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# Next-Generation Full-Stack Data Center: Reduce PUE with a Green Energy-Efficient Solution

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# It’s time to build green, energy efficient data centers

In countries where data center market is relatively mature, on average, 2%-3% of the national electricity is used to power data centers. Although the computing resource efficiency has been improved thanks to the technology advances and space increase with the construction scale of large and ultra-large data centers continues to grow in recent years, data center is still a major consumer of energy. The daily power consumption of a data center accounts for most of the operation & maintenance (O&M) expenditure, and it’s time to reduce O&M cost and improve energy efficiency.

The improvement of energy efficiency is reflected in the further reduction of the Power Usage Effectiveness (PUE) value, that is, to minimize the energy consumption of other components beyond the IT equipment, such as thermal management, power distribution, lighting, and other systems, among which thermal management consumes most of the energy. In traditional data centers, thermal management consumes about 25%-30% of the total power consumption, which means about 0.5%-1% of the national total power consumption is used for thermal management to meet the heat dissipation requirements of the data center.

However, with the rapid evolution of key components such as CPU and storage, advances in chip technology and processes lead more processors to enter the market with great performance but high-level power consumption. Currently the power consumption of CPU for data centers ranges from 165W to 275W, and it will increase to above 400W in the future. In addition, AI model training has a greater demand for parallel computing which consumes more power. With more AI chips releasing much more heat per unit area, the demand of servers for power will further grow. The increase in the number of processing units and power consumption of each processing unit far exceed the increase in computing power per watt predicted by Moore's Law.  Rapid growth of heat produced by servers means the lack of chip-level thermal management will be a bottleneck limiting their performance.

In addition, the number of servers in each cabinet is also increasing. The average power density per rack has increased from 2-4KW ten years ago to 7-10KW and is expected to go up to more than 25KW-50KW. For data centers densely deploying racks to improve space efficiency, thermal management in the computer room partly determines the upper limit of a data center's computing power. Even if there are new technologies such as application virtualization and containerization maximizing the use of physical servers, thermal management will still be a main factor affecting the load rate of data center.

Given these trends, the heat dissipation requirements of next-generation, high computing power data center will be much more demanding than ever before. It will be more difficult to keep balance between computing power, PUE, and cost, which becomes an obstacle for high energy efficiency. To improve energy efficiency and ecological environment, all countries have put forward lower target

PUE value for data centers within a certain period. To this end, while ensuring the normal operation of IT equipment, an advanced thermal management methods to achieve higher efficiency and lower energy consumption is required to reduce energy consumption and operating costs of components beyond IT equipment, and lay a foundation for building energy-efficient and low-cost data centers without human intervention.

# Reduce PUE by energy efficient thermal management

## Liquid cooling solutions to address heat dissipation challenges

To alleviate the conflict between computing power and energy consumption, the existing thermal management technology need to be upgraded into energy-saving and efficient solutions. For cabinets and servers, current mainstream cooling solution is the use of air-conditioning units to lower the temperature of IT equipment. This is a mature technology, but it consumes a lot of power and has limited space for energy efficiency upgrades. With the centralization of equipment and improvement of power density, the power used by air-conditioning units should be greatly increased accordingly to meet the heat dissipation requirement of normal operation. To ensure a safe and stable operation of the data center and a reasonable PUE range, high power consumption of air-conditioning units has become the main factor limiting the performance of high-performance IT equipment. The upper power limit of a single cabinet is 25KW, determined by the power constraint of the air conditioners supporting it.

In traditional data centers with low-density cabinets and computing power, there is a possibility to deploy low-power air-cooling solutions using natural cooling sources as an alternative to air-conditioning units. The advantage of natural air cooling lies in the adaptation to local conditions. By using natural cooling sources to dissipate the heat generated by IT equipment, it reduces the demand of the cooling system for electricity, resulting in a high energy efficiency ratio. In general, for both air-conditioner cooling and natural air-cooling solutions, air flow is used as the carrier of heat. To create the air path for heat dissipation, there are certain density requirements for the equipment in the rack to meet, which limits the increase in the density of a single cabinet and fails to keep up with the increase in power consumption and density of IT equipment.

