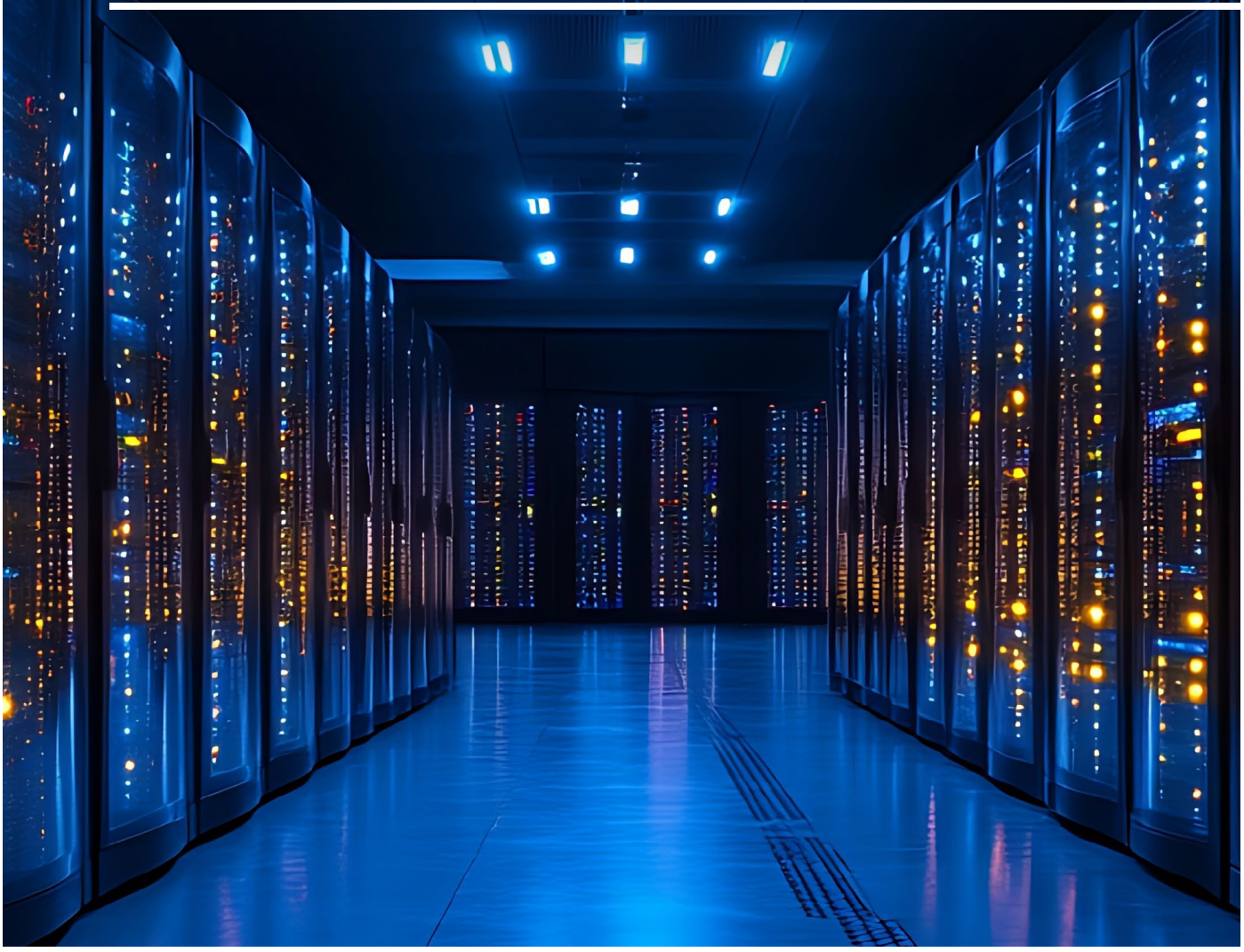
EVERY CONNECTION COUNTS

DIGITAL DATA NETWORKS TREND WATCH

THE EVOLUTION OF DATA CENTERS AND THE FUTURE OF COOLING AND CONNECTIVITY



With the emergence and rise of cloud computing, autonomous vehicles, Industrial Internet of Things (IIoT), and generative AI (artificial intelligence) technologies, the demands for data computing, storage, and network traffic continue to grow significantly.

