



PUE, WUE, ERE and CUE for AI Facilities: ISO/IEC 30134

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Why efficiency metrics break for AI racks

Every metric in this family is a ratio to IT energy or to total facility energy, so every one of them depends on where the line between "IT" and "facility" is drawn. Direct-to-chip liquid cooling moves load across that line. Server fans, which count as IT, shrink. Coolant distribution unit (CDU) pumps, rear-door heat exchanger (RDHx) fans and in-row coolers appear, and depending on which panel feeds them they land on either side.

The consequence: a liquid-cooling retrofit can cut total site energy substantially while PUE barely moves, and two halls with identical plants can report different PUEs because they meter at different points. Definitions below are cited to the standards and regulators that publish them; worked-example figures are hypothetical and labelled as such.

The ISO/IEC 30134 family

ISO/IEC 30134 is the international series of data center KPIs from ISO/IEC JTC 1/SC 39. It "does not specify limits or targets for any KPI" and does not aggregate KPIs into a combined score ([ISO/IEC 30134-2:2026, Introduction](#)). Status as listed on [iso.org](#) on 2026-10-28:

Part	KPI	Edition	Status
30134-2	Power usage effectiveness (PUE)	2, 2026-01	Published; 2016 edition withdrawn (ISO , ISO 2016)
30134-3	Renewable energy factor (REF)	2016 + amendment	Published (ISO)
30134-6	Energy reuse factor (ERF)	1, 2021-08	Stage 90.92, "to be revised" (ISO)
30134-8	Carbon usage effectiveness (CUE)	1, 2022-03	Published (ISO)
30134-9	Water usage effectiveness (WUE)	1, 2022-03	Stage 90.92, "to be revised" (ISO)

Part 1 sets common requirements; Part 7 covers the cooling efficiency ratio (CER). Full texts are paywalled (30134-2:2026 lists at CHF 159), so the definitions quoted here come from the free informative sections on ISO's Online Browsing Platform. In the EU, the binding rules are in [Delegated Regulation \(EU\) 2024/1364](#), which applies to sites with at least 500 kW installed IT power demand and references the parallel EN 50600-4-x standards "or equivalent".

PUE: definition, categories and the 2026 edition

ISO/IEC 30134-2:2026 defines PUE as the "calculated ratio of the data centre total energy consumption, within a 12-month continuous period, to information technology equipment energy consumption measured across the same period" ([ISO OBP](#), 3.1.2). The standard notes the KPI "was originally developed by The Green Grid", whose glossary describes it as "the energy entering the facility divided by the energy used by the IT equipment" ([The Green Grid](#)).

PUE = E_{DC} / E_{IT} , both in kWh over the same 12 months; the EU regulation uses the same expression ([Reg. 2024/1364, Annex III](#)). Heat recovered inside the facility already lowers E_{DC} , so PUE cannot fall below 1.0 by definition; exported heat needs a separate metric ([NREL](#), 2011).

The 2026 edition's foreword lists the changes from 2016: updated boundary measurement requirements; on-site generation measured in kWh; changed 12-month recording and watt-meter rules; a new requirement for electricity used to export non-electric energy outside the boundary; a new requirement for when E_{DC} or E_{IT} cannot be measured as specified; a mixed-use building derivative (mPUE); and more designed-PUE (dPUE) examples ([ISO OBP](#), Foreword). Other derivatives are iPUE (interim, any period other than 12 continuous months) and pPUE (partial, a defined sub-boundary).

Measurement categories

The 2026 text keeps three categories: Category 1 "basic resolution", Category 2 "intermediate" and Category 3 "advanced" ([VDE preview](#), 30134-2:2026). Meter locations are not in the free preview. The EU regulation ties Category 1 to UPS output and Category 2 to the PDU ([Reg. 2024/1364, Annex II\(e\)](#)), matching the 2011 multi-agency task force definitions ([DOE task force](#), 2011):

Category	IT meter location	Still counted as "IT"
1	UPS output, 12-month kWh	PDU and transformer losses; rack-mounted non-IT devices such as fans
2	PDU output	Rack-mounted non-IT devices such as fans
3	IT equipment input (receptacle)	Only the device, including its internal fans and PSU

The task force adds that non-IT equipment fed from the UPS or PDU, such as CRAH units or in-row coolers, "must be metered and subtracted" from the IT reading. GPU retrofits miss this often, because CDUs and RDHx fans get fed from the nearest circuit.

