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Leverage existing air-cooling infrastructure to streamline liquid cooling solutions

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Executive summary

There are many approaches to support AI workloads that require hybrid air and liquid cooling solutions, one of which is liquid-to-refrigerant coolant distribution units (L2R CDUs) with refrigerant-based heat rejection. In deploying L2R CDUs that integrate direct expansion (DX) refrigerant-based heat rejection with direct-to-chip liquid cooling technology, data center companies gain a faster path to deploying new liquid-cooled AI solutions. They can simultaneously harness the benefits of DX infrastructure to provide an internal chilled water loop and increase liquid-cooling capacity where needed. New pods can be added as required, providing the optimal balance of air and liquid cooling and creating a foundation for modular deployments without the complexity of a centralized chiller plant design. The technology offers flexibility not only in managing air and liquid cooling loads at the same time but also in deploying various IT loads or other CDUs with different liquid temperature requirements.

These technologies can be installed in both new and existing data centers, and this approach can enable teams to process different workloads at the same facility or within the same data hall. In this ebook, we:

- Discuss the benefits of using direct expansion heat rejection for hybrid air and liquid cooling heat loads emerging in today's data centers.
- Explain the pros and cons of leveraging this technology in both applications.
- Describe how operators can accommodate AI and high-performance computing (HPC) workloads that produce significant heat by setting up hybrid air and liquid cooling systems using DX technology.

AI growth is forcing a transformation in thermal management strategies

As enterprise demand for artificial intelligence (AI) workloads increases, rack density continues to rise. This increase in compute density leads to higher heat loads outpacing the capabilities of air-cooling infrastructure at hyperscale, cloud, and colocation facilities (hereafter called data center companies). Leaders and operators are evolving thermal management strategies at these enterprises to meet the demands of cooling high-density racks at 50kW and above.

However, not all data center leaders and operators are jumping to make this move, more because of the time, resources, and financial investment it entails. When companies install direct-to-chip cooling with an existing chilled water supply (chillers), it can take up to 11 months, provided new systems are available and not back-ordered. [1] Moreover, planning and installing new chilled water loops from equipment located outside to IT equipment inside requires careful planning and execution, often involving multiple suppliers or partners. Operators and businesses would prefer using or reusing existing infrastructure rather than completely replacing it with different technology, especially when the equipment is nowhere near the end of its life cycle.

[1] *Deploying Liquid Cooling in the Data Center, white paper, Vertiv, page 7, https://www.vertiv.com/en-emea/about/news-and-insights/articles/white-papers/how-to-implement-liquid-cooling-at-existing-data-centers/*

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Main challenges in deploying liquid cooling solutions

Data center leaders and operators are looking for other options to speed up the time to turn on liquid cooling capacity. Some of their main challenges in developing their respective liquid cooling strategies are:

1. Operators would like to quickly transition capacity in a phased manner to minimize upfront capital expense (CapEx) investments and operational disruption. When data center operators implement liquid cooling systems, they must take existing racks or rows offline and redesign mechanical and technical space to support new systems. This process reduces existing processing capacity and can harm data center companies' ability to meet demanding customer service-level agreements (SLAs).

2. Operators would like to standardize their approach. Rather than developing one-to-one solutions for each data center they manage, standardization simplifies all lifecycle processes for deploying new capacity. From minimizing upfront studies and space design to planning installations and managing new systems, a standard and repeatable approach helps teams enforce consistency of management and maintenance processes. This enables teams and vendors alike to gain economies of scale and avoid risks, such as mistakes when operators don't know how to operate and maintain systems.

3. Operators need to provide different liquid temperatures based on IT or physical infrastructure loads. The liquid cooling and data center industries are going through dynamic discussions on the best and the most optimized water supply temperatures for liquid cooling systems. For example, The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has identified several categories differentiated by the maximum temperatures. Different equipment—from graphic processing units (GPUs) and CPUs or servers to rear door heat exchangers (RDHx)— simultaneously require different temperature levels within the same data center.