As the increase in computing power per watt is limited, it is necessary to address the disadvantage of traditional air cooling solution in high computing power scenarios, focus on the cooling of main heat-generating units such as chips, and minimize unnecessary heat loss in the thermal conduction path, so that to meet the heat dissipation challenges posed by high-density and high computing power IT equipment in the next-generation data center. Air as a heat carrier can no longer meet this heat dissipation requirement. In this situation, a variety of cooling solutions using liquid as heat carrier have been favored by data center owners in recent years, becoming an important alternative to air conditioner in high computing power scenarios. In the past 10 years, liquid cooling technology has been used to cool mainframes, supercomputers, and high-performance personal computers. Only in the past 5 years has it been used by high computing power data centers to cool IT equipment

with huge power consumption, replacing air conditioning units to support high computing power applications from AI algorithms to Bitcoin mining.

Liquid cooling solutions for the data center can be divided into direct heat exchange scheme represented by the immersion cooling, and indirect heat exchange scheme represented by the cold plate cooling based on different contact methods between liquid and equipment. The latter, due to its lower cost, more flexible deployment achieving plate-level and cabinet-level cooling, and innovative solutions such as air/liquid hybrid and complete cold plate coverage, can replace air-conditioner according to actual conditions and increase the share of liquid cooling. Therefore, it is more suitable for data centers with higher heat density. Taking the cold plate liquid cooling as an example, its main advantages are as follows:

### Thermal conductivity

Some special liquid mixtures have higher specific heat capacity (SHC), and much higher thermal conductivity than that of air, that means compared with the air of same volume, it can carry away nearly 3000 times of the heat. Considering the flow rate, the heat dissipation capacity of liquid cooling solution is about 25 times that of the air-cooling solution. Therefore, it can support the normal operation of higher-performance IT equipment.

### Working noise

The pump pushes the heat-conducting liquid to flow in the closed tube. Compared with fans in the traditional air conditioner, it will not produce airflow noise, lowering the working noise by 20-35 decibels. This method is more friendly to operation & maintenance tasks and environment surrounded.

### Space utilization

Liquid cooling solution could bring about a significant improvement in the heat dissipation, enabling the racks and servers to be more densely installed, thereby reducing the demand for white space in the data center and improving the space utilization across the data center.

### PUE and energy consumption expenditure

The airtight heat-conducting liquid path is in direct contact with heat-generating elements such as chips. The heat loss is comparatively less in the flow path, and the same volume of heat dissipation consumes 50% less power than air cooling, which further improves the PUE. Its power consumption expenditure is also lower compared with the air-cooling solution.

### Use less of the air-conditioning units

Compared with the traditional air-cooling method using air conditioner, the liquid in the liquid cooling solution exchange heat with external cold sources, which reduces the use of and dependence on expensive refrigeration units and air-conditioning equipment, saves the complicated maintenance investment for air conditioning and refrigeration units, and is more friendly to the environment.

The significant advantages in design, operation, and applicability of liquid cooling solutions in high computing power scenarios have aroused resonance in the data center industry. Liquid, as an alternative to air as a cooling medium, has its uniqueness, so the experience and ideas from air cooling could not be used for the liquid cooling solution. This, combined with the fact that it is still in

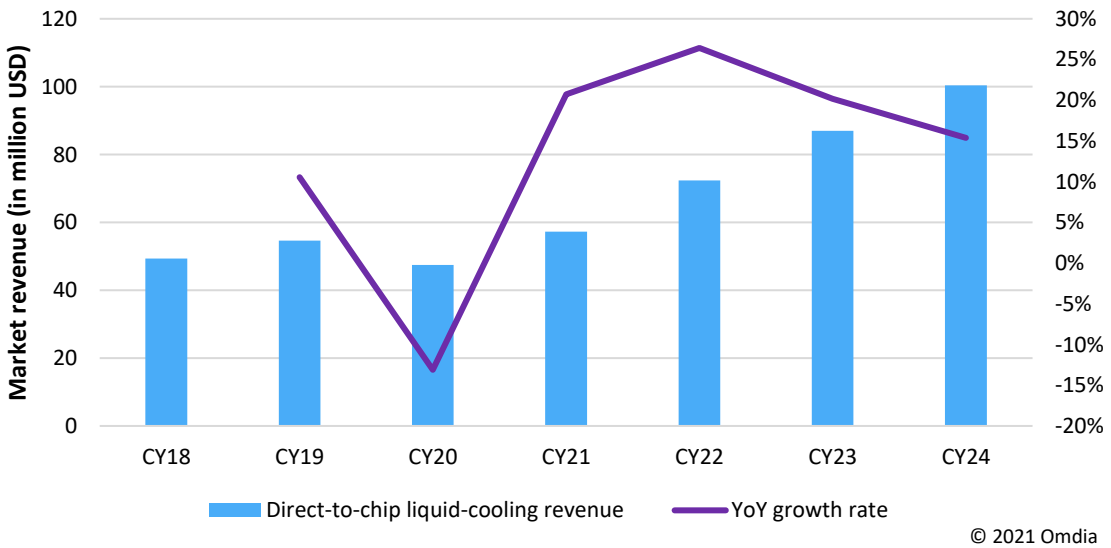
the early stage of application in the data center, calls for the adaptation based on the heat dissipation characteristics of the IT equipment.

