Data Centre Cooling Systems Guide

Matching Cooling Architecture to Rack Density and Facility Format

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The Core Job of a Cooling System

A data centre cooling system has exactly one job: remove heat from IT equipment at the same rate it is generated, keeping intake air temperature within the equipment manufacturer's specified range (typically per ASHRAE thermal guideline classes A1–A4). Every cooling architecture below is a different way of doing that job at a different density and scale.

Cooling Architecture Options

Room-Based Cooling (CRAC/CRAH)

Computer Room Air Conditioners (CRAC, with integral refrigerant compressor) or Computer Room Air Handlers (CRAH, fed by chilled water from a central plant) condition air at the room level, typically delivered via underfloor plenum or overhead ducting into the cold aisle.

- **Best suited to:** 3–8 kW/rack average density, standard enterprise and colo deployments.
- **Key design factor:** underfloor plenum depth and perforated tile placement must be engineered together — too few or poorly placed tiles starve distant racks of airflow even when total CRAC capacity is adequate.

Hot Aisle / Cold Aisle Containment

Not a cooling technology itself, but a containment strategy (physical barriers via doors and roof panels) that prevents hot exhaust air mixing with cold supply air — dramatically improving the effective capacity of whatever cooling technology sits behind it. See our Floor Plans guide for containment design details.

- **Typical efficiency gain:** containment alone can improve usable cooling capacity by 20–30% versus an uncontained room at the same CRAC/CRAH capacity, by eliminating recirculation losses.

In-Row Cooling

Cooling units placed directly within the rack row (rather than around the room perimeter), delivering air over a much shorter path directly into the adjacent cold aisle.

- **Best suited to:** 8–20 kW/rack density, especially in retrofits where room-perimeter CRAC capacity can't be economically increased.
- **Key design factor:** in-row units must be sized and spaced against actual row density — as a rule of thumb, sufficient in-row cooling capacity should sit within one or two rack positions of the load it serves.

Rear-Door Heat Exchangers (RDHx)

A liquid-cooled heat exchanger unit replaces or attaches to the rack's rear door, capturing heat directly at the point of exhaust using chilled water or refrigerant, before it ever enters the room air.

- **Best suited to:** 15–35 kW/rack, and increasingly the preferred solution for HPC-density racks that don't yet require full liquid cooling.
- **Key design factor:** requires liquid piping (chilled water or refrigerant) routed to each rack position — a materially different

facility design than pure air cooling, so this decision must be made early in the Build Guide process, not retrofitted into an air-only design.

Direct-to-Chip Liquid Cooling

Cold plates attached directly to high-heat-generating components (CPUs, GPUs) circulate coolant that removes heat at the source, before it is released into the chassis air stream at all.

- **Best suited to:** 40–100+ kW/rack, the density range now common in AI/ML GPU training clusters.
- **Key design factor:** requires a facility-side coolant distribution unit (CDU) and piping infrastructure; typically deployed alongside residual air cooling for the smaller heat load that isn't captured at the chip (memory, power supplies, etc.).

Immersion Cooling

IT equipment (typically without fans) is submerged in a dielectric fluid that absorbs heat directly from all components simultaneously.

- **Best suited to:** ultra-high-density deployments where floor space is at an absolute premium and equipment can be qualified for immersion operation.
- **Key design factor:** a genuinely different rack and equipment handling paradigm — most mainstream enterprise hardware is not designed or warrantied for immersion operation without qualification.

Free Cooling and Climate Dependency

In climates with sufficiently cool and/or dry ambient conditions for enough hours per year, air-side or water-side economisation can bypass mechanical refrigeration entirely for some or all of the year, substantially reducing PUE. This is a site-selection and climate-data question as much as an equipment question — the achievable free-cooling hours depend heavily on local wet-bulb temperature profile, which is why cooling architecture decisions should reference actual climate data for the facility's location, not generic regional assumptions.

Choosing a Cooling Architecture: A Decision Framework

1. **Start from your rack density target** (see our Space Utilisation guide) — this alone eliminates most unsuitable options immediately.
2. **Check climate suitability for free cooling** at your specific site — this affects achievable PUE and total cost of ownership more than almost any other single design choice.
3. **Confirm liquid infrastructure feasibility** if density requires RDHx or direct-to-chip — piping, CDU space, and water treatment/quality requirements must be designed in from the start, not added later.
4. **Match containment strategy to your chosen cooling technology** — see our Floor Plans guide for hot/cold aisle containment design appropriate to your cooling architecture.
5. **Plan for mixed-density zones** if your facility will host multiple workload types — segment by row or by hall rather than attempting a single cooling architecture to serve wildly different density zones.

Water Usage Effectiveness (WUE) Considerations

Evaporative cooling technologies (cooling towers, evaporative economisers) typically achieve excellent PUE in hot, dry climates but consume significant water — increasingly a scrutinised trade-off for sustainability-conscious operators. Where water stress is a site concern, closed-loop chilled water systems or air-cooled chillers (at some PUE cost) may be the more defensible long-term choice; treated wastewater reuse is an increasingly common mitigation where evaporative cooling is retained.

How Athena Rack Supports Cooling Architecture Decisions

Our rack range includes both standard air-cooled enclosures and liquid-ready platforms pre-configured for rear-door heat exchanger and direct-to-chip manifold integration, so your cooling architecture decision and your rack procurement can be specified together rather than as two disconnected purchasing processes.

Related Resources

- Space Utilisation & Capacity Planning — density modelling that drives cooling architecture selection
- Data Hall Floor Plans — containment design matched to cooling technology
- Rack Design & Selection Guide — liquid-ready and high-density rack platforms
- Power Distribution & Redundancy Planning — coordinating cooling redundancy with power redundancy