4. Not all CDUs are compatible with available physical infrastructure. As stated earlier, not all paths to liquid cooling are the same, and not every CDU is compatible with existing heat rejection technologies. To support liquid-to-liquid CDUs, data centers require chilled water on site to remove heat from the IT equipment. Operators anticipate that the complete removal and replacement of the existing infrastructure to support liquid-to-liquid CDU deployments will result in the surge of upfront CapEx. The central chilled water system also represents additional challenges to deploying fully redundant data center designs.

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Bridging the gap: Liquid-to-refrigerant CDUs

Compared to the time and resources needed to install a direct-to-chip cooling with an existing chilled water supply, choosing L2R CDUs with refrigerant-based heat rejection is a faster, easier way to deploy liquid cooling. These CDUs provide an isolated chilled liquid (water or water/glycol) loop through the secondary fluid network (SFN) for high-density cold plate applications while rejecting the heat outdoors using an external refrigerant loop and condenser. As a chilled water supply, L2R CDUs can be used to provide cooling via the chilled water loop to the RDHx and other CDUs. This solution also offers a modular approach where capacity can be added to support data center growth, providing teams with greater flexibility in meeting new AI workload demands. In addition, CDUs enable operators to run liquid at temperatures as high as 40°C (105°F), creating greater business flexibility and significantly reducing energy costs.

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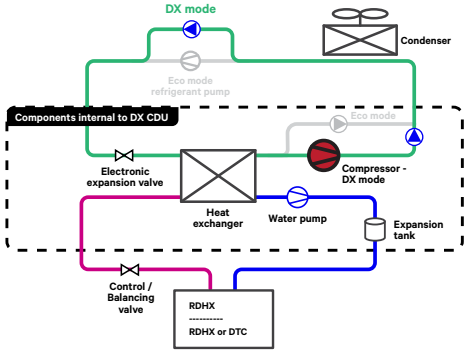
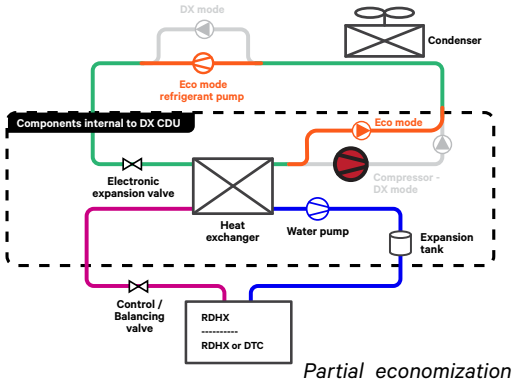
This system provides more hours of annual free cooling than comparative technologies. The L2R CDU system includes a pumped refrigerant economizer (PRE) on the roof that automatically adjusts between three operation modes based on ambient temperatures.

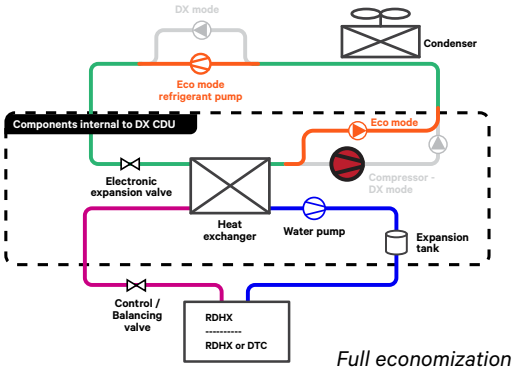
- **Compressor-only mode:** During warmer temperatures, the unit operates on its compressor alone, delivering standard DX heat rejection.
- **Partial economization mode:** During cooler temperatures (such as mild seasons and at night), the refrigerant economizer can provide partial free cooling to offset some of the compressor power usage. The refrigerant bypasses the first compressor and is instead pumped through the system, driving a net savings of over 90% compared to full compressor operation.
- **Full economization mode:** During cold temperatures (particularly in winter), both compressors are bypassed, and the system operates only on pumped refrigerant economization, maximizing operational efficiency.



