

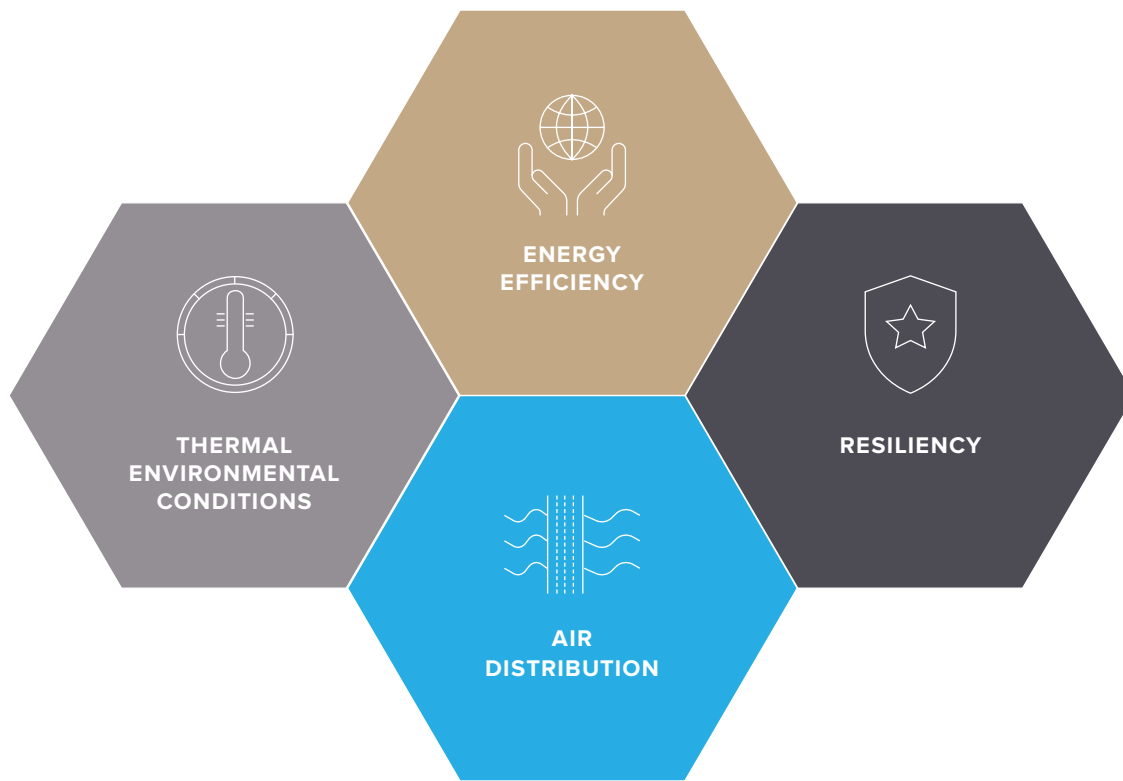


DATA CENTERS ENERGY USE + MECHANICAL SYSTEMS

APPLICATIONS, BENEFITS + OPPORTUNITIES

FEBRUARY 2022





DATA CENTERS **ENERGY USE + MECHANICAL SYSTEMS**

Data centers are critical in today's online world—powering businesses, e-commerce, communications, security, websites and more. With the ever-growing demand for real-time data transmission, data centers need to be productive and efficient. The scale and complexity of building, maintaining, and operating these facilities creates challenges which must be met with innovation and holistic solutions.

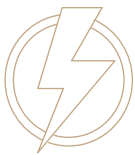
Harris is at the forefront of providing mechanical services for building systems including design, construction, building automation systems, and maintenance. This Technical Snapshot offers observations regarding the current practices and future trends of energy use and mechanical systems for data centers.

Thermal environmental conditions, energy efficiency and air distribution must be addressed in the design of data centers to allow long-term resilience and reliable performance of data infrastructure.

TECHNICAL SNAPSHOT: DATA CENTERS

As the global trend in digitalization continues to accelerate, service providers scramble to keep pace. Data centers play a significant role as experts work to manage massive energy consumption while keeping operations resilient and efficient.

In 2021, worldwide data center energy consumption was estimated to be nearly 190 billion kilowatt-hours.



76

BILLION KWH
IN 2022:

PROJECTED TO
BE CONSUMED
IN THE US



40%

OF THIS ENERGY
CONSUMED
COOLING
DATA CENTERS



KEY TERMS

DATA CENTER

A group of buildings, a single building, or a dedicated space in a building hosting IT operations and equipment for data storage, processing, and dissemination services.

DATA CENTER COMPONENTS

Computing: Servers

Storage: Hard disk drives, tape drives and other forms of internal and external storage.

Networking: Power, routers, switches and interfaces.

