International Institute of Refrigeration

ASEAN Centre for Energy
One Community for Sustainable Energy

Data centers at a crossroads: Energy, Cooling and Policy challenges

Tuesday, 12 May 2026

International Institute of Refrigeration

Founded in 1908 and based in Paris, the IIR is an intergovernmental organisation bringing together over 60 member states and a global network of leading refrigeration scientists and experts. Through its comprehensive knowledge database, peer-reviewed publications, and international conferences, it facilitates cutting-edge knowledge sharing and collaboration across the refrigeration sector.

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One Community for Sustainable Energy

The ASEAN Centre for Energy (ACE) is the regional intergovernmental organisation mandated to support ASEAN Member States in achieving sustainable and secure energy systems. Based in Jakarta, Indonesia, ACE facilitates regional energy cooperation, provides policy analysis, and promotes clean energy transitions across Southeast Asia.

Speakers:

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What we will discuss today

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Anticipating Uncertainty in Data-Centre Electricity Demand

Danfoss

EU Policy drivers and performance indicators for sustainable data centers

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Sustainable Cooling technologies for data centers

Practical notes :

— This session is being recorded and will be made available after the event.
— Use the chat to submit your questions at any time, we will address them during the Q&A.
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Anticipating Uncertainty in Data Centres Electricity Demand

IT infrastructure’s role in reshaping ASEAN planning agenda

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ASEAN Centre for Energy

About ACE

The ASEAN Centre for Energy ("ACE" or the "Centre") is an intergovernmental organisation driving multilateral energy cooperation and policy coordination among the ASEAN Member States. The Agreement on ASEAN Energy Cooperation in Manila, Philippines, on 22 May 1998, formally established ACE on 1 January 1999 in Jakarta, Indonesia. The formal establishment tasked ACE to serve as the regional energy think tank, catalyst, and knowledge hub to build coherent, coordinated, focused and robust energy policy agenda and strategy for ASEAN.

The three critical roles of ACE:

1. To advance the ASEAN energy goals by unifying and strengthening the ASEAN energy cooperation and integration.

2. To function as an energy data and knowledge hub by providing knowledge repository and services.

3. To serve as an ASEAN energy think tank by assisting in research and practical solutions for the Member States.

Keeping the region's improvement, sustainable and harmless to the ecosystem is a fundamental concern of the ASEAN energy sector. Hosted by the Ministry of Energy and Mineral Resources of Indonesia, ACE's office is located in Jakarta, Indonesia. For more information on ACE website: aseanenergy.org.

KEY HIGHLIGHTS

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AI-driven data-centre demand is placing growing pressure across ASEAN

Demand depends on three key levers
Future electricity use will be shaped by hardware power density, AI penetration and utilisation, and PUE.

Facility type matters
Hyperscale, colocation, and enterprise data centres have different demand profiles and policy implications.

Policy responses are already emerging
Global practices point to range of approaches to manage or reduce uncertainty that drives electricity demand levers from data centres.

ASEAN has an opportunity to learn regionally
AMS with more advanced data centre policies can provide useful lessons as the sector expands across the region.

ASEAN'S POWER SECTOR IS ENTERING A DIGITAL DEMAND ERA

"AI and digitalisation are emerging as new drivers of electricity demand in ASEAN. Beyond traditional drivers, cloud services, internet use, and AI applications are creating new sources of load that are harder to anticipate and integrate into long-term planning"

TRADITIONAL DRIVERS
Population growth, economic expansion, and urbanisation remain core demand driver across ASEAN

DIGITAL ECONOMY
Cloud services, internet use, and AI applications are adding fast growing electricity demand to the region's load outlook

PLANNING CHALLENGE
Digital Infrastructure Can Scale Quickly And May Not Follow The Assumptions Used In Conventional Demand Planning

Source: ASEAN Centre for Energy (ACE), 2024a, 2024b, 2025; Azalia, 2025; Davis, 2021

DATA CENTRES: DIGITAL GROWTH MEETS THE PHYSICAL GRID

Demand uncertainty is two-sided. ASEAN's ~2.9 GW announced pipeline overstates realised load. The build itself is constrained by global supply of chips, transformers, copper, water, and skilled grid labour.

Capex outruns physical scaling. Projection passed USD 400 billion in 2025, +75% projected for 2026 (IEA). Data centres complete in 2–3 years while transmission and generation in 5–10.

An AI winter is a credible planning case. A valuation reset within 2–3 years is plausible if compute scaling outpaces power, chip, and material supply. Linear extrapolation of 2024–2025 announcements risks overcommitting grid capital.

AI load is additive on a ~70% fossil grid. New MW raise system emissions where renewables expand alongside fossils rather than displacing them.

Grid cost allocation is a distributional choice. Concentrated hyperscale loads can shift transmission and capacity costs to compete with essential demand.

APAEC 2026–2030

The ASEAN Plan of Action for Energy Cooperation (APAEC) 2026–2030 explicitly recognises that:

> *"…the rapid growth of the digital economy is increasing electricity demand and creating new challenges for power load management."*

Source: Chen et al., 2025; Yiau, 2025

AI FACILITIES ARE A DIFFERENT LOAD CLASS

AI hardware raises rack-level power density by roughly an order of magnitude over 2021–2027 and shifts the load profile from flat baseload to sustained-high with minute-scale swings. Same floor area now houses materially more load.

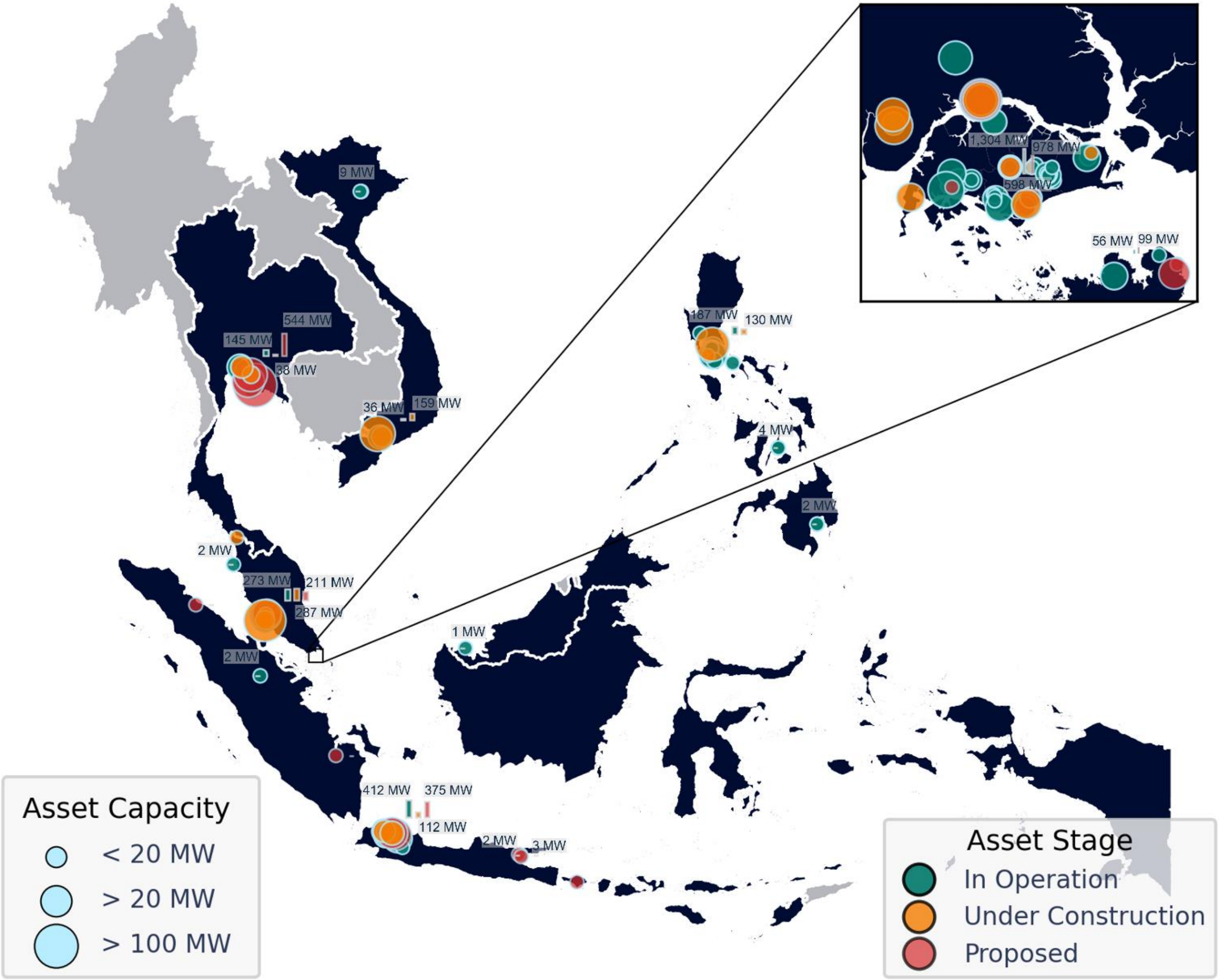
Dimension	Conventional	AI
Workload	Bursty, transactional	Sustained, parallel
Server power	250–600 W	7–10 kW
Rack density	~8 kW	12–120 kW
Networking	10–40 Gbps	100–800 Gbps
Cooling	Air	Liquid, direct-to-chip
Load profile	Flat baseload	Sharp swings

The issues?

- Tropical cooling adds 20–40% to every IT MW.
- Sustained load fits poorly with the solar daily curve.

Source: Chen et al., 2025; Yiau, 2025

DATA CENTRES IN ASEAN: WHERE THEY ARE TODAY



HIGHLY CLUSTERED IN MAJOR CITIES

Operational data centres are not evenly distributed they are highly clustered in major urban and metropolitan areas, currently ~5 GW of power capacity in ASEAN.

The **Singapore–Johor–Kuala Lumpur corridor** stands out as the region's most established data centre belt. Other operating clusters sit around **Bangkok, Jakarta, Metro Manila, and Ho Chi Minh City.**

This pattern aligns with submarine cable landings, terrestrial fibre backbones, and high-voltage power systems — the foundations for large-scale data centre investment.

Up to >50 GW of additional power capacity is reported to be on the picture collectively by the AMS

Source: ACE; IEA, 2025

ACE and AMS project current growth and it could account for up to *52% of national consumption in Malaysia* and 2–15% across other ASEAN Member States by 2030 — with the scenario range revealing even wider uncertainty.

1 Malaysia faces the most acute demand concentration.

23% of national demand in 2025 → 52% by 2030. High case may exceed total national consumption, the sharpest concentration in ASEAN.

2 Possible steep climb in coming months

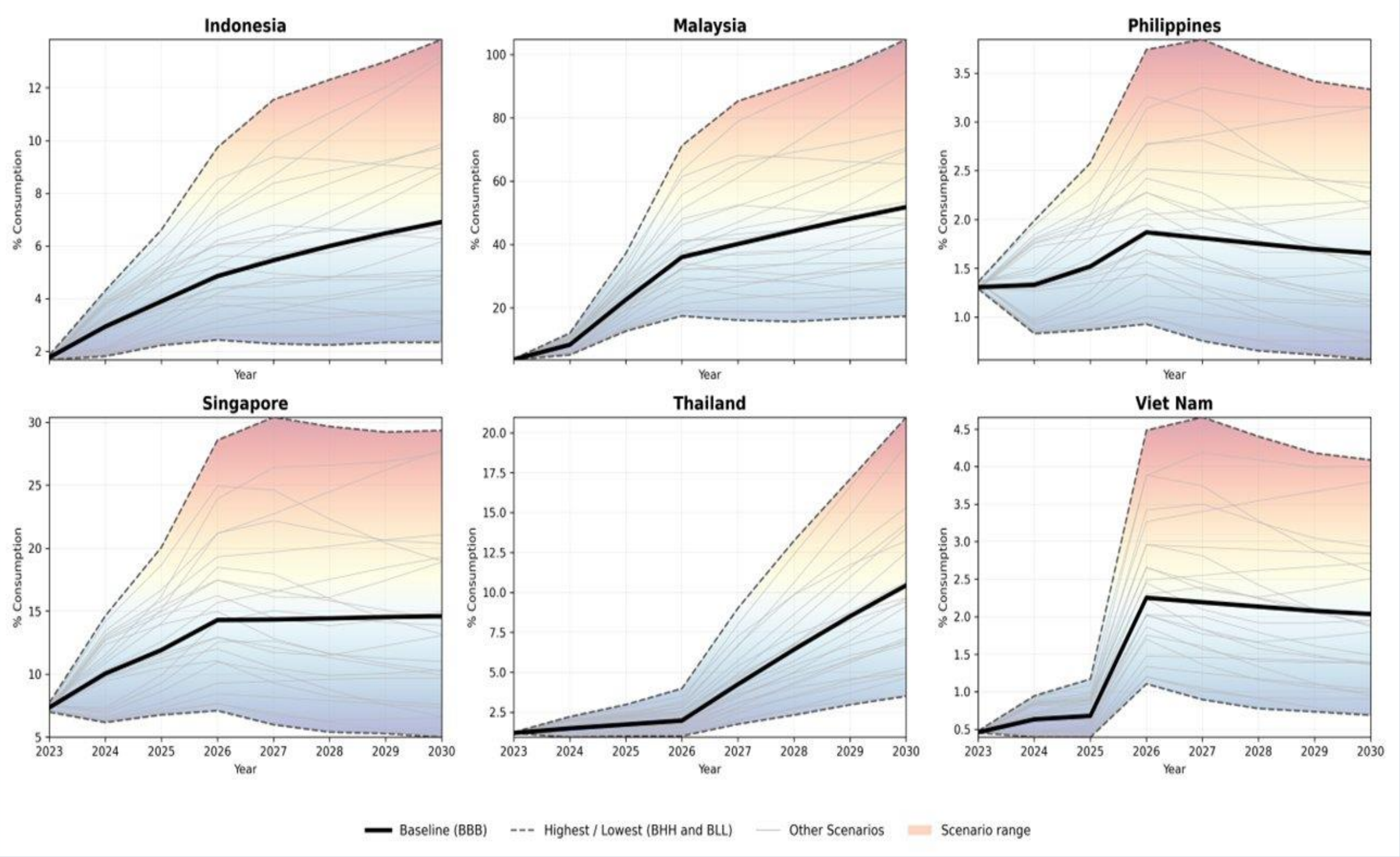
Proposed capacity comes online and uncertainty widens fast. Grid investment decisions lock in during this window as no strong policy is yet in place.

3 Other AMS is also facing potential jump

Scenario ranges could more than double these baseline values under high-demand assumptions, with Thailand showing particularly strong growth from under 2% in 2025.

4 Most are share similar uncertainties

Viet Nam (2%) and the Philippines (1.7%) show narrower but still policy-relevant ranges any current projection would understate the plausible demand envelope.



Data centre electricity consumption as a share of total national electricity consumption (%), 2023–2030, across 25 sensitivity scenarios.

Source: Authors' analysis; national consumption projections from ACE, 8th ASEAN Energy Outlook (AEO8), Baseline scenario

What this means for ASEAN: turn uncertainty into preparedness

Four areas where ASEAN Member States may strengthen policy responses and regional cooperation to better manage the energy implications of data centre growth.

01 Strengthen regional knowledge-sharing

Some AMS, particularly Singapore and Malaysia, are already implementing structured measures to address data centre energy implications. Sharing these experiences more systematically could help other AMS respond earlier and more effectively as the sector expands across the region.

