Water, Watts, & Workloads

How Data Centers Use (and Can Save) Water in the AI Era

Publication Date
December 2025

Estimated Reading Time
15 minutes

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Discipline
COOLING

Geography
GLOBAL

Perspective
TECHNICAL

Sections

Executive Summary

For two decades, many U.S. data centers lowered energy use by embracing evaporative heat rejection. The bargain was simple: better PUE (less electricity for cooling) in exchange for higher WUE (more on-site water evaporated). New guidance and standards – especially ISO/IEC 30134-9 for WUE and ISO/IEC 30134-2 for PUE – give data center operators a common language for reporting and comparing these effects without prescribing a one-size-fits-all answer. In practice, the "right" design depends on climate, grid mix, water availability, workload, and community expectations.

> *Water has quietly become the second "fuel" for compute.*

The rapid rise of AI/HPC densities is now reshaping that bargain. Direct liquid cooling (DLC) and rear-door heat exchangers move more heat into closed loops and higher coolant temperatures, enabling dry coolers or minimal adiabatic assist and, in many new builds, zero water for cooling at the site.[1]

Where evaporative systems remain the best fit - because of legacy plants, specific climates, or economics - the toolbox has matured. Reclaimed ("purple-pipe") water can materially reduce potable demand and often cuts operating expenses. California's Title 22 rules (widely mirrored across the U.S.) set the tone: disinfected tertiary quality for cooling towers that create mist or drift; cross-connection testing; and clear labeling and separation. Local programs in Loudoun County, VA and San Diego, CA illustrate how reclaimed pricing and permitting make the choice practical for many facilities.

Why This Matters Now

Three forces are converging to make cooling and water choices newly visible. AI-driven density is pushing heat rejection beyond traditional air systems, water stress is sharpening public and regulatory scrutiny, and utilities are increasingly signaling cost

1 Microsoft's next-generation data center design, launched in August 2024, explicitly targets zero cooling water by adopting chip-level liquid cooling.

Definitions

Short definitions here; full glossary at the end.

Evaporative Cooling
Cooling that lowers air or water temperature by evaporating water.

PUE - Power Usage Effectiveness
Total facility energy ÷ IT energy. Shows cooling/ power overhead; lower is better.

WUE - Water Usage Effectiveness
On-site water used per unit of IT energy (L/kWh or m^3/MWh).

AI/HPC - Artificial Intelligence / High-Performance Computing
High-density compute (50–100+ kW racks) driving adoption of liquid cooling and dry heat rejection.

DLC — Direct-to-Chip Cooling
Liquid is delivered directly to cold plates on CPUs/ GPUs.

and availability through rates rather than capacity alone. Decisions that once lived entirely inside the mechanical room now affect siting, permitting, and community acceptance.

At the same time, measurement is catching up. Standards like ISO/IEC 30134 for PUE and WUE have given operators a common language for comparing designs and disclosing trade-offs. What gets measured gets managed – and in this case, it is reshaping how facilities are designed, evaluated, and discussed beyond the fence line.

Background & Context: A Short History of Heat Rejection

In the mainframe era, computing often relied on water-assisted cooling at the hardware level as it was the most practical way to move heat from dense electronics. As data centers took shape in the 1990s and early 2000s, the dominant plant became familiar: raised floors, CRAC/CRAH units, chillers, and cooling towers. Evaporation of water in those towers provided a powerful thermodynamic advantage, lowering compressor work and – once we began tracking it – PUE. The trade-off, visible but rarely quantified at first, was greater on-site water use. Even then, a few pioneers experimented with air-only (dry) rejection in cooler climates, accepting a PUE penalty to simplify water, permits, and operations.

Over the last decade, economization and indirect/direct evaporative systems spread because they reliably cut energy use in many U.S. climates. At the same time, water stress and community concerns pushed operators to measure and disclose WUE, and to shift potable demand to reclaimed ("purple-pipe") supplies wherever utilities offered them. The modern U.S. fleet is therefore a mosaic: some facilities run air-cooled chillers or dry coolers (near-zero on-site water, somewhat higher PUE in hot conditions); others run towers or adiabatic systems (lower PUE, higher water) but manage consumption with tighter cycles of concentration, better filtration/chemistry, and sometimes blowdown recovery. The choice is increasingly site-specific – about climate, tariffs, utility programs, permitting, and community expectations – not ideology.