Security: Firewalls, biometrics and video surveillance systems.

POWER DENSITY

Refers to power draw of a single, fully populated server rack, as measured in kilowatts. Today, power densities of a data center range from 8 to >20 kW per rack. As the power density of the data center increases, the space required for the power and cooling equipment also increases.

Static Power Density: Same power density for all racks in data center.

Flexible Power Density: Data center is divided into different zones with variable power densities. This option helps clients who do not need higher power densities to save money.

MISSION CRITICAL

Infrastructure vital to the functioning of an organization.

RESILIENCE

A system's ability to continue operating during or recover from a fault and maintain service.

REDUNDANCY

The intentional duplication of system elements, components or distribution paths to increase a system's dependability by removing single points of failure.

N - Sufficient systems and equipment to meet capacity needs for operation

N+1 - Provision of one additional piece of equipment

2N - Sufficient systems and equipment to meet 2x capacity needs for operation

DATA CENTER TYPES

ENTERPRISE

Housed on corporate campus, built, owned and operated by the company

MANAGED SERVICES

Managed by a third party, companies lease the equipment and infrastructure

COLOCATION

Company owns IT equipment, rents space within a data center owned by a third party

CLOUD DATA CENTER

Off-premises data center, data and applications are hosted by a cloud service provider like Amazon Web Service (AWS)

EDGE

Smaller facilities close to end-user, deliver faster services and connected to a larger data center

BALANCING THE FUNDAMENTALS

The amount of electricity consumed by data centers indicates that there are significant energy saving possibilities. The challenge remains—meet the escalating demand for data while managing energy consumption and resilient operation. Creating a balance between offsetting the large heat loads and data center operational costs is key to optimal performance.

RESILIENCE

Data centers are mission critical facilities—any interruption can stop a business' operation and lead to critical data loss. That's why mechanical and electrical systems in data centers should comply with industry best practices for resiliency. The most widely adopted standard for data center design and infrastructure is ANSI/TIA-942. It includes standards for certification to show compliance with one of the four data center tiers.

Rated for levels of redundancy and fault tolerance, these classifications are the international standard for data center performance. The four classification tiers match a particular business function with criteria defined for maintenance, power, cooling and fault capabilities.

The tiers are progressive, each incorporates the requirements of the lower tiers. This progression does not mean that Tier IV is better than Tier II but rather that the levels fit different business operations. Data center tiers levels are:

TIER I:

Tier I is the basic capacity level with infrastructure to support information technology for an office setting and beyond. The characteristics of a Tier I data center are:

- 99.671% Guaranteed availability
- No redundancy required
- 28.8 hours of downtime per annum

TIER II:

Tier II facilities cover redundant capacity components for power and cooling that provide better maintenance opportunities and safety against disruptions. The characteristics of a Tier II data center are:

- 99.741% Guaranteed availability
- Central cooling generation redundancy (partial N+1)
—terminal equipment redundancy varies
- 22 hours of downtime per annum

TIER III:

Tier III is concurrently maintainable with redundant components as a key differentiator, with redundant distribution paths to serve the critical environment. Unlike Tier I and Tier II, these facilities require no shutdowns when equipment needs maintenance or replacement. The characteristics of a Tier III data center are:

- 99.982% Guaranteed availability
- Full System N+1
- No more than 1.6 hours of downtime per annum

TIER IV:

Tier IV is considered an enterprise-level service. Companies with international reach and high web traffic would likely be Tier IV candidates. Tier IV has approximately twice the site infrastructure of a Tier III location. The characteristics of a Tier IV data center are:

- 99.995% Guaranteed availability
- Zero single points of failure
- 2N+1 infrastructure
- No more than 26.3 minutes of downtime per annum
- 96-hour power outage protection

ANSI/ASHRAE STANDARDS AND GUIDELINES

DESIGN CONDITIONS

Choosing the right HVAC equipment for process cooling, adopting appropriate control strategies, operating within recommended or allowed ranges, and using appropriate air distribution methods are all necessary to provide a suitable environment for data centers. According to ANSI/ASHRAE Standard 90.4-2019, Energy Standard for Data Centers, data centers are mission critical facilities that demand careful attention to design requirements. This standard provides a comprehensive guideline to data center cooling and recommended environmental conditions.

Standard 90.4 offers a framework for the energy efficient design of data centers with special consideration to their unique load requirements compared to other buildings through establishing the minimum energy efficiency requirements for the design and operation of data centers.

The standard was updated in 2019 to allow a wider range of temperature and humidity in data centers. In addition to Standard 90.4, ASHRAE offers the “Thermal Guidelines for Data Processing Environments,” with descriptions of the recommended operating environment for A1 to A4 environmental classes.

