LG

Ahead of the Expected

Integrated Cooling Strategies for Data Centers

WHITE PAPER

Integrated Cooling Strategies

for AI-Driven Data Centers

01

The Role of Cooling in AI-Driven Data Centers

Introduction

Artificial intelligence is transforming the demands placed on data centers. AI workloads—spanning both training and inference—drive rack densities far beyond conventional IT, with thermal loads in some cases surpassing 80 kW per rack. In this environment, cooling is no longer a supporting function; it has become a decisive factor in ensuring uptime, energy efficiency, and long-term sustainability.

Conventional air-based systems on their own are insufficient for these requirements. Operators now need integrated thermal strategies that combine multiple technologies—chillers for baseline stability, air-side solutions for energy savings where climate allows, liquid cooling for high-density racks, and intelligent control platforms to unify operations. This paper examines these core elements, describes how they work together in AI-driven facilities, and highlights why integration is the key to achieving reliable, scalable, and efficient performance.

The Role of Cooling in AI-Driven Data Centers

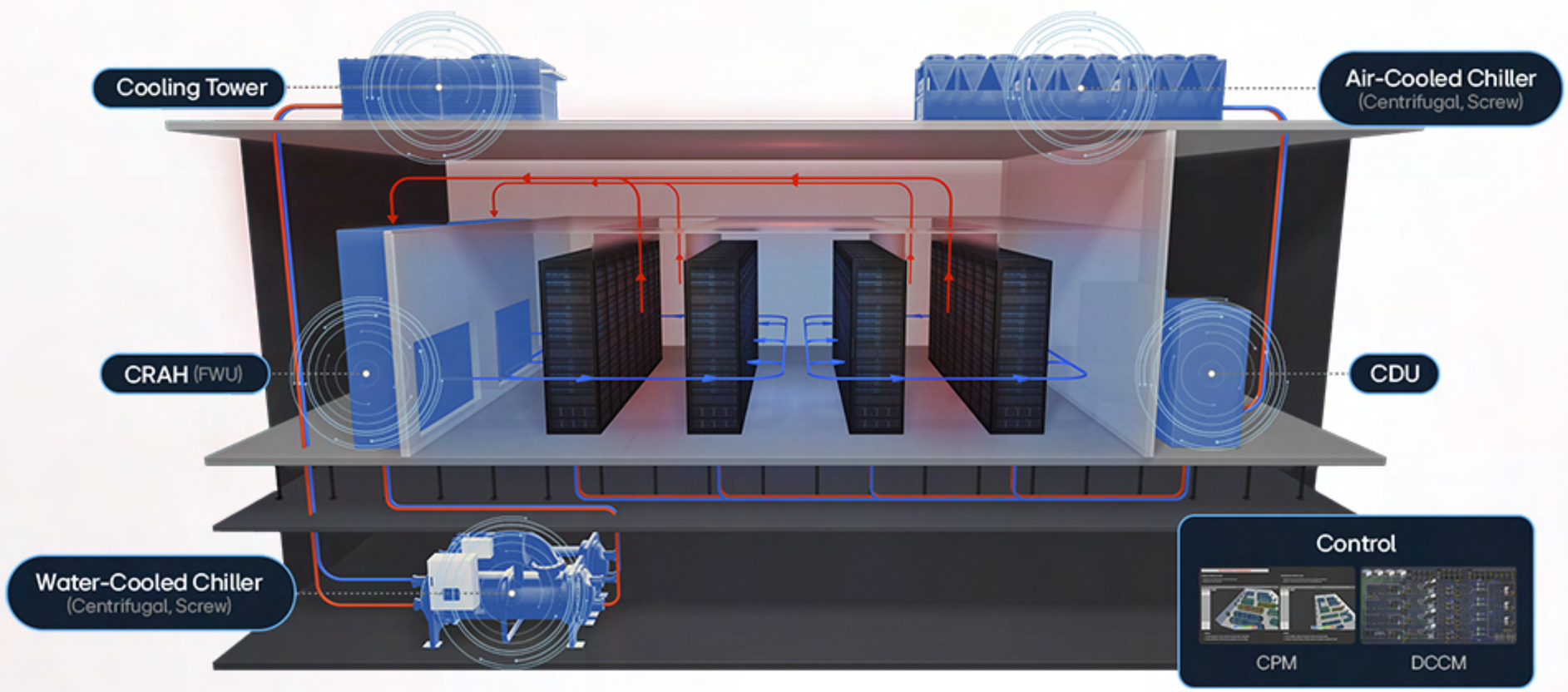
The shift from general-purpose computing to AI workloads has pushed data centers into new territory. Traditional racks drawing 5–10 kW have been replaced by AI systems consuming 30–50 kW, with some racks exceeding 80 kW. This dramatic rise in thermal density has made conventional cooling methods insufficient. To protect uptime, control costs, and meet increasingly strict efficiency targets, cooling must now be treated as a core element of data center performance rather than a background utility.