02 Enhance reporting frameworks for demand visibility

AMS may benefit from more detailed and standardised reporting for large data centres, including installed IT capacity, expected ramp-up schedules, and selected operational indicators. Clearer frameworks for large-load connection planning could also reduce the risk of infrastructure built ahead of realised demand.

03 Prioritise efficiency-focused measures as a practical entry point

Efficiency-related factors such as PUE and IT equipment performance are the most readily measurable and policy-actionable demand levers. Early attention to minimum energy-performance expectations for new facilities, supported by metering and verification, would help moderate demand growth.

04 Integrate data centre planning with wider energy and infrastructure planning

As data centres become larger electricity consumers, their development has broader implications for land use, grid readiness, generation adequacy, and investment planning. Closer coordination between digital, industrial, and energy authorities is needed — particularly in emerging growth corridors.

Source: Authors' compilation.

What this means for ASEAN: even deeper look at this issue

AI demand draws first from a finite grid. Every MW for hyperscale becomes a MW unavailable for cooling, food cold chain, water pumping, hospitals, and public transit electrification. In ASEAN's tropical climate, cooling load is non-negotiable

Materials for AI are also the materials for the energy transition. Copper, transformers, rare earths, and skilled grid labour are the same inputs renewables, EVs, and household electrification need. Allocation is zero-sum

Water for cooling competes with water for people. A 1 MW data centre consumes ~25 million litres per year, equivalent to daily water for 300,000 people. ASEAN dry-season constraints make this direct competition with drinking, irrigation, and sanitation.

Costs are socialised, benefits are concentrated. Grid expansion for hyperscale is paid through tariffs by all consumers. Compute, intellectual property, and revenue stay with a handful of foreign firms. Carbon inequality reproduced in electrons

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Thank you

EU POLICY DRIVERS AND PERFORMANCE INDICATORS FOR SUSTAINABLE DATA CENTERS

Analaura Ransdale
Public Affairs, Danfoss Climate Solutions

THE UPCOMING EU DATA CENTER ENERGY EFFICIENCY PACKAGE

- **2023** – Revised Energy Efficiency Directive introduces mandatory data center reporting and lays the foundation for an EU-wide rating scheme
- **2024** – Mandatory reporting begins
- **2025** – EU announces broader Energy Efficiency Package for data centers
- **2026** – EU rating label is introduced (May) under broader Tech Sovereignty Package

*Source: New impetus for energy efficiency - European Commission

INTRODUCING A RATING SCHEME FOR DATA CENTERS: A STEP-BY-STEP APPROACH

Reporting

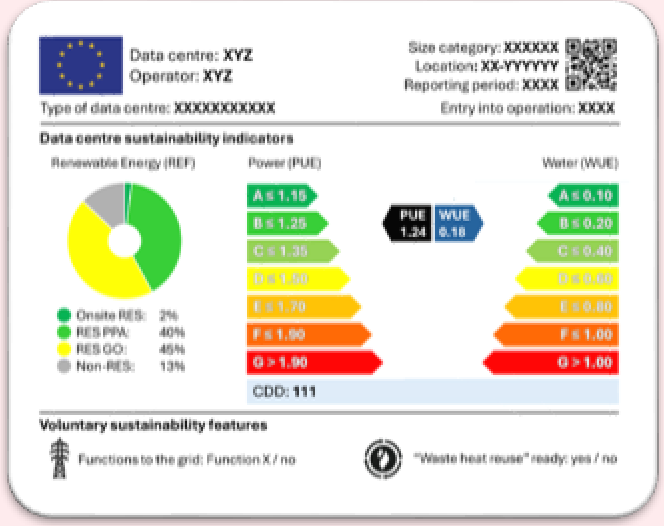
Increasing transparency & awareness by collecting data on energy and water consumption by data centers

Aggregated data is publicly available

Rating

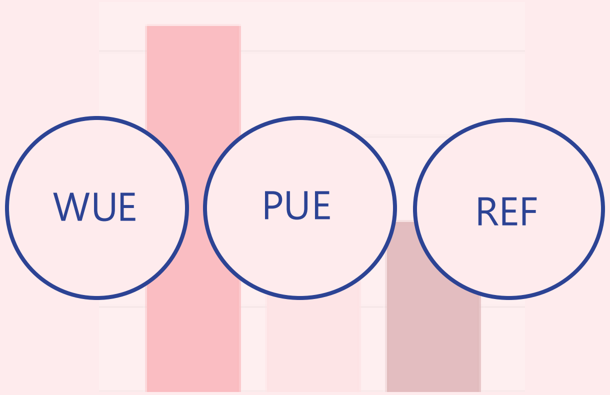
Based on reported data, to increase transparency and support policymaking, procurement, and investment towards sustainable data centers

Energy efficiency – rating scheme for data centres in Europe



Meeting minimum performance

Binding minimum performance on specific KPIs to raise the level of ambition and set a clear direction forward, supporting continuous improvement



FIRST STEP: REPORTING

Getting **accurate data** on **energy** and **water** performance of European data centers:

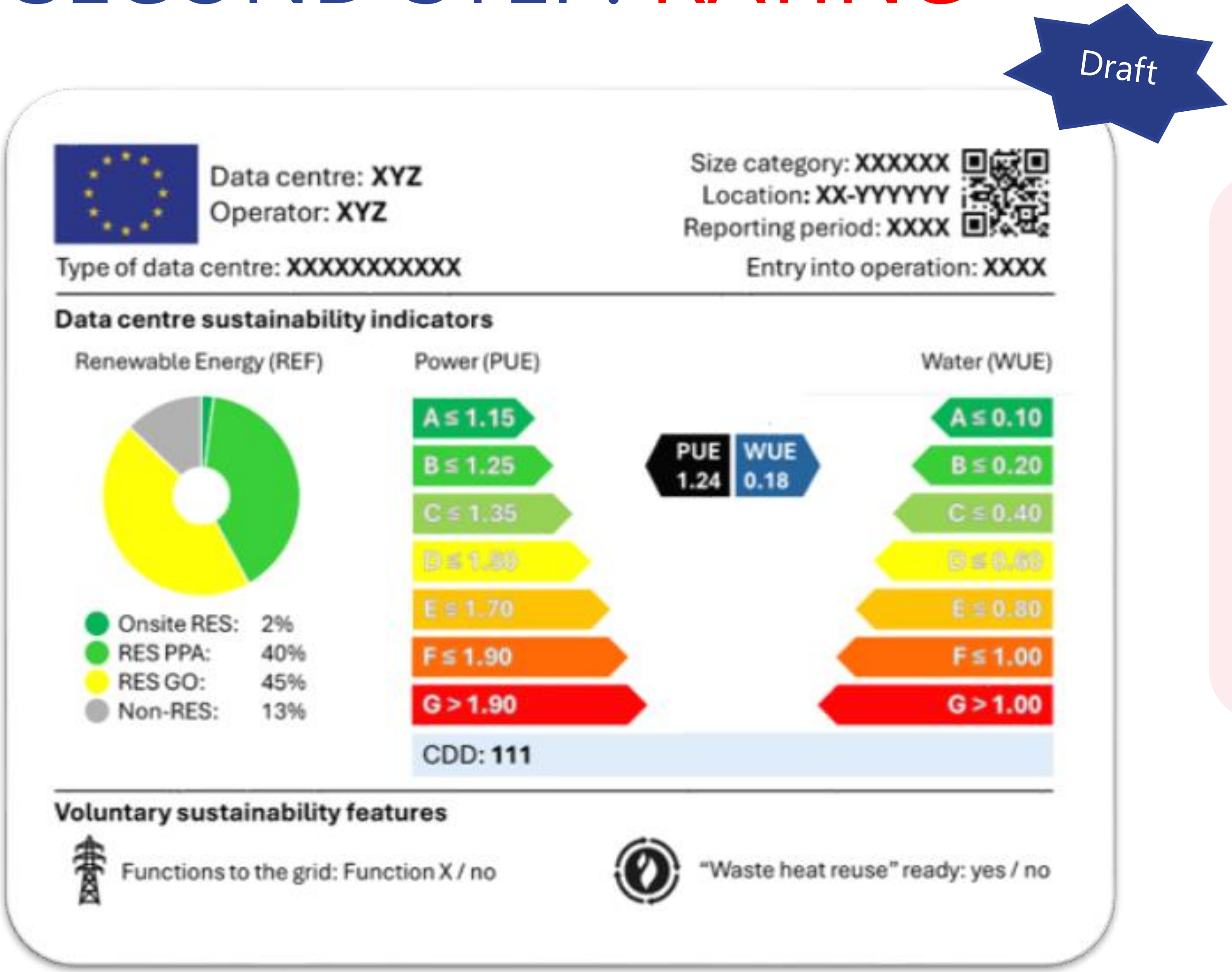
- Reporting requirements are mandatory for ≥ **500 kW** data centers
- Data to be reported annually to a common **European database**
- **Energy consumption**, **water use**, **heat reuse**, **waste heat temperature**, among the relevant data to be reported

Sustainability indicators calculated based on the reported data. 776 EU data centers (34%) reported in 2024:

- Power use - **PUE** (1.36)
- Water use - **WUE** (0.31)
- Energy reuse - **ERF** (0.02)
- Renewable energy - **REF** (90%)

Sources: Directive - 2023/1791 - EN - EUR-Lex ; Delegated regulation - EU - 2024/1364 - EN - EUR-Lex; Qlik Sense

SECOND STEP: RATING



The European Commission proposed in April 2026 a sustainability label for data centers (to be adopted in May) building on the reporting system:

- Applies to all data centers that report
- Is publicly available
- Will support organizations in choosing **where to run their digital services** based on sustainability performance

THIRD STEP: MEETING MINIMUM PERFORMANCE STANDARDS

Draft

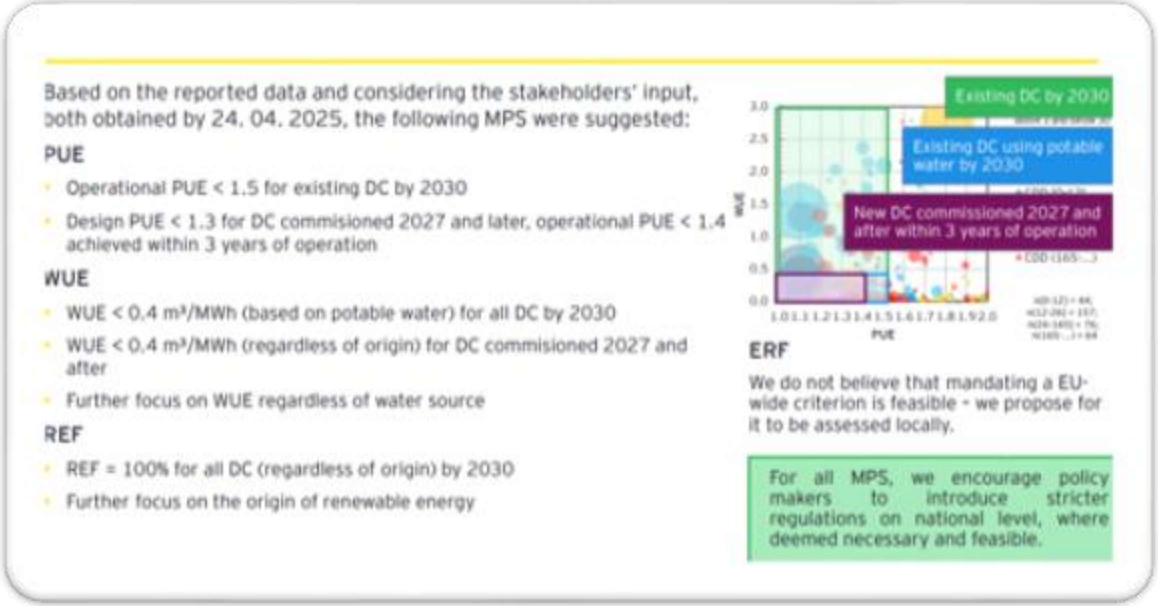
Potentially introducing EU-level **Minimum Perfomance Standards (MPS)** to raise the level of ambition

- Suggested for **PUE**, **WUE** and **REF**, based on the data from the reporting system
- MPS for **ERF** (energy reuse) recommended to be set at national/local level
- The proposed MPS are considered achievable across all European climate zones

Power Usage Effectiveness = Total Power / IT Power

Water Usage Effectiveness = Water usage / IT Power

Renewable Ener Factor = Total Power / Renewable Power


Based on the reported data and considering the stakeholders' input, both obtained by 24. 04. 2025, the following MPS were suggested:

PUE

- Operational PUE < 1.5 for existing DC by 2030
- Design PUE < 1.3 for DC commisioned 2027 and later, operational PUE < 1.4 achieved within 3 years of operation

WUE

- WUE < 0.4 m³/MWh (based on potable water) for all DC by 2030
- WUE < 0.4 m³/MWh (regardless of origin) for DC commisioned 2027 and after
- Further focus on WUE regardless of water source

REF

- REF = 100% for all DC (regardless of origin) by 2030
- Further focus on the origin of renewable energy

ERF

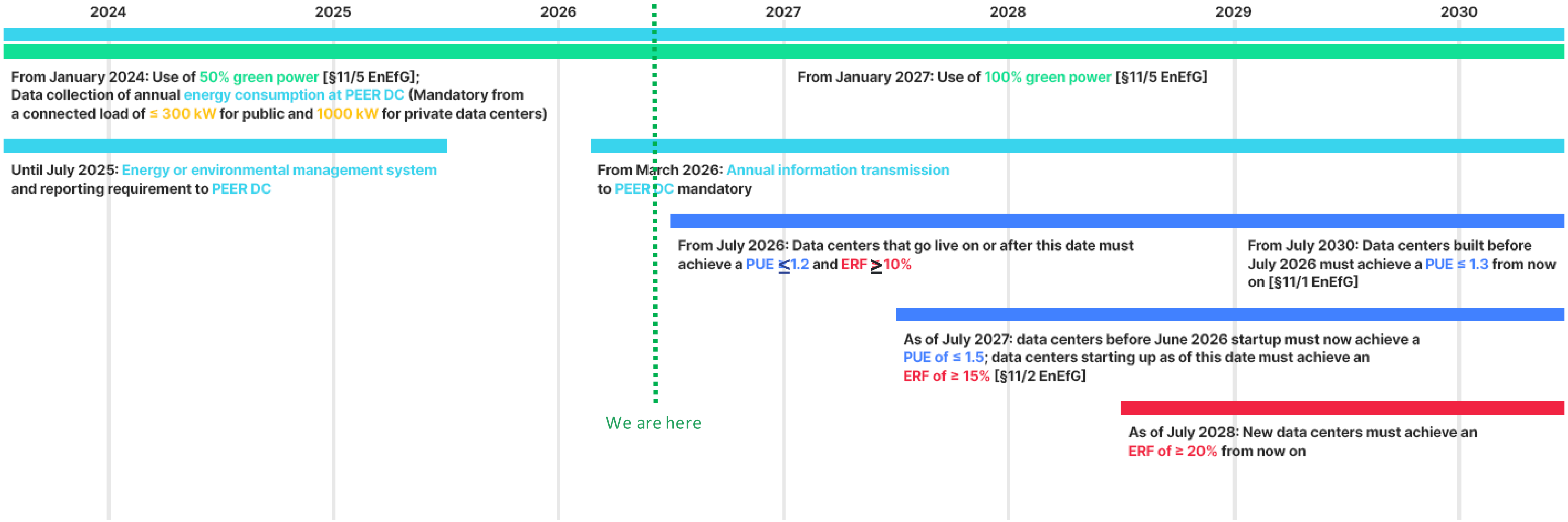
We do not believe that mandating a EU-wide criterion is feasible - we propose for it to be assessed locally.