CRAC / CRAH Units - Computer Room Air Conditioner / Air Handler
Traditional data center cooling units delivering conditioned air.

Cooling Towers
Evaporative heat-rejection systems that cool water by evaporating a small portion of water.

Economization
Using favorable outdoor air or water conditions to reduce or bypass mechanical cooling.

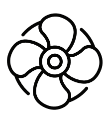
Cycles of Concentration
How many times dissolved solids build up in a cooling tower before blowdown.

Blowdown
The discharge of cooling tower water to remove minerals and contaminants.

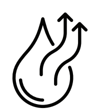
> *"IBM's first use of water to cool computers dates back to 1966, when IBM introduced the System/360."*
>
> — eWeek, "IBM Water-Cooling Technology Helps Computers Beat The Heat"

The AI/HPC wave is changing the physics on the floor. With racks regularly at 50–100+ kW, direct-to-chip liquid cooling and rear-door heat exchangers are becoming standard for dense clusters. Those approaches lift coolant temperatures and move heat into closed loops that can reject to dry coolers for most or all the year in many U.S. markets. In new builds, that enables zero water for cooling while keeping PUE competitive through efficient pumps, fans, and controls. Where legacy plants or economics still favor evaporation, operators are increasingly pairing towers with reclaimed water and best-practice Legionella programs to cut potable draw and risk. Either way, the direction of travel is clear: higher density pushes more liquid at the rack, and that in turn opens credible, near-waterless pathways at the site.

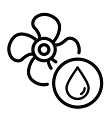
Exhibit A: Primary Heat Rejection Archetypes



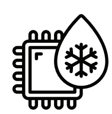
Dry Cooling
Air-based heat rejection
Low water use
Higher peak energy demand



Evaporative Cooling
Evaporation-assisted heat rejection
Higher water consumption
Lower energy use



Hybrid
Dry-first with wet assist at peaks
Seasonal optimization
Balanced energy-water trade-off



Liquid-to-chip + Dry
Closed-loop liquid cooling
Higher coolant temperatures
Near-zero on-site water use

Modern data centers rely on a small set of recurring cooling archetypes. Each rejects heat differently, with distinct implications for energy use, water consumption, and peak system sizing.

Adiabatic Assist
A mode adding brief upstream moisture to improve dry-cooler performance on hot days.

Wet-Bulb Temperature
The lowest temperature air can reach through evaporation at constant pressure. Captures the combined effect of heat and humidity; always ≤ dry-bulb temperature.

Dry Coolers
Air-cooled heat exchangers rejecting heat without evaporation.

ASHRAE
The American Society of Heating, Refrigerating and Air-Conditioning Engineers. Publishes industry standards and guidelines for data center thermal management, liquid cooling, and environmental classes.

PUE, WUE, and the Energy–Water Trade-off

At the facility level, cooling decisions are ultimately judged through two lenses: energy overhead and water consumption. Power Usage Effectiveness (PUE) captures how much electricity a site spends beyond the IT load itself, while Water Usage Effectiveness (WUE) measures how much water is consumed to deliver that compute. Taken together, they explain why designs that look efficient in one dimension often carry hidden costs in the other.

PUE expresses the ratio of total facility energy to IT equipment energy; the closer it is to 1.0, the less energy is being spent on cooling, power distribution, and other non-IT loads. WUE, reported in cubic meters per megawatt-hour (or liters per kilowatt-hour), tracks the site's water input per unit of IT energy delivered. Reading the two together makes the trade-off visible: evaporative systems tend to lower PUE by exploiting thermodynamics, while increasing WUE through on-site water use; dry systems reverse that balance.

The WUE standard also allows optional factors that widen the lens. The Energy Water Intensity Factor (EWIF) accounts for water embedded in electricity generation, and the Water Reuse Factor (WRF) captures on- or off-site reuse. As a result, a site that appears "waterless" on-site may still rely on water upstream through the grid, while a facility using reclaimed water may score higher on WUE but dramatically reduce potable demand. The metric doesn't declare winners – it clarifies consequences.