Meeting these demands requires a comprehensive approach. No single technology can handle AI-scale thermal loads on its own. Instead, modern facilities depend on integrated strategies that combine mechanical systems, air-side efficiency measures, liquid-based solutions, and intelligent centralized controls. Together, these layers form the backbone of next-generation cooling infrastructure, balancing reliability with scalability in AI environments.

Core Components of AI Cooling Strategies:

- **Chillers:** Deliver the chilled-water foundation that underpins the entire cooling system.
- **Air-side systems:** Utilize filtered and conditioned cool air to effectively prevent the formation of localized hot spots and maintain a stable thermal environment within the servers.
- **Liquid and direct-to-chip cooling:** Address extreme rack-level thermal densities by strategically capturing and removing heat directly at the processor level, maximizing cooling efficiency.
- **Integrated management:** Coordinate all subsystems to maintain efficiency, stability, and resilience.

By integrating these elements into a unified framework, operators can scale AI capacity while remaining within the boundaries of energy efficiency, cost-effectiveness, and environmental responsibility.



02
Chillers

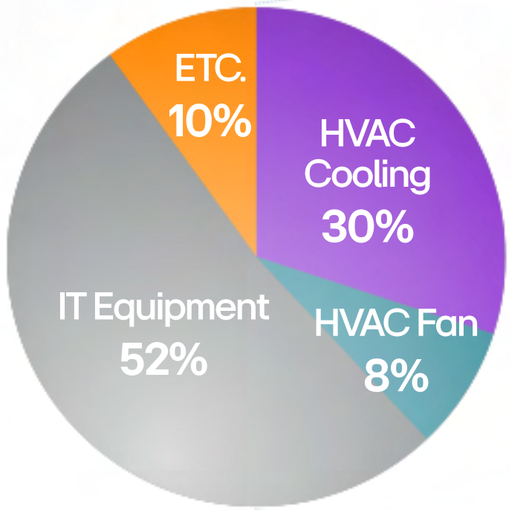
Chillers – The Core Thermal Infrastructure

Chillers form the foundation of modern data center cooling. By generating the chilled-water supply, they enable both air-based and liquid systems to operate effectively. In AI-driven environments—where workloads increase and rack densities can exceed traditional limits—chillers must deliver stability, efficiency, and adaptability. Because cooling accounts for as much as 40 percent* of total facility energy use, even incremental gains at the chiller level translate into meaningful savings in cost and carbon impact.

To address these requirements, manufacturers have introduced advanced chiller technologies engineered for large-scale computing. LG's portfolio reflects this progression, offering solutions tailored to the scale and intensity of AI workloads while maintaining operational resilience. Each model emphasizes high energy efficiency, eco-conscious refrigerants, and integrated free-cooling options that lower overall power consumption.

* https://www.boydcorp.com/blog/energy-consumption-in-data-centers-air-versus-liquid-cooling.html

Power usage breakdown by application within the data center



Improve Efficiency of HVAC Solutions

- In-house production of core components
- Rapid response to product issues

Reduce Data Center Operating Costs

- 10–15% reduction in CAPEX
- 5–10% reduction in OPEX

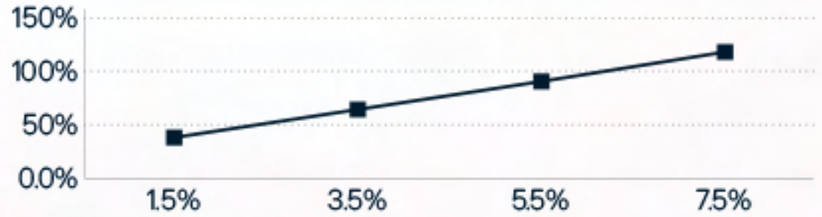
Key Technologies and Functional Benefits of LG Chillers:

- In-house developed oil-free magnetic bearing compressors (LeviTech™): Eliminate friction and wear, reducing maintenance needs and minimizing energy loss.
- Fast Recovery technology: Restores full operation rapidly after power interruptions, minimizing downtime.
- Broad capacity ranges from compact units to 5,000 RT: a complete lineup covering absorption, screw, scroll, and centrifugal models, including water-cooled magnetic centrifugal chillers utilizing low-GWP refrigerants (R-1233zd, R-513A).
- Free Cooling Operation: When outdoor air temperature conditions are favorable, the air-cooled chiller operates compressors at partial load or, without running compressors, uses only condenser fans to exchange heat with the outdoor air, thereby reducing energy consumption.
- High Partial Load Efficiency: Achieves high efficiency during variable workloads through the use of LG's in-house inverter technology, which precisely matches output to real-time demand.
- AI-based Surge Prevention Logic: Utilizes machine learning to predict and avoid surge conditions, ensuring stable and continuous chiller operation.
- Certified Reliability: Verified through AHRI testing and major international standards such as ETL, UL, CE, and ASME, ensuring globally recognized performance and safety.

LG's chiller portfolio brings these innovations together with a focus on reliability, convenience, and energy savings. The result is infrastructure capable of supporting the rapid growth of AI while reducing overall power consumption and ensuring uninterrupted performance.

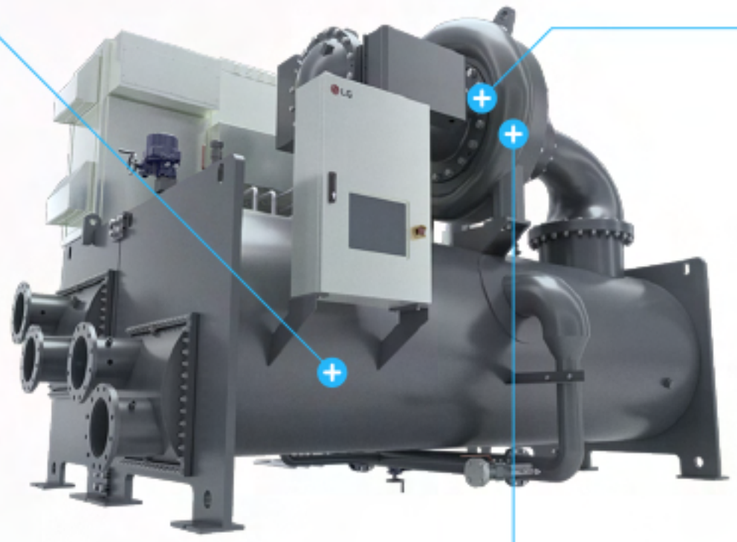
LG Water-cooled Centrifugal Chiller

HEX



Efficiency loss according to evaporator oil content
(Conventional)

High HEX efficiency



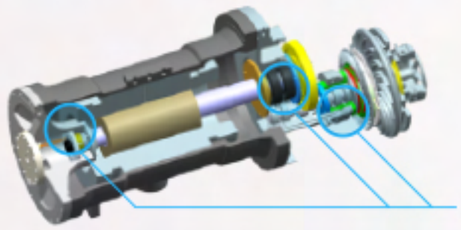
Inverter

Inverter speed modulation

High partial load efficiency

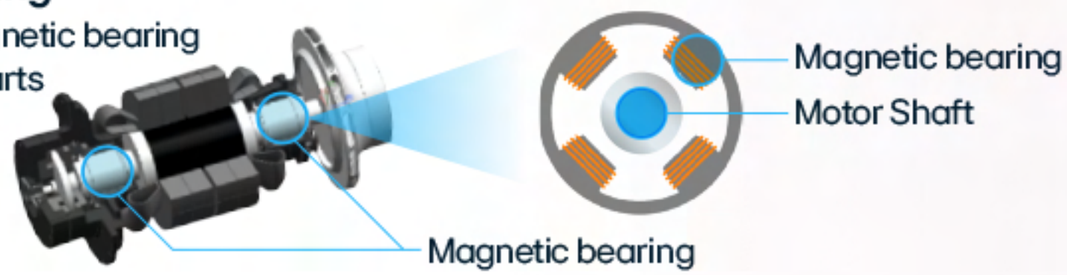
Compressor & Motor

Conventional (oil-based)



