HOW DIRECT LIQUID COOLING IMPROVES DATA CENTER ENERGY EFFICIENCY

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CoolIT systems™

Introduction

Data centers are experiencing increasing power consumption, space constraints and cooling demands due to the unprecedented computing power required by today's chips and servers. HVAC cooling systems consume approximately 40% of a data center's electricity. These systems traditionally use air conditioning, air handling and fans to cool the data center facility and IT equipment, ultimately resulting in high energy consumption and high carbon emissions. Data centers are moving to direct liquid cooled (DLC) systems to improve cooling efficiency thus lowering operating expenses (OPEX) as well as their carbon footprint.

This paper describes how CoolIT Systems (CoolIT) meets the need for improved energy efficiency in data centers. CoolIT is the global market and innovation leader in scalable DLC solutions for the world's most demanding computing environments. The company's products and services include end-to-end advanced cooling solutions that meet the rising demand in cooling and the rising demand for energy efficiency.

Data Center Efficiency Challenges

According to the IEA's Electricity 2024: Analysis and Forecast to 2026 report, in 2022 data centers, cryptocurrencies, and artificial intelligence (AI) consumed approximately 460 TWh of electricity worldwide – almost 2% of total global electricity demand. By 2026 data centre energy consumption is expected to more than double, growing to a range of between 620 to 1,050 TWh.

In most data centers, power consumption can be split into the following:

- 40% - Computing / Server
- 40% - Cooling System
- 20% - Other IT Equipment (Power Supply System (10%), Communication Equipment (5%) & Storage Equipment (5%)

Of this, cooling represents the largest opportunity for data centers to reduce power consumption.

Traditional data centers use air-cooling equipment to manage facility and IT infrastructure heat. This equipment includes chilling towers, pumps, computer room air conditioner (CRAC) units and computer room air handling (CRAH) units. Data center operators are starting to consider more efficient cooling alternatives due to:

- Increasing computing power;
- Increasing rack densities; and
- Sustainability regulations.

With the rise of AI, CPUs and GPUs are generating unprecedented heat while their operating temperature requirements for peak performance (case temperatures) are decreasing. Thermal Design Power (TDP) now exceeds 300W for CPUs and 600W for GPUs and is only expected to increase. In the next few years, processor roadmaps for server CPUs are expected to reach 500W to 600W. This raises the need for a more efficient cooling solution than what traditional air cooling can provide.

Server and rack designs are, also, densifying. Today, rack power densities can exceed 70kW per rack in normal operation, making it practically impossible to cool with traditional air-cooling methods that need space between servers to accommodate sufficient airflow with large heat sinks and server-level fans.

Data center operators are also responding to social pressure and, in some jurisdictions, regulations requiring implementing sustainability measures to decrease their carbon footprint. Regulations include improving Power Usage Effectiveness (PUE), lowering water usage, monitoring and reporting carbon emissions, and implementing heat reuse and renewable energy programs. Adopting technology that increases energy efficiency while enabling heat reuse programs would help a data center meet its sustainability goals as well as lower operating expenses (OPEX).

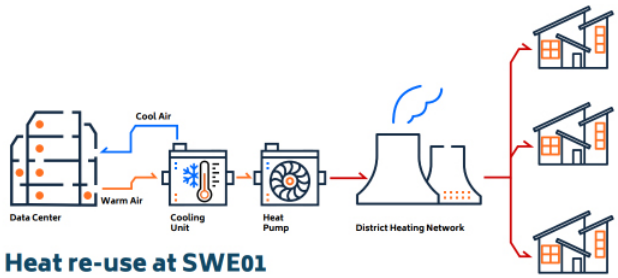
Direct Liquid Cooling by CoolIT Systems

One way to solve the efficiency problems that data centers are facing is through the implementation of Direct Liquid Cooling (DLC). As the global leader in DLC, CoolIT Systems (CoolIT) provides end-to-end solutions to optimize the performance of high-temperature processors and servers, increase rack densities and meet data center sustainability goals.

