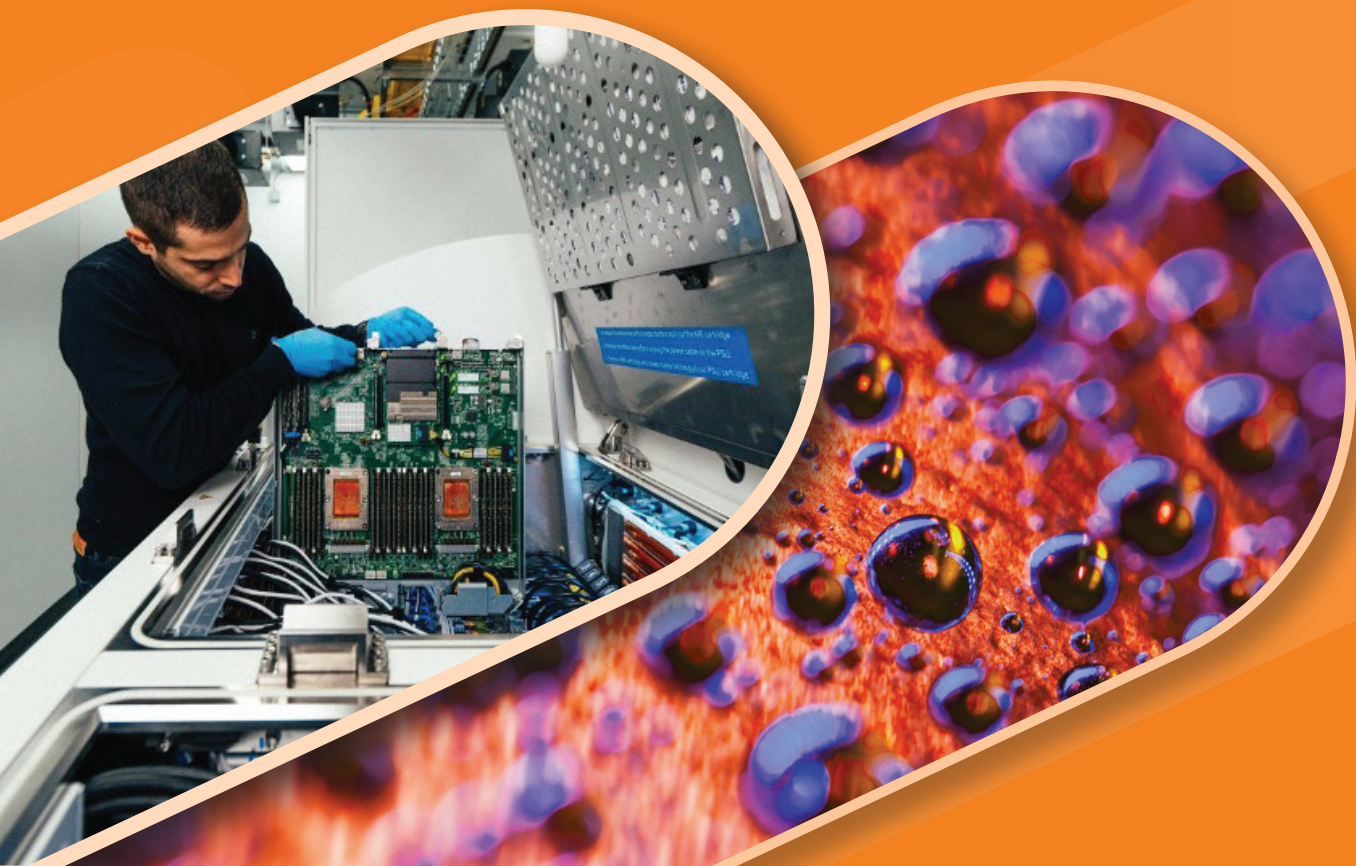


Spotlight by Bloor
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How Liquid Cooling is helping to manage growing data centre cooling challenges



The importance of liquid cooling in data centres lies in its ability to meet the demands of modern computing while addressing the environmental and economic limitations of traditional cooling methods. With the growth of cloud services, Artificial Intelligence, and the Internet of Things applications, data centres need to manage unprecedented levels of heat efficiently.