Data centers are essential for processing and distributing this data, forming the backbone of our digital existence. This unstoppable expansion of digital data networks is fundamentally reshaping the infrastructure that powers our connected world, driving critical changes in power and cooling solutions for these facilities. Such workloads require increasingly high levels of power and efficiency in data centers — requirements that exceed the capabilities of existing air-cooled configurations.

As data center technology evolves, liquid cooling and immersion cooling have emerged as solutions for some of these challenges. This trend paper explores how data centers are evolving to help meet increasing demands with a focus on new design approaches and connectivity solutions.

THE GROWING PRESSURE ON DATA CENTERS

As needs grow exponentially to sustain global information demands, data centers are carrying a significant amount of the workload, stressing existing infrastructures and accelerating the need for upgrades. Data centers accounted for roughly 1.5% of the world's total electricity consumption in 2024, according to the International Energy Agency. The agency projects that electricity consumption will more than double by 2030, with AI as the driving factor. The ability to move information faster is critical for AI, data centers and the activities they support.

KEY CHALLENGES:

- **LIMITED RESOURCES**
- **INCREASING WORKLOADS**
- **EFFICIENCY AND PERFORMANCE PRESSURES**

INCREASING DEMAND CREATES THREE KEY CHALLENGES:

LIMITED RESOURCES

Power, water, and physical space are all resources that data centers require in ever-growing amounts. Supplying enough power to meet computing demands is a major hurdle. Power consumption translates directly to operational costs, making it a significant expense. And because many data centers rely on water-based cooling systems to dissipate heat, the global issue of water availability and scarcity is increasingly a concern. Data centers also require vast amounts of physical space to house servers, networking equipment, and cooling systems. Finding suitable locations with adequate space and infrastructure is challenging and can add to operational costs.

INCREASING WORKLOADS

Data centers must be able to handle increased workloads due to large numbers of operating end applications. The explosion of information generated by applications like AI, machine learning, and IIoT puts immense strain on data center infrastructure. These workloads often require high-performance computing and low latency, demanding significant processing power and bandwidth. The power requirements of the rack level power systems used in these facilities are increasing at an unprecedented rate, and chips are carrying more power than ever before.

EFFICIENCY AND PERFORMANCE PRESSURES

There is constant pressure to optimize cost-efficiency and performance. The increasing competition for electrical power from growing consumer demand means data centers will need to become more efficient to realize their full potential. Rising energy costs, hardware expenses, and maintenance fees can significantly impact profitability. Downtime is very expensive and must be avoided. In addition, facilities must keep up with technology upgrades to stay competitive and cost-efficient. The 2025 Industrial Technology Index from TE reports that for many companies, financial goals have taken precedence over longer-term sustainability ambitions, likely driving organizations to emphasize cost-saving initiatives in the near term.

Data centers are finding LIQUID AND IMMERSION COOLING TECHNOLOGIES to be efficient and viable methods for managing their increasing power demands.

ADDRESSING INCREASING DATA CENTER DEMANDS

Data centers are full of devices that generate heat. As a result, the elevated temperatures in a facility can affect product and component reliability, leading to increased downtime. The world's constant flow of information necessitates reliable and efficient power delivery to keep data centers operational, along with innovative cooling technologies to manage the heat generated by their immense computing power.

The good news is that engineers are already innovating to increase data center capabilities and sustainability. The growing volume of data and increasing speed at which that information moves means that small-scale improvements in cables, connectors, and heat dissipation equipment can have a significant impact on the amount of energy those facilities consume. Especially when multiplied across millions, or potentially billions, of interconnects in a modern data center. Much of the industry has transitioned to 48-volt distribution systems, and data centers may look to higher-voltage distribution systems in the future for additional reductions.

MORE INNOVATIVE COOLING SOLUTIONS

With data center rack level power requirements rapidly increasing, facilities and equipment OEMs are looking for more innovative cooling solutions, since traditional air-cooling configurations cannot keep pace with power demands and are no longer cost-effective.