DLC Benefits for a Data Center

With DLC enabled, server component heat is targeted and captured in a liquid path resulting in the following benefits for a data center:

- Performance: Optimized processor and server performance due to more efficiently lowering chip and server temperatures compared to air.
- Density: Increased rack density, enabling 100% utilization of rack and data center spaces due to the lower profile of DLC on servers and higher cooling capacity compared to air.
- Scalability: Enabled scalability by connecting servers manufactured by multiple vendors into one fluid network.
- Energy efficiency: Increased energy efficiency and decreased PUE due to DLC requiring warmer facility water (ASHRAE W4) and less power to cool high TDP components compared to air.
- OPEX / TCO: Lowered OPEX and lowered Total Cost of Ownership (TCO) due to decreased usage, or elimination, of chillers, CRACs, and CRAHs.
- Sustainability: Increased sustainability by decreasing power consumption, decreasing water consumption for evaporative cooling, and enabling heat reuse programs.



DLC-enabled heat reuse program in Sweden; a partnership between atNorth and CoolIT Systems

(Image credit atNorth)

To take advantage of the benefits that DLC has to offer, CoolIT provides end-to-end solutions that make DLC implementation an efficient and turnkey experience for data center operators.

End-To-End Solutions for Data Center Efficiency

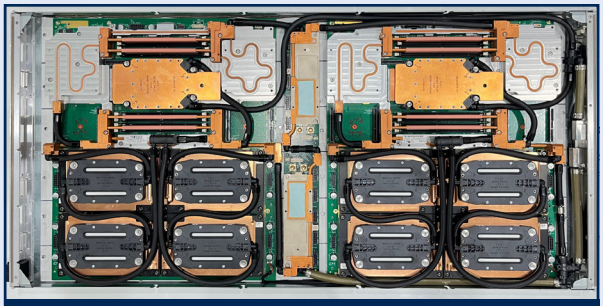
CoolIT System's complete end-to-end liquid cooling solution consists of its patented spit flow cold plates, passive coldplate loops (PCL), rack manifolds, secondary fluid networks (SFN) and coolant distribution units (CDUs).

CoolIT's New Product Introduction (NPI) team works closely with semiconductor and server manufacturers to produce PCLs adapted to each generation of their high-performance computing products. Their Professional Service group and global network of Authorized Service Providers (ASPs), provide data center operators with design, installation, and commissioning services, plus training, SLA-based maintenance programs and warranty support.

CoolIT also offers rear door heat exchangers (RDHx) as another tool for managing highly dense heat loads.

The following is a breakdown of CoolIT System's products and services:

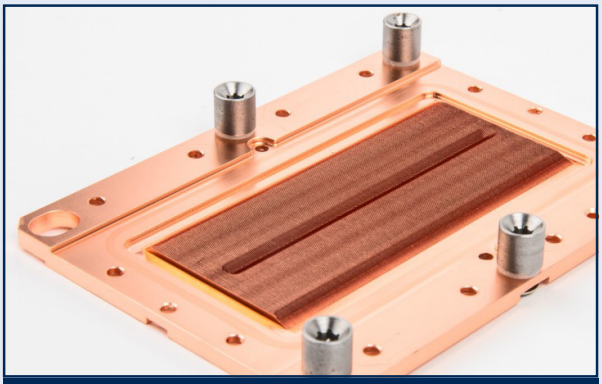
Passive Coldplate Loops (PCL) are installed directly on a server to enable DLC. PCLs are engineered in close collaboration with server manufacturers to enable warranty approved, liquid cooled servers direct from the server manufacturing facility. PCLs make direct contact with and cool any component on a server, including central processing units (CPUs), Voltage Regulators (VR), dual in-line memory modules (DIMMs), and PCIe cards.



CoolIT's Passive Coldplate Loop (PCL) that provides 100% heat capture on the HPE Cray EX server found in Frontier, the fastest supercomputer in history.

All custom PCL programs include CoolIT's New Product Introduction (NPI) Services. A dedicated team of CoolIT engineers and program managers work directly with the server manufacturer on the custom PCL design, engineering, and manufacturing for their next generation server programs. Each PCL system is fully tested and validated to ensure reliability.

CoolIT's patented Split-Flow Coldplates are a key component of PCLs. These solid copper components deliver superior performance by using a unique microchannel architecture that minimizes pressure drop, maximizes coolant flow, and directs the coolest liquid to the hottest area of the processor first.