The Energy-Water Trade-off in Practice

In U.S. operations, the pattern is consistent. Non-evaporative approaches – air-cooled chillers and dry coolers – avoid on-site process water almost entirely. They simplify compliance and community conversation, but in hot climates they often raise PUE as fans and compressors work harder against higher ambient temperatures. Evaporative approaches – cooling towers and adiabatic systems – do the opposite: they ride the wet-bulb advantage to reduce energy, but they consume water through evaporation and blowdown. There isn't a winner in the abstract; there is a best fit for this workload, on this grid, at this site.

Most sites don't live at one extreme; they blend approaches

EWIF - Energy Water Intensity Factor

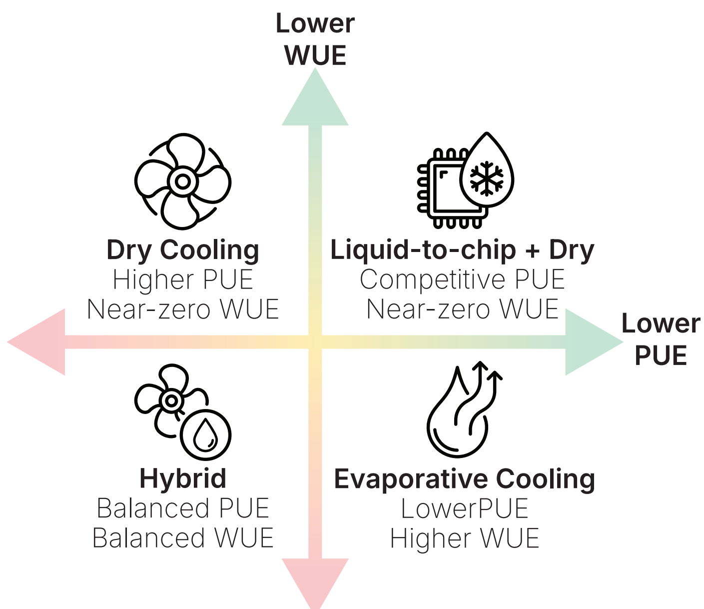
EWIF extends WUE by accounting for water used upstream to generate the electricity supplying a data center. It captures the embedded water intensity of the grid, highlighting that on-site "waterless" designs may still rely on water indirectly through power generation.

WRF - Water Reuse Factor

WRF measures the extent to which water used on-site is reused or offset, either within the facility or through external systems. It helps distinguish between total water use and potable water impact, particularly for sites using reclaimed or recycled water.

across the year. Controls usually run dry-first and only add an evaporative stage on the hottest hours, which keeps annual water use down while holding energy steady. Where a purple-pipe supply exists, that short “wet” window can draw on reclaimed water instead of potable. The hybrid also improves resilience: operators can run dry during drought restrictions or smoke events, and go wet when the grid is strained and every kilowatt matters. As AI/HPC spreads, rack-level liquid cooling raises coolant temperatures and makes the “dry-most-of-the-year” strategy even more achievable.

Exhibit B: The Energy-Water Trade-off Space



PUE and WUE describe different costs of the same thermodynamic decision. Cooling designs move through this space based on climate, workload, and water source—clarifying consequences rather than declaring winners.

The AI Shift: Liquid Cooling and Near-Waterless Paths

AI racks at 50–100+ kW are fast outgrowing traditional air-only cooling. The response is direct-to-chip liquid and rear-door heat exchangers, which pull heat off components into facility loops that can reject to dry coolers for much of the year nationwide, sometimes entirely. This is the design logic behind new “zero water for cooling” builds – proven out in Microsoft’s 2024 announcement – where water is still used for domestic and safety systems, but not for process cooling. The standards landscape (ASHRAE) now offers practical guidance on CDUs, materials compatibility, water quality, and resiliency so these systems can scale safely in U.S. markets.