For all MPS, we encourage policy makers to introduce stricter regulations on national level, where deemed necessary and feasible.

Assessment of next steps to promote the energy performance and sustainability of data centres in EU, including the establishment of an EU-wide rating scheme - Publications Office of the EU, and stakeholder workshops held in H1 2025

NATIONAL LEGISLATION CAN EXCEED EU LEGISLATION
EXAMPLE: GERMANY

National implementation of EED has led to **stricter** legislation than on EU level:



green power:	Proportion of electricity procured from renewable energies
PEER DC:	Public energy efficiency register for data centers
PUE:	Power Usage Effectiveness, value for energy consumption effectiveness
ERF:	Energy Reuse Factor, value of waste heat used

https://datacenter-group.com/en/company/sustainability/energy-efficiency-act/

GLOBAL TRENDS IN DATA CENTER SUSTAINABILITY

Reporting & performance mandates

- ✓ Energy reporting frameworks (some mandatory, some voluntary)
- ✓ MPS for **PUE** & **WUE** on the rise

Heat reuse interest is rising

- ✓ Highly encouraged, not yet mandatory (though expected for EU data centers above 1MW, where technically and economically feasible)
- ✓ **Waste heat recovery** seen as a critical opportunity to decarbonize (colocation with industrial offtakers or district heating)

Opportunities in emerging economies

Combining **innovative business models** and **targeted financial instruments** to promote efficiency and unlock investments

Table 5.2 ▷ Policy landscape in selected economies

Economy	National strategy	Government financial support			Reporting requirements		Performance mandates	
		R&D	Data centres	Chips	Emissions	Electricity consumption	PUE	WUE
Argentina	●							
Australia	●	●	●		●	●	●	
Brazil	●	●	●	●				
Canada	●	●	●	●	○	○		
China	●	●	●	●		●	●	●
European Union	●	●	●	●	●	●		
France	●	●		●	●		●	
Germany	●	●		●	●	●	●	
India	●	●	○	●				
Indonesia	●	●	●	●				
Italy	●	●		●	●			
Japan	●	●	●	●	●	●	●	
Korea	●	●	●	●				
Mexico	●							
Russian Federation	●	●	●		●			
Saudi Arabia	●	●	●	●				
South Africa	●	●						
Türkiye	●	●	●	●	●			
United Kingdom	●	●	●	●	●	●		
United States	●	●	●	●	○	○	○	

Notes: ○ = subnational only; PUE = power usage effectiveness; WUE = water usage effectiveness.

Table 5.1 ▷ Data centre energy efficiency mandates for selected economies

Region	PUE (2023)	PUE mandate
Australia	1.44	1.4 by 2025
China	1.56	1.5 by 2025
France	1.36	40% building energy use reduction by 2030
Germany	1.42	1.2 by 2026 (new), 1.3 by 2030 (existing)
Japan	1.53	1.4 by 2022
California (United States)	1.21	1.5 by 2014
Global	1.43	-

Note: PUE = power usage effectiveness.

Energy & AI Special Report 2025, IEA; Business Models and Finance to Enhance Energy Efficiency in AI and Data Centres in Emerging Economies – UNEP-CCC

CONCLUSIONS: POLICY DRIVERS FOR SUSTAINABLE DATA CENTERS

Why sustainability matters:

- ✓ From "nice-to-have" to **"must-have"** for resilience, competitiveness and public acceptance
- ✓ Stricter rules ahead driving uptake of **energy efficiency solutions**
- ✓ **Efficiency enables growth** supporting digital & IT expansion

Key benefits:

- ✓ **Lower PUE** and **WUE** for optimized energy and water use
- ✓ **Reuse heat** instead of wasting it, supporting **local decarbonization** (e.g., district heating)
- ✓ **Transparency through standardized reporting** builds trust
- ✓ **MPS drives retrofitting** of existing facilities to meet new standards
- ✓ **Global impact:** Success in Europe sets a benchmark for other regions

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Sustainable Cooling Technologies for Data Centres

Shuangquan Shao

2026-5-12

Huazhong University of Science and Technolgy

Contents

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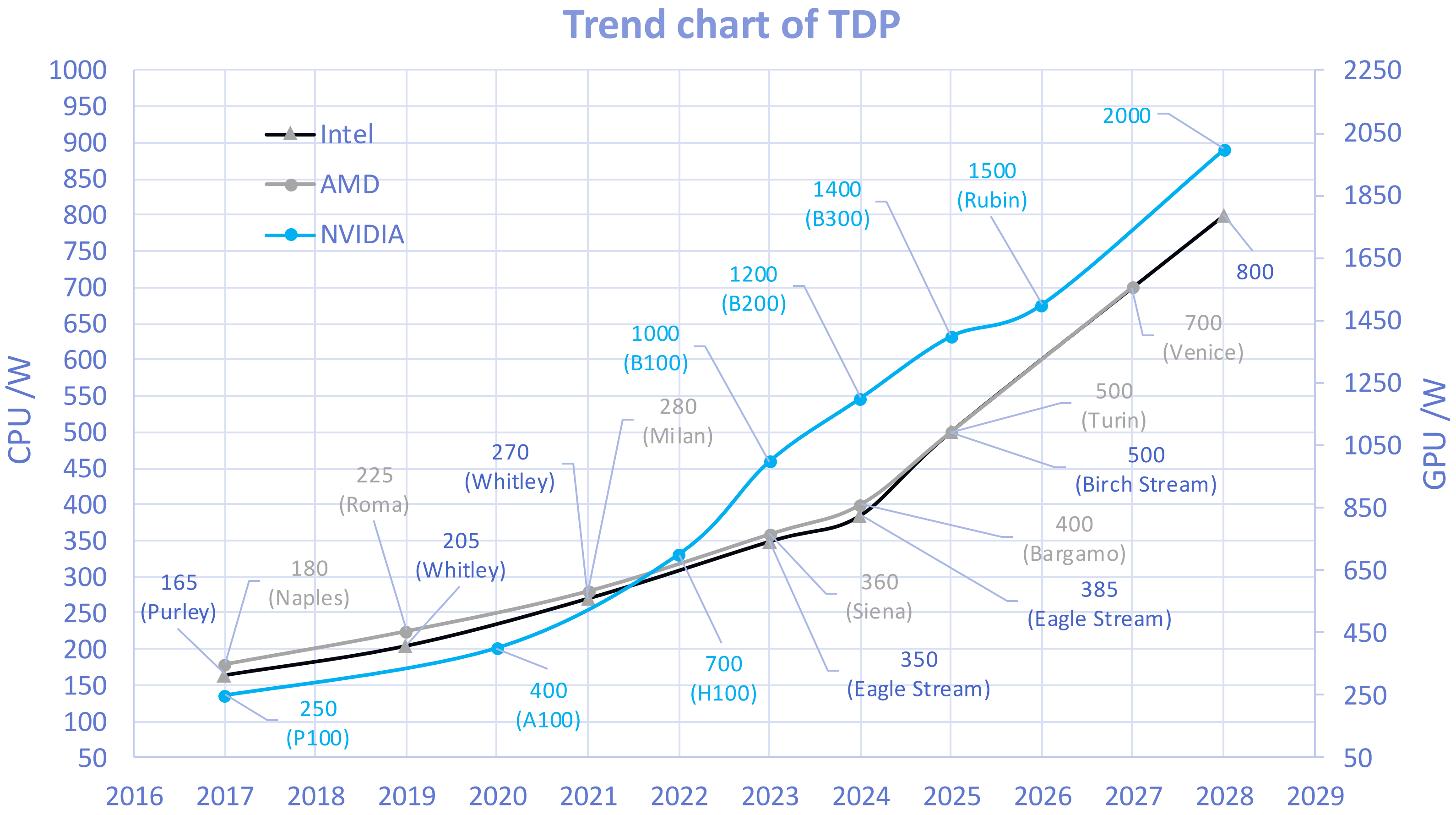
1.1 Rapid growth of data center market

● Data center supports Artificial Intelligence, IoT, Big Data Analysis……

Artificial intelligence

Industrial IoT

Big data analysis

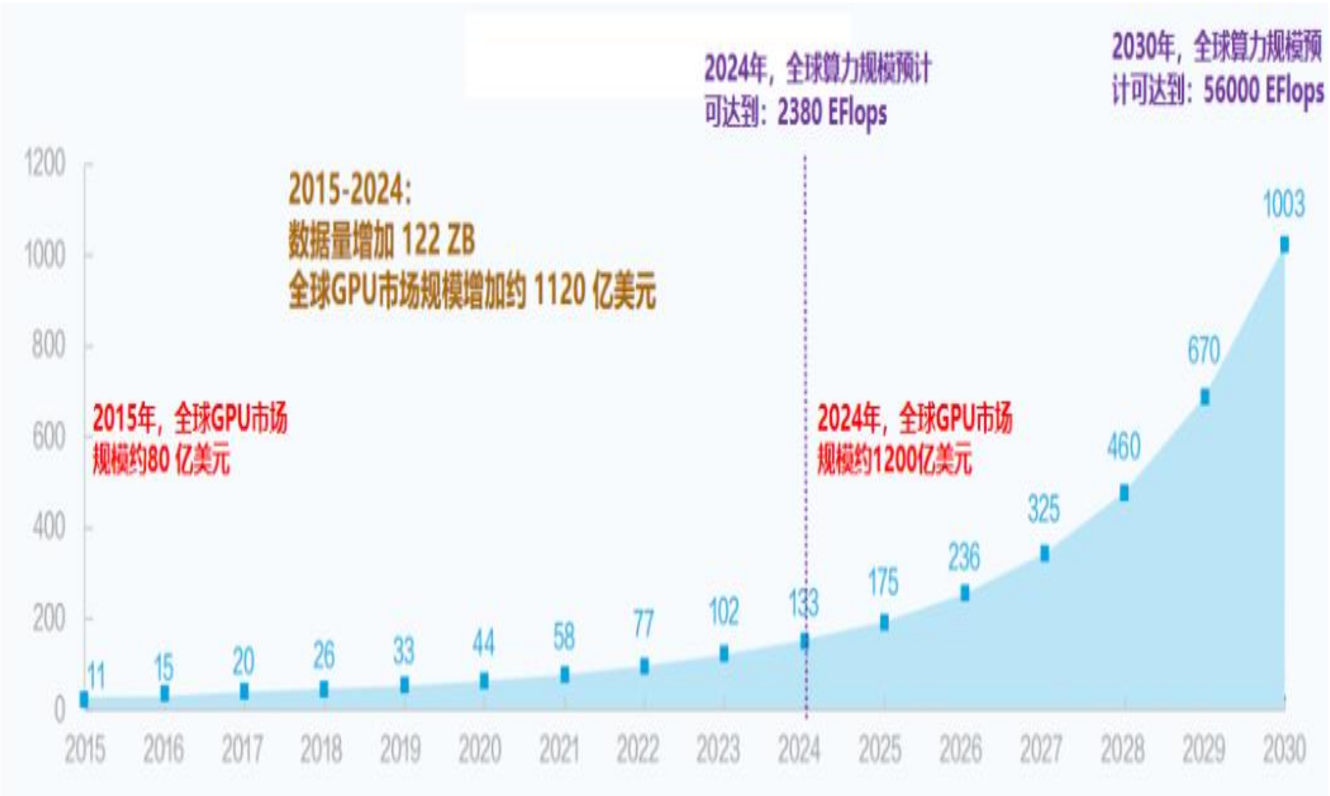


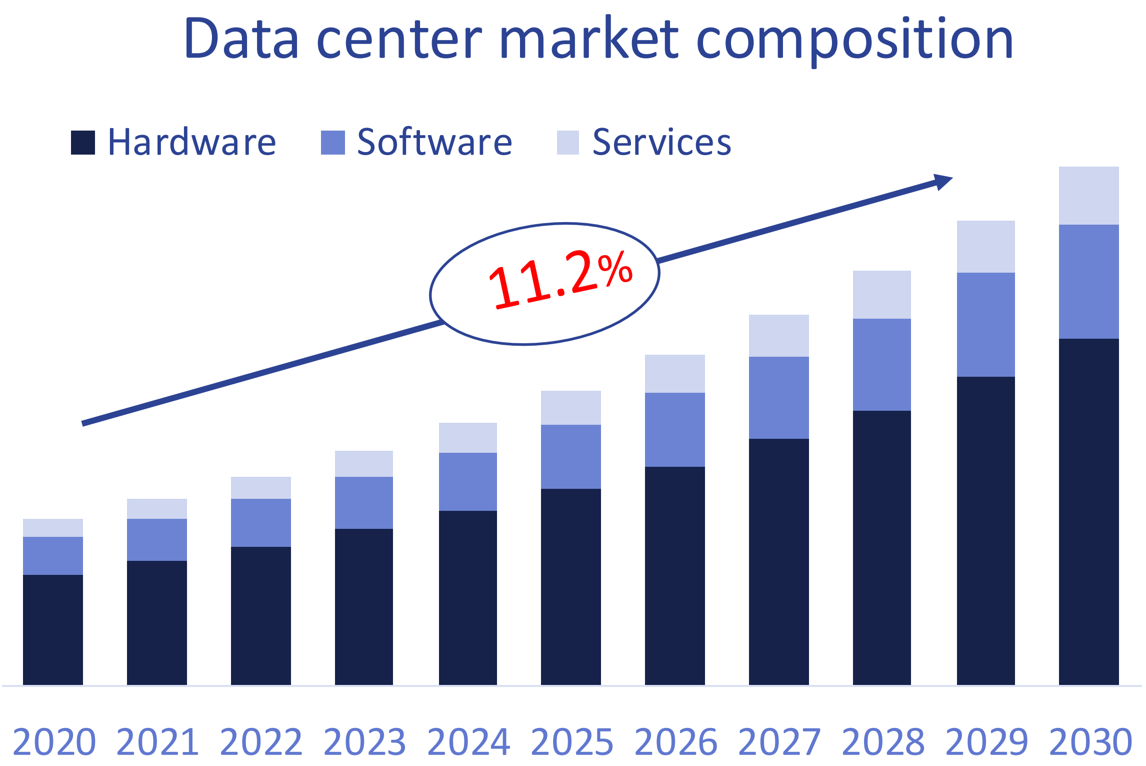
● Power density of CPU and GPU increase fast