CoolIT's 90+ patents include the Split-Flow Coldplate with 'skived' microchannels for superior cooling capacity with a minimal pressure drop.

CoolIT's Rack Manifolds are made of reliable stainless steel. Combined with dry-break, quick disconnects, these manifolds are safe and effective building blocks when paired with PCLs. Rack Manifolds allow for fluid connections at either the front or back of the rack and can be arranged vertically or horizontally within a rack.

Coolant Distribution Units (CDU) are built to meet the increasing demands of today's data centers. Reliability, performance and intelligence are at the core of CoolIT CDUs. Capable of managing a wide range of heat loads in remarkably dense packages, these systems provide centralized pumping and intelligent controls to distribute coolant to PCLs installed in an IT rack. CDU options include AHx (liquid-to-air), CHx (liquid-to-liquid), rack-based or row-based.

Secondary Fluid Networks (SFN) enable the distribution of coolant from row-based CDUs to multiple racks. The SFN is a modular assembly containing polypropylene piping, connections, valves, flow setters, air bleed valves, mounting hardware and coolant. Quality and reliability are ensured by cleaning, pressure testing and verifying onsite during the commissioning process of the cooling solution.

Rear Door Heat Exchangers (RDHx) enable hybrid cooling by providing additional air-cooling to DLC solutions when 100% heat capture and room neutralization is required. RDHx attach directly to the rack and can either operate independently or use the same liquid loop as the CDU, rack manifold and coldplate loops to provide a seamless customer solution. RDHxs are either active (with fans) or passive (without-fans) and are available in multiple sizes.

For system level cooling solutions, CoolIT's Professional Services team provides managed services to ensure the successful deployment and maintenance of their technology in data centers. CoolIT Professional Services consists of Project Engineers, Service Technicians and Authorized Service Providers (ASPs) who provide a one-stop, total service solution to design, deploy and maintain advanced cooling solutions. The Professional Services team also provides on-site and remote training for data center teams around the world, including data center operators, thermal engineers, technical sales and ASPs.

DLC at a data center with SFN above the racks and row-based CDU on the right.

With the complete end-to-end solution, CoolIT provides expertly engineered and thoroughly tested DLC products and turnkey services that data center operators can rely on.

Hybrid Cooling: DLC for Air-Cooled Data Centers

If an air-cooled data center is not equipped with facility warm water cooling (ASHRAE W4), operators can leverage the benefits of DLC by deploying air-assisted liquid cooling (AALC) or hybrid cooling solutions.

Liquid-to-air CDUs allow for the installation of DLC-enabled servers in air-cooled data centers. Available in rack-based or row-based configurations, these liquid-to-air CDUs work with traditional cold/warm aisle layouts without the need for facility water. These AALC solutions manage up to 100kW of heat load from DLC-enabled racks and can be customized to fit various data center environments.

Active Rear Door Heat Exchangers (RDHx) enable hybrid cooling by providing additional air-cooling to DLC solutions when 100% heat capture and a room neutral solution is required. The RDHx can operate independently when directly connected to facility water, providing additional air-cooling to a DLC rack. Alternatively, the RDHx can be connected to the same liquid loop as the CDU, rack manifold and passive coldplate loops (PCL) to provide a seamless and easily scalable hybrid solution. Traditional in-row coolers can also be installed along a DLC-enabled row to provide a hybrid cooling solution with additional air cooling.

A row of racks with RDHxs connected to the same fluid loop as the CDU and PCL at TACC.

Results of Direct Liquid Cooling

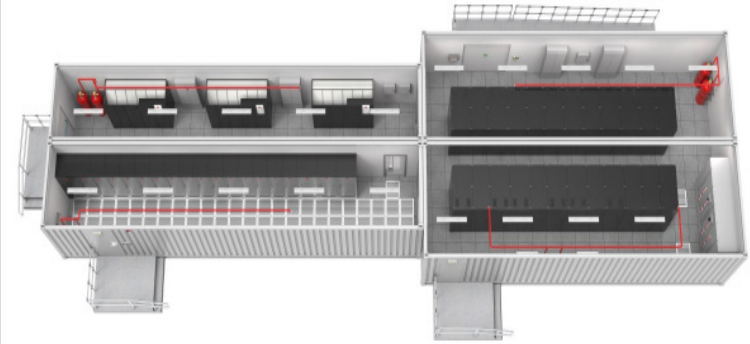
With the implementation of DLC, data centers can see improvements in energy efficiency, operating costs and sustainability practices as can be seen in the case studies below.

