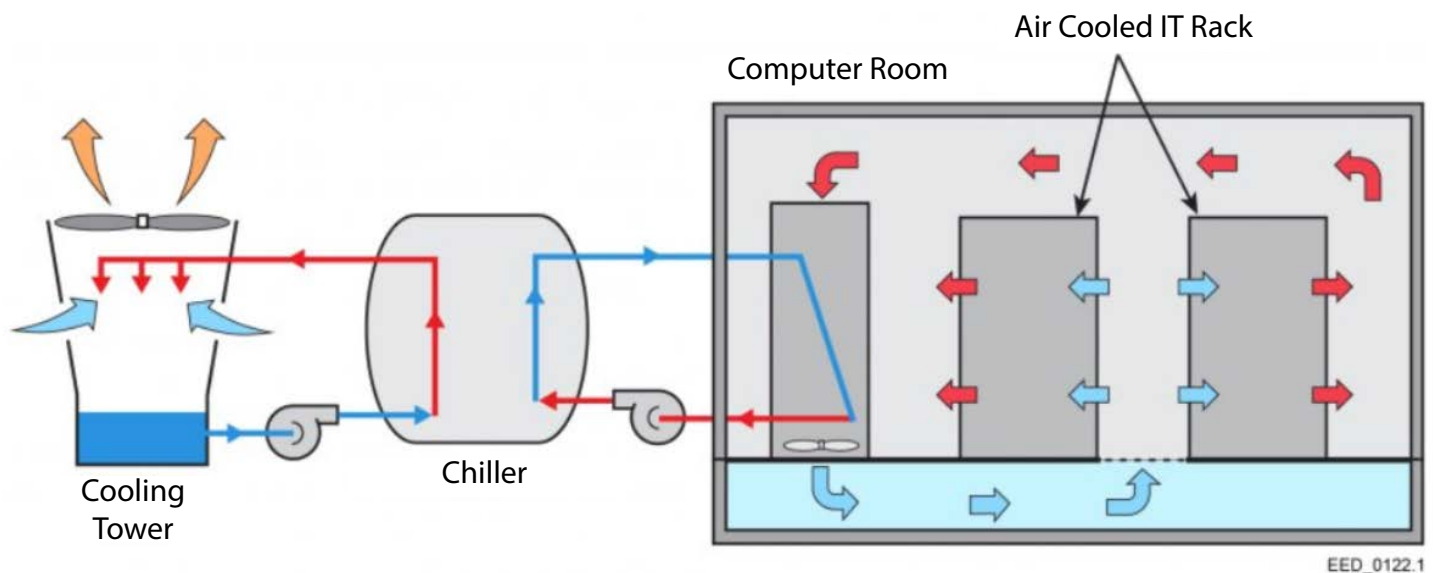


Figure 1: Schematic of a Typical Data Center Evaporate Cooling System

(Source: <https://www.energy.gov/femp/cooling-water-efficiency-opportunities-federal-data-centers>)

Wastewater naturally gets generated during the cooling process for various reasons:

Evaporation and Drift: In cooling systems, especially those using cooling towers, a significant amount of water is lost through evaporation as it absorbs heat from the data center environment. Additionally, small water droplets, known as drift, can be carried away with the exhaust air from the cooling towers. This loss needs to be compensated by fresh water, which becomes part of the wastewater stream after treatment to remove impurities.

Blowdown: To prevent the concentration of minerals and chemicals from becoming too high, which can lead to scaling and corrosion, part of the water in the cooling system (known as blowdown) needs

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to be regularly discharged and replaced with fresh water. The discharged water contains higher concentrations of these minerals and chemicals, making it unsuitable for immediate release into the environment without treatment.

Chemical Treatment: The water used in data center cooling systems is often treated with chemicals to prevent microbial growth, scaling, and corrosion. Over time, the accumulation of these chemicals in the water necessitates its disposal. If discharged untreated, the chemical-laden water could harm the environment, necessitating proper wastewater treatment processes.

Condensation: Air conditioning and other cooling methods can produce condensate, which may contain lubricants from the cooling equipment and chemicals from treated air. This water typically needs to be collected and treated before disposal or reuse.

