

Elliott 
GROUP

Data Centre Liquid Cooling
A Comprehensive Narrative

Overview

The global data centre industry is undergoing one of the most significant technological transitions in its history.

As digital transformation accelerates across all sectors; driven largely by the proliferation of artificial intelligence (AI), cloud computing, remote work, and increasingly complex digital services, the infrastructure that supports these technologies is being pushed to new limits.

Traditional air based cooling systems, once sufficient for typical server loads, are no longer able to manage the increasing heat density produced by modern High Performance Computing (HPC) using cutting edge Graphics Processing Units (GPUs) and other AI workloads.

In this context, **liquid cooling** has emerged as a critical solution, capable of delivering the **efficiency, sustainability, and thermal performance** required in next generation data centres.

The following narrative explores the reasons behind liquid cooling adoption, key market trends, challenges to standardisation, design concepts and the technical foundations of the technology.

Drivers Behind the Adoption of Liquid Cooling

The rapid adoption of liquid cooling has been driven by a convergence of global disruption and energy constraint.

Impact of the COVID 19 Pandemic

Events such as the COVID-19 pandemic and subsequent geopolitical instability fundamentally reshaped digital demand, infrastructure density, and the economics of power consumption within data centres. The onset of the COVID 19 pandemic triggered an unexpected and unprecedented surge in global digital demand. Remote working became the norm, streaming services experienced explosive growth, and online collaboration platforms formed the backbone of daily business operations.

This sudden shift placed immense pressure on existing data centre infrastructure, pushing operators to expand capacity and deliver higher performance under constrained timelines. As workloads intensified, so did rack level heat generation.

This environment accelerated the need for more efficient and scalable cooling systems, making liquid cooling an increasingly viable and attractive solution for an industry known for adopting disruptive innovation.

Geopolitical Pressures and Energy Market Constraint

The Russia Ukraine conflict profoundly impacted global energy markets, particularly natural gas and electricity supplies across Europe. Energy prices spiked dramatically, placing additional operational cost burdens on data centre operators; organisations already struggling with the rising power demands of AI and high density computing and the balance of aligning this to existing environmental, social and governance boundaries.

This energy shock created a strong incentive to pursue cooling technologies that deliver greater efficiency per Watt of power usage. Liquid cooling, which is significantly more energy-efficient than traditional air cooling, became a strategic priority. Its ability to reduce overall power consumption, especially in high density environments, made it an essential tool for improving resilience and maintaining cost effective operations in a volatile energy landscape.



Market Trends and Growth Projections

Rapid Market Expansion

The Data Centre Liquid Cooling Market is forecast to grow at an impressive 25.6% Compound Annual Growth Rate (CAGR) between 2024 and 2030. In 2023, the global market size was estimated at €2.53 billion, with projections expecting it to reach €12.5 billion by 2030 - a nearly five fold increase.

This dramatic growth reflects not only the rising computational demands of AI but also the recognition that traditional cooling approaches cannot scale sustainably to meet future performance requirements.

Emerging Technology Trends

Several key trends are shaping the forward trajectory of the liquid cooling industry:

- Adoption of immersion cooling and direct liquid cooling across both hyperscale and enterprise data centres.
- Integration of renewable energy into facility design and operations.
- Expansion of hyperscale data centres, driven by cloud providers and major AI focused companies.
- Shift toward sustainability, with operators seeking cooling solutions that reduce water consumption, energy waste, and carbon emissions.

These trends collectively create strong momentum for continued adoption of advanced liquid cooling technologies in the global data centre ecosystem.

Challenges: The Lack of Standardisation

Despite rapid growth, one of the most significant barriers to widespread liquid cooling adoption is the absence of globally accepted standards. The market currently comprises a variety of competing and non dominant technology types, each with unique interfaces, performance profiles, and infrastructure requirements. The primary cooling methodologies include:

- Direct Chip Impingement
- Immersion Cooling
- Cold Plate Cooling
- Rear Door Heat Exchangers (RDHx)
- Overhead Manifold Distribution
- Liquid to Air Cooling
- Liquid to Liquid Cooling

The diversity of approaches makes it difficult for operators to commit to a single technology without risking future incompatibility or stranded investments. This fragmentation also influences facility design, procurement strategies, design risk transfer and long term scalability decisions.