The EU rule measures E_{DC} before the supply transfer switchgear, with back-up generator energy reported separately, and E_{IT} at Category 1 unless there is no UPS. Category 1 and Category 3 PUEs for the same building differ by construction: PDU losses leave the IT denominator but stay in total energy, so Category 3

reads higher.

Where PUE misleads with liquid cooling

In a Vertiv and NVIDIA study moving a facility from 100% air to 75% direct-to-chip cooling, total data center power fell 10.2% but PUE fell only 3.3%. Server fan power dropped 80%, and because fans sit in the IT denominator, IT power fell 7%. Between two intermediate studies, total power fell 1.8% while PUE stayed at 1.35 ([Vertiv, 2023-03-03](#)). Removing fan kWh shrinks numerator and denominator equally, which pushes PUE up while total energy falls. CDU pumps do the reverse: fed from an IT PDU and not subtracted, they inflate E_{IT} and flatter PUE.

Worked example (hypothetical)

An air-cooled GPU hall is retrofitted to direct-to-chip. Values are average kW; compute load (GPUs, CPUs, memory, NICs, PSU losses) is held at 920 kW.

kW	A: air	B1: liquid, CDU on IT PDU	B2: liquid, CDU sub-metered as facility
Compute	920	920	920
Server fans	80	20	20
CDU pumps	0	15 (in IT)	15 (in facility)
E_{IT} as metered	1,000	955	940
Facility overhead incl. CDU where applicable	350	280	295
E_{DC}	1,350	1,235	1,235
PUE	1,350/1,000 = 1.350	1,235/955 = 1.293	1,235/940 = 1.314
E _{DC} / compute	1.467	1.342	1.342

Total energy falls $(1,350 - 1,235)/1,350 = 8.5\%$; PUE falls 2.7% (B2) or 4.2% (B1), and the 0.021 gap between B1 and B2 is purely a metering choice. The last row is a simplified total-power usage effectiveness (TUE), proposed by Patterson et al. in 2013: total energy divided by energy delivered to computational components, equal to ITUE x PUE ([Patterson et al., ISC 2013](#)). Full TUE also removes PSU and voltage-regulator losses, which this table does not.

Rules for GPU halls:

1. Sub-meter CDUs, RDHx fans and in-row coolers and classify them as facility load.
2. Publish PUE with its category, plus absolute E_{DC} in MWh. Falling E_{DC} with flat PUE is the expected signature of a good liquid retrofit.
3. Track server fan power from BMC telemetry; it is the term that hides the benefit.

- Do not rank air-cooled against liquid-cooled halls on PUE; the Vertiv authors say it "shouldn't be used to compare the efficiency of liquid and air-cooling systems".

Plant design and commissioning are covered in [GPU data center cooling design](#) and the [cold plate commissioning checklist](#).

ERF and ERE: crediting exported heat

Warm return water from liquid-cooled racks makes heat export more practical. Two metrics credit it.

ERF (ISO/IEC 30134-6:2021) is "the ratio of energy being reused divided by the sum of all energy consumed in a data centre" (ISO), counting only use "for an alternate purpose outside the data centre boundary" (ISO OBP 30134-6). The EU uses **ERF = E_{REUSE} / E_{DC}** , measured at the hand-off to the other party, minus any reused heat that cools the data center itself (Reg. 2024/1364, Annex II(j)).

ERE is The Green Grid's metric (white paper #29, member-gated); NREL's 2011 report, citing it, keeps the IT denominator: **ERE = (Total energy - Reuse energy) / IT energy**, which can fall below 1.0. NREL's Research Support Facility data center reported a PUE of 1.16 and an approximate ERE of 0.91 (NREL, 2011).

Substituting $E_{REUSE} = ERF \times E_{DC}$ (our algebra): **ERE = (1 - ERF) x PUE**.