Magnetic bearing

- No contact magnetic bearing
- No oil related parts

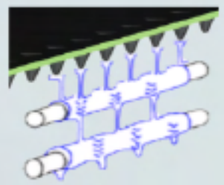


LG Air-cooled Chiller

High Efficiency

Inverter Screw

Magnet compressor

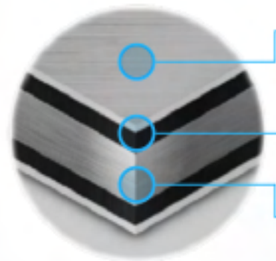


Falling Film Evaporator

Falling Film Evaporator

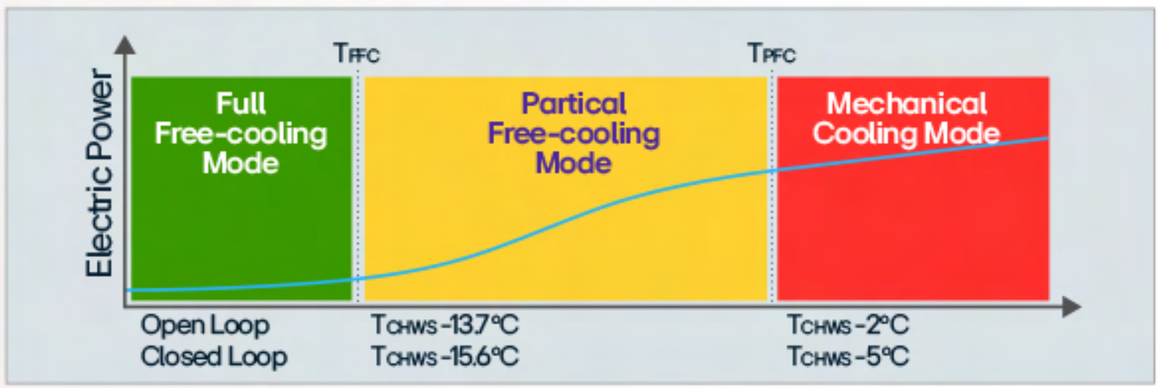
Reliability

Corrosion resistant fin

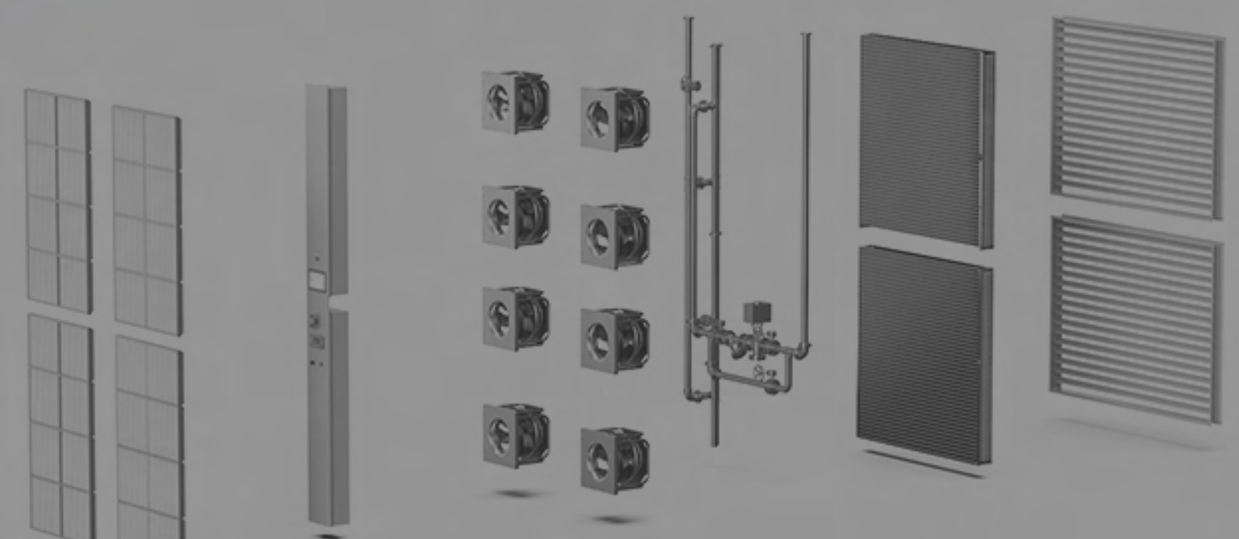


Multi circuit back-up operation