Technical Foundations of Liquid Cooling

Cooling Medium

Liquid cooling systems typically use a solution composed of purified water mixed with glycol. This blend provides excellent thermal conductivity while minimising corrosion and preventing freezing in the colder climates gaining ever more market dominance.

The use of glycol based mixtures also extends the lifespan of cooling components by reducing mineral deposits and improving overall system reliability.

Pipework and Distribution

Liquid cooling infrastructure requires durable, corrosion resistant pipework capable of withstanding high flow rates and long term exposure to cooling fluids. Two primary materials are deemed to dominate the future liquid cooled industry with skilled trades in these areas seen as being an inevitable future market constraint:

- Fully Welded stainless steel, used for high integrity, high availability systems.
- Fusion Welded High Density Polyethylene (HDPE), valued for its flexibility, chemical resistance, and lower installation cost.

Both materials offer long service life, and the choice between them typically depends on facility scale, existing infrastructure, operator preference and tier classification.

Rising Computing Demands and Power Density

Growth of AI Workloads

AI and machine learning are among the most power intensive workloads ever deployed in data centres to date. Modern AI racks can range from electrical loadings of 50 kW nominal to 130 kW peak which is far beyond what traditional air cooling can effectively manage. As AI models grow in size and complexity, the thermal loads they generate will continue to increase, further strengthening the need for liquid based solutions.

Rack Level Distinctions

Data centres will increasingly adopt a hybrid approach to cooling based on workload type:

- Network Racks - Nominally 30 kW these racks are expected to remain predominantly air cooled, as they do not require extreme thermal management.
- Compute Racks - Nominally 130 kW+ these racks are now transitioning to liquid cooling, especially for AI, HPC, and GPU dense servers.

This separation allows operators to optimise both cost and performance while gradually phasing in more advanced cooling technologies. With a requirement for both rack types to be included within production whitespaces a hybrid of both air cooled and liquid cooled mission critical environments are now on the rise.

Business Drivers Supporting Liquid Cooling Adoption

Rising Rack Power Density

As servers pack more processing power into smaller footprints, the resulting heat load increases dramatically. Liquid cooling provides significantly greater thermal transfer efficiency, making it the only viable option for extremely dense compute deployments.

Advances in Cooling Fluids and Materials

Modern engineered fluids, improved heat exchangers, and innovations in cold plate and immersion technologies have made liquid cooling safer, more reliable, and more efficient. These advancements broaden its applicability across a range of data centre configurations.

Expansion of Cloud Computing

Cloud providers, particularly hyperscalers, are driving major increases in demand for liquid ready infrastructure. As cloud workloads evolve toward increasingly AI centric operations, cooling performance has now become of top priority.

Sustainability and Energy Efficiency

Liquid cooling systems consume significantly less power than traditional chilled-air systems, often reducing cooling energy consumption by 30% to 50% or more per Mega Watt consumed providing significant impact on Power Usage Effectiveness (PUE). This improved efficiency directly supports operators' sustainability goals and reduces operational expenditure in regions facing high electricity costs.

Carbon Reduction Commitments

Many companies have pledged to meet aggressive carbon reduction targets. With cooling accounting for a substantial portion of total facility energy consumption, transitioning to liquid cooling is seen as an impactful way to reduce a data centre's environmental footprint.



Waste Heat Recovery

Turning Thermal Output into a Valuable Resource

As liquid cooling becomes more widely adopted, data centres gain access not only to better thermal efficiency but also to high quality waste heat that can be harnessed and reused. Liquid cooling systems operate at much higher outlet temperatures than traditional air cooled systems, making the captured heat valuable for a wide range of secondary uses. This new resource has transformed data centres from being sole energy consumers to new energy contributors and prosumers, supporting circular economy initiatives and reducing environmental impact.