Most mission critical data center equipment currently falls into class A1 or A2, as this equipment requires a tightly controlled environment. It is likely that more data center equipment manufacturers will produce a broader range of class A3 and A4 equipment in the future with technical innovations. The recommended and allowable environmental specifications for A1 to A4 classes are presented in Table B.1 below.

Prolonged exposure of operating equipment to conditions outside its recommended range can result in decreased equipment reliability and longevity.

EQUIPMENT ENVIRONMENTAL SPECIFICATIONS FOR AIR COOLING

RANGE	CLASS	TEMPERATURE (DRY BULB) –°F	HUMIDITY RANGE (NON-CONDENSING)
RECOMMENDED	ALL A	64.4 - 80.6	15.8 DP TO 59 DP 70% RH OR 50% RH
ALLOWABLE	A1	59 - 89.6	10.4 DP and 8% to 62.6 DP and 80% RH
	A2	50 - 95	10.4 DP and 8% to 69.8 DP and 80%
	A3	41 - 104	10.4 DP and 8% to 75.2 DP and 85%
	A4	41 - 113	10.4 DP and 8% to 75.2 DP and 90%

TABLE B.1 FROM 2021 ASHRAE THERMAL GUIDELINES FOR DATA PROCESSING ENVIRONMENTS

DP stands for dew point and RH is the relative humidity.
Provided for example only, refer to current version of applicable standards.

ENERGY EFFICIENCY

With 40% of the energy consumed by data centers associated with cooling, it's no surprise that new technologies and methods with higher energy efficiency are emerging.

PUE

Power Usage Effectiveness (PUE) is the predominant metric that describes how efficiently a computer data center uses energy under normal operating conditions; specifically, how much energy is used by the computing equipment related to cooling and other indirect power uses. PUE is the ratio of energy used by a computer data center facility compared to that used by computing equipment.

PUE is formulated as follows:

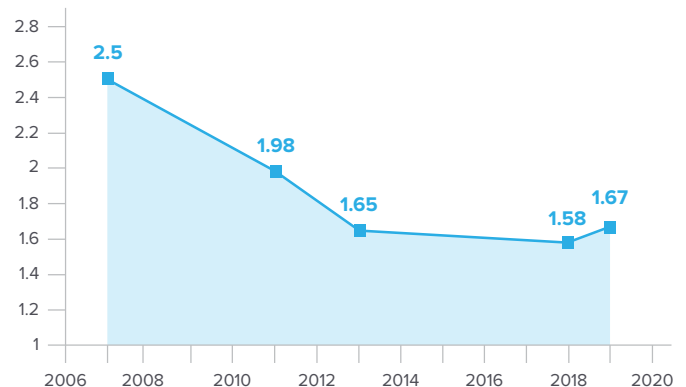
$$\text{PUE} = \frac{\text{the total facility power}}{\text{the energy used by IT equipment}}$$

The minimum PUE is 1.0, where all energy input to the data center is used only on IT equipment, and it is impossible to achieve.

More than 10 years ago, the average PUE as reported by Uptime was 2.5, based on surveys of global data centers ranging in size from 1 megawatt (MW) to over 60 MW, of varying ages. That has since improved.

Significant strides in energy efficiency were made from 2007 to 2013. By 2012, the average data center PUE was 1.65. It continued to improve slightly but has since leveled off. In 2019, the average data center PUE ticked up to nearly 1.7.

DATA CENTER EFFICIENCY GAINS HAVE STALLED



This average value isn't the full picture, however, as it includes existing data centers that have not been upgraded. New data centers are achieving PUEs in the range of 1.2 to 1.4 due to improvements in technology and practices.

PRESSURIZATION AND FILTRATION

Good air quality is critical for data centers. Dust can adversely affect the operation and reliability of data processing equipment due to stray currents. Dust control is accomplished through both pressurization and filtration.

The IT environment should be positively pressurized to reduce infiltration from the surrounding areas. In addition, all air entering the data center environment is required to be filtered to MERV 11 or 13, and MERV 8 for recirculated air.