Free-cooling operation



03
Air-side Systems



Air-side Systems – Enhancing Efficiency Through Advanced Airflow Control

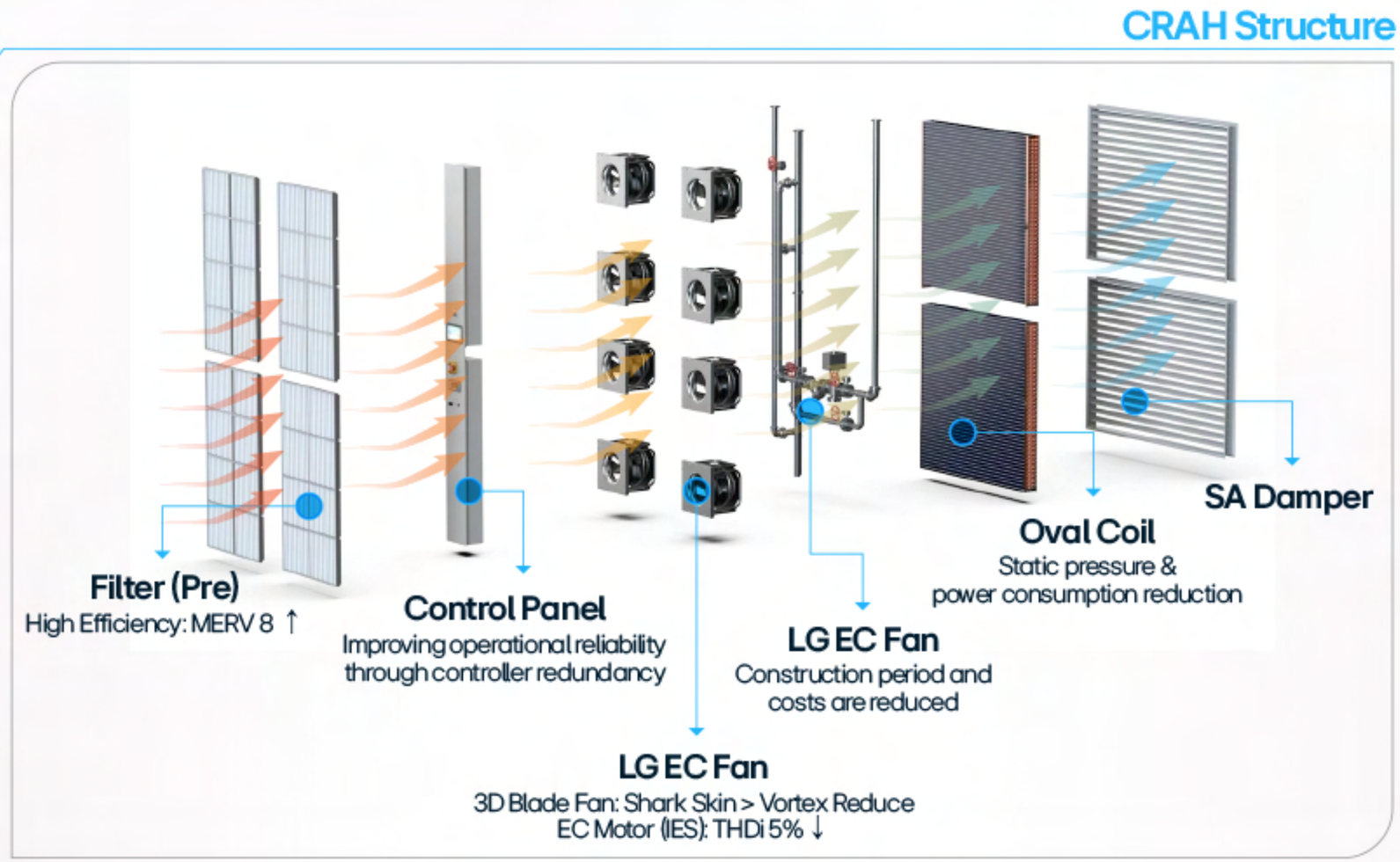
LG's CRAH (Fan Wall Unit) focus on maximizing heat exchange efficiency within the data hall rather than introducing outdoor air. Designed for precision and reliability, these systems use advanced airflow management and high-efficiency components to maintain stable conditions for AI workloads.