Data Center Market Size, Share, & Trends Analysis Report

1.1 Rapid growth of data center market

● The demand of computility



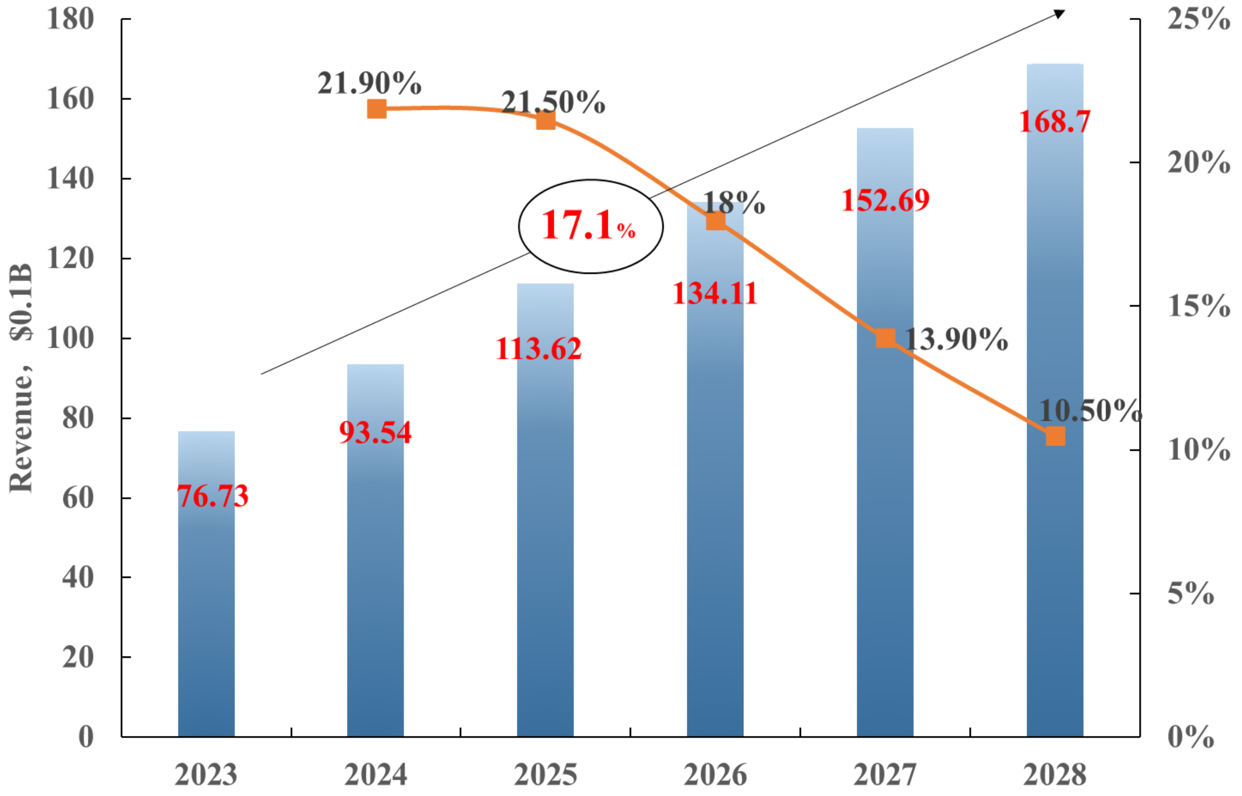


● Market projections indicate a compound annual growth rate of 11.2%

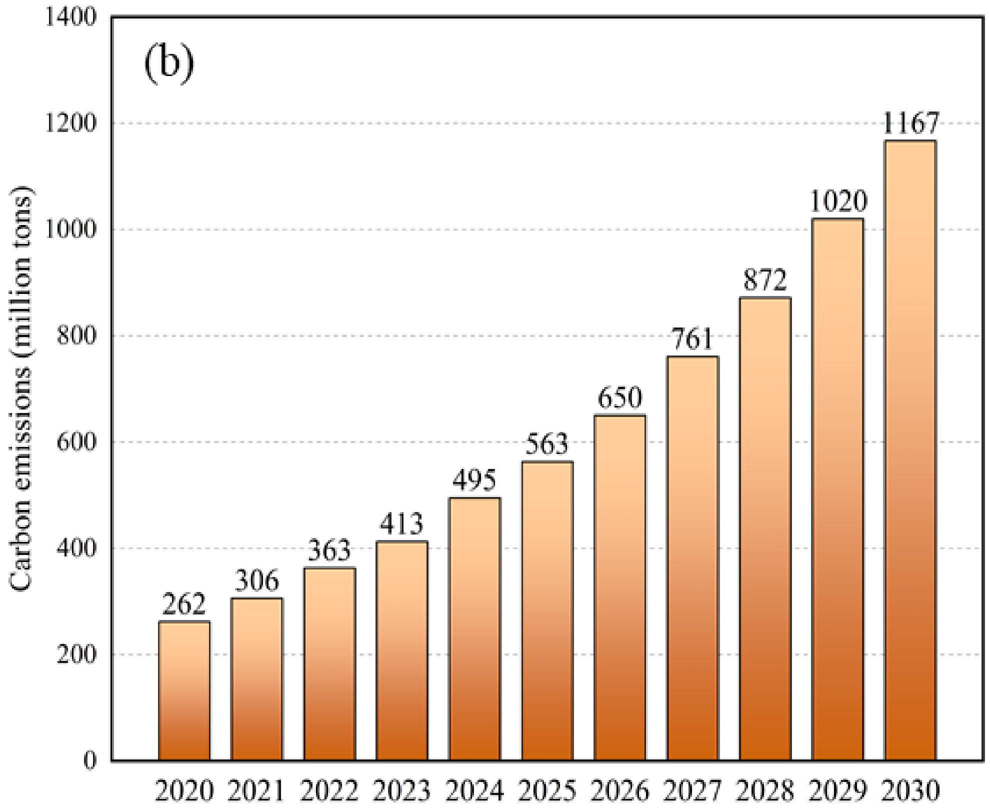
Data Center Market Size, Share, & Trends Analysis Report

1.2 Fast expansion of DC cooling demand and emission

Global data center cooling market size



Global carbon emissions from data centers



Increased utilization of data centers →

Elevated energy consumption and carbon emissions

China Data Center Industry Development White Paper (2023) and Data Centers and Data Transmission Networks

Contents

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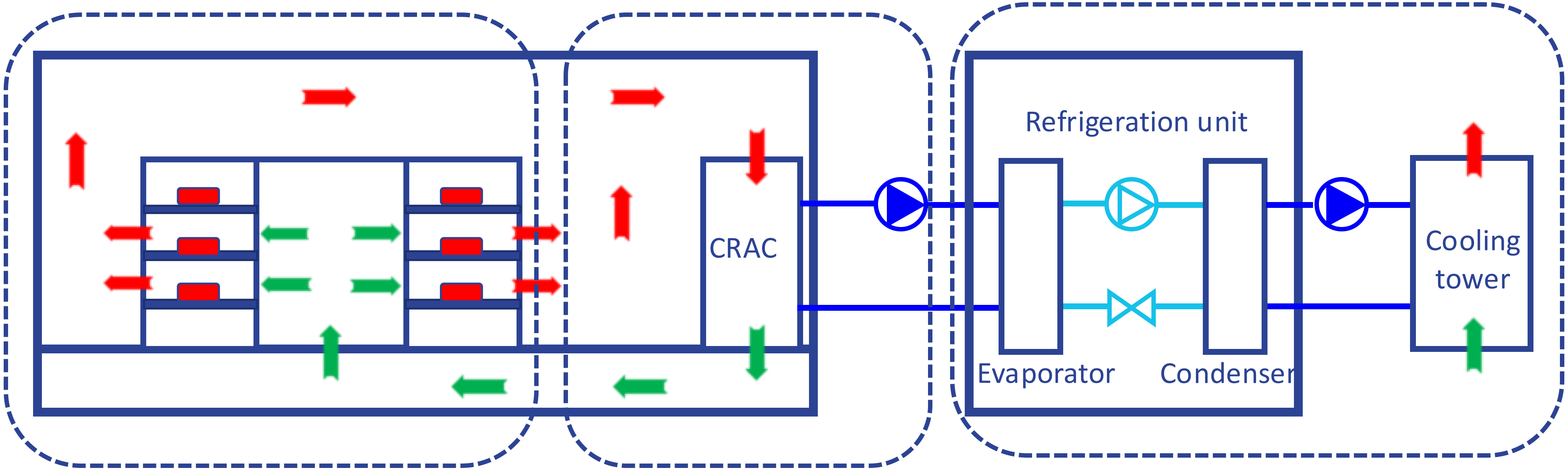
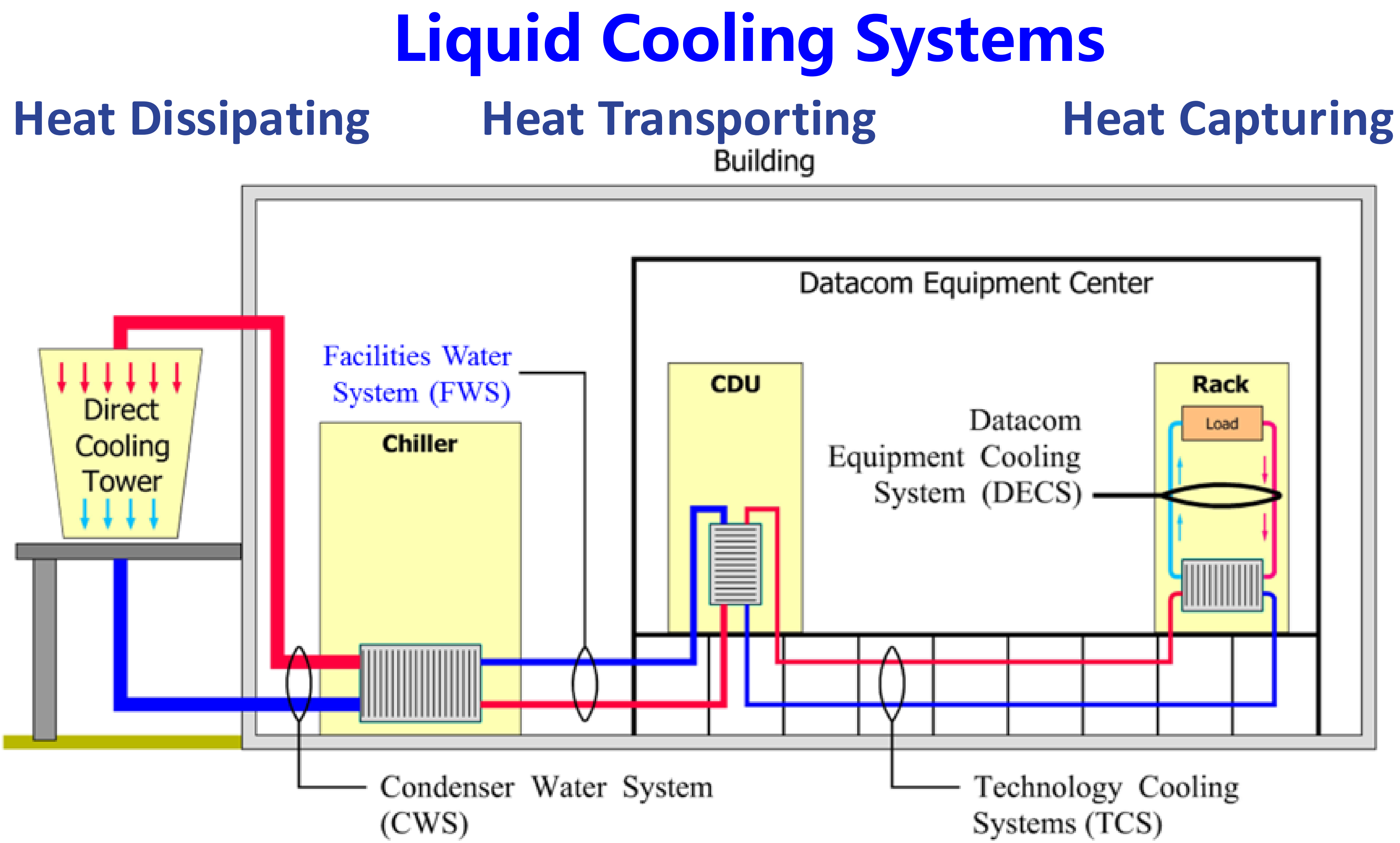
2.1 Typical Air Cooling System for Data Center

Air Cooling System

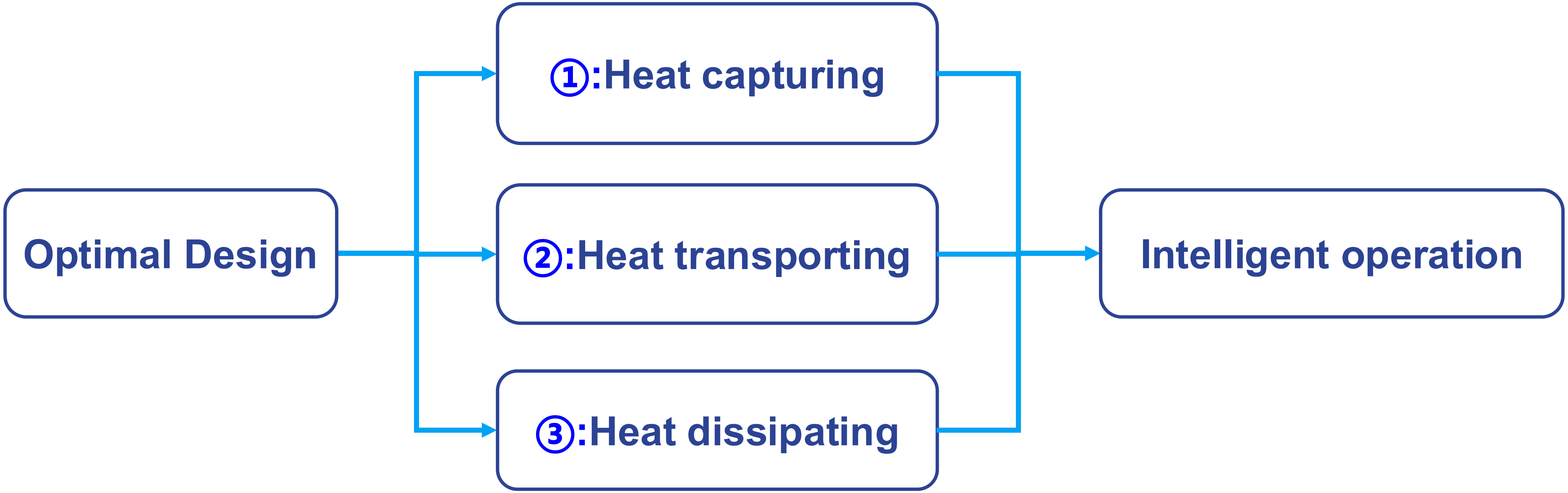


Heat Capturing   Heat Transporting   Heat Dissipating

2.2 Typical Liquid Cooling System for Data Center



2.3 Pathways for Sustainable Cooling of Data Centers



Contents

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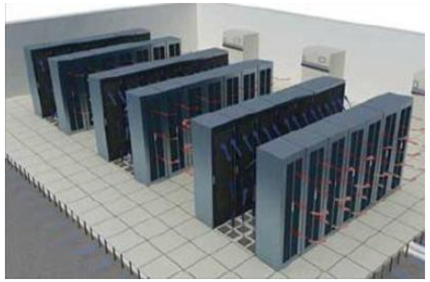
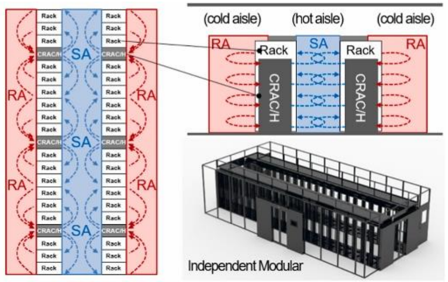
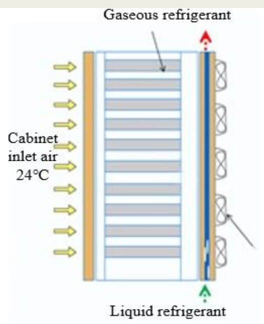
3.1 Heat Capturing