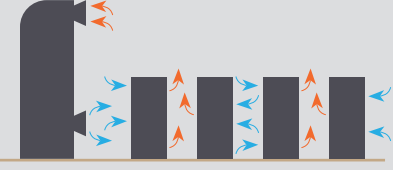
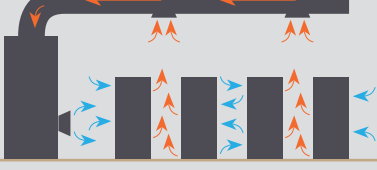
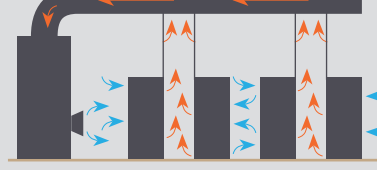
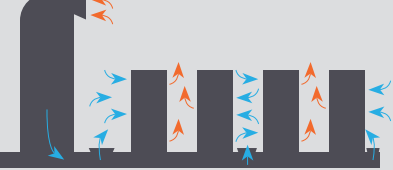
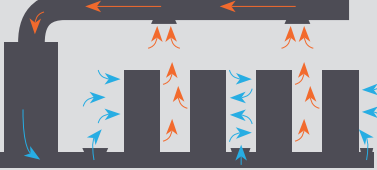
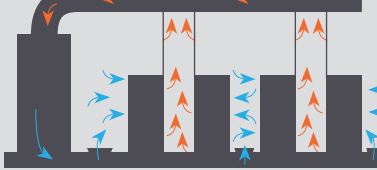
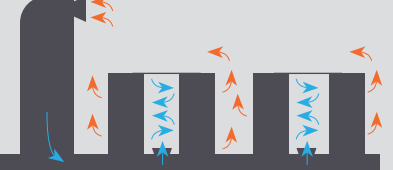
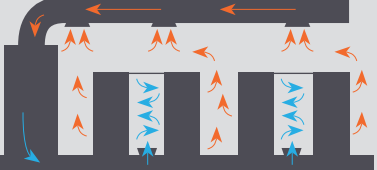
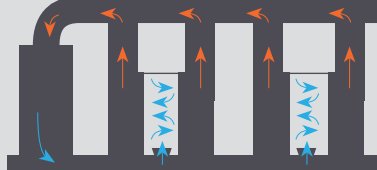


AIR DISTRIBUTION IN DATA CENTERS

Air distribution implementation and management practices strongly influence the achievable power density in all nine air distribution types. In general, the cost, complexity and power density capability (kW per rack) of

the air distribution implementations is lowest at the top and left of the following table and increases for the types that are down and to the right.

The nine types of air distribution (traditional room-based cooling implementations) are as follows:

	FLOODED RETURN	TARGETED RETURN	CONTAINED RETURN
FLOODED SUPPLY	 SMALL LAN ROOMS <40kW - Low cost, simple installation - Least energy efficient of all air distribution architectures because 100% of the cold supply air is allowed to mix with hot return air - Distribution type can cool up to 3kW per rack - Not suitable to meet the needs of modern data centers	 GENERAL USE - Low cost, ease of install - More energy efficient than flooded return since 40-70% of IT hot exhaust air is captured and delivered back to the cooling unit - Supply air more predictable than flooded supply since less hot air is allowed to mix with cold supply air - Distribution type can cool up to 6kW per rack - Not suitable to meet the needs of modern data centers	 LARGE DATA CENTER/COLOCATION - Upgradeable (vendor specific) - Most energy efficient of all air distribution architectures since it allows increased cooling unit supply temp resulting in increased economizer hours 70-100% of IT equipment hot exhaust air is captured and delivered back to the cooling unit - Supply air temperature is more predictable since no hot air is allowed to mix with cold supply air - Distribution type can cool up to 30kW per rack
TARGETED SUPPLY	 DATA CENTERS WITH STATIC POWER DENSITIES - More energy efficient than flooded supply since more IT equipment hot exhaust air is diverted from the room before mixing with supply - Distribution type can cool up to 6kW per rack - Not suitable to meet the needs of modern data centers	 SMALL TO MEDIUM DATA CENTERS - More energy efficient than flooded return since 60-80% of IT equipment hot exhaust air is captured and removed from the space - Supply air more predictable since less hot air is allowed to mix with cold supply air. - Distribution type can cool up to 8kW per rack	 HOT SPOT PROBLEM SOLVER - Upgradeable (vendor specific) - More efficient than targeted supply and return since 70-100% of IT equipment hot exhaust air is captured and removed from the space - Supply air is most predictable since no hot air is allowed to mix with cold supply air - Allows increased cooling unit supply temp resulting in increased economizer hours. - Distribution type can cool up to 30kW per rack
CONTAINED SUPPLY	 MAINFRAMES/RACKS WITH VERTICAL AIRFLOW - More energy efficient than targeted supply but less efficient than contained return - Containing the supply air forces the rest of the room to become the hot aisle which limits the number of economizer hours - Minimal hot air is allowed to mix with cold supply air - Distribution type can cool up to 30kW per rack	 MAINFRAMES/RACKS WITH VERTICAL AIRFLOW - More energy efficient than targeted supply but less efficient than contained return - Containing the supply air, forces the rest of the room to become the hot aisle which limits the number of economizer hours - Supply air is more predictable since little hot air is allowed to mix with cold supply air - Distribution type can cool up to 30kW per rack	 HARSH NON-DATA CENTER ENVIRONMENTS - Slightly less efficient than contained return with flooded or targeted supply—requires more fan energy - Allows increased cooling unit supply temp resulting in increased economizer hours - Distribution type can cool up to 30kW per rack

DATA CENTER COOLING

Dissipating Heat in the IT Environment

There are several fundamental heat removal methods used to cool the IT environment and transfer unwanted heat from IT equipment out of the space. One or more of these methods is used to cool virtually all mission critical computer rooms and data centers.