The Wastewater Footprint of a Typical Data Center

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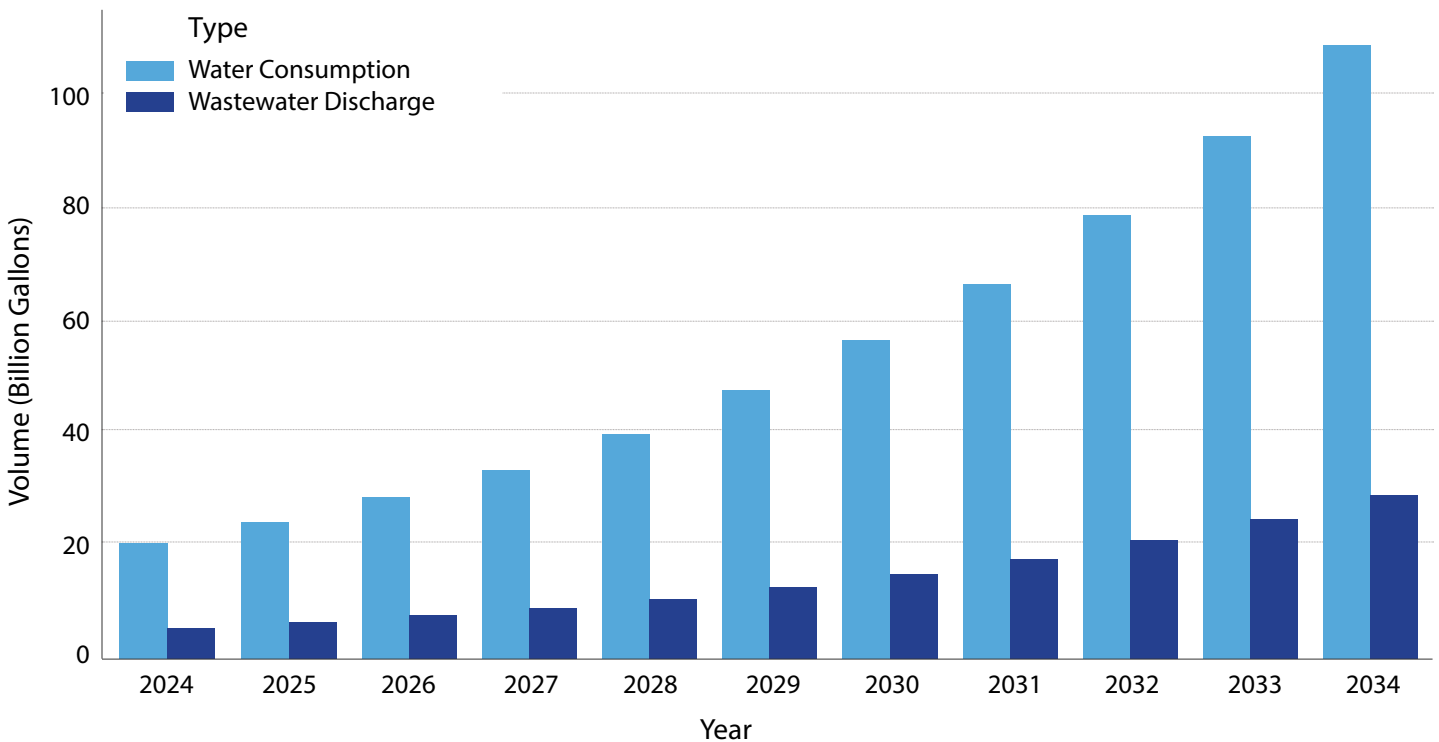
Category	Details	Estimated Value	Units	References
Overall Water Consumption	Total annual water used by a typical data center	6,870,000	Gallons	Uptime Institute Blog [4]
Wastewater Discharge	Estimated wastewater generated by traditional cooling methods	1,370,000 - 2,060,000	Gallons	Uptime Institute Blog [4]

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Using 3000 as a lower bound for the total number of data centers in North America in 2024 [5] this results in a total water consumption of 21 billion gallons of water and a discharge of about 6 billion gallons of wastewater into public waters.