Why Liquid Cooling Unlocks Waste Heat Opportunities

In an air cooled data centre environment, most server heat is expelled into the atmosphere through rapid air changes and chilled air streams, typically at low temperatures that are impractical for reuse. Liquid cooling, by contrast, delivers:

- Higher temperature water return loops (often at 40°C to 60°C or higher)
- More consistent and predictable heat output
- A concentrated thermal source that is easier to transport and manage

These characteristics make liquid captured waste heat more economically viable to recover and repurpose.

Methods of Waste Heat Recovery

District Heating Systems

One of the most promising use cases is supplying local district heating networks. Heated water from data centre cooling loops can be fed into municipal systems to:

- Warm residential buildings.
- Supply heat to commercial and industrial facilities.
- Support hospitals, schools, and public offices with resilient heat sources.

This not only reduces the carbon footprint of the surrounding community but also generates new revenue streams for operators through heat offtake agreements increasing competitiveness in the market.

Industrial Process Heating

Industries such as manufacturing, food processing, and pharmaceuticals often require low to medium grade heat. Data centre waste heat can provide:

- Pre heating for industrial boilers
- Support for cleaning or sterilisation processes
- Heating for controlled environment manufacturing spaces

This can offset fossil fuel use in energy intensive industries.

Methods of Waste Heat Recovery

Building Heating and Domestic Hot Water

For data centres located near residential districts or business parks, waste heat can directly support:

- On site office heating.
- Adjacent high density apartment complexes.
- Hot water supply for nearby facilities.

Liquid cooling's stable heat output makes it ideal for predictable building services loads.

Heat to Power Conversion

In some cases, especially where heat cannot be piped to external users, a novel approach to adopting waste heat will be to generate electricity using technologies such as:

- Organic Rankine Cycle (ORC) Systems
- Thermoelectric Generators
- Low Temperature Heat Engine technologies

While efficiency is lower than direct heat reuse, these systems help maximise energy recovery in isolated or space constrained environments.



Environmental and Economic Benefits

Reduced Carbon Emissions

By substituting data centre waste heat for heat produced from fossil fuels, operators can provide measurable reductions in CO₂ emissions. This directly supports corporate sustainability goals and aligns with regional carbon neutrality targets.

Lower Operational Costs

Data centres can reduce or eliminate the energy required for heat rejection systems such as chillers or cooling towers, lowering operational expenditure.

New Revenue Streams

Heat sale contracts with local authorities or industrial partners create consistent, predictable income, improving the long term financial viability of data centre operations, particularly in the enterprise operator market.

Enhanced Brand and Community Value

Operators that contribute useful heat to surrounding neighbourhoods often benefit from stronger relationships with local communities, regulators, and environmental stakeholders.

Jargon

Acronym Explainer

Many with experience in the data centre sector will know that acronyms provide quick references to complex technologies, cooling methods, and operational standards, enabling efficient and succinct communication between engineers, designers, and operators alike across highly technologically serviced environments. The dawn of liquid cooled computing has provided for the next tranche of acronyms to be developed with some of the most prevalent from within this sphere being included below:

ADRS – Air Detection and Removal System	CDU – Coolant Distribution Unit
CDM – Coolant Distribution Manifold	FWU – Fan Wall Unit
FWS - Facility Water System	HPC – High Performance Computing
GPU – Graphics Processing Unit	LCE - Liquid Cooled Evaporator
HLS – Hydronic Loop System	RDHx – Rack Door Heat Exchanger
LDS – Leak Detection System	TST – Thermal Storage Tank
MUPS – Mechanical Uninterruptible Power Supply	

Concept Schematic

The below Figure represents a concept schematic of a Liquid Cooled Data Centre inclusive of a primary chilled facility water system, thermal storage, cooling distribution units and heat loads.