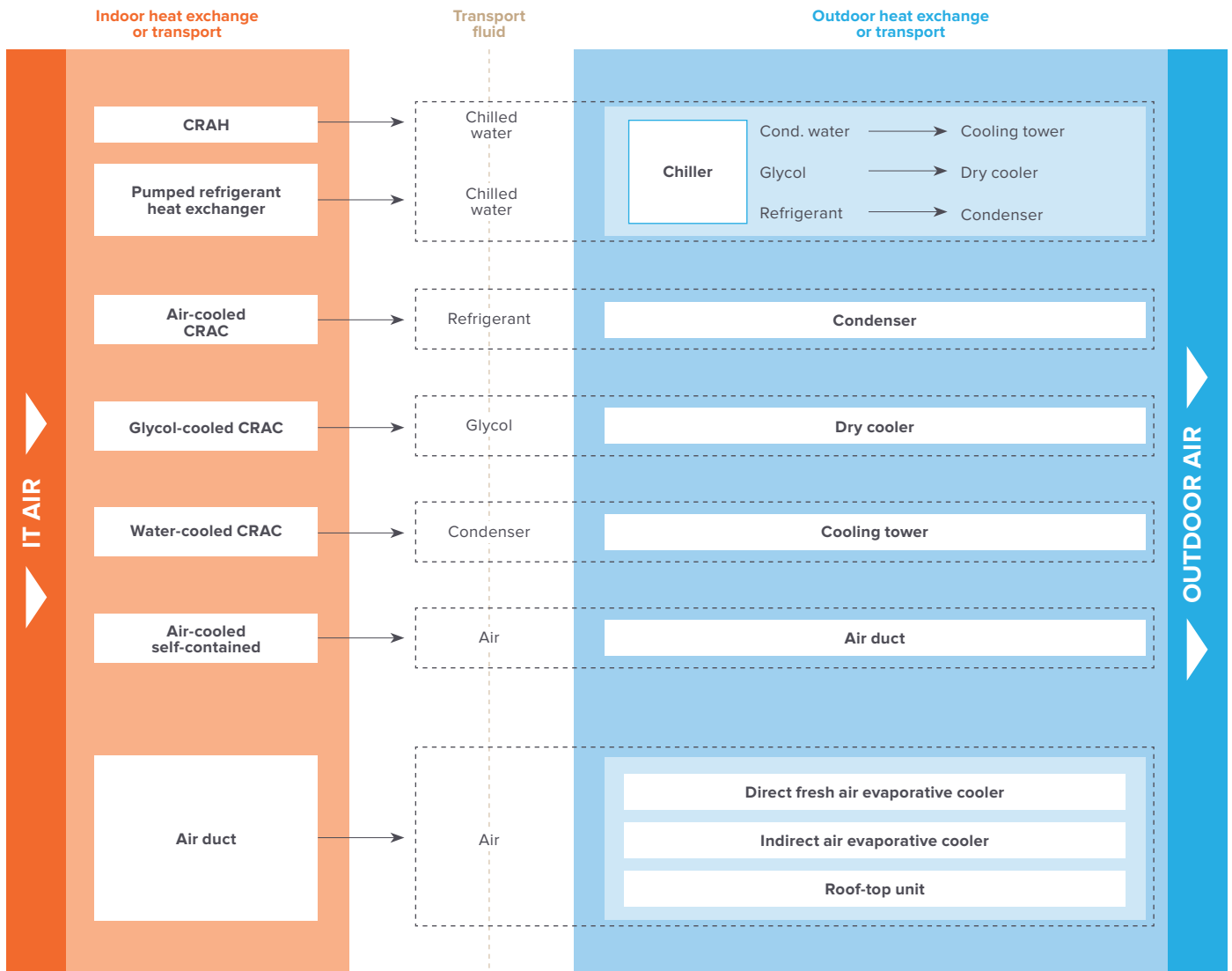
Of these methods, Computer Room Air Handlers (CRAH) and Computer Room Air Conditioners (CRAC) are the most common.

CRAC (pronounced “krak”) units use a direct expansion (DX) refrigeration cycle. Air is cooled by blowing over a refrigerant coil. The refrigerant is kept cold by a compressor within the unit. The excess heat is then expelled using air, water, or a glycol mixture.