Assuming a realistic CAGR in data center capacity of 18% (midpoint of available estimates for growth in the literature in [1] and [5]), this would imply a total annual wastewater discharge of about 30 billion gallons of wastewater. This is almost 50% more than the total annual data center water consumption in 2024 and constitutes, in our opinion, a crisis of unprecedented levels.



Typical Wastewater Contaminant Profile

To understand why we are sounding the alarm on this topic, it is instructive to examine the wastewater contaminant profile of the typical data center. Note that the table below does not assume any treatment prior to the discharge of wastewater into public waters. Note also that this is not an exhaustive list. The list of contaminants in the wastewater profile of a typical data center is likely to be larger than the one shown below.

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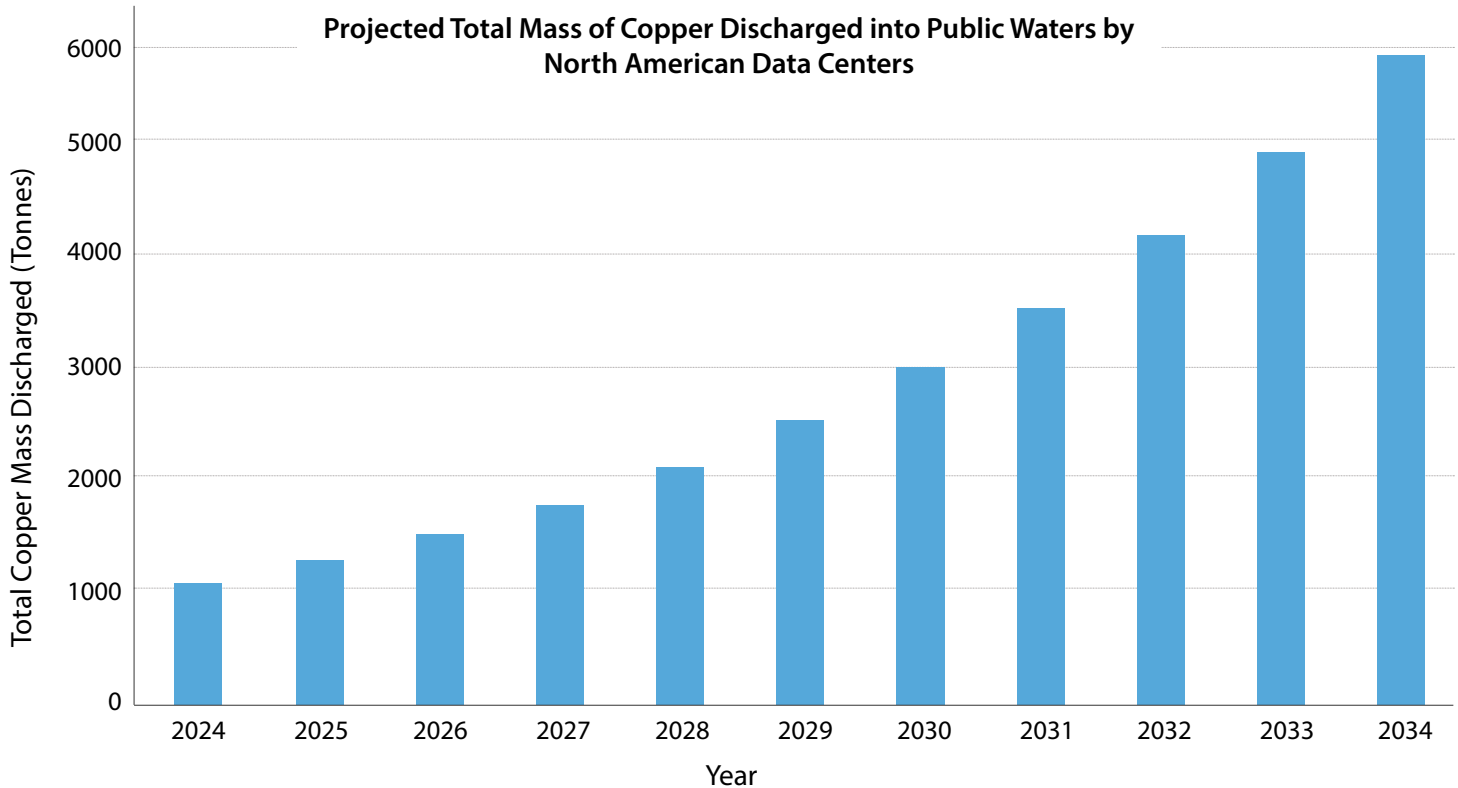
Not all contaminants listed are regulated and required to be reported by the EPA. For instance, while copper, chromium, and zinc have EPA Maximum Contaminant Levels (MCL - of 1.3 mg/L, 0.1 mg/L and 0.5 mg/L, respectively), phosphates, molybdates and biocides have no such MCL requirements.

