LIQUID COOLING — GUIDE

Water Use and PUE in Liquid-Cooled Data Centers

Understand Water Usage Effectiveness (WUE), Power Usage Effectiveness (PUE), and the trade-offs between water-free and evaporative cooling for AI data centers.

Updated November 1, 2026

Liquid cooling changes both power efficiency (PUE) and water efficiency (WUE). This guide explains the metrics, trade-offs, and design choices for AI data centers.

Key metrics

Power Usage Effectiveness (PUE)

PUE = Total Facility Energy / IT Equipment Energy

- Ideal: 1.0 (all energy goes to IT)
- Typical air-cooled: 1.4-1.8
- Modern air-cooled hyperscale: 1.1-1.3
- Liquid-cooled (direct-to-chip): 1.05-1.15
- Liquid-cooled (immersion): 1.01-1.08

Source: Wikipedia PUE (2026); industry reported values.

Water Usage Effectiveness (WUE)

WUE = Annual Water Consumption (L) / Annual IT Energy (kWh)

- Units: L/kWh (liters per kWh of IT energy)
- Air-cooled with evaporative cooling: ~2.6-4.3 L/kWh (PUE 1.3-1.6, COC 3-10)
- Air-cooled with dry coolers: ~0 L/kWh (but higher PUE)
- Liquid-cooled with dry coolers (closed-loop): <0.1 L/kWh
- Liquid-cooled with cooling towers: ~2.1-3.2 L/kWh (PUE 1.03-1.2, COC 3-10)

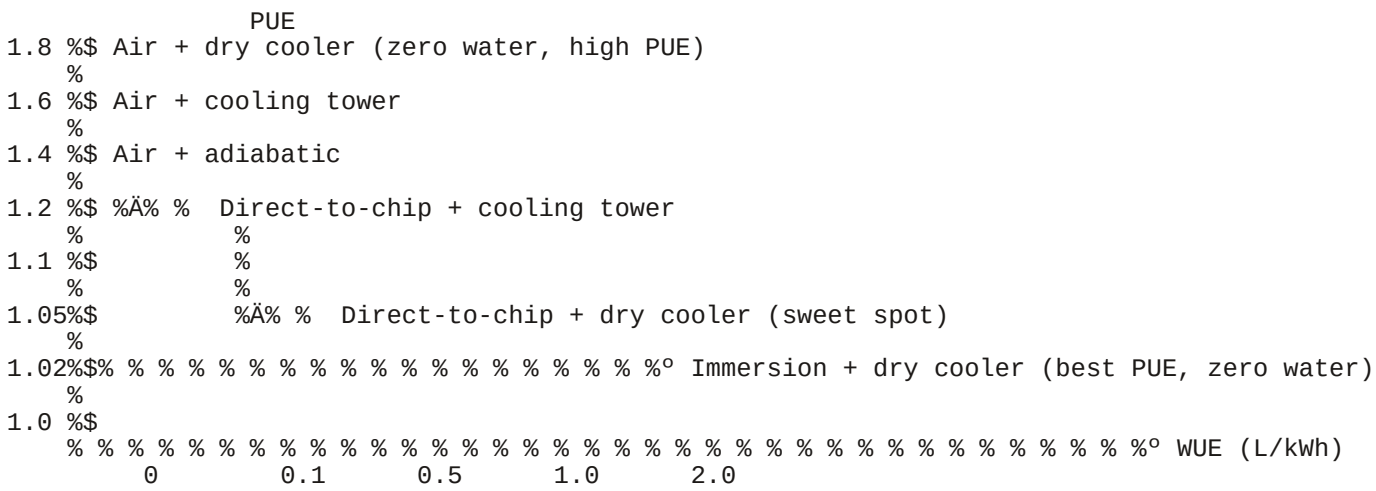
Source: The Green Grid; industry reported values; Brazil REDATA regime (MP 1.318/2025).

Water use by cooling architecture

Architecture	Heat rejection	Water use	PUE range	Notes
Air + cooling tower	Evaporative	High (2.6-4.3 L/kWh)	1.3-1.6	Legacy standard
Air + dry cooler	Sensible (air)	Zero	1.4-1.8	High fan energy, climate-limited
Air + adiabatic cooler	Hybrid	Medium (0.2-0.5 L/kWh)	1.2-1.4	Water only at peak
Direct-to-chip + dry cooler	Sensible (liquid-to-air)	**Zero (closed-loop)**	1.05-1.15	Microsoft Fairwater model
Direct-to-chip + cooling tower	Evaporative	High (2.2-3.2 L/kWh)	1.1-1.2	Open facility loop
Immersion + dry cooler

Sensible (liquid-to-air) | **Zero (closed-loop)** | 1.01-1.08 | Highest density, best PUE | |
Immersion + cooling tower | Evaporative | High (2.1-3.0 L/kWh) | 1.03-1.10 | Fluid loop closed; facility loop open |

The PUE-WUE trade-off



Sweet spot: Direct-to-chip or immersion with dry coolers (closed-loop) achieves both low PUE (~1.05-1.15) and near-zero WUE.