Case Study 1: Increased Density and Improved PUE at Emmy Supercomputer

The Emmy Supercomputer System (Emmy) provides high performance computing power for scientists as a part of the NHR Alliance, the National High Performance Computing organization of Germany. Installed in GWDG in Göttingen, Germany, this containerized Modular Data Center (MDC) by STULZ Modular consists of the following two phases:

- **Phase 1:** 19 air-cooled racks, fully operational in July 2020
- **Phase 2**: 14 DLC racks set up for hybrid cooling, fully operational in October 2020

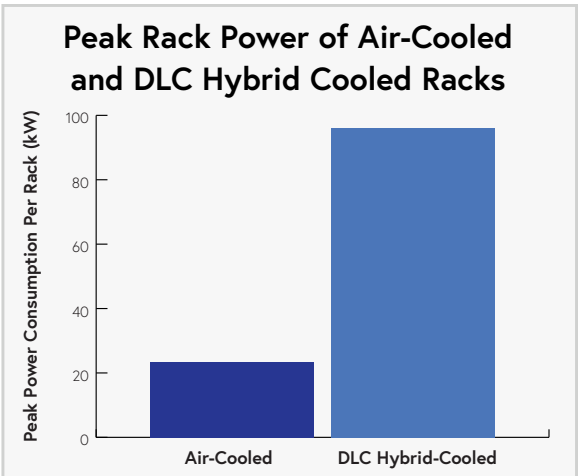
The hybrid cooling solution for the DLC racks included 3 row-based CDU's by CoolIT Systems and 6 in-row coolers by STULZ for residual heat.



Emmy Supercomputer; Phase 1 on the left; Phase 2 on the right

(Image credit Stulz Modular)

During the first year of operation, peak power consumption for the air-cooled systems reached 23.5 kW per rack while peak power consumption for the DLC systems reached 96 kW per rack. The 4X increase in rack power density means 4X more computing power in one DLC rack than one air-cooled rack, as can be seen in the chart to the right:



Peak power consumption per air-cooled rack and DLC hybrid-cooled rack.

Power usage effectiveness (PUE) also improved over the first year of operation. The average PUE of the DLC systems was 1.07 while the average PUE of the air-cooled systems was 1.24. The implementation of the DLC systems overall improved full data center PUE by an average of 8.9% and up to 13.7% over the first year of operation, as can be seen in the table below:

	Air-Cooled Systems	DLC Systems	Full Data Center	Full Data Center PUE Improvement with DLC
Average PUE	1.24	1.07	1.13	8.9%
Max PUE	1.39	1.09	1.2	13.7%
Min PUE	1.17	1.04	1.1	6.0%

Air-cooled vs. DLC vs. full data center PUE during Year 1 of operation.

For more information on Emmy efficiency, see Efficient HPC data center operation with direct liquid cooling by GWDG.

Case Study 2: Decreased OPEX and Energy Consumption in Hybrid Data Center

When comparing an air-cooled data center and a DLC data center with the same ITE heat load, the DLC data center provides significantly lower OPEX and energy consumption as can be seen in the Hybrid Cooling Case Study by CoolIT Systems and STULZ.

The following facility cooling infrastructure was considered to cool 1 MW of ITE heat load in each data center:

Air-Cooled Data Center	DLC Data Center with Hybrid Cooling
• 10 thirty-ton CRACs with economizer coils • 5 six-fan fluid coolers with economizer controls • 1 60HP dual pump package	• 2 25-ton Cyberair CRACs with Economizer coils (CRAC) • 1 five-fan fluid coolers with economizer controls (CRAC) • 3 four-fan fluid coolers with economizer controls (DLC) • 1 10HP Dual Pump Package (CRAC) • 3 3HP Dual Pump Package (DLC)

Air cooled vs DLC hybrid-cooled facility infrastructure.