CRAH (pronounced “kraw”) units use fans and chilled water coils to remove heat. Because CRAH units do not contain compressors, they are more energy efficient than CRAC units.



FUNDAMENTAL HEATING REMOVAL METHODS



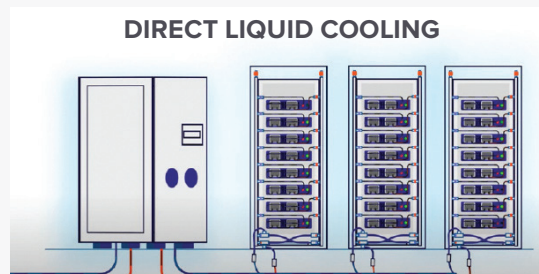
FUTURE TREND IN DATA CENTERS

COOLING

Cutting edge technologies are also being developed to increase the cooling efficiency of data centers, taking maximum advantage of natural cooling methods. Direct liquid cooling and liquid immersion are some of the most promising cooling techniques being tested and implemented by pioneers such as Google and Microsoft as they bring more environmentally friendly and improved thermal environments to data centers.

DIRECT LIQUID COOLING (DLC)

- Heat from the servers is exchanged to liquid coolants with exceptional thermal conductivity to provide dense, concentrated cooling
- Reduces power demand and energy use
- Increases cooling efficiency and rack density
- Liquid leakage concerns

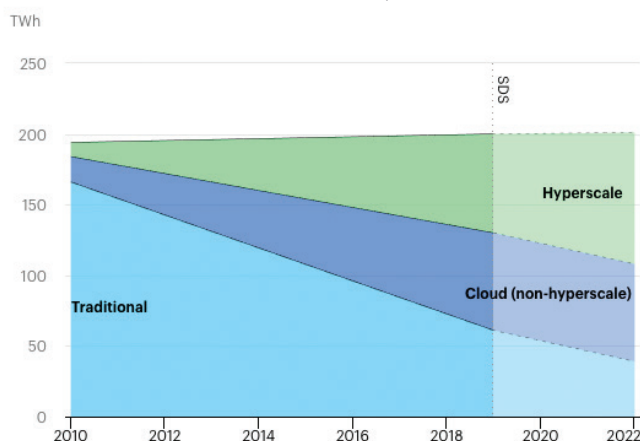


HYPERSCALE DATA CENTERS

Strong growth in demand for data center services continues to be offset by ongoing efficiency improvements and the shift from traditional data centers to much greater shares of cloud and hyperscale data centers.

- Hyperscale data centers are large-scale cloud data centers that are designed with power efficiency in mind, due in part to virtualization software that enables data center operators to deliver greater work output with fewer servers
- They use greener technology like solar and wind to improve power consumption
- Hyperscale data centers are moving to colder areas of the world to help these facilities stay cooler at lower costs

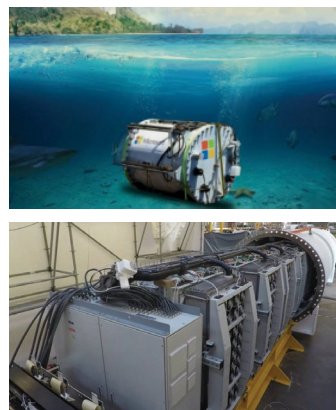
GLOBAL DATA CENTER ENERGY DEMAND BY DATA CENTER TYPE, 2010-2022



UNDERWATER DATA CENTER

- Microsoft tested their underwater data center — immersed 117 feet — to be reliable, practical and sustainable compared to air cooled data centers
- More than 40% of the world's population lives within 62 miles of the coast. Hence, a submerged data center close to the user will reduce latency and promote quicker responsiveness (edge computing)
- 50% more effective than air cooling
- Sea acts as a giant heatsink
- Server rack is tightly sealed
- Renewable solar, hydro or wind power supply available

MICROSOFT UNDERWATER DATA CENTER



Photos: <https://www.bbc.com/news/technology-44368813>,
<https://www.colocationamerica.com/blog/worlds-most-unique-data-centers>

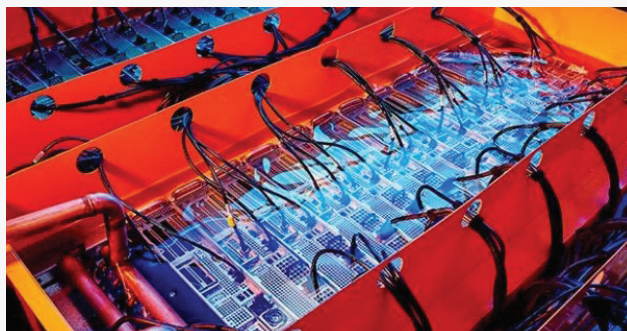
FUTURE TREND IN DATA CENTERS

COOLING

OPEN BATH OR LIQUID IMMERSION

- Servers immersed in a non-toxic, non-convective coolant with higher thermal capacity than air
- Heat directly transferred to the fluid without needing additional cooling components, such as heat sinks or fans
- More effective at dissipating heat and allows servers to be packed closer, paving the way for high density computing
- Liquid has a low boiling point and evaporates due to heat transferred from chip. After, a condenser turns the vapor to liquid form, which flows back into the bath and renews the cycle

