U-3ARC TRAINING WEBINAR Nº 27

IMMERSION COOLING FOR DATA CENTRES AND ITS POTENTIAL CONTRIBUTION IN PHASE OUT OF GLOBAL WARMING REFRIGERANTS USE

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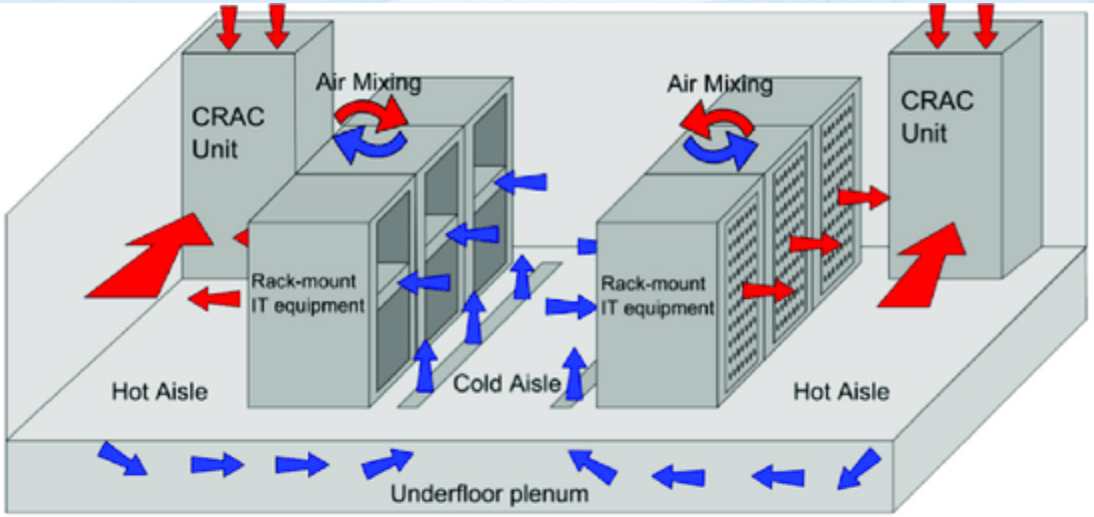
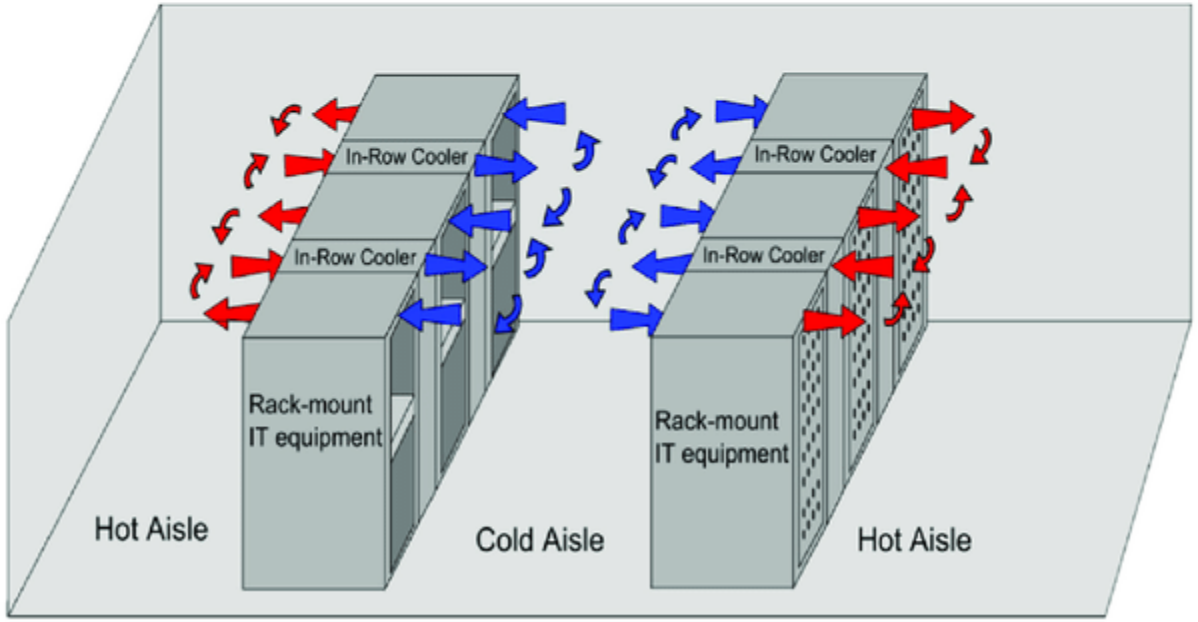
TO BE COVERED

1. REVIEW OF ORDINARY DATA CENTER COOLING LAYOUT
2. BRIEF ON ENERGY CHANGE WITH AI TECHNOLOGY INFLOW
3. EVOLUTION OF THERMAL MANAGEMENT SYSTEMS
4. IMMERSION COOLING INTRO
5. COMPARISON WITH AIR COOLING
6. CO2 EMMISSION COMPARISON OF TWO DATA CENTERS
7. SUMMARY – REFRIGERANT GAS QUANTITY REPLACED BY IMMERSION COOLING CONVERSION