As the following chart shows, managing 1 MW of ITE heat load for one year at $0.10 USD per kW-hr resulted in a 72.4% savings in cooling power consumption and OPEX:

	Air-Cooled Data Center	DLC Hybrid Data Center	Delta	Savings
Cooling Power Consumption	3,578,371.10 kW-hr	986,726.22 kw-hr	-2,591,644.88 kW-hr	72.4%
OPEX	$357,837.11	$98,672.62	-$259,164.49	

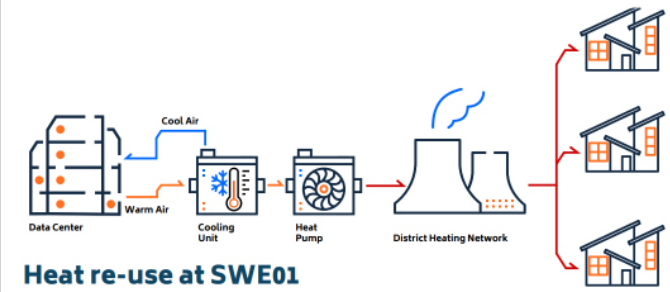
Air-cooled vs. DLC hybrid-cooled power consumption and OPEX.

For more information on the case study as well as ROI calculations, see Direct Liquid Cooling: CAPEX and OPEX, the Complete ROI Story by STULZ and CoolIT Systems.

Case Study 3: Increased Sustainability with Heat Reuse at atNorth

atNorth is a leading Nordic data center services company offering environmentally responsible, power-efficient, cost-optimized data center hosting facilities and high-performance computing services. To achieve performance, density, and sustainability goals, atNorth collaborated with CoolIT Systems for their SWE01 data center facility in Stockholm, Sweden. In addition to increased rack density, decreased power consumption, and increased computing performance, CoolIT Systems also increases the efficiency of atNorth's heat reuse program.

In partnership with Stockholm's energy provider, Stockholm Exergi, the SWE01 facility captures its data center heat output and recycles all residual heat through Stockholm Exergi's district heating plant to distribute heat and hot water to local residents. The following graphic illustrates atNorth's heat reuse partnership with Stockholm Exergi:



Heat reuse program at atNorth's SWE01 campus

(Image credit atNorth)

atNorth's data center cooling systems utilize heat pumps. For air-cooled servers, warm air exhaust goes into cooling units to heat water. The water then travels into heat pumps which raise the temperature of the water before it is sent into the district heating network. With CoolIT's DLC technology, the water is heated by the servers via CoolIT's CDUs and connected directly to atNorth's cooling system, increasing the efficiency of heat capture and giving greater control over the heat reuse process.

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Summary

The rise of CPU and GPU power, rack densification and sustainability pressures are forcing data centers to look at alternate cooling solutions to improve energy efficiency. Direct liquid cooling (DLC) solutions optimize computing performance, increase rack densities, and enable scalability, resulting in increased energy efficiency, lowered OPEX and improved sustainability practices.

CoolIT Systems is the industry standard in providing end-to-end DLC products and services. Their trusted technology and engineering expertise provide scalable, turnkey DLC deployments for data center operators. As the market and technology leader in DLC, data centers and HPC systems operators around the world look to the benefits provided by CoolIT, including improved PUE, decreased OPEX, increased density, and increased sustainability. Implementing direct liquid cooling is a proven way to improve a data center's energy efficiency.

About CoolIT Systems

CoolIT Systems specializes in scalable liquid cooling solutions for the world's most demanding computing environments. In the desktop enthusiast market, CoolIT provides unparalleled performance for a range of gaming systems. In the enterprise data center and high-performance computing markets, CoolIT partners with global leaders in OEM server design to develop the most efficient and reliable liquid cooling solutions for their own leading-edge products. Through its modular Direct Liquid Cooling technology, CoolIT enables dramatic increases in rack densities, component performance, and power efficiencies. Together, CoolIT and its partners are leading the way for the widespread adoption of high-performance computing.

For more information about CoolIT Systems and its technology visit https://www.coolitsystems.com/ and follow @CoolIT Systems on LinkedIn.