Liquid doesn’t make PUE free: fans, pumps, and approach temperatures still matter. But it changes the math. Higher coolant temperatures increase the hours when dry rejection is economical, slashing on-site water without throwing energy efficiency overboard – especially on grids where the carbon and water intensity of electricity is falling. The result is not just a thermal solution for GPUs; it's a siting and community relations strategy.

Reclaimed ("Gray") Water: Policy, Equipment, Operations

Across the U.S., water reuse policy is state-led but broadly consistent. The EPA's Water Reuse Action Plan frames national priorities, while California's Title 22 remains a touchstone others echo. The rule of thumb is straightforward: if the cooling method creates mist/drift (towers, evaporative condensers), recycled water must be disinfected to tertiary quality; if it does not create mist (fully closed systems), lower grades may be allowed. Dual-plumbed sites require cross-connection testing and documentation at commissioning and set intervals thereafter, along with "purple pipe" labeling and backflow protection.

Designing for reclaimed use usually adds a few elements to a data center's mechanical scope: a dedicated reclaimed header with clearly identified purple distribution; air gaps or backflow preventers at any potable interfaces; sidestream filtration to raise cycles of concentration; chemical dosing (oxidizing/non-oxidizing biocides, scale and corrosion inhibitors); and drift eliminators on towers. None of this is exotic anymore – it's standard diligence in permitting and operations.

> *"When the residents of the county take showers and flush their toilets, they're helping to cool our data center."*
>
> — Joe Kava (Google), quoted in WIRED on Douglas County, GA

Utilities increasingly price-signal reclaimed water for industrial cooling. In Loudoun County, VA, reclaimed water is listed at $1.80 per 1,000 gallons (2024) with an adopted glide path to $1.93 (2025), $2.07 (2026), and $2.21 (2027). Loudoun's developer FAQ underscores the economics: no availability charge for reclaimed connections and only a 10% potable backup availability charge. In San Diego, the 2025 recycled water commodity rate is $2.46 per HCF (748 gallons) versus a comparable potable rate at $9.37 per

Heat Exchangers (Rear-Door / Rack-Level)
Devices that transfer rack heat into a liquid loop before it enters the room, reducing air cooling demand.

CDU — Coolant Distribution Unit
A skid or cabinet that circulates coolant for liquid-cooled IT equipment and isolates the IT coolant loop from the facility water system.

Reclaimed ("Purple-Pipe") Water
Treated municipal wastewater supplied for non-potable cooling uses.

California Title 22 Rules
Recycled-water standards requiring disinfected tertiary quality, plus cross-connection testing and labeling.

HCF for irrigation customers – an order-of-magnitude signal that makes reclaimed compelling where a purple network exists.

Meanwhile, hyperscalers are scaling reclaimed at fleet level. AWS has announced expansion to 120+ U.S. locations using recycled water for cooling by 2030, projecting ~530 million gallons per year of potable savings – evidence that reclaimed is not a niche solution but a strategic one when water and grid realities point toward evaporative designs.

Decision Guide: When Each Cooling Type Tends to Win

Climate	Best Fit	Why
Cool / Dry	Liquid-to-chip + Dry	Energy + zero water
Hot / Dry	Hybrid	Wet assist for peak hours
Hot / Humid	Evaporative	Best PUE; potable-efficient
Low water / drought	Liquid-to-chip + Dry	Resiliency
Cheap water / expensive power	Indirect/Direct Evaporation	Strong economics

What Changes Next

The industry is steadily accepting higher coolant temperatures. As liquid loops run warmer, the number of hours when dry rejection is economical increases, even in traditionally challenging climates. That shift alone expands the feasibility of dry-first and dry-dominant designs without forcing large energy penalties.

At the same time, standardized liquid cooling interfaces are reducing risk. Clearer guidance from ASHRAE and vendors around CDUs, materials compatibility, water quality, and redundancy is turning what were once bespoke engineering exercises into repeatable patterns that can scale across fleets.

Finally, water disclosure pressure is rising. As utilities, municipalities, and regulators ask for clearer accounting of water use, designs that minimize potable demand gain an advantage – not because they are mandated, but because they are easier to explain, permit, and defend. Together, these forces are making low-water cooling less of an exception and more of a planning assumption.