Further, if we assume that the eventual discharge caused by data centers is treated to be within EPA safe limits eventually, this only addresses the concentration of contaminants in the discharge, not the total volume of contaminants that will be discharged into public waters.

Contaminant Category	Contaminants	Concentration Range	Health Impact	Reference
Biocides	Isothiazolinones, Glutaraldehyde	0.1-1.0 mg/L	Allergies, skin irritation	[6], [7]
Corrosion Inhibitors	Phosphates, Molybdates	0.5-10 mg/L	Eutrophication (affects marine life)	[6], [7]
Heavy Metals	Zinc, Copper, Chromium	0.05-2 mg/L	Carcinogenic, affects skin, respiratory system and kidneys	[8]
Total Dissolved Solids	Common dissolved minerals and salts	500-2000 mg/L	Kidney stones, organ stress	[8]

To illustrate our point more clearly, let us assume lower limits of copper discharge at typical data centers (0.05 mg/L). Using the CAGR of 18% of total volume increase, this results in a total of about 6000 tons of copper discharged into public waters through data center water usage alone. Even if our estimates are off by a factor of 100, 60 tons of copper released into public waters, in addition to existing sources of discharge, has major downstream water treatment and ecological costs associated with it.

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Mitigating the Impacts of Data Center Wastewater Discharge: A Data Center Case Study

While the trend analysis above seems alarming, KETOS views this as an opportunity to critically examine every facet of the data center water consumption and discharge cycle.

Having worked with many industrial facility operators across industry verticals—automotive, food and beverage, mining, and data centers—KETOS has found that the vast majority of operators are environmentally conscious and do their best to minimize the impact of their operations on public waters.

KETOS is currently working with a utility customer that treats water discharged by a hyperscale data center. The water that occurs here naturally in ponds and groundwater is already high in nitrogen. In the normal course of operation, the data center re-circulates water through its systems several times a day prior to discharge into the utility’s input stream. While the recirculation allows for significant reuse of water by the data center, the resultant discharge stream has a concentration of nitrates that is almost ten times the original concentration.

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Looking Forward

Exponential increases in resource consumption might seem worrisome initially, but at KETOS, we pride ourselves on being technological optimists. We believe that there are reasonable technological solutions to the most daunting problems and that companies don't have to choose between sustainability and responsible management or profitability.

In this regard, we welcome industry initiatives such as Microsoft's Water Positive, which aims to be a net generator of water in local communities in the coming years. Even so, our whitepaper shows that, while a noble endeavor, eliminating wastewater discharge entirely in the coming years is not yet an economic possibility, even given the prevalence of energy-efficient water-based cooling in data centers. Therefore, while companies work to reduce water usage (through recycling initiatives), it's equally important to also consider how they will ultimately handle wastewater.



While KETOS is aware that data center operators discharge into waters that likely have other sources of industrial and agricultural wastewater discharge, and effective filtration and treatment are eventually needed, we'd like to reiterate that "you can't manage what you don't measure." Having an in-depth understanding of the wastewater contaminant profile through real-time, online, on-demand and capex-free solutions such as KETOS SHIELD allows data center operators and their partners (such as utilities) to monitor heavy metals (copper, zinc, chromium) and inorganic contaminants (phosphates, nitrates, molybdates) as well as physical parameters (pH, Oxidation Potential, Conductivity) to optimize their spend on water coolants while minimizing wastewater contamination.

KETOS SHIELD makes it possible to minimize your wastewater contaminant footprint while maintaining operational efficiency. If you are a data center operator or a utility that works with a data center operator, we'd love to help (info@ketos.co).

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