OPEN BATH OR LIQUID IMMERSION

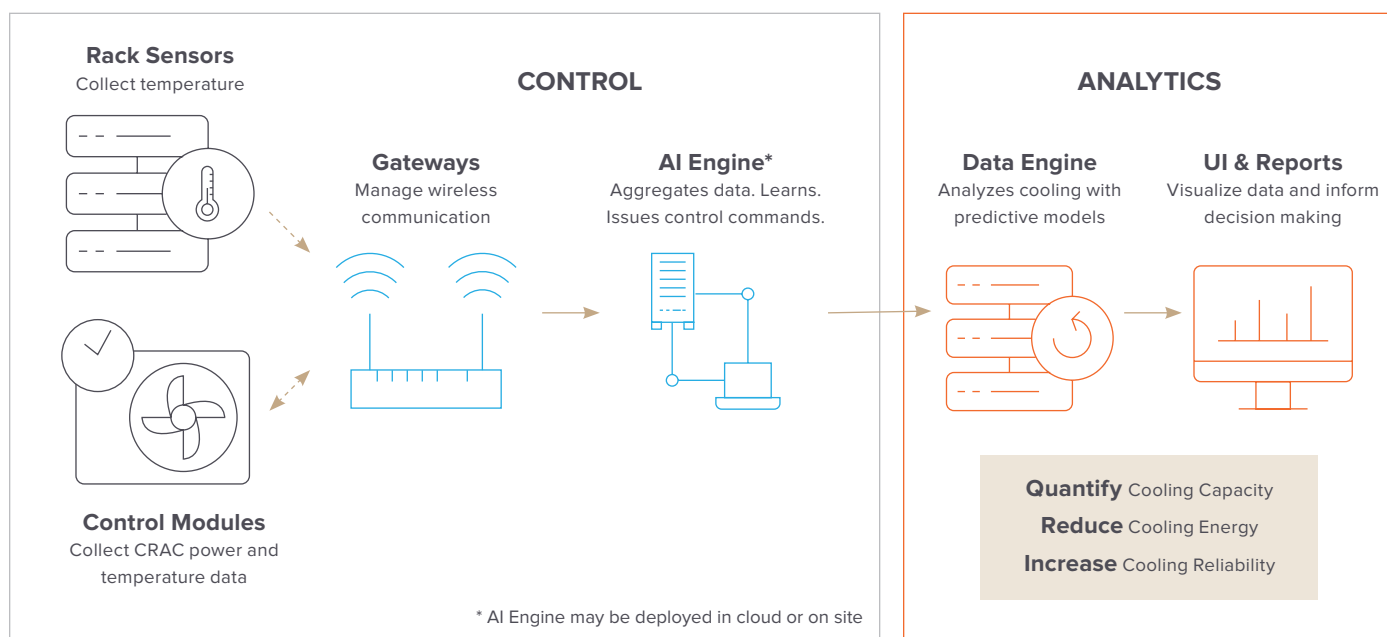


DATA CENTER SMART ASSISTANT

- Uses AI and machine learning to prevent overprovision of cooling
- In most data centers 75% of cooling is wasted or not needed
- Google has said that with AI, they can save about 35% of cooling costs
- AI can be specifically useful for edge data centers as they are located remotely and require automated facility management

- CPU (heat source) temperature is measured to control cooling system
- Less sensors in data centers required
- Acts like a smart thermostat for data centers
- Helps to understand what is happening in the IT environment (feedback system)
- Calculates the temperature set point for cooling in real-time

DATA CENTER SMART ASSISTANT PROCESS



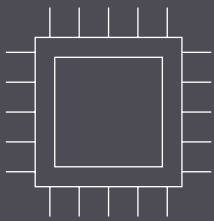
FUTURE TREND IN DATA CENTERS

EDGE DATA CENTER

By 2025, more than 75% of data will be processed outside of the traditional data center or cloud.

As the need for data centers increases, as well as the demand for higher capacity, speed, availability, safety and security, scientists and engineers are continuously searching for ways to improve the efficiency and efficacy of existing data centers. New technologies are being developed to lower the environmental impacts of their operations and new types of data centers are emerging as they become more feasible to implement.