DATA CENTER COOLING LAYOUT

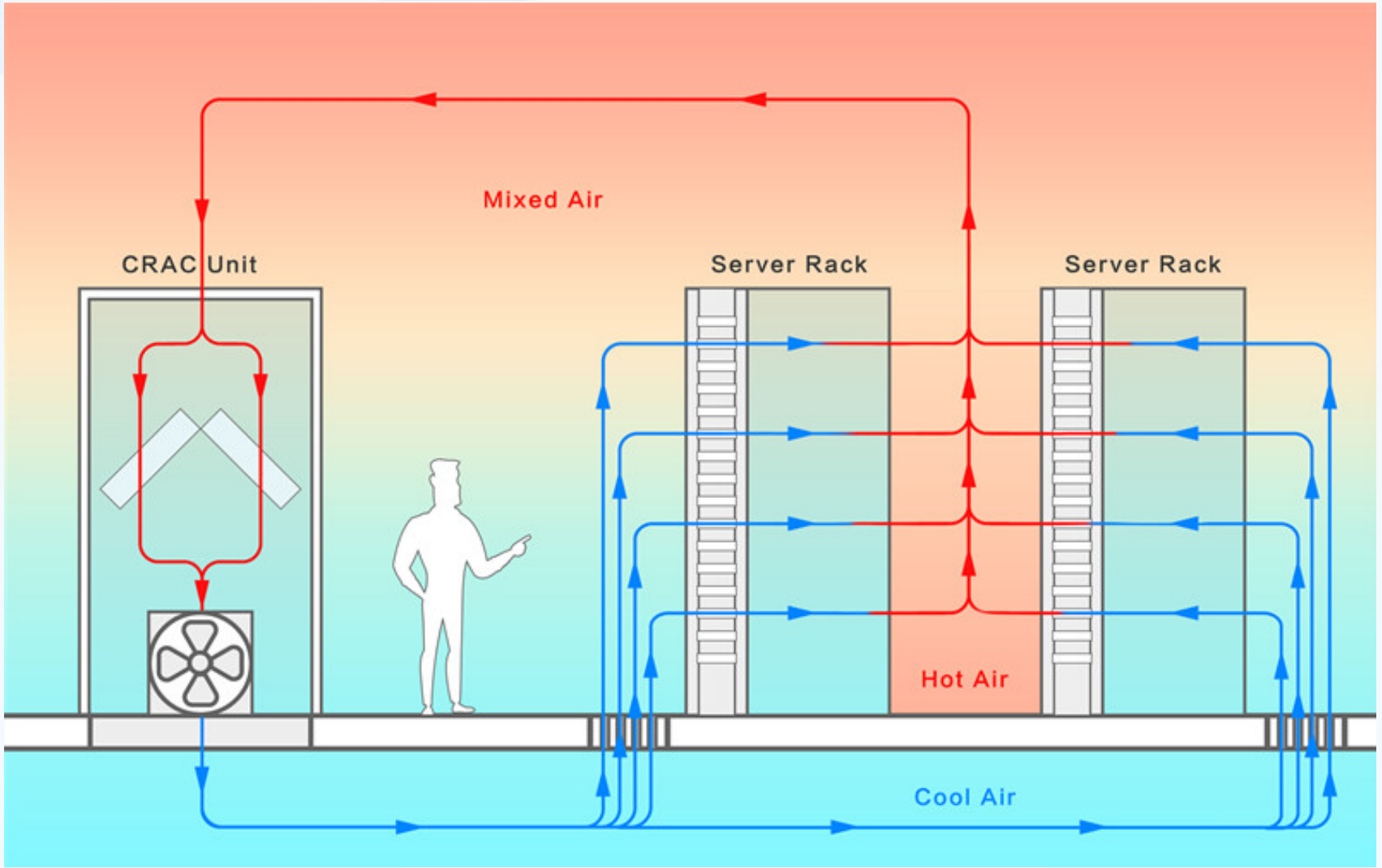


a- Traditional raised floor cooling system

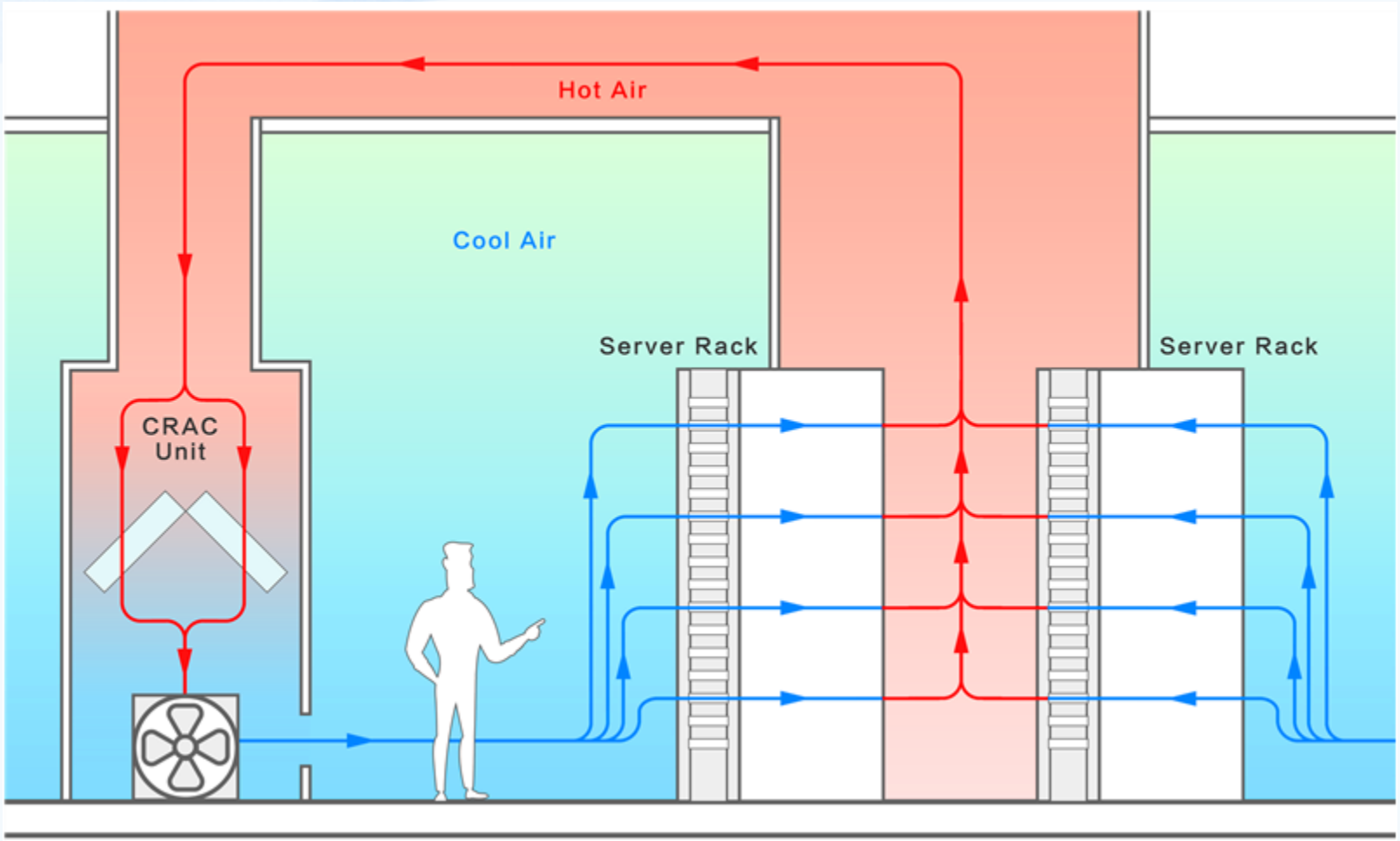


b- In-row cooling Architecture

RAISED FLOOR SYSTEM



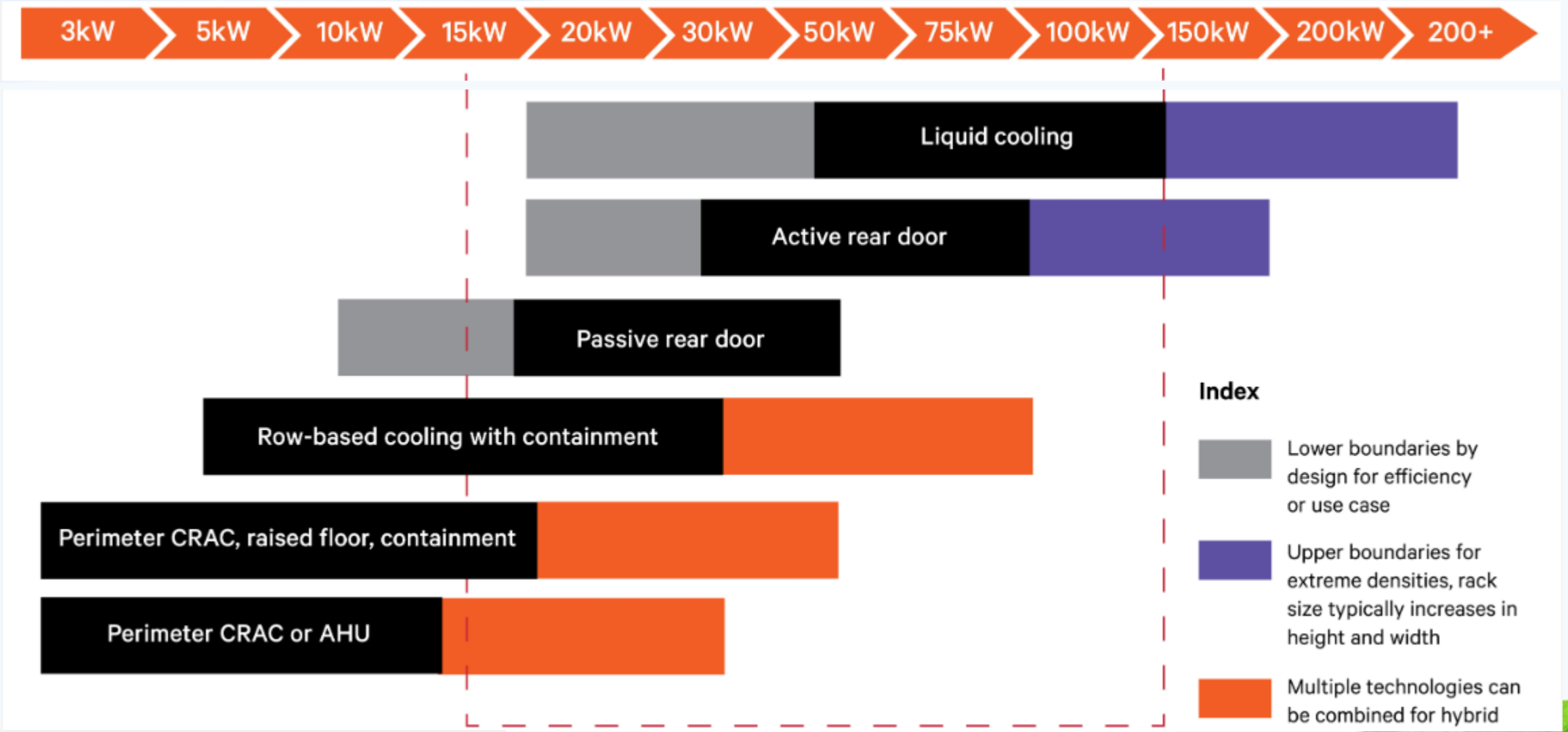
HOT AND COLD AIR AISLE SOLUTIONS CONTAINMENT LAYOUTS



AI HARDWARE IMPLICATIONS FOR THERMAL MANAGEMENT

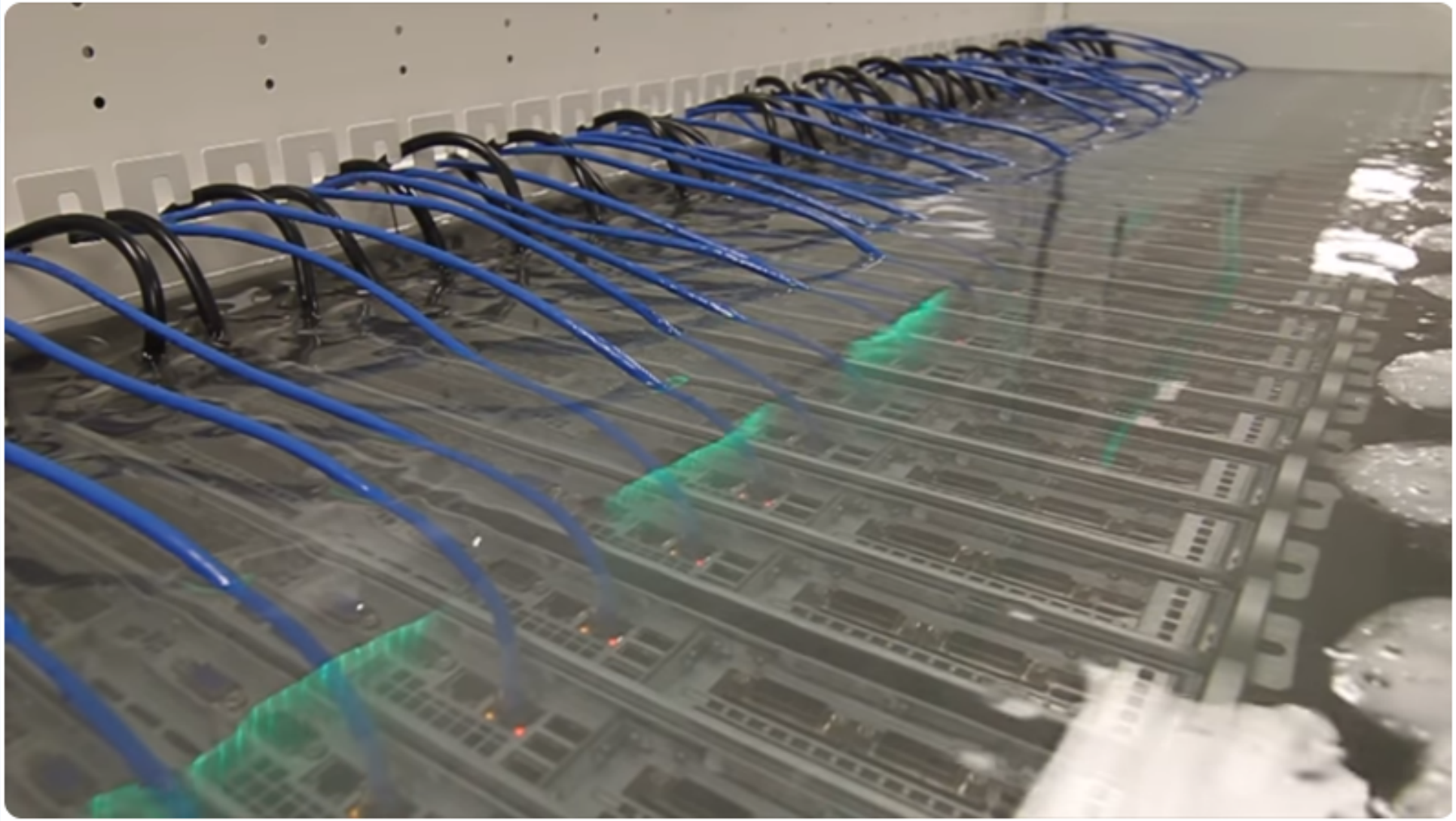
- Currently, data centers support rack power requirements in excess of 20 kilowatts (kW), but the market is headed to 50 kW or more.
- Newer-generation central processing units (CPUs) and graphics processing units (GPUs) have higher thermal density properties than previous-generation architectures. In addition, server manufacturers are packing more CPUs and GPUs into each rack to meet the accelerating demand for high-performance computing and AI applications.
- Air processing is now showing its limits. Traditional air cooling can't cool these high-density racks efficiently and sustainably.
- As a result, data center operators are investigating their liquid cooling options. Liquid cooling leverages the higher thermal transfer properties of water or other fluids to support efficient and cost-effective cooling of high-density racks and can be up to 3000 times more effective than using air.
- Long proven for mainframe and gaming applications, liquid cooling is expanding to protect rack-mounted servers in data centers worldwide.

LIQUID COOLING VERSUS AIR COOLING: HOW THERMAL MANAGEMENT SYSTEMS ARE EVOLVING



Note: Red boundary is viable options for liquid cooling.