Key Technologies and Functional Benefits of LG Air-side Systems:

- EC Fan (High Efficiency): Delivers powerful airflow at reduced power consumption, lowering operating costs and ensuring quiet, reliable operation.
- Modular Fan Wall Unit: Simplifies installation, allows flexible capacity expansion, and supports quick servicing and component replacement, minimizing downtime and improving reliability.
- Oval Coil Heat Exchanger: Increases surface area for enhanced heat transfer while minimizing pressure loss, improving overall system efficiency.
- Integrated Control: Coordinates fan speed, coil temperature, and airflow balance to maintain optimal cooling performance under varying loads.

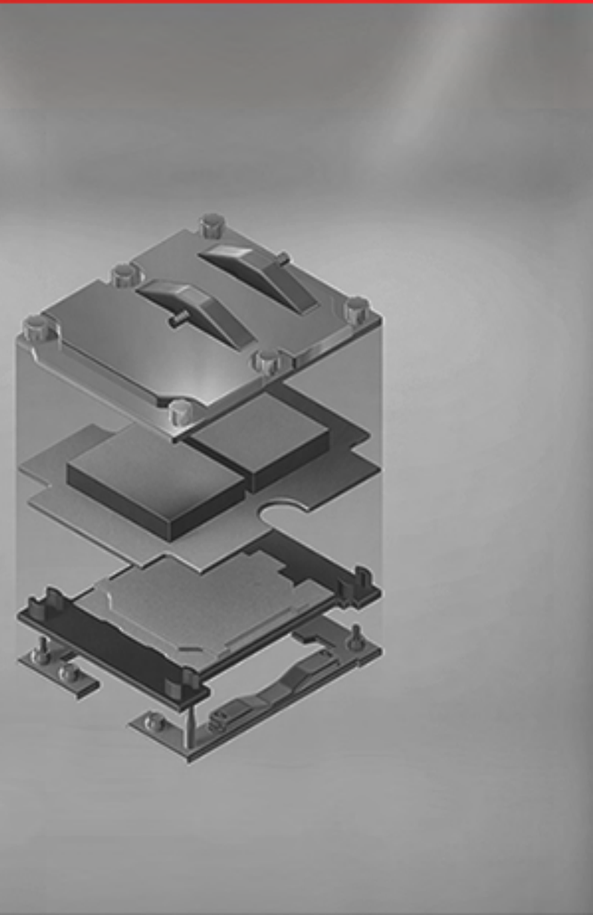
Together, these technologies enable LG's air-side solutions to maintain optimal environmental conditions while improving energy efficiency and operational simplicity. By focusing on internal airflow precision rather than outdoor air intake, they provide consistent, predictable cooling performance ideally suited for AI-driven facilities.

LG CRAH (Computer Room Air Handler)



04

Liquid and Direct-to-Chip Cooling



Liquid and Direct-to-Chip Cooling – Enabling High-Density, Scalable Performance

As rack densities climb into the 30–80 kW range and beyond, air-based systems alone can no longer provide sufficient cooling. Liquid cooling has emerged as the essential solution, transferring heat directly from processors and components to maintain peak AI performance. Within this framework, Direct-to-Chip Cooling systems —featuring integrated Cooling Distribution Units (CDUs) and Cold Plate modules—provide both facility-level liquid management and chip-level thermal precision.

To meet the requirements of AI-driven, mission-critical environments, LG has developed advanced liquid cooling technologies designed for durability, stability, and scalability. The CDU and Cold Plate systems operate as a unified solution, ensuring efficient, stable operation even under variable workloads.