Data centers need scalable cooling solutions that can be updated as they grow and evolve. These solutions must also be able to support higher current capacities without overheating. Lastly, data center cooling must offer efficiency, high performance, and cost-effectiveness.

Liquid cooling and immersion cooling technologies have emerged as viable and efficient solutions for data centers to meet growing demands.

LIQUID COOLING

Uses a liquid to transfer heat away from components. A common form of liquid cooling circulates liquid through pipes and heat exchangers to cool specific components (like a CPU). This is often referred to as "direct to chip" liquid cooling.

- More efficient at transferring heat compared to air cooling, allowing data centers to support much higher power densities per rack.
- Often more compact than its air-cooled counterparts, so data centers can make more efficient use of valuable real estate.
- Maintains lower and more stable operating temperatures, thereby reducing thermal stress on components like CPUs and GPUs.
- Requires less energy to achieve optimal temperatures compared to air-based systems.

IMMERSION COOLING

A specific type of liquid cooling that can also be referred to as liquid immersion cooling. Power usage efficiency (PUE) of the data center is greatly reduced by fully submerging all IT components in a non-conductive, dielectric fluid. The liquid absorbs and transfers the heat away from the hardware and into a cooling system, where the heat is then extracted.

- Reduces energy consumption, enabling higher-density compute deployments.
- Critical for sustaining growth of data center technology.
- Lowers overall footprint and overall operational costs so data centers can operate at higher densities.*

THERMAL COOLING

A broader term that encompasses any method of removing heat. It can include air cooling (using fans), liquid cooling, and heat sinks. Data center design challenges include increasing computing performance in higher-power data racks while managing thermal performance. Achieving this requires electrical and electronic components engineered to operate at maximum speeds and at rated thermal conditions, which requires thermal cooling.

- Higher power requirements of AI computing generate more heat, which makes greater thermal dissipation a critical concern.
- Thermal cooling is important for sustainability because heat generated by devices goes up almost exponentially as power used in these devices increases.

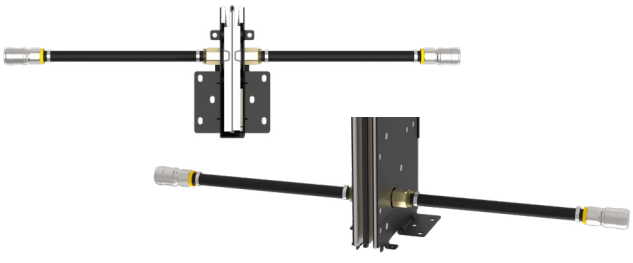
**This information was pulled from our partner Submer: https://submer.com/blog/impact-of-immersion-on-data-center-sustainability/*

THE FUTURE OF DATA CENTER COOLING AND CONNECTIVITY

Data center operators understand that they need to address their power consumption to ensure the future of the industry, especially as AI technology continues to develop. TE Connectivity (TE) is helping customers meet this goal through product innovations that enable the next-generation busbar solutions needed to power the future of AI and high computing requirements that are driving data center demand.

TE's liquid-cooled vertical busbar technology provides higher power distribution for next-gen AI racks, allowing for high current capacities while maintaining lower temperatures and reducing the amount of energy required to cool the data center. TE's breakthrough solution enables rack power of up to 750 kW (vs. 140 kW with air cooling) at 48 V. It's projected that by 2027, 800 kW will be enabled at the rack level, with the 1-megawatt threshold on the horizon by the end of the decade. This is all made possible by innovative liquid cooling solutions.

Liquid-cooled busbar universal quick disconnects (UQD) platform design utilizes standard off-the-shelf components for fluid connection.



TE's breakthrough Open Rack Version 3 (ORv3) Liquid Cooled Vertical Busbar solution enables rack power of up to 750kW at 48V.

THERMAL SIMULATION DATA

TE's liquid-cooled vertical busbar (VBB) technology delivers significant power distribution capabilities. This innovative solution can achieve higher power densities, ranging from 200 kW to 750 kW, while maintaining lower temperatures compared to air-cooled systems.