Key Takeaways

- Measure both sides of the trade: Pair PUE (energy) with WUE (water) and be explicit about what WUE includes. These ISO metrics make apples to apples comparisons possible.
- AI/HPC changes the math: High density racks push direct liquid and rear door cooling, which can enable dry rejection and even zero water for cooling in new builds.
- Design is local: Climate, utility rates, and community expectations matter more than abstract best practices. Water is local – generalities don't apply.
- If you stay evaporative, squeeze the gallons: Higher cycles of concentration, good filtration/chemistry, and blowdown recovery can materially cut water with solid paybacks.
- Use reclaimed where available: "Purple pipe" programs reduce potable demand and often lower OPEX; in places like Loudoun County, VA and San Diego, CA, tariffs make the choice compelling.
- Compliance is operational: For recycled water with mist/drift, states modeled on California Title 22 require disinfected tertiary quality, cross connection testing, drift control, and a Legionella plan.

Glossary of Terms

Adiabatic assist
A mode that briefly adds moisture upstream of a dry cooler to boost heat rejection during hot periods while using far less water than full evaporative cooling.

AI/HPC (Artificial Intelligence / High Performance Computing)
Compute workloads (e.g., AI training/ inference, scientific simulation) that drive very high rack densities (often 50–100+ kW) and favor liquid cooling approaches.

ASHRAE 188 (Legionella management)
The standard that requires water management programs to control Legionella risk in cooling systems.

Blowdown
The controlled discharge of concentrated cooling tower water to keep minerals and contaminants in check.

CDU (Coolant Distribution Unit)
A skid or cabinet that pumps and controls the facility liquid cooling loop and often isolates IT coolant from building water.

Cooling tower
A heat rejection device that removes heat by evaporating a small portion of recirculating water; efficient electrically, but it consumes water and requires chemical treatment and drift control.

Cycles of concentration
How many times dissolved solids are concentrated in a tower loop; higher cycles usually mean less make up water but require better filtration/chemistry.

Direct to chip (DLC) liquid cooling
Liquid channels or cold plates mounted on CPU/GPU packages to move heat into a facility loop with minimal airflow.

Dry bulb temperature (DBT)
The "normal" air temperature (ignores humidity) measured by a thermometer shielded from sun and moisture.

Dry cooler / air cooled heat rejection
A fin and fan heat exchanger that rejects heat without evaporation; on site water use is near zero.

Economization (free cooling)
Using favorable outdoor conditions (air side or water side) to reduce or bypass mechanical refrigeration.

Evaporative cooling (indirect/direct)
Cooling that relies on evaporation to lower air or water temperature; excellent energy performance, at the cost of water.

Rear door heat exchanger (RDHx)
A liquid cooled door on the back of a rack that captures server exhaust heat and transfers it to a liquid loop.

Reclaimed / recycled ("purple pipe") water
Treated municipal wastewater supplied for non potable uses (e.g., cooling towers); in California and many U.S. jurisdictions, tower applications that create mist/drift require disinfected tertiary quality.

Title 22 (California)
California's recycled water regulation that sets water quality, cross connection, labeling, and

drift control requirements; widely echoed by other U.S. programs.

Wet bulb temperature (WBT)
The lowest temperature air can reach via evaporation at constant pressure; captures the combined effect of heat and humidity and is always ≤ dry bulb.

WUE (Water Usage Effectiveness)
Site water input per unit of IT energy (typically L/kWh or m^3/MWh). Generally reflects on site process water unless optional factors are used.

PUE (Power Usage Effectiveness)
Total facility energy divided by IT energy. Lower is better; it shows how much overhead (cooling, power distribution, lighting, etc.) is required to run the IT load.

Scope & Methodology

Volterra Reports are based on a combination of publicly available data, industry standards, operator and municipal disclosures, and first-hand market experience. Technical examples and metrics are illustrative, reflecting modern hyperscale and colocation facility designs under typical climate, load, and operational assumptions. Where ranges are shown, they are intended to clarify relative trade offs rather than prescribe specific designs.