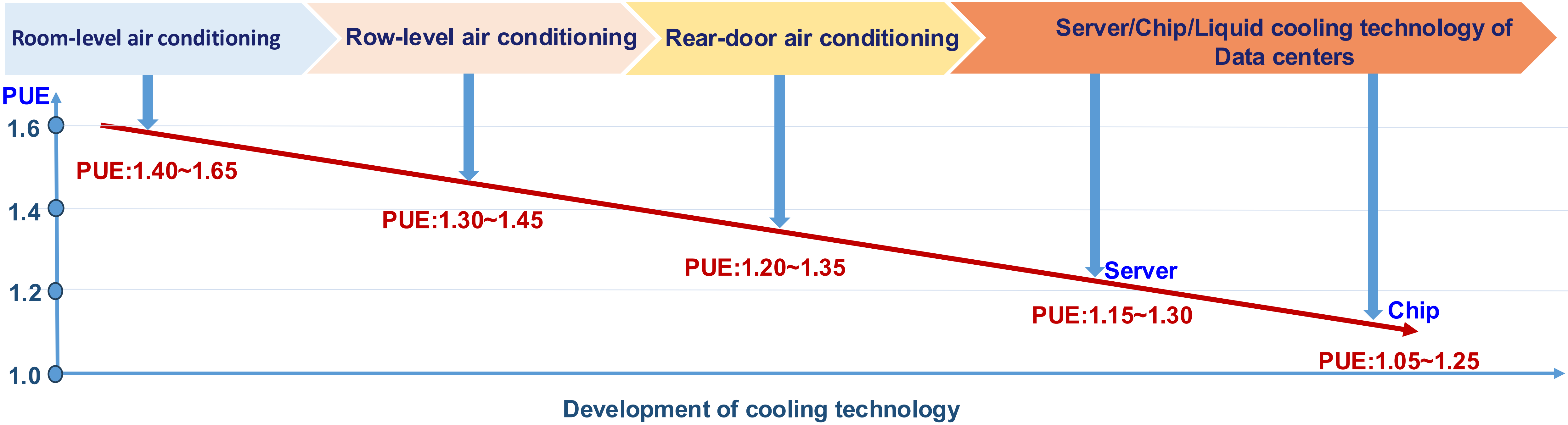
Target: **1) Decrease the heat exergy degradation** (by heat transfer or mixture), and

2) Enhance the heat transfer intensity



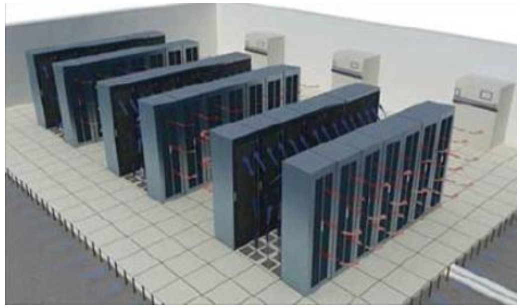




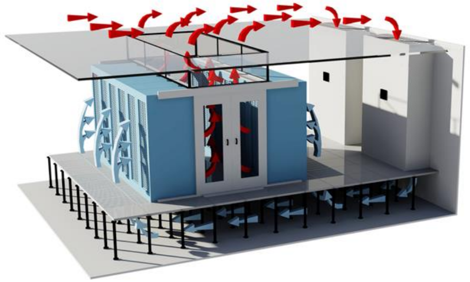


3.1 Heat Capturing

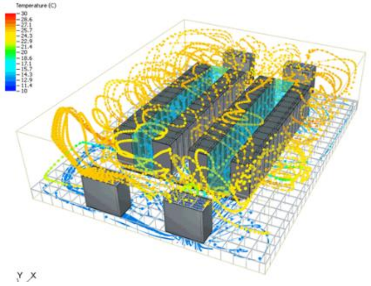
①Room-level air conditioning



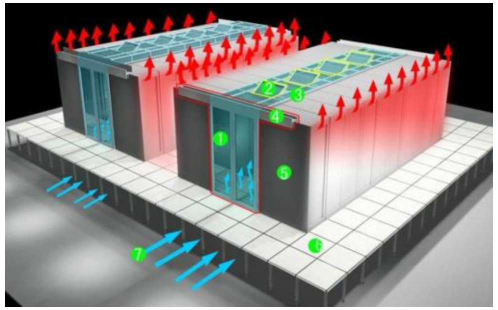
Hot aisle/cold aisle
without containment



Underfloor air supply
with hot aisle closure

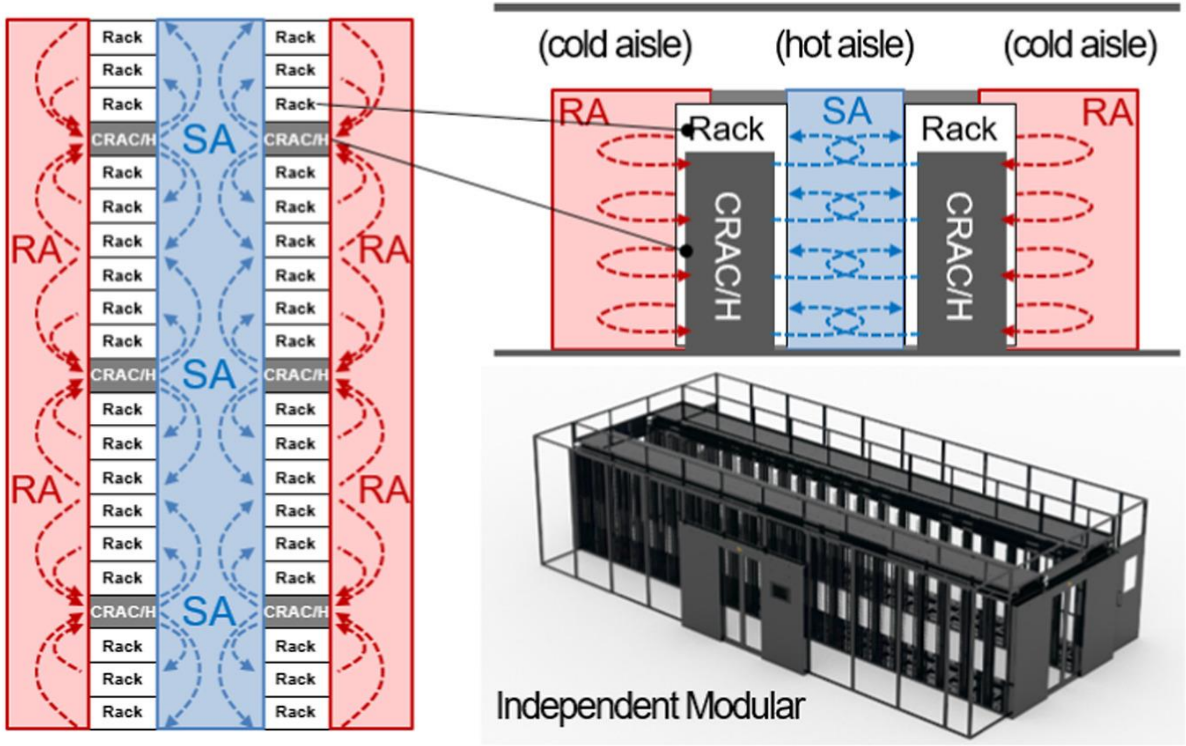


Airflow management



Underfloor air supply
with cold aisle closure

②Row-level air conditioning

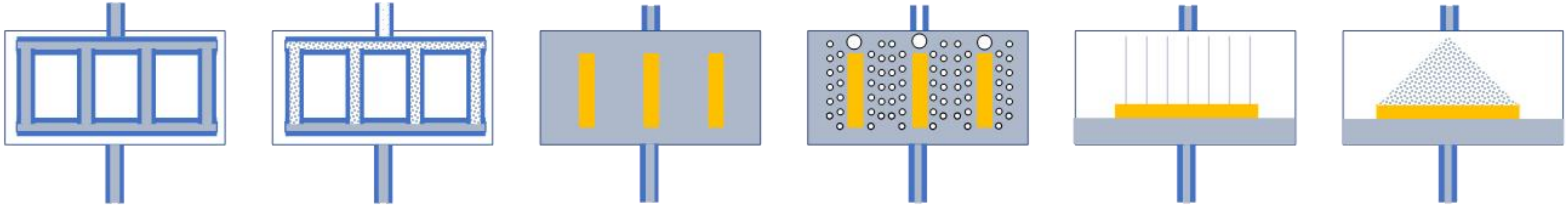


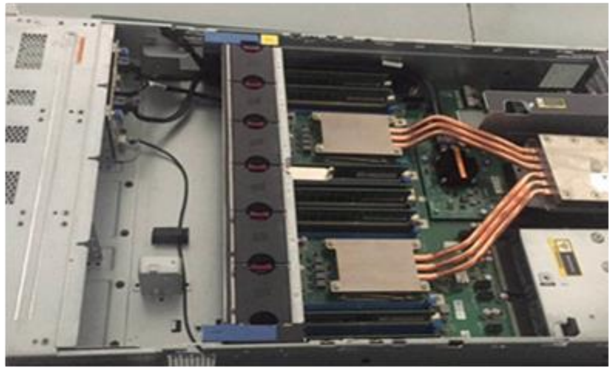
minimizes airflow distance, enables precise demand-driven cooling, and consequently enhances energy efficiency

3.1 Heat Capturing

③Liquid cooling technology of data centers

- cold plate liquid cooling
  - Single-phase
  - Phase-change
- immersion liquid cooling
  - Single-phase
  - Phase-change
- spray/jet liquid cooling
  - Single-phase
  - Phase-change





Cold plate

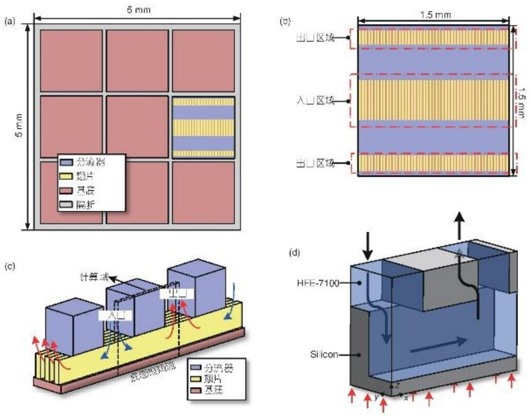
Immersion liquid cooling

Spray liquid cooling

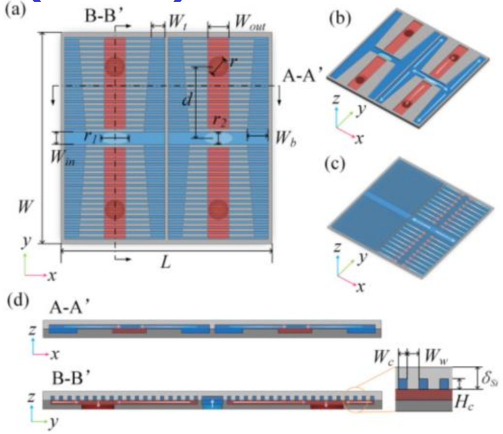
3.1 Heat Capturing

Single-Phase Cold Plate

➢(2020)



➢(2022)



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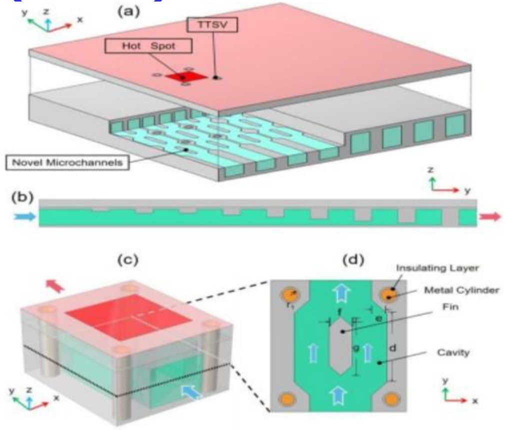

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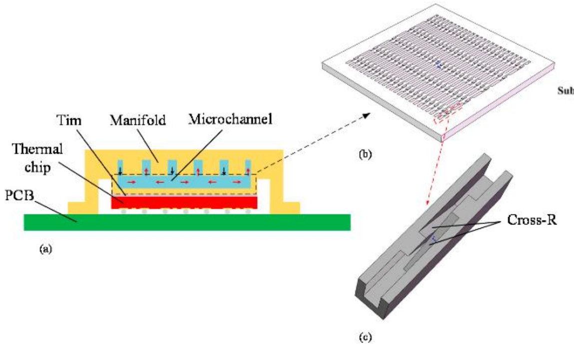

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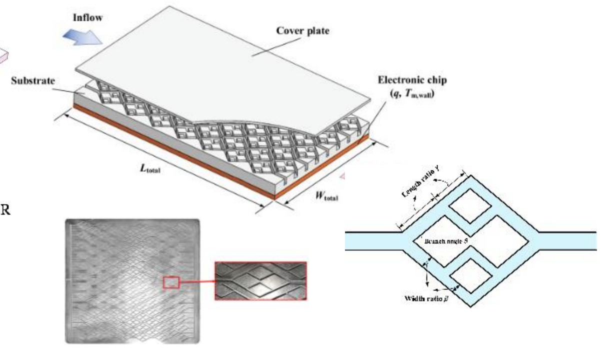
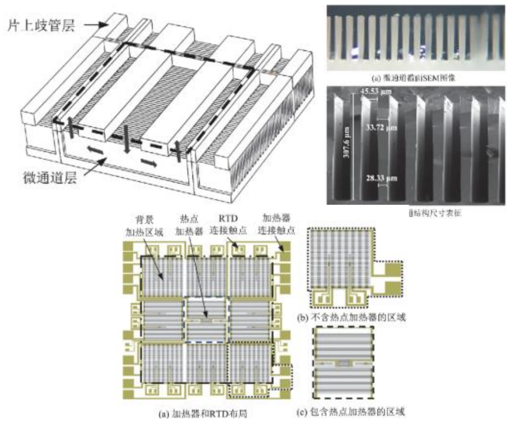
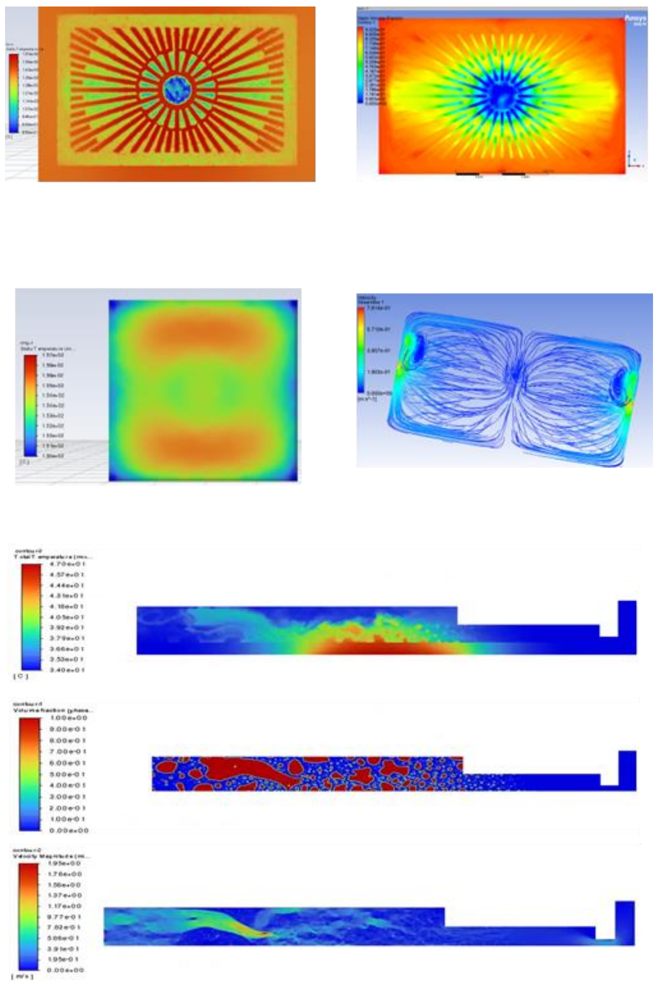