Edge data centers, for example, are becoming more common as small businesses, or more geographically distributed businesses, seek higher processing speed, security and network performance. For example, quick real-time decisions like 'low fuel alert' in a well-known electric car are processed at the edge data center level. But the back-end application programming, scalability and large storage of the software lives in the cloud or 2N data center.



DEFINITION OF EDGE COMPUTING

Data acquisition and control functions, storage of high bandwidth content, and applications are close to the end user in an edge computing system.

DEFINITION OF EDGE DATA CENTER

Smaller facilities located close to the populations they serve that deliver cloud computing resources and cached content to end users (usually data center < 10 kW)

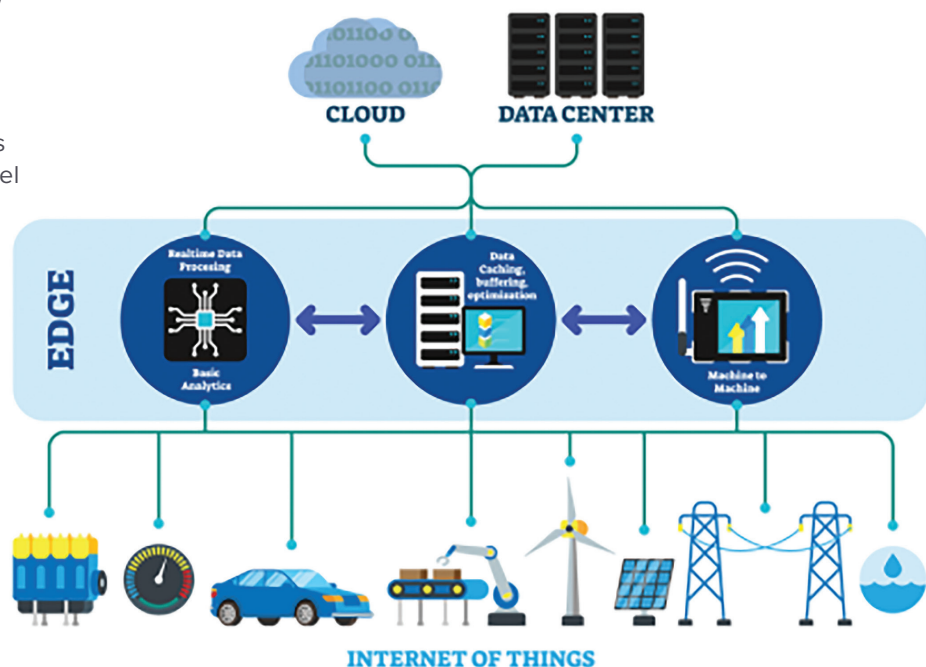
BENEFITS

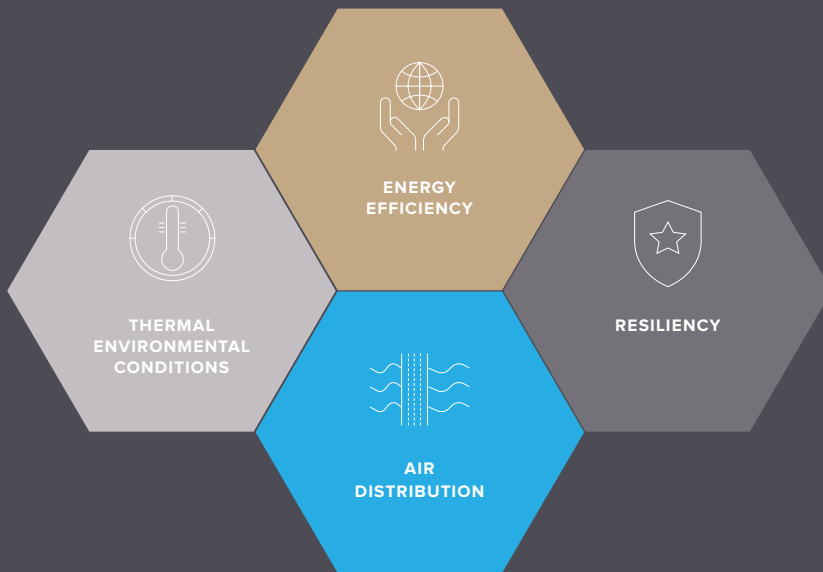
- Data processed locally (geolocation)
- Near instantaneous data gathering and processing
- Bandwidth on the cloud does not increase with the addition of devices as the data is processed at edge level
- Increased network performance
- Increased security
- Less expensive scalability
- Increased reliability

CHALLENGES

- Require remote monitoring system for network, connections, cooling, security, etc.
- Physical and digital security is challenging
- Easy target for hackers and malicious codes (Bots)
- IT security needs to be adjusted to reduce exposure

EDGE COMPUTING





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