Executive summary

The nub of the business issue we spotlight here is that data centre operators are under growing economic and environmental pressures to lower costs, mitigate public concerns about electricity consumption and conserve valuable water resources while, at the same time, enabling a huge increase in computer processing capacity.

Traditional heating, ventilation, and air conditioning (HVAC) systems that regulate the temperature, humidity, and air quality in data centres will struggle to deal with the power demands and heat output of a new breed of Artificial Intelligence, Big Data Analytics and 5G systems. In the most extreme cases, for example a data centre dedicated to running High-Performance Compute (HPC) applications on the latest, power hungry Graphics Processor Units (GPU), the HVAC units would need to circulate chilled air at wind speeds of around 40 miles per hour. This would create an uncomfortably noisy and uncomfortable working environment with unacceptably high power and water usage, and the costs that go with that.

The adoption of liquid cooling technology allows data centres to handle greater processing power and density per rack, which is essential for supporting emerging applications in AI, 5G, and cloud computing. Liquid cooling is increasingly favoured for its energy efficiency, enabling energy savings of up to 40% over traditional cooling methods with the potential, in some use cases, for Year 1 return-on-investment (ROI).

The adoption rate of liquid cooling solutions is growing rapidly. In 2023, from the variety of figures we have seen, and taking a fairly conservative view, we think the global data centre liquid cooling market was valued at approximately \$2.5 billion. Growth projections vary widely. But, taking the most conservative projections, they still show a Compound Annual Growth Rate (CAGR) of 19% and a projected 2032 value of \$8.45 billion, depending on factors like the pace of digital infrastructure expansion, AI adoption, and sustainability initiatives.

There are 3 main types of liquid cooling:

- Rear Door Cooling
- Direct -To-Chip (DTC) Cooling
- Immersion Liquid Cooling

These will be described in a more detail in the body of this paper. Each has its place that will be based on such factors as the type and scale of compute requirements and the nature of any existing I.T. infrastructure investments.

Liquid cooling in data centres has become a transformative approach to handling the increasing power demands and thermal loads of modern computing equipment. As technology advances and data processing demands continue to grow, so does the need for efficient and sustainable cooling solutions that go beyond traditional air-cooling systems. Here's a detailed exploration of what liquid cooling in data centres entails, how it works, why it's crucial in today's technological landscape, and the steps businesses need to consider for effective adoption.

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What is Liquid Cooling?

Liquid cooling is a technique that uses liquid as a thermal conductor to dissipate heat from computer systems, servers, and other high-density computing equipment. Unlike traditional HVAC systems that rely on air circulation and cooling to regulate temperature, liquid cooling directly interfaces with heat-producing components, such as CPUs, GPUs, and memory units. There are three

main types of liquid cooling technologies used in data centres: rear door cooling, direct-to-chip cooling and immersion cooling. All three types of liquid cooling can dramatically reduce or even, in some cases, eliminate the need for traditional air cooling, offering a more efficient and sustainable approach to managing heat in data centres.

Direct-to-Chip Cooling

This method circulates a liquid coolant through cold plates attached to the chips or processors within the servers. The coolant absorbs heat directly from the components and is then pumped away, where the heat is expelled through a heat exchanger. There are two types of direct-to-chip cooling:

Single Phase DTC:

Coolant or a water mixture circulates through the cold plate and heat is moved with the liquid, radiating it off within the CDU

Two-Phase DTC:

Specialty heat transfer fluid circulates through the cold plate, then boils off, changing phase to a gas removing the heat.