200 kW LIQUID-COOLED VBB

TOTAL POWER	MAX DC CURRENT	MAX T-RISE	MAX VOLT. DROP	TEMP. RANGE
200 kW	4166 A	7.79 C	0.1 V	40 – 47.7856° C
300 kW	6250 A	18.12 C	0.15 V	40 – 58.1241° C
400 kW	8333 A	33.59 C	0.21 V	40 – 73.5890° C

750 kW LIQUID-COOLED VBB

TOTAL POWER	MAX DC CURRENT	MAX T-RISE	MAX VOLT. DROP	TEMP. RANGE
750 kW	15625 A	29.6 C	0.05 V	40 – 69.6543° C

POWER LAYOUT

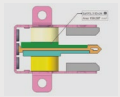
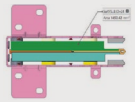
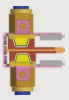
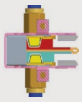
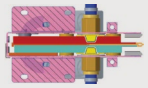
Power shelves on top/bottom. Power distribute to IT loads from shelf #10 to 36

44	Rack Power Input - X kW	44
43		43
42		42
41		41
40		40
39		39
38		38
37		37
36	Compute Tray - X*(1/10) Load	36
35	Compute Tray - X*(1/10) Load	35
34	Compute Tray - X*(1/10) Load	34
33	Compute Tray - X*(1/10) Load	33
32	Compute Tray - X*(1/10) Load	32
31	Compute Tray - X*(1/10) Load	31
30	Compute Tray - X*(1/10) Load	30
29	Compute Tray - X*(1/10) Load	29
28	Compute Tray - X*(1/10) Load	28
27	Switch Tray - X*(1/45) Load	27
26	Switch Tray - X*(1/45) Load	26
25	Switch Tray - X*(1/45) Load	25
24	Switch Tray - X*(1/45) Load	24
23	Switch Tray - X*(1/45) Load	23
22	Switch Tray - X*(1/45) Load	22
21	Switch Tray - X*(1/45) Load	21
20	Switch Tray - X*(1/45) Load	20
19	Switch Tray - X*(1/45) Load	19
18	Compute Tray - X*(1/10) Load	18
17	Compute Tray - X*(1/10) Load	17
16	Compute Tray - X*(1/10) Load	16
15	Compute Tray - X*(1/10) Load	15
14	Compute Tray - X*(1/10) Load	14
13	Compute Tray - X*(1/10) Load	13
12	Compute Tray - X*(1/10) Load	12
11	Compute Tray - X*(1/10) Load	11
10	Compute Tray - X*(1/10) Load	10
9		9
8		8
7		7
6		6
5		5
4		4
3		3
2	Rack Power Input - X kW	2
1		1

200 kW liquid vertical busbar is limited by a maximum voltage drop 0.1 V

AIR-COOLED BUSBAR VS. LIQUID-COOLED BUSBAR

Comparing the maximum power capacity, rated current, size, and approximate weight of busbar configurations showcases the increased power capabilities of liquid-cooled solutions over air-cooled alternatives. Liquid-cooled busbars like TE's ORv3 LC 750kW can handle significantly higher rated currents and power capacities.

	MAX. POWER CAPACITY *ASSUMING DUAL ZONE*		RATED CURRENT	SIZE OF BBA IN MM³ *(L*W*H)*	APPROX. BBA WEIGHT
AIR-COOLED BUSBAR		ORv3 36 kW	~375 A	2196 mm x 35 mm x 61.76 mm	14 KG
		ORv3 HPR 140 kW	~2900 A	2196 mm x 35 mm x 187 mm	80 KG
LIQUID-COOLED BUSBAR		ORv3 LC 200 kW	~4150 A	2196mm x 35mm x 61.76 mm	16 KG
		ORv3 LC 400 kW	~8300 A	2196 mm x 35 mm x 87 mm	45 KG
		ORv3 LC 750 kW	~15600 A	2196 mm x 35 mm x 187 mm	85 KG