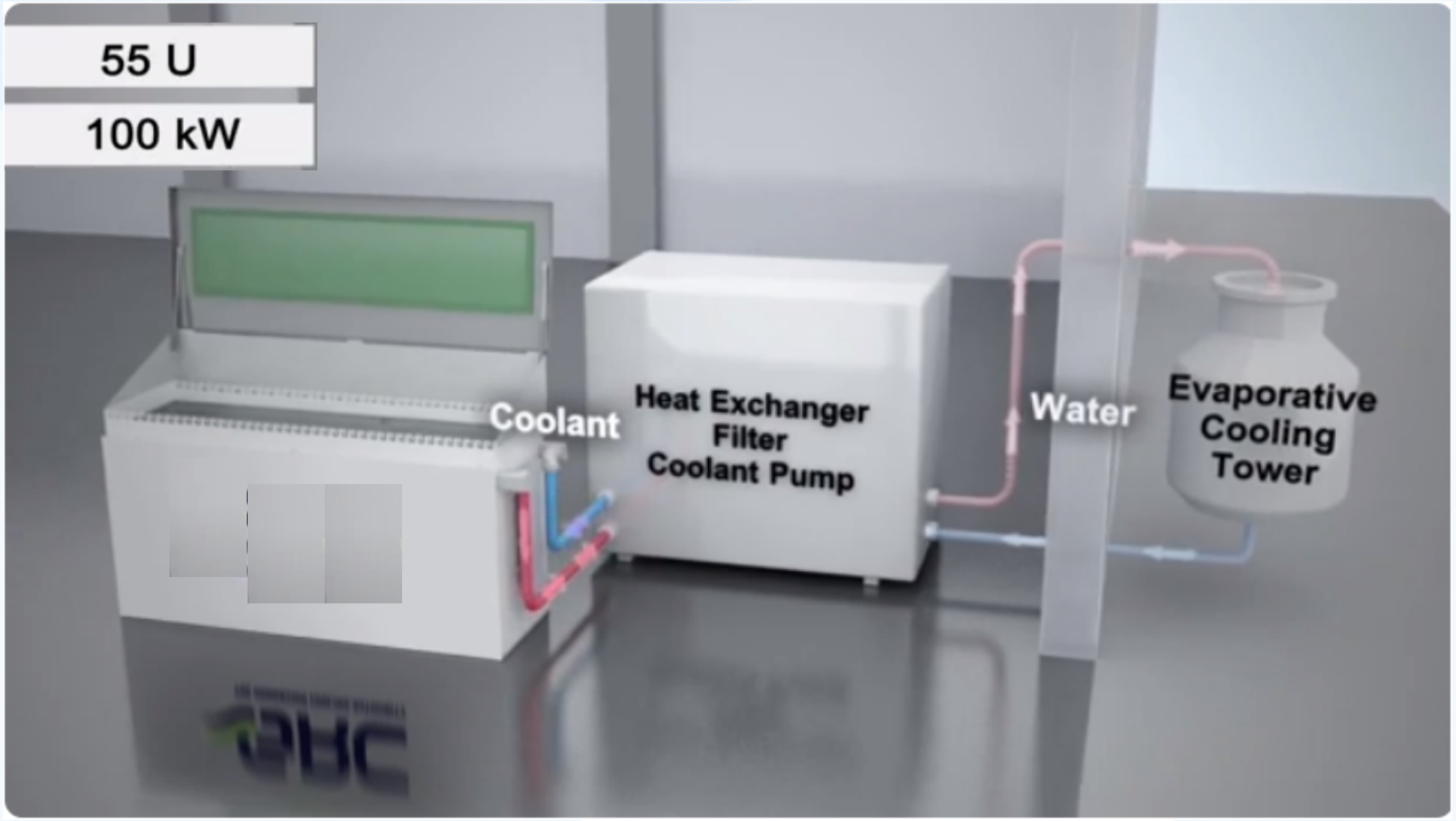
RACKS IMMERSED IN A DIELECTRIC LIQUID



DIELECTRIC LIQUID PROPERTIES

What are dielectric fluids?

Dielectric liquids are used as electrical insulators in high voltage applications, e.g. transformers, capacitors, high-voltage cables, and switchgear (namely high voltage switchgear).
Their functions are to provide electrical insulation, suppress corona and arcing, and serve as a coolant.
Split into two categories, fluorochemical, and hydrocarbons.
Fluorochemical fluids, generally with a lower boiling point, are predominantly used for two-phase immersion cooling.
Hydrocarbons typically are not used for Two-Phase immersion cooling systems, as most hydrocarbons are combustible and/or flammable. Therefore, hydrocarbons are typically only used in Single-Phase applications.
Both **fluorochemicals (or fluorocarbons)** and **hydrocarbons (e.g., mineral oils, synthetic oils, natural oils)** can be used for Single-Phase immersion cooling. Fluids with a higher boiling point (above the maximum temperature of the system) are necessary to ensure the fluid remains in the liquid phase.
Considerations when deciding among various fluorochemicals and hydrocarbons include heat transfer performance (stability and reliability over time, etc.), ease of IT hardware maintenance, fluid hygiene, and replacement needs, material compatibility, electrical properties, flammability or combustibility, environmental impact, safety-related issues, and total fluid cost over the lifetime of the tank or data centers.


55 U
100 kW
Coolant
Heat Exchanger
Filter
Coolant Pump
Water
Evaporative
Cooling
Tower

How Does Immersion Cooling Work?