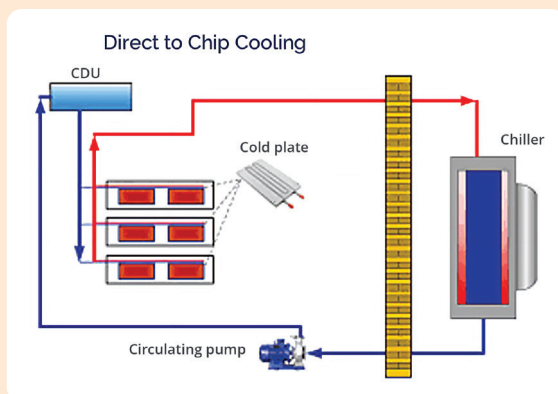


Figure 1 – Direct to Chip Cooling

Immersion Cooling

Unlike Direct-to-Chip cooling, immersion cooling submerges the entire server or computing unit in a non-conductive, dielectric liquid that absorbs heat from all the components it contacts. There are two types of immersion cooling:

Single-Phase Immersion:

The liquid absorbs heat without evaporating, and heat exchangers circulate and cool it down.

Two-Phase Immersion:

The liquid evaporates upon contact with heat, removing energy from the system, then condenses back into liquid form to be recirculated.

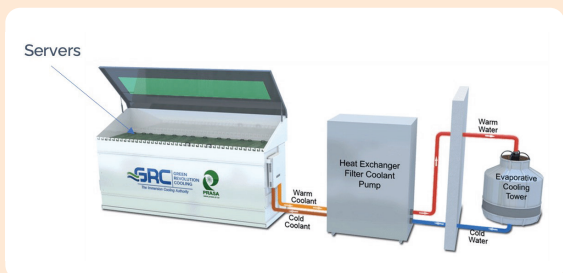


Figure 2 – Immersion Cooling

Rear Door Cooling

Rear door cooling is an efficient data centre cooling solution where a heat exchanger or cooling unit is installed where a heat exchanger or cooling unit is installed on the rear door of a server rack. The system draws hot air from the back of the servers and cools it down before releasing it back into the data centre space. This method directly targets the hot air exiting the equipment, minimising the amount of heat that enters the data centre room and helping maintain a stable, cooler environment without needing extensive airflow management.

What does Liquid Cooling do?

Liquid cooling enhances heat removal from servers and computing components, particularly those involved in high-performance computing (HPC), artificial intelligence (AI), and machine learning (ML) applications, which generate significantly more heat than traditional computing tasks. Liquid cooling is essential for cooling high-density racks that air-based systems cannot efficiently support. Let's have a look at some of the key functions and benefits of liquid cooling.

Provides efficient heat dissipation

Due to the higher thermal conductivity of liquids compared to air, liquid cooling systems can remove heat from components faster and more efficiently, enabling data centres to manage high-density computing loads without the risk of overheating.

Delivers energy and cost savings

By reducing reliance on fans, chillers, and other HVAC components, liquid cooling systems can lower energy usage, leading to operational cost savings. Data centre operators have reported reductions of up to 50% in energy consumption with the implementation of liquid cooling solutions.

Enhances computing density

As demand for data-intensive computing increases, liquid cooling enables the deployment of denser and more powerful racks. Traditional air-cooled systems may only support up to 10-15 kW per rack, while liquid-cooled racks can handle loads of up to 100 kW, significantly increasing computing capacity per square foot.

Extends hardware lifespan

Liquid cooling provides stable and efficient thermal management, which can reduce thermal stress on hardware components, potentially extending their operational lifespan and reducing maintenance costs over time. For an estate of 700 servers with a standard maintenance contract you might expect to see annual maintenance savings of between \$50,000 and \$100,000.

Reduces environmental impact

Many liquid cooling systems, especially immersion cooling, require little to no water use compared to traditional evaporative cooling, which depends on water-based cooling towers. Furthermore, the higher energy efficiency reduces the carbon footprint of data centre operations, aligning with sustainability goals.

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Why is Liquid Cooling important and why now?

Liquid cooling for computers is not exactly a new idea... think of the top end IBM System/360 Model 91 from 1966 and, more recently, some power-hungry gaming PCs. Even full immersion of servers in a dielectric liquid first saw the light of day about 10 years ago. But, up to now it has very much been a niche requirement for certain HPC configurations. So why is liquid cooling getting such attention now?