Scenario B2 with a hypothetical 2,000 MWh/year heat-export contract:

- $E_{DC} = 1,235 \text{ kW} \times 8,760 \text{ h} = 10,818.6 \text{ MWh}$; $E_{IT} = 940 \times 8,760 = 8,234.4 \text{ MWh}$
- $ERF = 2,000 / 10,818.6 = \mathbf{0.185}$
- $ERE = (10,818.6 - 2,000) / 8,234.4 = \mathbf{1.071}$; check: $(1 - 0.185) \times 1.314 = 1.071$

Report ERF for ISO and EU purposes; if you quote ERE, quote PUE beside it, since ERE alone hides whether the facility got more efficient.

WUE: which water, against which energy

ISO/IEC 30134-9:2022 defines WUE as the "ratio of the data centre water consumption divided by the energy consumed by IT equipment", with water in m3 and energy in MWh (ISO OBP 30134-9). m3/MWh equals L/kWh numerically (1,000 L per 1,000 kWh), the unit most operators publish. The Green Grid introduced WUE in March 2011 for water "used on-site in operating a data center, including water used for humidification and water evaporated on-site for energy production or cooling" (Trellis, 2011).

ISO's symbols separate water input, water returned, water usage and reused water, and define an energy water intensity factor (EWIF, m3/MWh) for water used to produce energy. That is the site-versus-source split: site water crosses your meter; source water was consumed by generators making your electricity. The combining formulas are in the paid clauses and were not reviewed.

The EU rule is simpler: **WUE = W_{IN} / E_{IT}** , where W_{IN} is all water entering the boundary for data center functions (EN 50600-4-9 Category 2, else Category 1), E_{IT} in MWh, with potable input reported separately (Reg. 2024/1364). W_{IN} is an input quantity, not net consumption.

Published figures mix bases. Microsoft reported a fiscal-2024 global average "withdrawal WUE of 0.30 L/kWh" and says its closed-loop chip-level design will avoid "more than 125 million liters of water per year per datacenter", while replacing evaporative systems with mechanical cooling "will increase our power usage effectiveness (PUE)" ([Microsoft, 2024-12-09](#)). Lower site water for higher energy is the central WUE trade.

Worked example (hypothetical): evaporative versus dry heat rejection

Scenario B2, E_IT = 8,234.4 MWh/year:

	Evaporative	Dry coolers
Site W_IN	12,000 m3	500 m3 (domestic)
E_DC	10,818.6 MWh	1,275 kW x 8,760 = 11,169.0 MWh
Site WUE	12,000 / 8,234.4 = 1.457 L/kWh	500 / 8,234.4 = 0.061 L/kWh
Source water at EWIF f	10,818.6 f	11,169.0 f

Combined water is equal when 12,000 + 10,818.6 f = 500 + 11,169.0 f, so 11,500 = 350.4 f and **f = 32.8 m3/MWh**. Below that grid water intensity, dry cooling uses less total water in this example. The break-even moves with the dry-cooling energy penalty and the local grid, so a site WUE without PUE and EWIF beside it is incomplete. For volumes, see [how much water data centers use](#).

CUE: carbon per unit of IT energy

ISO/IEC 30134-8:2022 defines CUE as the "ratio of the data centre annual CO2 emissions and IT equipment energy demand", emissions in kg and energy in kWh, so kg CO2e/kWh ([ISO OBP 30134-8](#)). Its symbol list includes emissions from on-site generation, generator testing and refrigerant leakage, and it considers seven greenhouse gases including HFCs and SF6.

For an all-electric site with grid factor f_e and no other emissions, $CUE = f_e \times E_{DC} / E_{IT} = \mathbf{f_e \times PUE}$ (our algebra). At a hypothetical 0.35 kg CO2e/kWh in scenario B2: 0.35 x 10,818,600 kWh = 3,786,510 kg; CUE = 3,786,510 / 8,234,400 = **0.460 kg CO2e/kWh** (= 0.35 x 1.314). Refrigerant leakage and generator tests then add to the numerator independently of PUE.

The emission factor dominates. The GHG Protocol Scope 2 Guidance requires companies operating in markets with contractual instruments to report scope 2 "in two ways", location-based and market-based ([GHG Protocol, 2015](#)); a revision consultation ran from 2025-10-20 to 2026-01-31 ([GHG Protocol](#)). Whether 30134-8 prescribes either method is in the paid text and was not verified, so state the basis next to every CUE. The EU regulation does not use CUE; it reports $REF = E_{RES-TOT} / E_{DC}$, summing guarantees of origin, PPAs and on-site renewables.