To successfully improve PUE in the data center through liquid cooling solution, it is crucial to meet key requirements of system security, intelligence, standardization, and operability, including path sealing and pluggability, liquid safety and thermal conductivity, intelligent matching with instantaneous power consumption and a higher degree of standardization, etc. Apart from saving energy consumption of thermal management, lowering the threshold for implementing liquid cooling solutions in new and upgraded data centers, ensuring the safety of long-life electrical equipment, and promoting the standardization of liquid cooling upgrade process solutions and products from a long-term perspective will accelerate the development of technology and market.

# Liquid cooling solution market outlook

As a relatively new cooling technology, the liquid cooling solution (direct contact liquid cooling at chip level) market is small but rapidly growing. In 2019, it increased by 11% year-on-year. However, in this new market, the ecosystem of product and supplier is relatively vulnerable for its short history. Severely affected by the COVID-19 pandemic, it has reduced by 13% in 2020. At the same time, the pandemic also gives end users more time and resources to understand the advantages of liquid cooling solution, successful use cases, and challenges to overcome. Therefore, liquid cooling solution providers have confidence in this new market. There is a common belief that the liquid cooling market will witness recovery and significant growth when the global pandemic begins to ease in 2021.

**Figure 1: Revenue and growth trend of chip-level liquid cooling market**




Source: Omdia

Omdia expects that the revenue growth rate of liquid cooling solution market will be 21% and 26% in 2021 and 2022 respectively. From 2019 to 2024, its five-year compound annual growth rate (CAGR) is expected to be 13%, reaching 100 million US dollars in 2024. Its contribution to the global data center thermal management market will also increase from 1.4% in 2020 to about 2.3% in 2024.

# Summary

Energy consumption is the largest cost item in the later operation of current data centers. To improve the competitiveness of the next-generation data center, addressing the key pain point of energy cost is crucial. Technical methods can be used to maximize energy efficiency in data center, reducing the energy consumption of large data centers while increasing computing power. As the largest power consumption item except IT equipment, thermal management plays an important role in the energy saving initiatives across data center. The successful improvement of its energy consumption enables the data center to take a big step towards the goal of energy saving and efficiency.

Current mainstream air-conditioner cooling solution has a bottleneck when applied to the next-generation data center for it limits the improvement of IT equipment performance and cabinet density and consumes a large amount of power to cool the equipment. Therefore, in the upgrade of future data center, natural air cooling can be partly adopted for general scenarios, using natural cold sources such as cold air to efficiently exchange heat from IT equipment with lower energy consumption, which further improves cost effectiveness while reducing PUE. For high computing power scenarios, there is a trend of replacing some air-conditioning solutions with liquid cooling methods, which can realize more refined and intelligent thermal management and effectively control the heat dissipation of high-computing power, high-density equipment by changing heat conducting medium. These characteristics means that liquid cooling solution can reduce the waste of cooling energy and improve energy efficiency, making it one of the key means for data centers to improve PUE.

The liquid cooling solution for data center is still in the growth stage, and the implementation is mostly customized. Some deployments are still combined with traditional air-cooling solution using air-conditioner, as part of the hybrid heat dissipation solution applied to some racks in the data center. However, there are also practices that use complete chip/server-level liquid cooling solution across the data center. The data center market needs a deeper understanding and practical use cases of advanced thermal management technologies such as liquid cooling. When the technical and cost advantages of liquid cooling solutions for improving PUE in high computing power scenarios are deeply felt by the market, its adoption rate will have much space for improvement.

# Appendix

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