Full compressor mode



Partial economization



Full economization

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Business and operational benefits

These L2R CDUs provide business, operational, and financial benefits. Financial benefits are discussed under the TCO section following this section. Companies can look forward to the following gains:

- **Continue deploying free-cooling systems:** Free-cooling solutions are some of the world's most widely deployed PRE systems[2] for data centers. Knowing they are compatible with these CDUs, data center operators can continue purchasing free-cooling systems, phasing their path to air-assisted liquid cooling, using different temperatures onsite, and gaining greater business flexibility.
- **Gain single-point accountability:** Liquid cooling is new for many companies. As a result, leaders and operators often want to work with one manufacturing company that has business and technical expertise and provides end-to-end solutions. Designers can get their questions answered, purchasing teams can sole-source equipment buys, and strategists and operators can speed up the deployment of new air-assisted liquid cooling capacity as they only need to communicate and collaborate with one provider with a comprehensive portfolio for thermal management technology, power management solutions, and hardware and software solutions, services, and controls that enable a more seamless transition.
- **Reduce site works:** With less site preparation, CDUs can be deployed faster than a chiller, which requires transforming mechanical and technical space. This enables data center companies to capture more business and remain competitive in a demanding market where customers expect to access near-term AI workload processing capabilities.
- **Increase business and operational flexibility:** CDUs provide data center companies with a standardized, scalable solution that accommodates AI and HPC business growth and enables cooling workloads with different heat loads at varying temperatures in the same space. Operators can convert racks and rooms at their desired pace, use CDUs independently or in a teamwork mode, and leverage this solution to provide new liquid cooling capacity across facilities and regions.
- **Increase visibility:** By adding unit controls to the CDU, data center operators can create a single pane of glass across their liquid cooling operations, monitoring temperature, pressure, and flow rate. This allows them to rapidly detect and address any anomalies that could harm operational performance before they occur.

[2] *PRE's advantages are discussed in the TCO section.*

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- **Streamline the path to business continuity:** Many AI and HPC workloads are critical loads requiring higher levels of redundancy. Instead of immediately deploying multiple facility-level chillers with unused capacity, data center operators can deploy smaller capacity CDUs in increments. This would allow for phased deployments of solutions that have higher redundancy, take up less space, and are quicker to deploy.

Total cost of ownership (TCO) for Vertiv™ L2R CDUs

Deploying CDUs to match chiller capacity requires similar capital. However, data center companies can phase these deployments, spreading the capital investment over extended periods and reducing TCO. They can install CDUs instead of air-cooled CRAC units as rack density increases and liquid cooling is needed. The TCO model includes:

- **Achieving higher rack densities with liquid cooling:** With Vertiv™ L2R CDUs, data center companies may accommodate higher rack densities more quickly than with a complete liquid cooling retrofit to deploy chilled water infrastructure. As a result, data center companies can drive more AI business sooner.
- **Avoid facility redesign:** Data center operators who want to preserve as much floor space for high-density IT equipment as possible can use RDHXs and CDUs to enable cold plate applications without creating new mechanical space or digging trenches for new liquid cooling equipment.
- **Reuse existing infrastructure:** Data center operators can continue to purchase and use free-cooling systems and install Vertiv L2R CDUs when ready to enable liquid cooling. In addition, operators can reuse existing condensers, refrigerant piping, and electrical wiring, reducing deployment costs. This means operators don't need to conduct extensive upfront studies, disrupt operations with new site works, or redesign power infrastructure, simplifying and accelerating the path to liquid cooling and enabling the deployment of pods of new capacity.
- **Increase capital efficiency:** Vertiv L2R CDUs enable data center leaders and operators to turn on new capacity in smaller increments for near-term demand, conserving upfront capital compared to purchasing and implementing a large chiller and liquid-to-liquid CDUs and redesigning piping and electrical connections.
- **Accelerate time to payback:** Ohio-based engineering firm TechSite conducted an independent TCO study of a free-cooling condenser and Vertiv L2R CDU system versus a competitor chiller at four data center locations across the United States. The study assessed all costs to plan, deploy, manage, and maintain the systems over a year. The highly efficient free-cooling and L2R CDU solutions delivered faster payback than the competitor chillers in all situations but one.[3]