Design choices for water-free liquid cooling

1. Closed-loop facility water (dry coolers)

- Dry coolers reject heat to ambient air via sensible cooling
- No evaporation = zero water consumption
- Requires W-class high enough for dry cooler approach temperatures
- **W27-W32**: Dry coolers viable in most climates
- **W32-W45**: Dry coolers viable even in hot climates; adiabatic assist only at peak

2. Adiabatic assist (minimal water)

- Dry coolers with evaporative pre-cooling at peak ambient
- Water used only 50-200 hours/year in typical climates
- WUE ~0.01-0.05 L/kWh
- Good compromise for W27-W32 in warm climates

3. Cooling towers (high water, lower facility Capex)

- Evaporative heat rejection; lower Capex than dry coolers
- Water use: ~2.1-3.2 L/kWh for liquid-cooled systems, scaling with PUE and cycles of concentration (see worked example below)
- Requires water treatment, blowdown management, legionella control
- **Not compatible** with water-positive/net-zero water commitments

Real-world examples

| Operator | Site | Cooling | PUE | WUE | Source | |----------|------|---------|-----|-----|--------| | Google | Fleet (2025) | Water and air cooling, chosen per site with a water risk framework | 1.09 fleet-wide average (report PDF p. 15) | WUE not stated; 10.9 billion gallons (41 billion liters) of water consumed across data centers and offices in 2025, up 34% from 2024 (report PDF p. 35) | Google 2026 Environmental Report | | Switch | SUPERNAP 7, NV | Air + advanced HVAC | 1.18 | Not disclosed | Wikipedia PUE, 2026 | | Allied Control | Hong Kong | Two-phase immersion (3M Novec 7100) | 1.02 | Low (closed-loop) | Wikipedia PUE, 2026 | | OVH | Europe/NA | Proprietary liquid cooling | 1.09-1.29 | Low | Wikipedia PUE, 2026 | | Research Institutes of Sweden | Luleå | Direct-to-chip, free cooling | 1.015 | ~0 | Wikipedia PUE, 2026 |

Regulatory landscape

| Jurisdiction | Requirement | Impact on cooling choice | |--------------|-------------|--------------------------| | **Brazil (REDATA, MP 1.318/2025)** | Water-efficiency conditions for tax incentives | Favors dry coolers or high-COPT cooling towers | | **Germany (EnEfG)** | Annual Annex 3 reporting for "e300 kW | Drives efficiency transparency; favors low PUE/WUE | | **EU (proposed)** | Minimum data center performance standards (Q2 2027) | Likely to set PUE/WUE thresholds | | **China (GB 40879-2021)** | Covers air-cooled; liquid cooling scope expansion proposed | May mandate liquid cooling efficiency metrics | | **US (FERC/interconnection)** | Large-load tariff reform | Indirect; favors efficient designs that reduce peak demand |

Source: Mordor Intelligence, 2026.

Calculating your WUE

For closed-loop dry cooler system:

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WUE = (Makeup water for facility loop + Humidification + Irrigation + Domestic) / IT kWh
    "H 0.001-0.01 L/kWh (mainly humidification and minor leaks)
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For cooling tower system:

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WUE = (Evaporation + Blowdown + Drift) / IT kWh
Evaporation = Heat rejection × 1.8 L/kWh_th
Blowdown = Evaporation / (COC - 1)
    where Heat rejection "H IT load × PUE (all facility power ends up as heat)
    and COC = Cycles of Concentration (typically 3-10)
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Example: 1 MW IT load, PUE 1.15, heat rejection "H 1.15 MW, *COC=5 !' Evaporation = 1.15 MW × 1.8 L/kWh*th × 8760 h = 18,133,200 L/yr !' Blowdown = Evaporation / (COC-1) = 4,533,300 L/yr !' Total = ~22.67 ML/yr !' WUE = 22.67 ML / (1 MW × 8760) ≈ **2.6 L/kWh**

Recommendations for AI data centers

1. **Target closed-loop dry coolers** for new builds. Zero water, PUE ~1.1, future-proof for regulation.
2. **Specify W32 or higher** to maximize dry cooler hours. Match to OEM server spec (NVIDIA GB200 NVL72, AMD Helios).

3. **If retrofit with cooling tower**: Maximize cycles of concentration (COC "e 10 with advanced treatment), monitor WUE monthly.
4. **Report both PUE and WUE** at facility and rack level. Rack-level PUE enables optimization.
5. **Design for waste heat capture**: Liquid cooling at W32-W45 produces 40-50°C return water usable for district heating (Mordor Intelligence, 2026 notes Brescia, Italy district heating pilot).

Sources

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Frequently asked questions

Does liquid cooling always save water?

Not necessarily. Direct-to-chip with dry coolers (closed-loop) eliminates evaporative water use. But liquid cooling with cooling towers can use more water than air-cooled systems if not designed for water efficiency. Microsoft's Fairwater AI datacenter relies on a closed-loop liquid cooling system filled once during construction; only a small portion of the facility uses water for cooling on the hottest days (Microsoft, 2025).

What is a good WUE target for a liquid-cooled AI data center?

WUE < 0.1 L/kWh is achievable with closed-loop dry coolers. Brazil's REDATA tax regime (MP 1.318/2025) sets water-efficiency conditions for qualifying data centers. Cooling-tower designs land around 2.1-3.2 L/kWh at design load.

How does PUE change with liquid cooling?

PUE improves because fan energy is eliminated and heat rejection is more efficient. Allied Control claimed PUE 1.02 with two-phase immersion (Wikipedia PUE, 2026). Google reports a 2025 fleet-wide average PUE of 1.09 (Google 2026 Environmental Report, PDF p. 15). Switch SUPERNAP 7: 1.18 third-party audited (Wikipedia PUE, 2026).

Can I claim PUE 1.0 with liquid cooling?

No. PUE = Total Facility Energy / IT Equipment Energy. Even with perfect heat rejection, you have pump energy, control systems, lighting, and power distribution losses. Theoretical minimum is ~1.01-1.02 for two-phase immersion with passive heat rejection.