Key Technologies and Functional Benefits

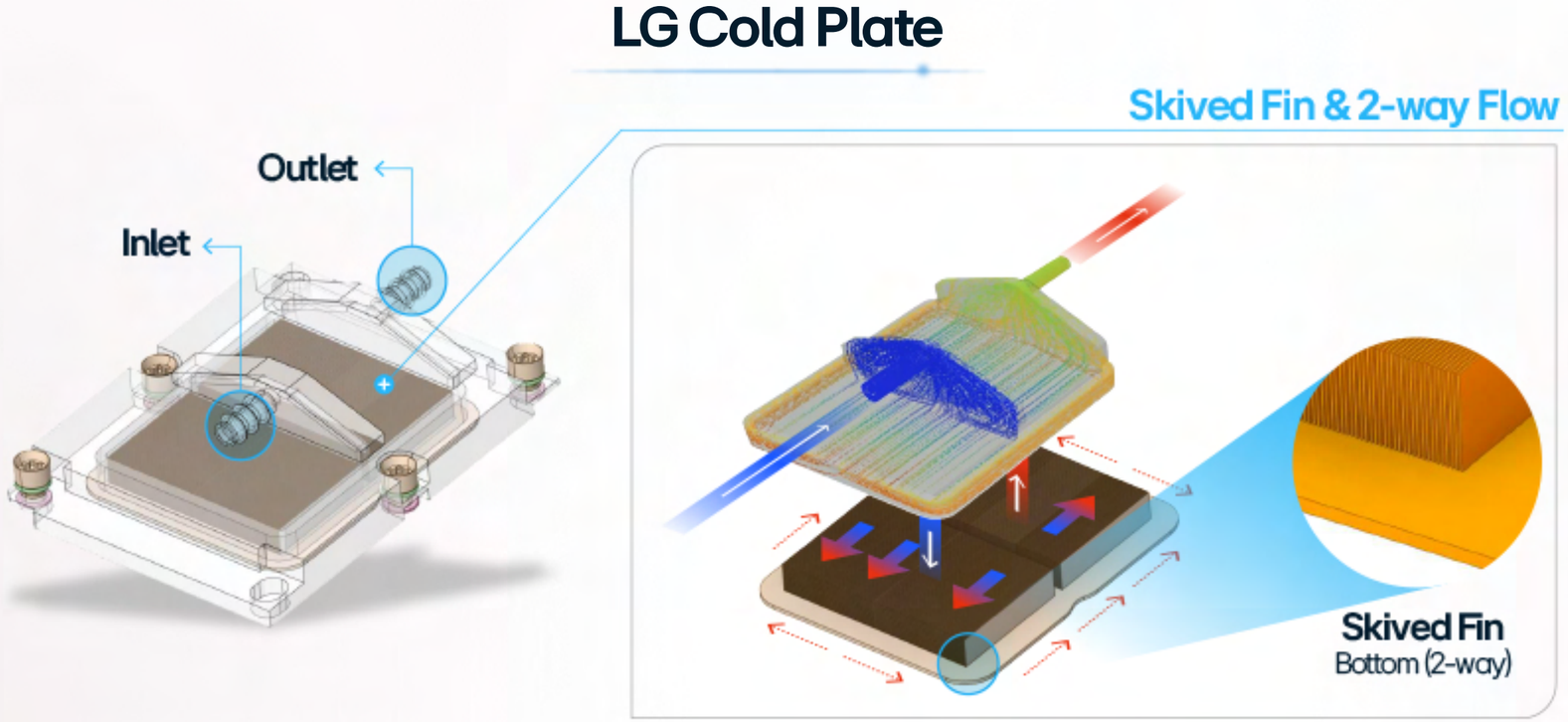
a. Coolant Distribution Unit (CDU):

- AI-based Virtual Sensors with Redundant Logic: Utilize machine learning algorithms to continuously detect sensor drift or failure and automatically compensate through virtual redundancy, offering uninterrupted system performance and maintaining stable coolant delivery under all load conditions.
- High-capacity CDU with Scalable Design (up to 2.5 MW planned by 2026): Provides flexible configuration for future data center expansion, maintaining efficiency at varying loads.
- Precise Control of TCS Temperature and Flow Rate: Automatically adjusts flow and pressure to match real-time cooling demand, optimizing energy use while protecting high-performance servers.

b. Cold Plate System:

- Skived Fin & Two-Way Flow Structure: Enhances heat transfer efficiency by increasing the cooling surface area through precision skiving, while the bidirectional flow design minimizes pressure loss and enables uniform temperature distribution across high-power chips.
- Parallel Coolant Supply: Secures stable cooling performance by supplying coolant at the same temperature in parallel.
- CDU-Compatible Adjustable Flow Rates: Supports coolant delivery from the CDU, providing precise temperature control for high-performance chips (0.25–3 LPM/kW).
- Leakage Prevention: Provides long-term reliability through brazing bonding technology that integrates the Cold Plate into a single sealed unit, verified with helium, ultrasonic, and pneumatic leak tests.
- AI-powered Optimization: Predicts cooling performance and recommends optimal fin geometry using an AI-trained model derived from extensive CFD analysis data, continuously improving design accuracy.

LG's CDU and Cold Plate solutions together support up to 80 kW per rack, offering a scalable and reliable foundation for high-density AI workloads. By combining centralized CDU control with chip-level cooling precision, LG delivers high-performance, safe, and energy-efficient operation optimized for AI data centers.



05

Integrated Management

Integrated Management – Intelligence Behind the Infrastructure

Even the most advanced subsystems can fall short if they operate in isolation. Centralized control platforms ensure that chillers, air-side systems, and liquid infrastructure work as a coordinated whole rather than as separate components. In AI data centers where workloads fluctuate rapidly, this coordination is crucial to maintaining energy efficiency, temperature stability, and operational reliability.

To meet this challenge, providers are deploying predictive, AI-driven platforms that continuously optimize operations. LG's BECON system illustrates this approach, delivering real-time coordination and intuitive management across diverse cooling assets.

Key Technologies and Functional Benefits:

- BECON DC Cooling System Integrated: Unifies chillers, CRAH units, CDUs, and Cold Plate systems under one cohesive control framework.
- AI-driven Predictive Control: Anticipates workload fluctuations and adjusts cooling in real time.
- LG DC Digital Twin: Enables operators to model scenarios and plan responses proactively.
- Simulation and Fault Diagnosis: Detects anomalies, prevents system errors, and enhances uptime while minimizing manual intervention.
- 3D Visualization: Offers clear, real-time insights and simplified control for efficient operation.

By transforming cooling management into a proactive, intelligent, and fully integrated process, BECON minimizes complexity, maximizes efficiency, and reinforces system reliability in AI-ready facilities.

Conclusion

As AI reshapes data center operations, cooling is no longer just an operational requirement—it has become a strategic advantage. Dense compute environments demand more than high-performance servers; they require a complete rethinking of thermal strategy.

No single technology can address every challenge. Success depends on integration, where:

- Chillers provide the stable foundation of cooling capacity.
- Air-side systems enhance internal heat exchange efficiency through precise airflow control and advanced fan technology.
- Liquid and direct-to-chip solutions manage the most extreme rack-level heat loads.
- Centralized controls unify all elements into a coordinated, adaptive architecture.

Equally important, these technologies must function as part of a system, with design, deployment, operation, and maintenance aligned under one vision.

LG Electronics delivers this unified approach through its comprehensive portfolio and deep expertise across every layer of HVAC technology. From consulting and system design to deployment and lifecycle management, LG provides end-to-end solutions tailored to the evolving needs of AI facilities.

By combining advanced technologies with integrated execution, LG enables operators to scale AI infrastructure confidently—building data centers that are resilient, efficient, and prepared for the future.

LG Data Center Cooling Solutions Lineup

Chiller

Scroll Chiller
(Air Cooled)

Screw Chiller
(Air Cooled)

Absorption Chiller

Scroll Chiller
(Water Cooled)

Screw Chiller
(Water Cooled)

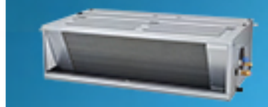
Centrifugal Chiller
(Water Cooled)

Air-side

AHU
(Air Handling Unit)

CRAH
(Computer Room Air Handling)

Cassette Type FCU



Duct Type FCU

Liquid Cooling

CDU
(Coolant Distribution Unit)

Cold Plate

VRF

Multi V
(VRF)

Multi / Single

GHP
(Gas Heat Pump)

LG BECON (Building Solution)

BECON controller

BECON Energy

BECON
(Building Solution)

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