[3] In the Dallas location study, due to lower costs of electrical energy, the competitor's chiller offered the second-fastest payback, while the R2L CDU was in third place. At the other three locations, free-cooling and R2L CDU solutions ranked #1 and #2 for TCO.

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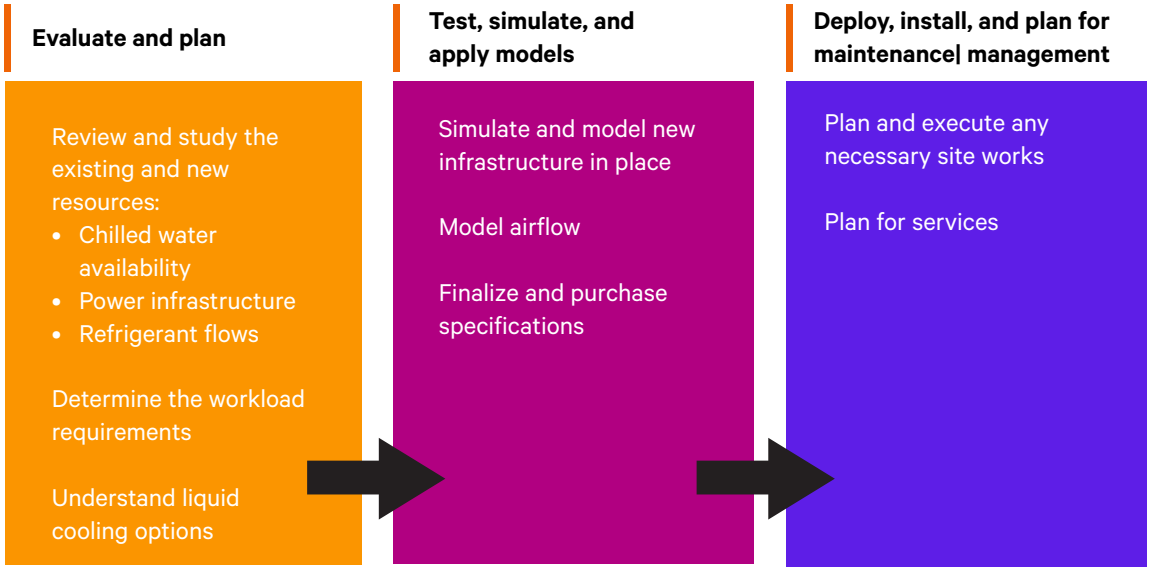
- **Increase energy efficiency:** Vertiv L2R CDUs capture and reject heat at the server level and utilize PRE for heat rejection, which is more efficient than fans or compressors. They can also provide higher water temperatures (up to 40°C or 105°F), which decreases the installations' power usage efficiency (PUE).

  Data center companies can also use cooling unit controls and variable-speed pumps to coordinate system components, automatically changing the flow of PRE based on load demands. Enterprises are using CDUs to run liquid cooling to the chip at temperatures as high as 86°.

  By reducing the maximum connected load for cooling, operators can save on costs or free up more computing power. For example, deploying an efficient hybrid air and liquid cooling system at an 8MW data center hall could enable operators to free up 0.5MW for IT, supporting 8.5MW of IT load.[4]

Strategic deployment and roadmap

The path to implementing Vertiv™ L2R CDUs will depend on whether existing Vertiv™ free-cooling solutions exist at the site. Here's a strategic overview for planning, testing, and deploying the transition to liquid cooling.