➢(2020)

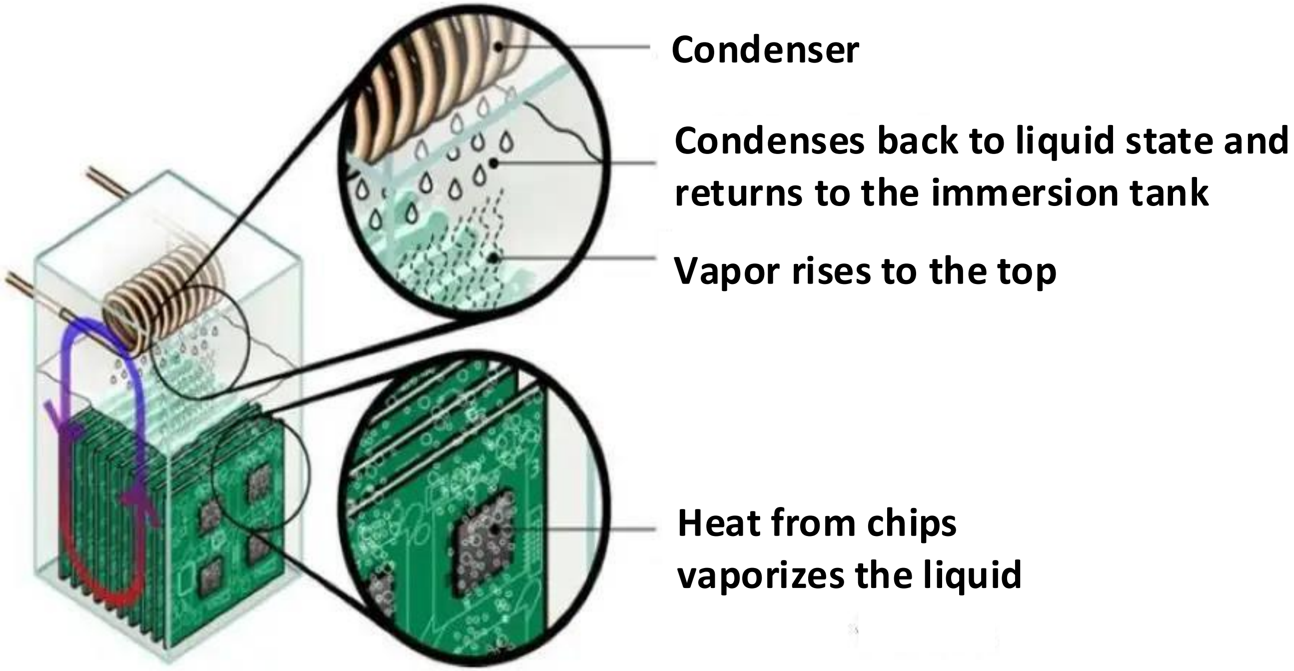


2-Phase Cold Plate



3.1 Heat Capturing

Two-phase immersion liquid cooling

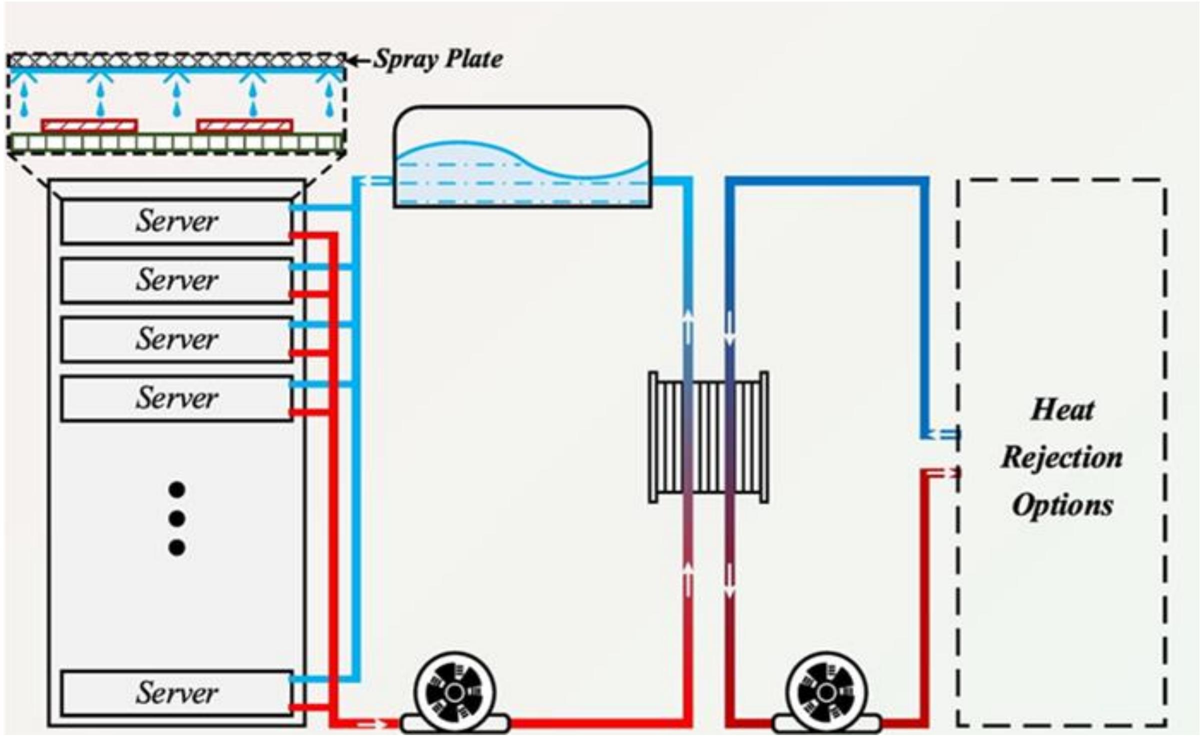


- Eliminating airflow-dependent cooling infrastructure
- Achieving near-theoretical energy efficiency limits
- Supporting ultra-high power density deployments

3.1 Heat Capturing

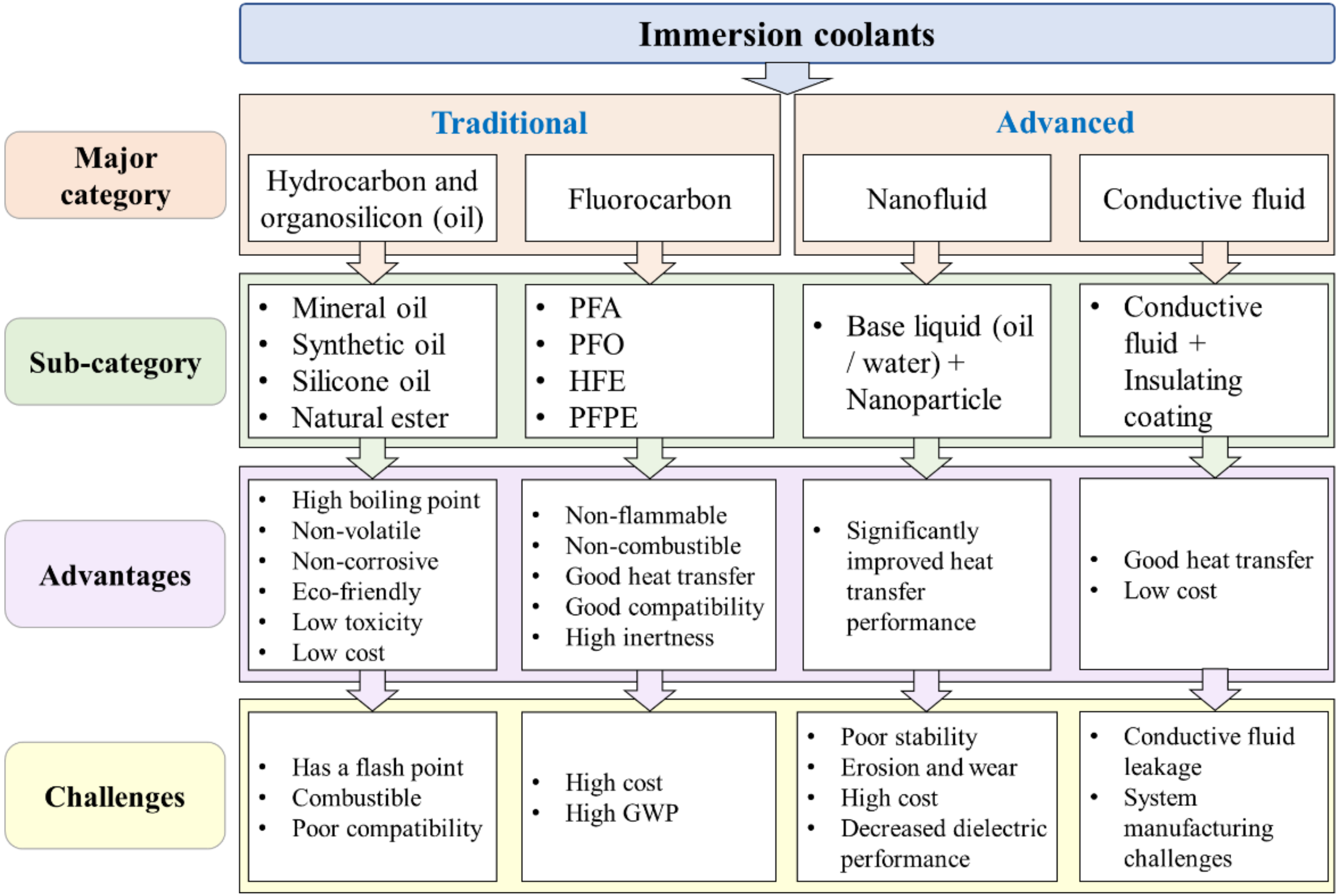
Spray/Jet liquid cooling

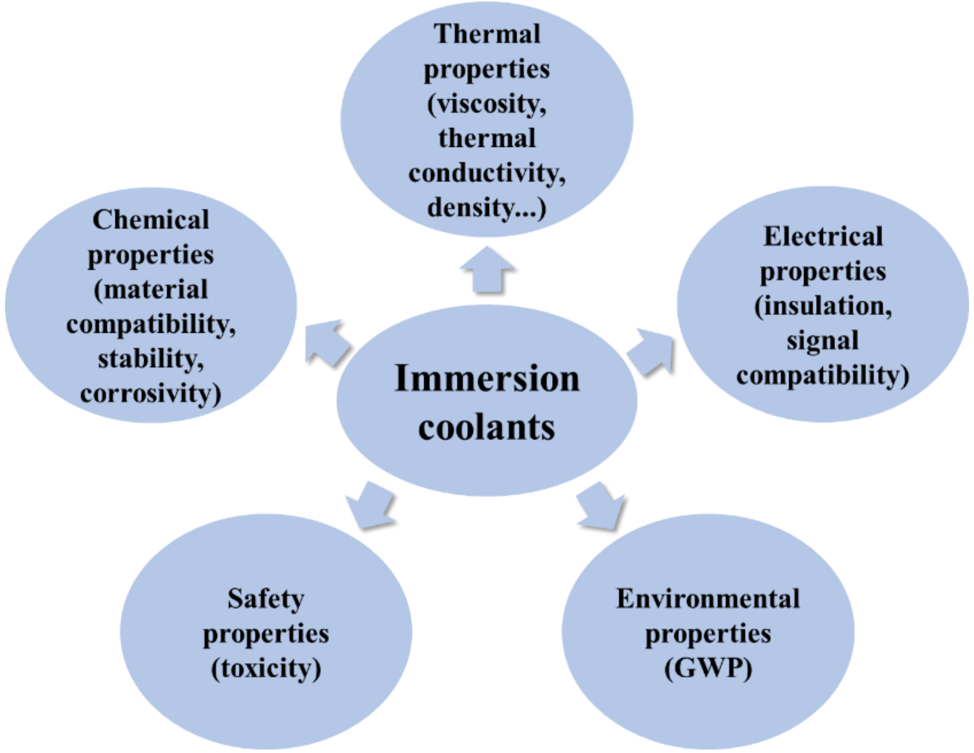
- Targeted spraying based on localized heat flux density
- **Reduces coolant consumption**
- Decreases structural floor loading



3.1 Heat Capturing

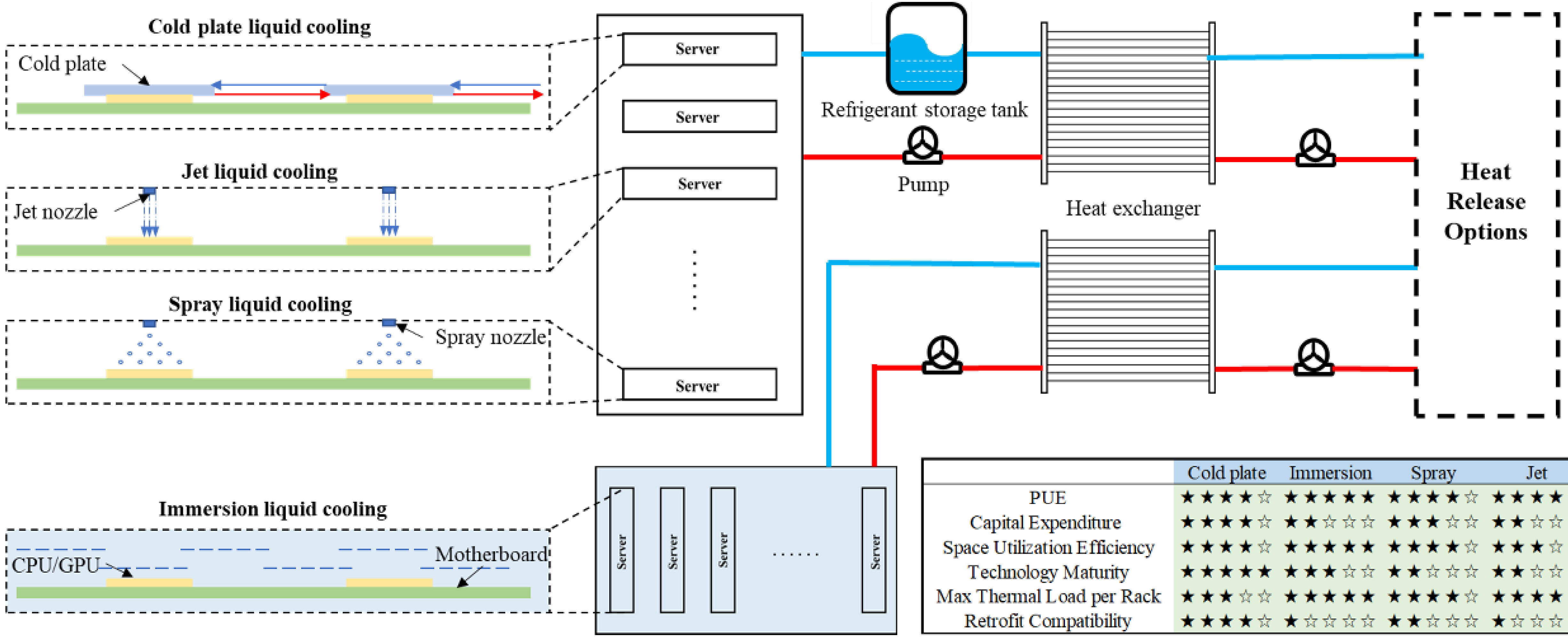
Coolant s for Immersion, Spray/Jet liquid cooling