Analysis focuses on facility-level systems and local, on-site impacts unless otherwise noted, and does not attempt to model upstream grid effects, full life-cycle emissions, or site-specific engineering constraints.

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About Volterra

Volterra Advisors is a boutique advisory platform dedicated to accelerating growth across the digital infrastructure and data center sectors. Founded by Jeramy Utara, a recognized industry veteran with nearly two decades of experience, Volterra helps developers, investors, landowners, and operators navigate the decisions that matter most — from power and land strategy to leasing, platform growth, and market expansion.

Jeramy began his career in 2007 at DuPont Fabros Technology (later acquired by Digital Realty), supporting the development of some of the earliest large-scale hyperscale campuses in North America. He later joined CloudHQ as its first employee, where he helped grow the company from concept to one of the world's most successful privately held data center developers. Over more than a decade at CloudHQ, Jeramy played a leading role in leasing more than 1 gigawatt of capacity and driving over $15 billion in revenue, shaping relationships with the world's largest cloud, AI, and enterprise clients.

Through Volterra, Jeramy now partners with digital infrastructure platforms to define and execute strategies around site selection, powered land, leasing, marketing, and organizational growth. His advisory work emphasizes clarity, momentum, and execution — translating complex market forces into tangible outcomes for emerging and established platforms alike.

How We Can Help

Market Intelligence
We analyze power, permitting, and competitive dynamics to identify where the next generation of data center growth will land.

Site Identification & Readiness
We help landowners and developers qualify, position, and advance properties into premier data center ready sites.

Utility & Power Engagement
We maintain direct relationships with utilities nationwide to confirm capacity, align on timing, and support interconnection strategy.

Marketing & Positioning
We produce investor-grade materials - from decks to data sheets - that clearly communicate technical strengths and value.

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We connect landowners and developers directly with hyperscalers, operators, and investors ready to transact.

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We bring trusted engineering, permitting, and development partners to every opportunity - ensuring readiness, speed, and credibility.

Capital & Transaction Support
We support capital formation, deal structuring, and JV alignment - keeping incentives tied to successful outcomes.

Strategic Advisory
We serve as an extension of your leadership team - providing guidance, relationships, and insight from concept to close.

About Volterra Reports

Volterra Reports examine the systems, markets, and decisions shaping digital infrastructure – connecting power, land, cooling, policy, and technology into a coherent view of how the sector operates and evolves.

Each publication combines technical understanding with strategic perspective to explain how legacy decisions and emerging trends influence today's investments and tomorrow's platforms.

Average Read Time	Release Frequency	Audience	Distribution Format
15 minutes	Monthly	Digital Infrastructure	PDF + web

Example Reports

Waste Heat, Warm Cities JAN 2026

Heat is the inevitable output of computation, yet most data centers are designed solely to remove it as efficiently as possible. Waste Heat, Real Value analyzes the physics, infrastructure, and economics behind data center heat rejection — and the conditions under which that heat can be captured and reused. The report reviews European case studies where hyperscale facilities serve as anchor thermal loads for district heating systems, contrasts them with regions lacking heat distribution infrastructure, and examines how liquid cooling, large-scale heat pumps, and new policy frameworks are changing the feasibility equation. The result is a clear-eyed assessment of when waste heat reuse is practical, when it is not, and how it could influence future site selection and facility design.

From the Curb to the Computer Room FEB 2026

Data centers are often discussed in terms of megawatts, efficiency metrics, and uptime statistics, but those abstractions obscure the physical reality that ultimately determines reliability. *From the Curb to the Computer Room* walks through the spaces and systems that make a modern data center function — from perimeter security and logistics to power distribution, cooling infrastructure, and the data hall itself. Drawing on first-hand operational experience, the report follows the physical path of people, equipment, electricity, and heat through a facility, explaining how design decisions made early shape safety, operability, and resilience over decades of operation. Rather than prescribing best practices, it offers a practical framework for understanding how reliability is built room by room — and why physical design has become increasingly visible as data centers grow larger, denser, and more scrutinized by communities, utilities, and regulators.

Volterra Reports are written for clarity, momentum, and practical application — bridging technical depth with real-world decisions.