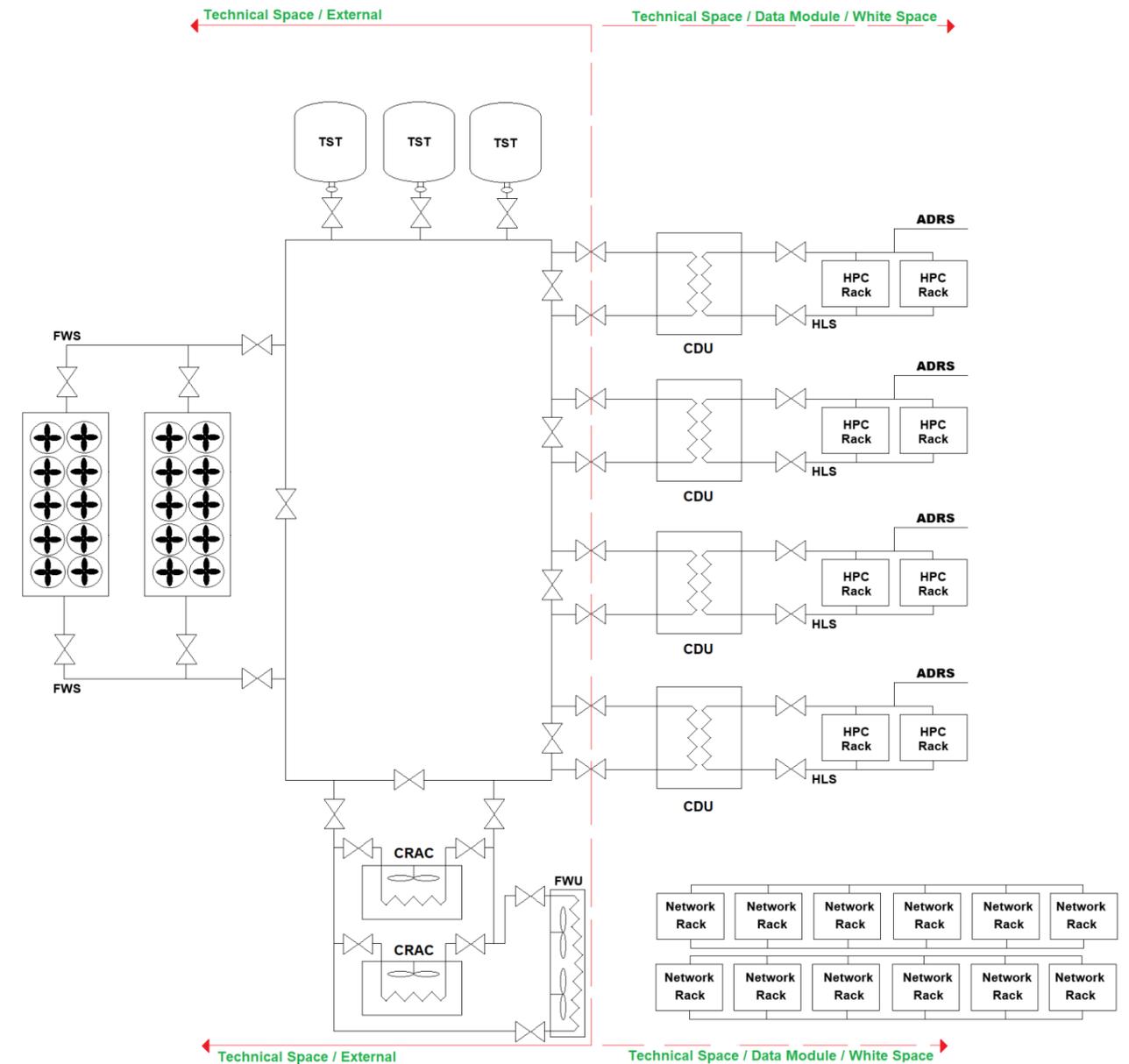


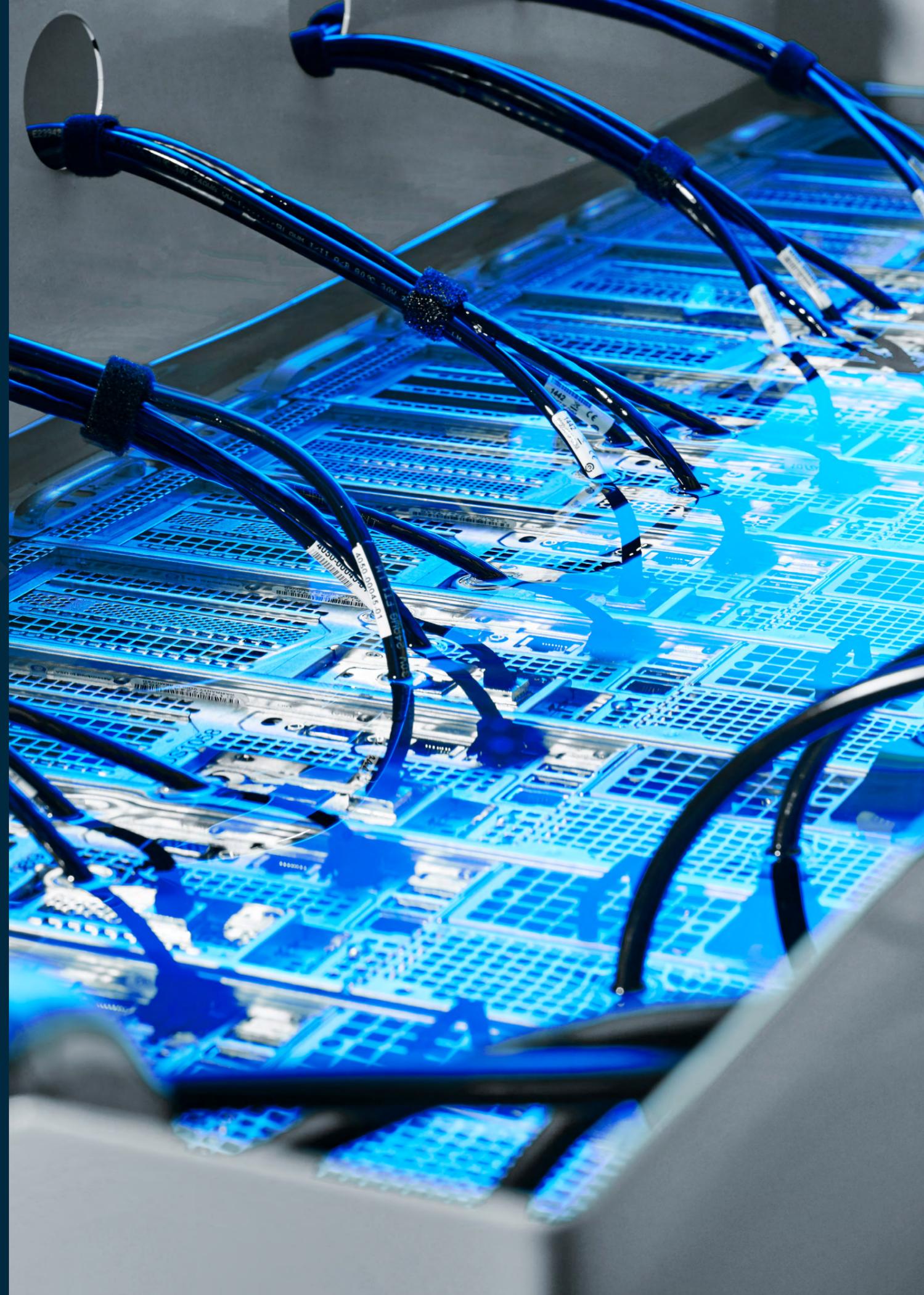
Figure 1- Data Centre Liquid Cooled Concept Schematic

Summary

The data centre industry stands at a transformational crossroads.

As global energy markets fluctuate, AI workloads increase exponentially, and sustainability becomes a universal imperative, liquid cooling is shifting from an optional technology to a strategic necessity. The combination of superior thermal performance, reduced energy consumption, and compatibility with next generation compute demands positions liquid cooling as a cornerstone of future digital infrastructure.

While standardisation challenges remain, the momentum behind liquid cooling continues to accelerate. With market size expected to grow from €2.53 billion in 2023 to €12.5 billion by 2030, the technology is poised to become a dominant force in data centre design and operation.





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Exceeding the quality standards of your mission critical project safely and on time is our core focus. Our end-to-end capability is your certainty in delivering assets that power progress



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