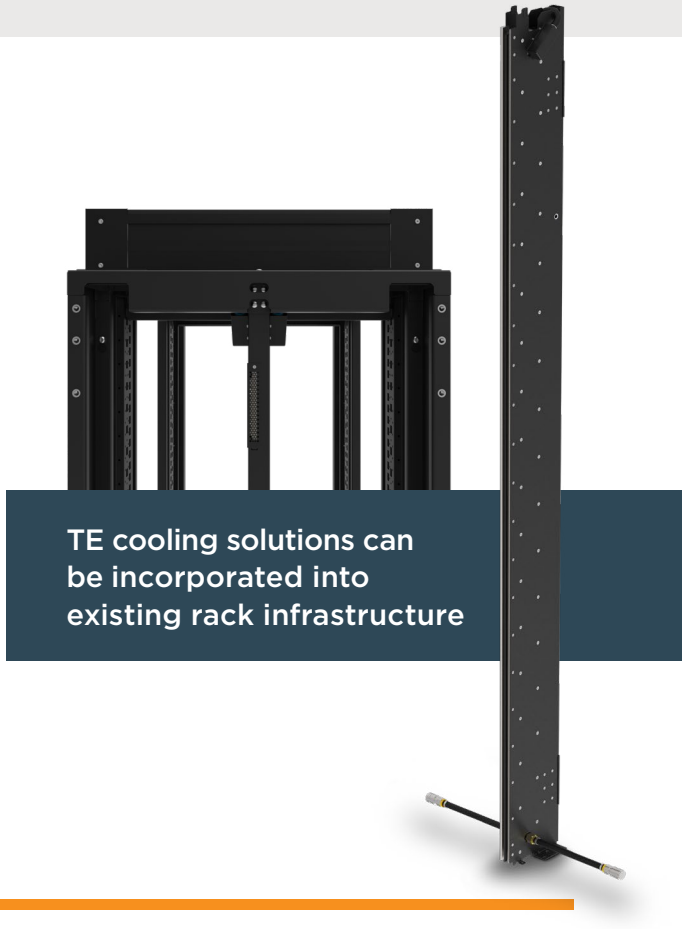
TE'S LIQUID COOLING SOLUTIONS DELIVER SEVERAL KEY BENEFITS:

UP TO FIVE TIMES MORE CURRENT CAPACITY while maintaining lower temperatures with TE's Liquid Cooled Vertical Busbar compared to air-cooled solutions.

Sustainable and cost-effective solutions that help **IMPROVE OVERALL INFRASTRUCTURE EFFICIENCY AND POWER**.

200 kW, 400 kW, and 750 kW configurations available to **PROVIDE FLEXIBILITY**.

ORv3-compatible and can be incorporated into existing rack infrastructure, allowing customers to **MEET THE GROWING POWER DEMANDS** of AI workloads in a cost-effective way **WITHOUT INCREASING BUSBAR FOOTPRINT**.



TE cooling solutions can be incorporated into existing rack infrastructure

REAL-WORLD RESULTS WITH TE SOLUTIONS

IMMERSION COOLING SOLUTION

As one of the leading innovators in immersion cooling technology, Submer, in collaboration with TE and other Open Compute Project (OCP) partners, launched Europe's first ORv3 immersion cooling deployment. This installation seamlessly integrates immersion cooling technology with the ORv3 infrastructure, helping set essential industry standards to support next-gen cooling solutions. Hosted at Stellium Data Centres, in Newcastle upon Tyne, UK, the technology helps provide cutting-edge solutions supporting the future of data center sustainability.

The integration, featuring busbars from TE, significantly enhanced energy efficiency and thermal management capabilities, offering an innovative solution for modern data center challenges.

TE's ORv3 compatible busbar solution helped support a more flexible rack-level infrastructure.

LIQUID COOLED I/O AND THERMAL BRIDGE HYBRID SOLUTION

TE also provides a cooling solution that includes a combination of thermal bridge components with a liquid cooling cold plate structure, integrated into TE I/O connectors.

This solution delivers up to two times better thermal resistance, as compared to traditional thermal technologies.

This efficient and innovative technology addresses some of the most challenging thermal problems in data centers today.

At TE, we are committed to creating more efficient power connectivity solutions. To meet a data center's thermal requirements, system designers should look for a partner with expertise and a component portfolio engineered to address the difficult thermal challenges. In choosing TE, you gain a partner who can help effectively address operating requirements and tailor your system design to achieve optimal performance

Connect With Us

Ready to learn more about TE solutions that address cooling and connectivity challenges as data centers evolve? **Connect with us today.**

te.com/ai