The very simplistic answer to "why now", is AI. Looking back 15 years or so, there was a concern in large data centres about rack densities growing beyond 5 to 10 kw/h per rack, up to 15 kw/h. This was more a power availability concern within older data centres rather than a cooling issue. In any case we weren't seeing rack densities increasing rapidly.

Data centres with CRAC units (Computer Room Air Conditioning) was and remains the most used solution to cooling the space. But with, initially, bitcoin mining and highly graphical multi-player on-line gaming, rack densities moved towards 20kw/h. The rapid increase in AI LLM (Large Language Models) training and on-going deployment of AI based applications has already pushed rack densities well beyond that point and the latest Nvidia Blackwell processors each have a potential power draw of 1200 watts each, which could see rack densities exceeding 100kw/h. At that point you would need gale force, chilled winds inside the data centre to keep the servers cool. Clearly, that is not an option from either a power usage or noise point of view.

The importance of liquid cooling in data centres lies in its ability to meet the demands of modern computing while addressing the environmental and economic limitations of traditional cooling methods. With the growth of cloud services, AI, ML, and IoT applications, data centres need to manage unprecedented levels of heat efficiently. Other key reasons for the importance of liquid cooling also include:

Sustainability and energy efficiency

Data centres must navigate a mix of standards and regulations to manage their energy and water usage. Compliance with frameworks like ISO 50001 and ASHRAE 90.4, along with regional mandates from the EU, the U.S., and other nations, allows data centres to minimise environmental impact, reduce operating costs, and achieve sustainability goals. Adopting these standards is also essential to meet future targets, such as climate neutrality goals set by the EU, and individual nations or emerging water usage guidelines.

Rising costs and energy constraints:

The cost of electricity is rising globally, and the demand for sustainable, energy-efficient operations is higher than ever. Liquid cooling's energy efficiency and ability to reduce dependency on electricity-intensive HVAC systems make it an appealing option for data centre operators facing high energy costs.

The shift towards greener energy consumption is critical as data centres become significant consumers of global energy. It's estimated that data centres consume about 1% of the world's electricity, and a large portion of that is used for cooling. In countries like Ireland, the energy used by the rapidly growing number of data centres accounted for 21% of its total energy supply capacity in 2023, leading to calls for a moratorium on new data centre construction. By enabling more efficient energy use, liquid cooling aligns with sustainability goals and corporate environmental, social, and governance (ESG) mandates that could help assuage local concerns and prevent a slowdown in data centre build outs.

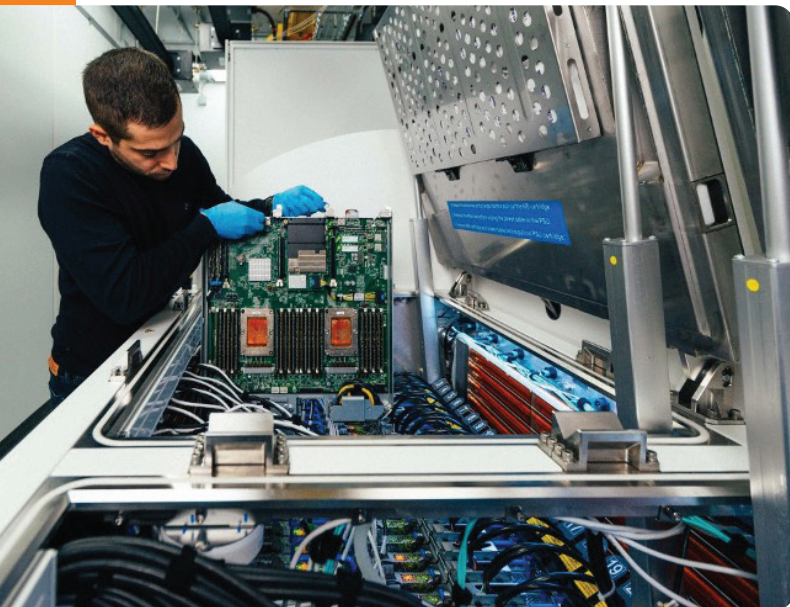


Figure 3 – Full Immersion of servers in a tank

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Economic pressure and cost efficiency:

As energy costs rise, especially in regions with strict environmental regulations, the cost-effectiveness of liquid cooling becomes more attractive. While initial setup costs for liquid cooling might be higher, specifically when retrofitting into existing data centres, the long-term operational savings from reduced energy and water use will result in lower total cost of ownership (TCO) for data centre operators. In a greenfield environment, if you were to compare an indicative TCO over 3 years for 700 DTC cooled servers versus 700 air cooled servers, the saving on your total cost of ownership could be in excess of \$17 million dollars. Annual energy costs savings alone could amount to \$1 million a year.

Regulatory compliance and future proofing:

Governmental and environmental regulations, particularly in regions like the EU, are setting stricter guidelines on data centre efficiency, requiring better cooling practices and the reuse of waste heat. Liquid cooling is one of the few solutions that can meet these stringent standards by achieving very low Power Usage Effectiveness (PUE) and Water Usage Effectiveness (WUE) ratios.

Maturity of Liquid Cooling Technology:

Advances in liquid cooling technology, such as improved dielectric fluids for immersion cooling and efficient direct-to-chip cooling systems, have made liquid cooling safer, more reliable, and more effective. This technological maturity has encouraged more data centres to adopt these solutions.

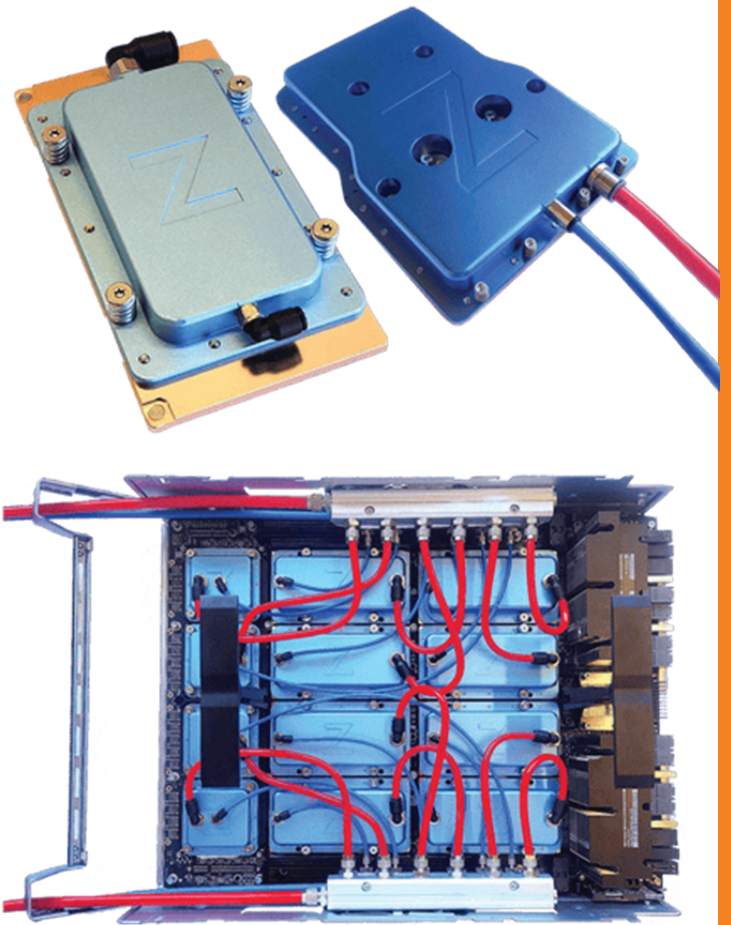


Figure 4 – Direct to Chip water cooled plates

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What you need to do next

As liquid cooling becomes more prominent, businesses looking to transition to this technology need to consider several critical steps to ensure successful implementation and ROI.