3.1 Heat Capturing

Comparison of different Liquid cooling technologies



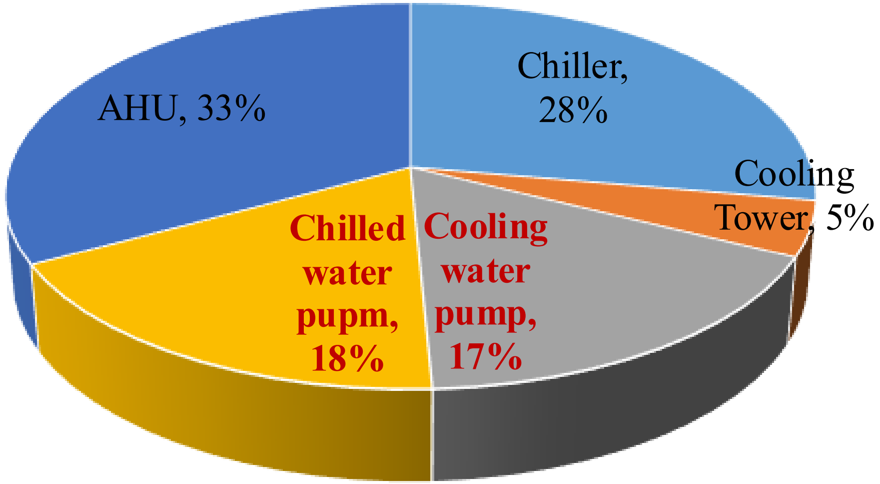
	Cold plate	Immersion	Spray	Jet
PUE	★★★★☆	★★★★★	★★★★☆	★★★★☆
Capital Expenditure	★★★★☆	★★☆☆☆	★★★☆☆	★★☆☆☆
Space Utilization Efficiency	★★★★☆	★★★★★	★★★★☆	★★★☆☆
Technology Maturity	★★★★★	★★★☆☆	★★☆☆☆	★★☆☆☆
Max Thermal Load per Rack	★★★☆☆	★★★★★	★★★★☆	★★★★☆
Retrofit Compatibility	★★★★☆	★☆☆☆☆	★★☆☆☆	★☆☆☆☆

3.2 Heat Transporting

✓**Minimal transport power required**

✓**Environmentally friendly refrigerant alternatives**

Coolant choose



$$Q = \dot{m}Cp(T_i - T_o)$$

→ **Larger heat transfer temperature differentials** increase exergy destruction

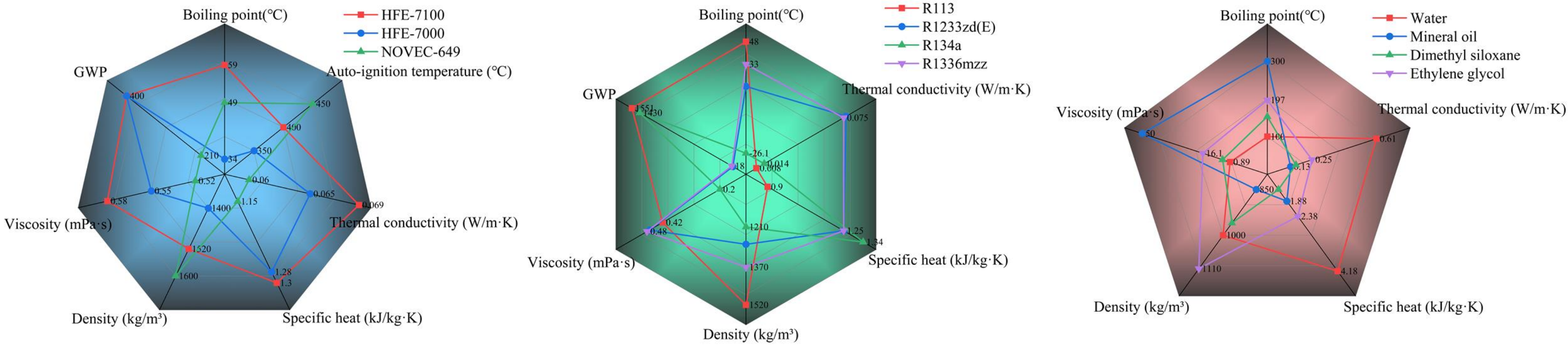
→ **Lower flow rates** reduce fluid transport energy consumption

$$P = \dot{m}\Delta H$$

→ **Refrigerants' lower viscosity** versus water, coupled with vapor-liquid density differences, enable reduced transport energy

→ **Higher fluid density** permits smaller piping diameters, conserving space

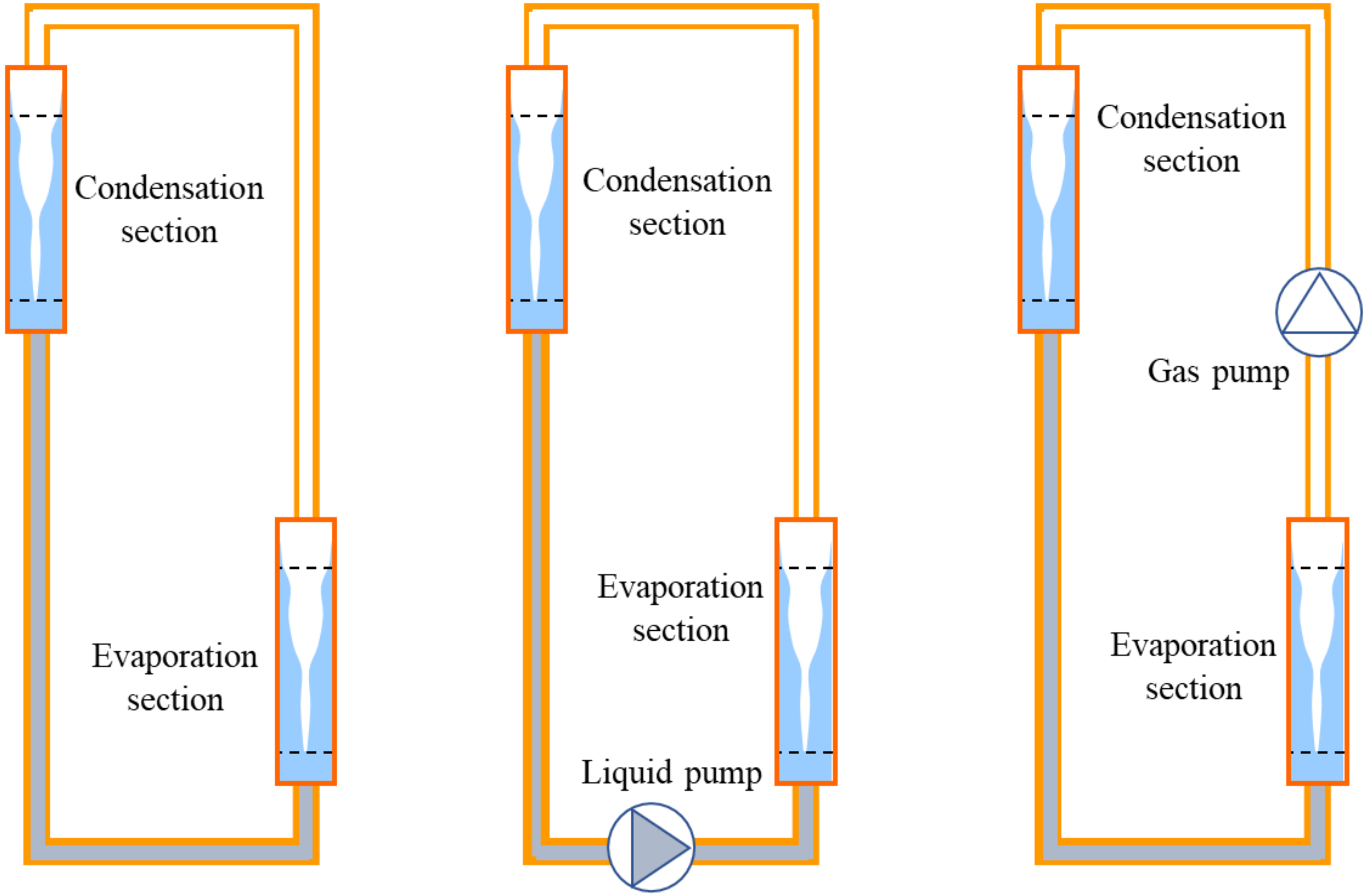
The proportion of distribution system energy consumption within data centers' annual total energy usage is continuously rising.



(a) Fluorinated Fluids (b) Refrigerants Fluids (c) Common Fluids

3.2 Heat Transporting

Heat pipe loop



(a) Gravity-driven(thermosyphon) (b) Liquid pump driven (c) Gas pump driven

Gravity-driven(thermosyphon)

Utilizes gravity potential and density differential as circulation driving force.

Liquid pump driven

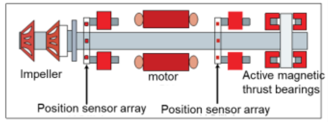
Utilizes liquid pump as circulation driving force; cavitation prevention required.

Gas pump driven

Utilizes vapor compressor as circulation driving force; liquid slugging prevention required.

3.3 Heat Dissipating

Integrated system architecture

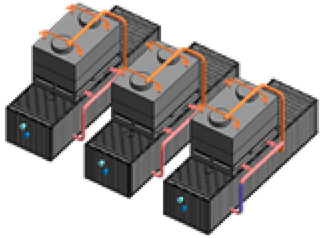


⑤ High-Efficiency Chillers

→**Magnetic bearing variable frequency** drive chillers
→Water/air-cooled VFD chillers
→Low condenser water temperature operation

⑥High-Efficiency Customized Terminal Units

→Electronically commutated (EC) fans
→Fresh air / full recirculation mode

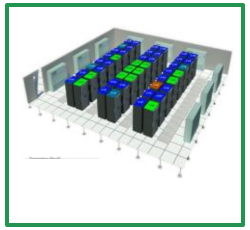


⑦ Packaged Cooling Plant System

→ Prefabricated modular units
→ Unitary integrated cooling plant
→ Integrated building management system