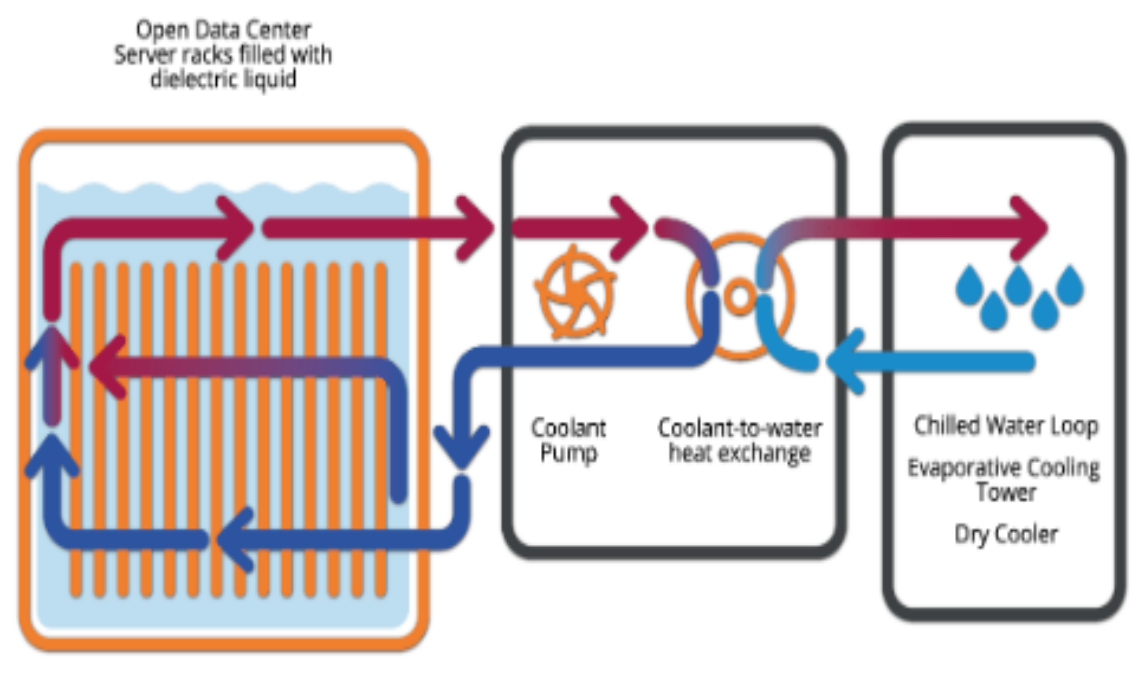
Immersion cooling system basically consists in completely **submerging a server** into a **dielectric liquid**. This type of liquid does not conduct electricity; therefore, it is totally safe for the electronics components to be emerged without any risk of shortcuts and oxidation.

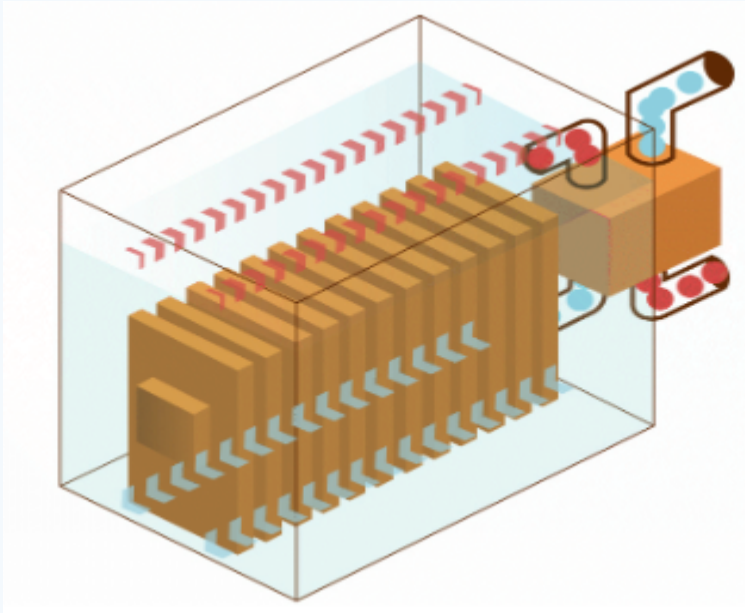
This way, all waste heat generated by the components is captured by the dielectric liquid inside the tank, which is capable of absorbing around **1500 times more heat than air**, for the same volume. The heat then flows to a heat exchanger where it's cooled by a secondary air to liquid or liquid to liquid heat exchanger to be dissipated or **reused**.

Why choosing Immersion Cooling?

A data center facility has servers, computers, and networks that produce a great amount of heat, called “fatal heat” or “waste heat”. It is generated by the Joule conversion of electrical energy into heat. In a data server, all IT component’s energy is converted to heat.
Heat is counterproductive for all type of IT equipment and can alter its performance and lifespan. Thus datacenters are constantly cooled to be kept at a stable temperature. The cooling is done by cooling energy-consuming units such as fans, which have a negative impact on the environment in the long run.
Nowadays, environment issues are in the center of every debate and old cooling techniques are no longer satisfying.
Data center market growth is expected to be over 2% from 2019 to 2025 and its value to reach $105.6 billion by 2026 (*Mordor Intelligence*). This industry is also expected to consume 20% of the world’s energy supply by 2025 (*Danfoss*).
These figures prove the importance of new technologies and the urgent need to try to reduce the carbon footprint of data centers worldwide.
New methods to cool IT equipment in all type of settings, such as direct on chip cooling or **immersion cooling** is thus very necessary.
Your infrastructure consumes more than 80 kW per rack? You need extreme density, flexibility? You wish to cut back on maintenance costs and increase power efficiency? Immersion cooling can be the solution for you.
Comes in single phase or two phase systems in reference to the behavior of the dielectric