[4] *Interview with Vertiv expert.*

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I. Evaluate and plan

A. Review and study the existing and new resources needed:

- Chilled water: Sites without chilled water availability or that lack additional chiller capacity are good candidates for Vertiv™ L2R CDUs.
- Power infrastructure: Review the energy infrastructure in relation to planned growth. New Vertiv L2R CDU users should conduct a power design study to determine whether the current infrastructure, such as breaker sizes and amps, is sufficient for target workloads. If not, they'll need to add another breaker or feed.
- Refrigerant flows: Teams should review refrigerant and water piping—whether to reuse existing piping or install new ones—to ensure they can support new flows from the CDU.

B. Determine workload requirements: Consider how many kW or MW of new IT load will be supported by liquid cooling, existing footprint constraints or options (such as roof and data hall space availability), and desired water temperature for cooling workloads. Data center companies typically use customer demand and SLAs to drive liquid cooling adoption:

- New customer demand
- Contract renewals
- Market growth and other drivers in crafting hybrid air and liquid-cooling business cases

C. Understand liquid cooling options: Vertiv L2R CDUs may be the best solution for adding liquid cooling capacity to a site. However, it's essential to evaluate all options: consider liquid cooling approaches against goals, budgets, existing infrastructure, space available, and customer SLAs, among other considerations.

II. Test, simulate, and apply models

A. Model new infrastructure in space: Once teams and consultants agree to move ahead with Vertiv™ L2R CDUs, determine and simulate deploying modular liquid cooling capacity in 300 kW increments. They may deploy L2R CDUs individually, in teamwork mode, or to create pods of new capacity. Onsite, CDUs' slimline form factor makes them easy to place in data centers.

B. Model airflow: Teams should conduct an airflow study to determine how adding one or more CDUs will change airflow patterns. Typically, these units will be located throughout the data center space to minimize airflow impacts.

C. Finalize and purchase specifications: Teams should work with Vertiv to finalize specifications for Vertiv L2R CDUs and any other systems purchased. For new customers, teams will have to determine the number of L2R CDUs that will be deployed. For those with free cooling units to be replaced, L2R CDUs provide 2:1 replacement for free-cooling systems and can be scaled as desired. Data center operators can reuse free-cooling systems, condensers, piping, and power connections.

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III. Deploy, install, and plan for maintenance management

A. Plan and execute any necessary site work: After purchasing the CDUs and other supporting technologies, work can include creating or expanding piping, upsizing electrical connections, and more. Vertiv offers other equipment to provide data center companies with a complete hybrid air and liquid solution, such as heavy-duty racks, high-amperage busways, high-density rack power distribution units, and controls.

B. Plan for services: Liquid cooling demands greater service planning and management. In addition to installing and commissioning new systems, Vertiv will provide correct and preventive maintenance services to enable liquid systems' business continuity, fluid sampling and testing services, and remote monitoring and management capabilities.

Conclusion

Enterprise demand for AI/HPC workloads is heating up, placing pressure on data center companies to develop liquid cooling strategies and approaches that meet business demands, budgets, and operational requirements.

Rather than develop a one-to-many approach for each site they manage, operators would like to standardize their approach, leveraging existing templates and modular solutions to deploy new liquid cooling capacity. They'd also like to accommodate different heat loads, as they will process traditional and AI/HPC workloads at the same site.

L2R CDUs provide a modular solution that gives data center companies incredible business flexibility. They can

- Phase their approach to liquid cooling, reducing upfront CapEx investment.
- Gain a standard solution that can be dropped in and integrate with existing free cooling capacity.
- Run mixed heat loads in the same room.
- Use PRE to run liquid at higher temperatures, increasing energy efficiency and reducing energy costs.

Deploy Vertiv™ L2R CDUs and gain a standardized, modular solution that will support fast-paced AI/HPC business growth while maintaining operational continuity across a network of data center sites.

Learn more at Vertiv.com

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