Metering plan

Quantity	Meter point	Notes for liquid-cooled halls
E_DC	Every supply before transfer switchgear, plus generators	Generator kWh separately
E_IT (Cat. 1)	Every UPS output feeding IT	Subtract CDUs, RDHx, in-row units on UPS circuits
E_IT (Cat. 2/3)	PDU outputs or rack PDU receptacles	Enables per-hall pPUE
CDU / RDHx	Dedicated sub-meters	Facility load
Thermal energy	Flow and delta-T on secondary and heat-export loops	Needed for pPUE and ERF
E_REUSE	Hand-off to heat customer	Net of heat reused on site
W_IN, potable	Every water supply at the boundary	Separate cooling make-up from domestic
Carbon inputs	Bills, contracts, refrigerant logs, generator hours	Location- and market-based

The EU regulation also requires annual average waste heat temperature, measured where heated fluid enters the heat exchangers at the computer-room boundary ([Reg. 2024/1364, Annex II\(k\)](#)); in direct-to-chip halls, plan that sensor at commissioning. A site in operation for less than a year reports "only for the period the data centre has been in operation" (Art. 3), which makes the value an interim figure; label it as one. A new GPU hall at 30% load will show a poor iPUE because fixed overhead is spread over little IT energy.

Benchmarks and comparability

Uptime Institute's 2025 survey reports "average PUE levels show little change for the sixth consecutive year", few facilities above 30 kW per rack, and no improvement in sustainability-metric reporting ([Uptime Institute, 2025-07-29](#)). Survey averages mix categories, climates and load factors; they are context, not a target.

Before comparing two PUEs, check category, a full 12-month basis, treatment of CDU and RDHx loads, and load factor. For WUE, check withdrawal versus consumption and whether source water is included. For CUE, check the emission-factor method and refrigerant treatment.

Europe is forcing a common basis. Regulation 2024/1364 required reports by 15 September 2024, then by 15 May each year from 2025, covering PUE, WUE, ERF and REF. On 21 September 2026 the Commission adopted a delegated regulation, C(2026) 3472, creating a mandatory A-to-G label graded on PUE and WUE for sites of at least 500 kW, subject to a two-month (extendable) scrutiny period, with first labels expected in 2027 ([Linklaters, 2026-10-14](#); [Commission](#)). As of 2026-10-28 it was still under scrutiny and not yet in the Official Journal; take grade thresholds from the published text.

Reporting template for colocation and internal teams

Field	Content
Boundary	Diagram; mixed-use status (mPUE)

Field	Content
PUE	Annual value, category, period dates
E_DC, E_IT	MWh, generator MWh separately
Cooling on IT circuits	CDUs, RDHx, in-row units and whether subtracted
pPUE	For your hall or suite, if sub-metered
WUE	L/kWh, withdrawal or consumption, potable share, EWIF if source water included
ERF	E_REUSE MWh and hand-off point, or none
CUE	Location- and market-based, refrigerant in or out
Gaps	Estimated or unmetered quantities

Example contract clause: "Provider shall report annual PUE per ISO/IEC 30134-2:2026 (state category), with coolant distribution and rear-door heat exchanger energy metered separately and excluded from IT energy, and shall provide monthly E_DC and E_IT in kWh." A PUE commitment without category and boundary can be met by moving a meter.

Using PUE in energy and cost models

Facility MWh = IT MWh x PUE only holds when both share a period and a boundary; the [GPU cluster energy calculator](#) follows that structure. Three cautions:

- **Boundary.** IT energy built from measured node power is effectively Category 3; multiplying it by a Category 1 PUE understates PDU losses. Ask for the matching category or a pPUE.
- **Load.** Use a PUE measured or designed at the load you will run, not at full design load.
- **Cooling changes.** After a liquid retrofit, model E_DC from the new plant, fan and pump loads, as in the worked example, rather than applying the old PUE to an IT figure that no longer contains the same fans.

GPU Smith works on these boundary and metering questions in private GPU facility planning.

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