SINGLE PHASE IMMERSION COOLING





SINGLE-PHASE IMMERSION COOLING

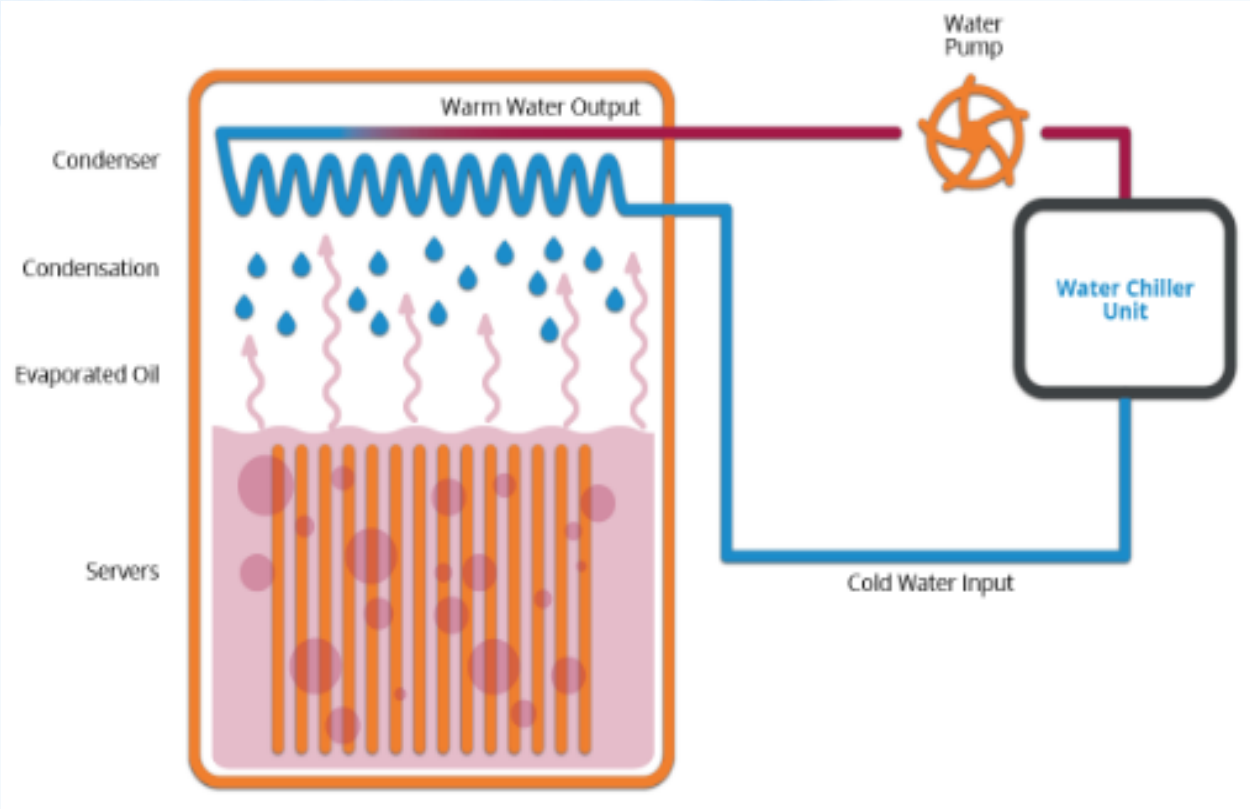
Servers are totally submerged vertically in a coolant bath filled with a hydrocarbon-based dielectric liquid. The heat produced is then transferred to the coolant through direct contact with the components. It is then sent to a cooling tower through a **cooling distribution unit** (CDU) to be cooled and sent back in the tank.

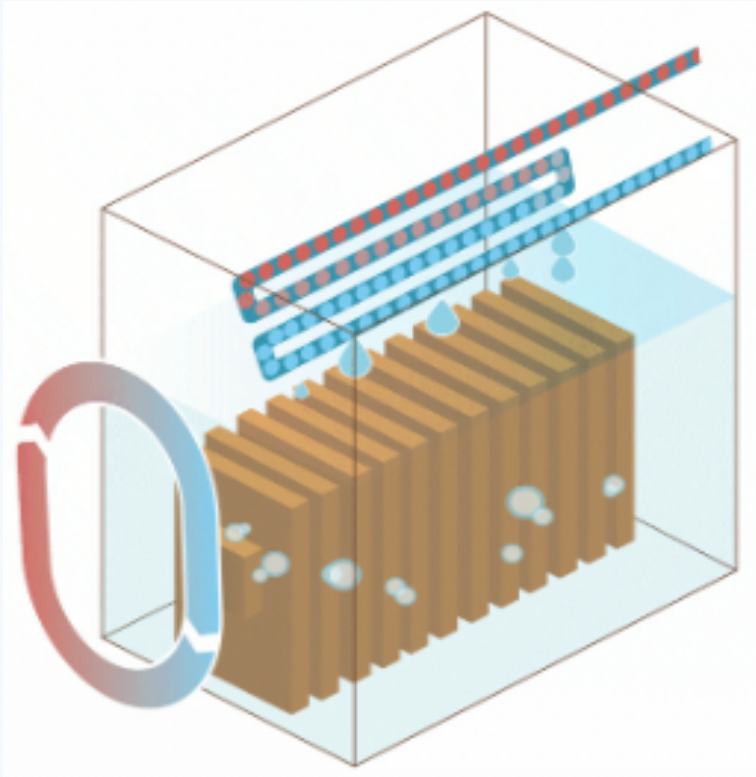
Single-phase immersion cooling system is simple, affordable, easier to manage and needs less maintenance.

Advantages versus air-cooling:

- Quiet operation
- Lower CAPEX and OPEX (per kW)
- Better TCO (per kW)
- About 10x more heat rejection capacity
- Less space required
- More energy efficiency and sustainability

TWO-PHASE IMMERSION COOLING





TWO-PHASE IMMERSION COOLING

The servers are sealed into a tank filled with a fluorocarbon-based liquid. This liquid has a low boiling point and the heat generated by the components makes it boil rather easily.
The boiling liquid is the core of the two-phase system, as the heat turns the liquid into gas, causing a phase change.
The gas goes through a water-cooled condenser coil, placed into the top of the sealed racks. Inside, the vapor is transformed back into liquid which drips back into the tank to be recycled through the system.
Two-phase system has two downsides: the fluorocarbon-based liquid is expensive and must be handled with care.
Advantages of two-phase liquid cooling solution:

- Quiet operation
- Faster builds than air cooling
- Less space requirement (compared to single-phase)
- Lower CAPEX and OPEX (per kW)
- Better TCO (total cost of ownership) (per kW)
- Best efficiency in any form of cooling
- Around 2x more heat rejection capacity (compared to single-phase)
- Waste heat can be reused

How Effective is Liquid Immersion Cooling?