Step One has to be, evaluating your workloads and density requirements. You need to assess your data processing requirements and computing density. There are a number of capacity planning and workload placement tools available to help determine if and where liquid cooling is necessary and which type (rear-door, direct-to-chip or immersion) is most suitable. Clearly high-density applications, like AI or HPC, will benefit the most from liquid cooling. But there are other considerations.

Consider infrastructure investments

As a rule of thumb, Direct-to-chip cooling is best for extreme density or maximum heat removal efficiency, especially in greenfield projects or where full-scale modernization is possible. Full immersion cooling is best suited in situations that require extreme density or maximum heat removal efficiency, especially in greenfield projects or where full-scale modernisation is possible. And rear-door cooling can be considered for moderate density data centres looking for an efficient, cost-effective cooling upgrade without substantial infrastructure overhauls.

Greenfield implementations are fairly simple to understand and cost from an investment point of view. However, if you are implementing liquid cooling into existing data centres, this may require retrofitting existing facilities or constructing new ones that support the unique requirements of liquid cooling systems. This could include specialised piping, tanks for immersion cooling, and additional space for heat exchangers.

Focus on compatibility and standards

Since liquid cooling interacts directly with hardware components, businesses must work with vendors to ensure compatibility with their equipment. Several industry standards and guidelines from bodies such as ASHRAE, the Open Compute Project and the European Union address the use of liquid cooling in data centres, focusing on efficiency, sustainability, and operational safety. These standards ensure the proper design, implementation, and management of liquid cooling systems in alignment with global best practices.

Partner with experienced technology companies:

Partnering with vendors can provide guidance on system design, implementation, and maintenance. These vendors offer expertise in liquid cooling solutions and can help customise setups based on an organisation's specific needs. Just be aware of the risk that the vendor may only focus on one of the three liquid cooling technologies highlighted in the Spotlight paper

Liquid cooling requires specialised maintenance and safety protocols to prevent leaks and handle dielectric fluids. Therefore, it may be better to partner with third party maintenance companies or systems integrators who have focused, consulting led liquid cooling programs that are not focused solely on a single, specific technology.

Consider long-term sustainability and cost benefits:

You should weigh the upfront costs of liquid cooling against the long-term savings in energy, water, and maintenance expenses. Calculating the total cost of ownership (TCO) can help justify the investment and align with corporate sustainability goals.

Stay updated on technological developments:

Liquid cooling technology continues to evolve, with advancements in fluid types, cooling efficiency, and system designs. Staying informed about these developments can help you optimise your liquid cooling investments over time.

Analysis and conclusion

Liquid cooling has emerged as a vital technology in data centres, enabling high-density computing while meeting sustainability and efficiency goals. With the proliferation of AI and high-performance computing, liquid cooling's importance will only continue to grow. By assessing workloads, investing in infrastructure, partnering with experienced vendors, and focusing on long-term benefits, businesses can leverage liquid cooling to build more resilient, sustainable, and cost-effective data centre operations.

The business drivers for adopting liquid cooling revolve around balancing the demands of modern IT workloads, energy efficiency, regulatory compliance, and cost-effectiveness. As data centre operators face increasing pressure to optimize performance while reducing environmental impact, liquid cooling offers a compelling solution that aligns with both technological and business goals.

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About the author



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Paul has had a 40-year career in industry that started in logistics with a variety of operational management roles. For the last 33 years he has worked in the IT industry, mostly in sales and marketing, covering everything from mainframes to personal computers, development tools to specific industry applications, IT services and outsourcing. In the last few years he has been a keen commentator and analyst of the data centre and cloud world. Until recently he was also a non-executive director in an NHS Clinical Commissioning Group.

Paul has a deep knowledge and understanding about the IT services market and is particularly interested in the impact of Cloud, Software Defined infrastructure, OpenStack, the Open Compute Project and new data centre models on both business users and IT vendors. His mix of business and IT experience, allied to a passionate belief in customer focus and "grown-up" marketing, has given him a particular capability in understanding and articulating the business benefits of technology. This enables him to advise businesses on the impact and benefits of particular technologies and services, and to help IT vendors position and promote their offerings more effectively.

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