Compared to other cooling systems such as air cooling, using **immersion liquid cooling** drastically decreases the total cost of ownership (TCO). In other words, the cost to buy something plus the cost to operate it over its useful life.

- Improves IT hardware's lifespan by 20%, reducing replacing costs,
- 30% of TCO saving,
- 39% reduction of carbon emissions,
- 91% reduction of water consumption,
- Reduction of noise pollution.

Immersion cooling allows a certain temperature homogeneity compared to other cooling methods thanks to the dielectric fluid. Consequently, the components are not as stressed by sudden temperature changes.

Working conditions can be harsh when dealing with a conventional data center using air cooling. Ambient noise can reach up to 90 decibels, leading to poor and dangerous working conditions. With an **immersion cooling system**, fans are out of the equation, therefore noise pollution is avoided.

Using immersion cooling in a data center also results in a **reduction of carbon emissions up to 39%** and of **water consumption up to 91%**,

HOW EFFECTIVE IS IMMERSION COOLING

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Using immersion cooling in a data center also results in a **reduction of carbon emissions up to 39%** and of **water consumption up to 91%**, according to research by 2CRSI.

APPLICATIONS OF IMMERSION COOLING

The great aspect of immersion cooling is that its domain of applications is vast and spread across many industries. The industry requires high-power computing and low latency? Cooling by immersion is the best solution to handle that much data and dealing with the heat produced.

In short: industries like **cloud gaming** and cloud computing, **health**, **IoT** and **Edge** or **surveillance** would benefit from servers cooled using an immersion cooling system.

AIR COOLING VS IMMERSION COOLING

Comparison of the water consumption of two data centers

A measuring system called WUE (Water Use Efficiency) was created to measure water and energy consumption in data centers. This metric is calculated by dividing data center annual energy source and site water usages (in Liters) by total IT power consumption

		Data Center A	Data Center B
		Air cooling	Immersion cooling
Electricity	Total IT Power Consumption	4.2 MW	3.36 MW
	Total Facility Power	5.7 MW	3.5 MW
Water	Daily site water usage	507 300 L	43 750 L
	Energy source water per year	94.07 million L	57 million L
	Site Water Usage per year	185.16 million L	15.97 million L
WUE	Site WUE	7.59 L/kWh	2.48 L/kWh

AIR COOLING VS IMMERSION COOLING

Comparison of the carbon footprint of two data centers

Carbon emissions come mainly from the extraction of raw materials and their transformation into electronic components, as well as the electrical production of electricity. The carbon footprint of each country differs.

In France, 1kWh of electricity is equal to 0.014 kg of CO_2. Thanks to nuclear plants, France's carbon footprint is lesser than the USA, which reaches 0.454 kg of CO_2 for 1 kWh of electricity.

Carbon Usage Effectiveness (CUE) is a metric that calculates and determines the amount of carbon gas emitted by a data center daily. It was developed by the Green Grid and adopted around the world. It is calculated by dividing the total CO_2 emissions equivalents of the facility's energy consumption by the total IT energy consumption.

Comparison of the carbon footprint of two data centers

		Data Center A	Data Center B
		Air cooling	Immersion cooling
Electricity	Capacity	12 000 servers	12 000 servers
	Average Power Consumption (per server)	350 W	280 W*
	Total IT Power Consumption	4.2 MW	3.36 MW
	Cooling Overhead	30%	2%
	Electrical Overhead	6%	1%
	Effective PUE (Power Usage Effectiveness)	1.36	1.03
	Total Facility Power	5.7 MW	3.5 MW
	Energy Consumption per year	50 million kWh	30.3 million kWh
CO2	USA Carbon emissions per year	22.7 million kgCO2	13.8 million kgCO2
	FRANCE Carbon emissions per year	5.2 million kgCO2	3.2 million kgCO2
CUE	USA Effective CUE	0.62 kg CO2/kWh	0.47 kg CO2/kWh
	FRANCE Effective CUE	0.1 kg CO2/kWh	0.12 kg CO2/kWh

SUMMARY

Table 2 - Comparison between some of the most common refrigerants

Refrigerant	ODP	GWP	Type	Classification
R12	1	10900	CFC	A1
R22	0,05	1810	HCFC	A1
R134a	0	1430	HFC	A1
R1234yf	0	<1*	HFO	A2L
R1234ze	0	<1*	HFO	A2L
R170 (Ethane)	0	6	Natural (Hydrocarbon)	A3
R290 (Propane)	0	3	Natural (Hydrocarbon)	A3
R600a (Isobutane)	0	3	Natural (Hydrocarbon)	A3
R717 (Ammonia)	0	0	Natural	B2L
R744 (CO_2)	0	1	Natural	A1

SUMMARY

100kw AIR-COOLED CHILLER REFRIGERANT QUANTITY

Refrigerant-R407C

Air Cooled Chiller Unit (Screw Type Compressor-one compressor)	
Model ESGA-	**75STN**
Number of Refrigeration Circuit	1
Capacity Control (%)	0, 50, 75, 100
Refrigerant Charge (Kg)	**78**

78KG OF REFRIGERANT GAS = 8 CYLINDERS REMOVED FROM CIRCULATION AND POSSIBLE LEAK TO THE ENVIRONMENT

SUMMARY

55 U

100 kW

COMPACT 100KW IMMERSION SYSTEM DRY COOLER/CONDENSER – DUTY AND STANDBY SET

SUMMARY

55 U
100 kW

COMPACT 100KW IMMERSION COOLER RACK FILLED WITH THE DI-ELECTRIC FLUID

THANK YOU

ANY QUESTIONS

UNION OF ASSOCIATION OF AFRICAN ACTORS IN REFRIGERATION & AIR-CONDITIONING

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