⑧ AI-Driven Energy Management Platform

→ All-variable speed drive configuration
→ Free cooling; redundant hot standby

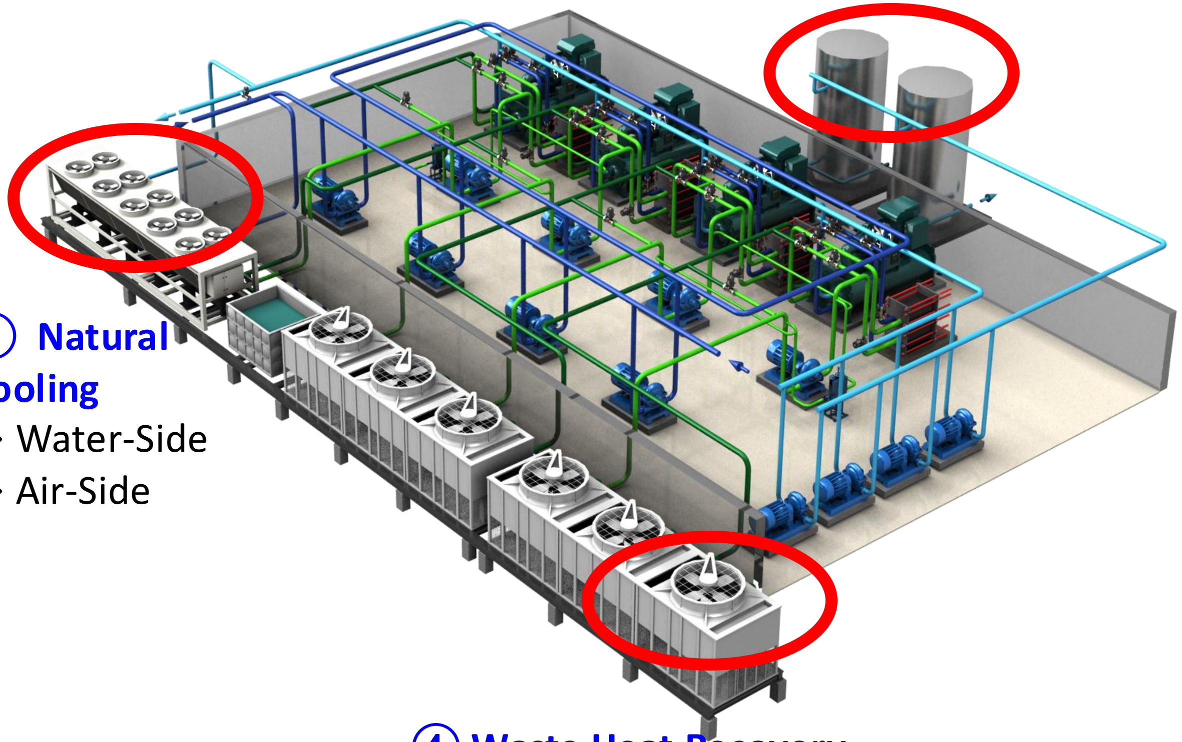


③ Evaporative cooling

→ reduction of cooling source temperature

② Thermal Energy Storage

→Ice-based thermal energy storage
→Water-based sensible thermal energy storage



① Natural Cooling

→ Water-Side
→ Air-Side

④ Waste Heat Recovery

→ Condenser Heat Recovery System
→ Total Heat Recovery

3.3 Heat Dissipating

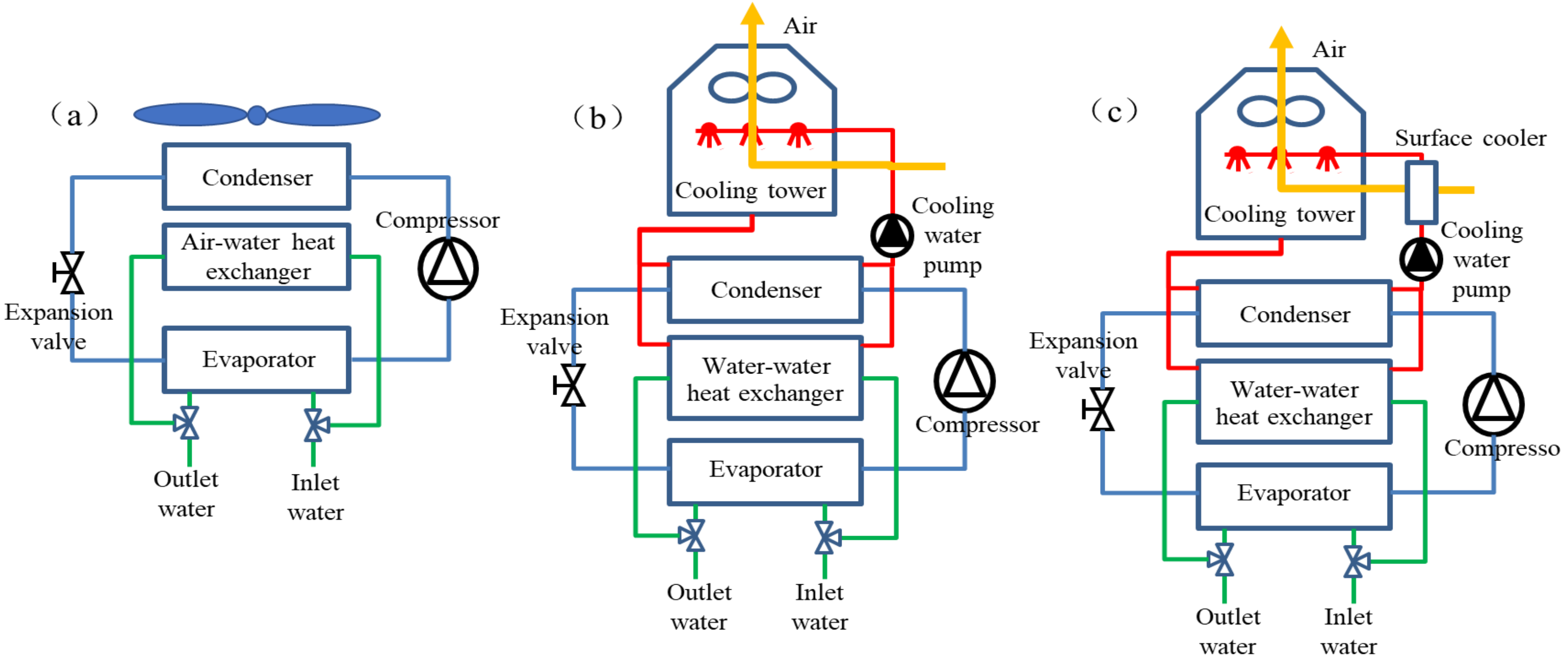
① Natural cooling

Types of natural cooling system

Classification	Type
Air-side	Direct Indirect
Water-side	Direct water-cooling Air-cooling Cooling tower /evaporative cooling
Heat pipe	By driving force By system By outdoor cooling

Advantages:

- Environmental Sustainability
- Economic Viability



Air-cooled chillers
Dry-bulb temperature

Chiller + Direct evaporative cooling
Wet-bulb temperature

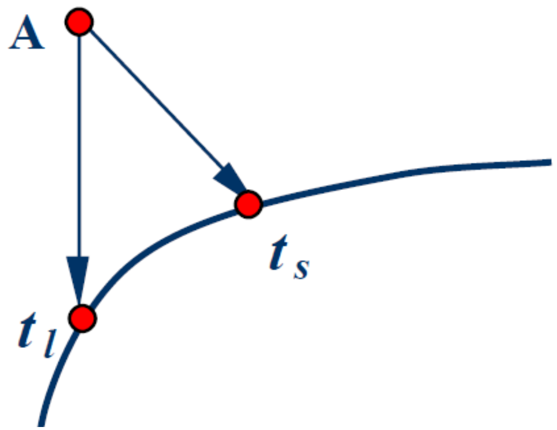
Chiller + Indirect evaporative cooling
Dew-point temperature

Active/natural cooling integrated systems

3.3 Heat Dissipating

② Evaporative cooling: reduction of cooling source temperature

Typical Evaporative Cooling Heat Transfer Process

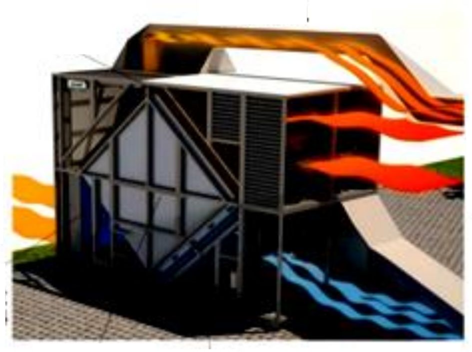


→ Heat removal via water evaporation

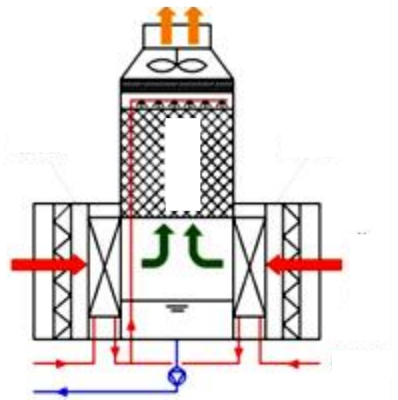
→ Direct evaporative cooling (*ts*) / Dew-point evaporative cooling (*tl*)

→ Generates chilled air/water or condenses refrigerant (evaporative condensation)

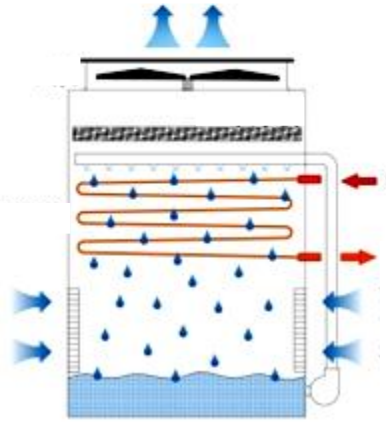
Internally-cooled indirect evaporative air handling unit



Externally-cooled indirect evaporative air handling unit



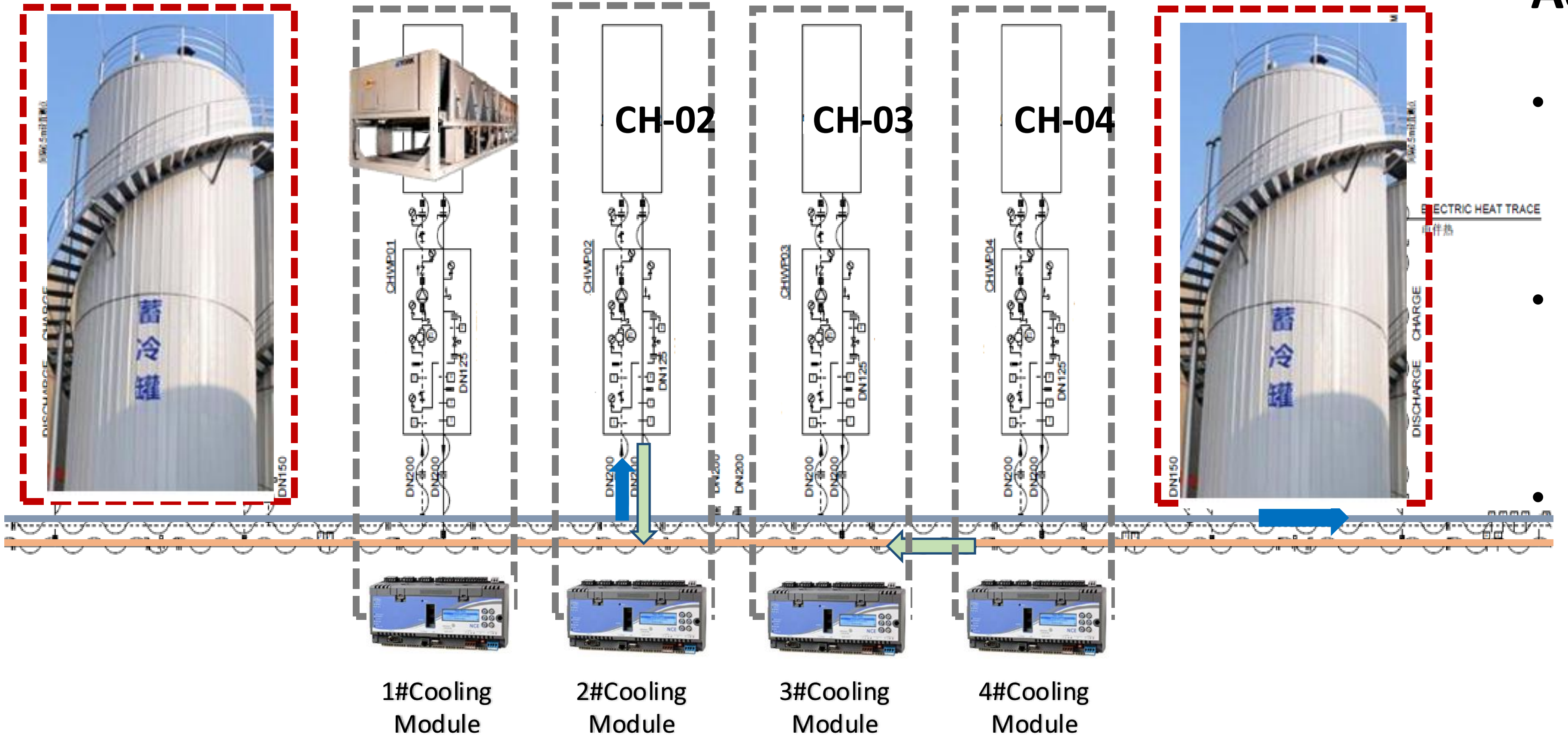
Indirect evaporative chiller



Evaporative condenser unit

3.3 Heat Dissipating

③ Data Center Cooling Thermal Storage



Advantages:

- **Increasing Cooling Capacity**: Enhances the operational resilience of data center cooling systems
- **Customer-Side Energy Storage**: Improves grid reliability and increases renewable energy utilization rate
- **Time-of-Use Electricity Pricing**: Reduces operational costs

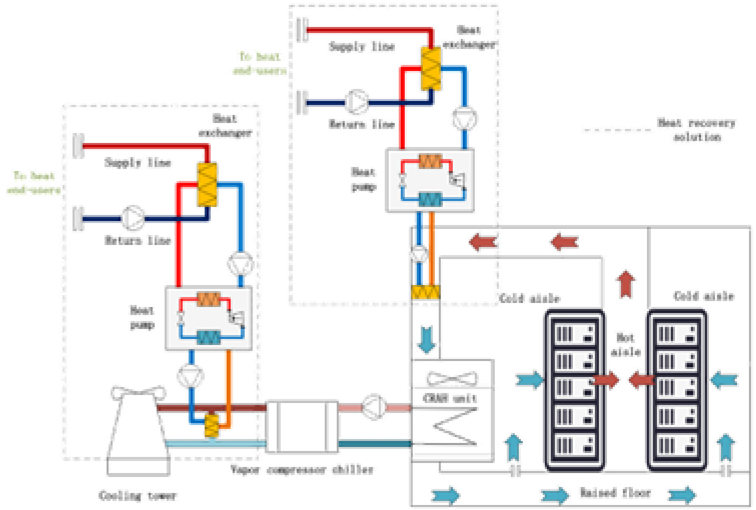
3.3 Heat Dissipating

④ Data Center Waste Heat Recovery Technologies

Various heat sources

Air Cooling Thermal Sources: High-temperature exhaust air, condenser water, chilled water

Liquid Cooling Thermal Sources: Coolant return flow, process cooling liquid



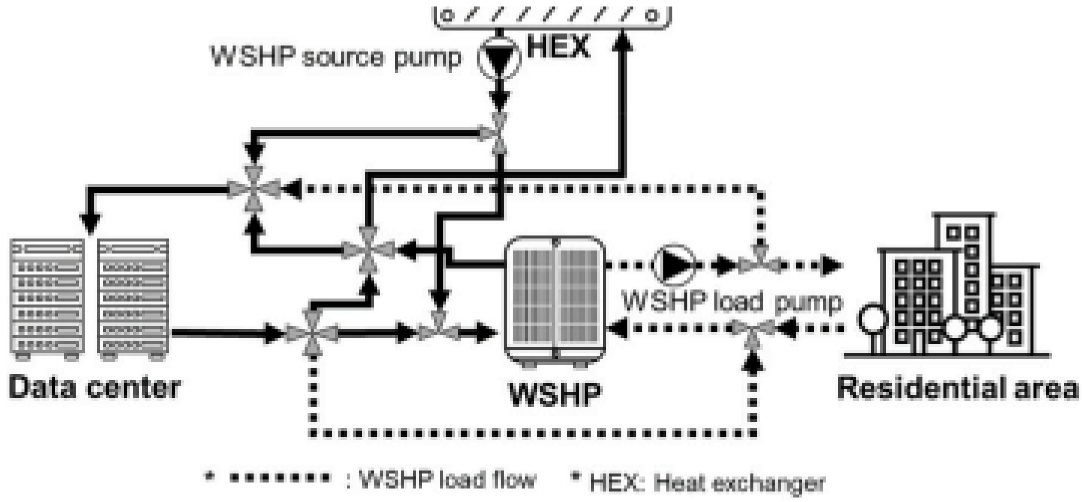
Air Cooling Thermal Sources

Various heat sinks

District Heating: Supplies hot water/space heating

Preheating for Power Generation: Directly offsets electricity consumption

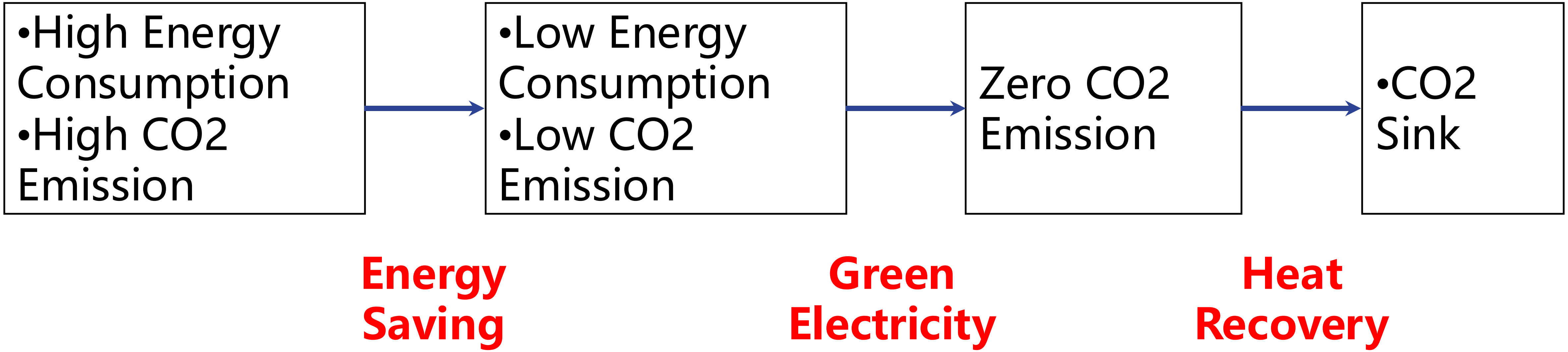
Supplementary Cooling: Waste heat-driven refrigeration compensating cooling load



District Heating

4 Conclusions

Data Center Prosumer

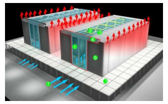


4 Conclusions

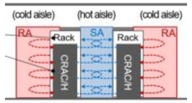
Heat capture

Air cooling

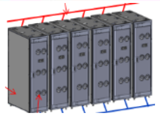
Room level



Row level



Cabinet level



Liquid cooling

Cold plate

Immersion

Spray

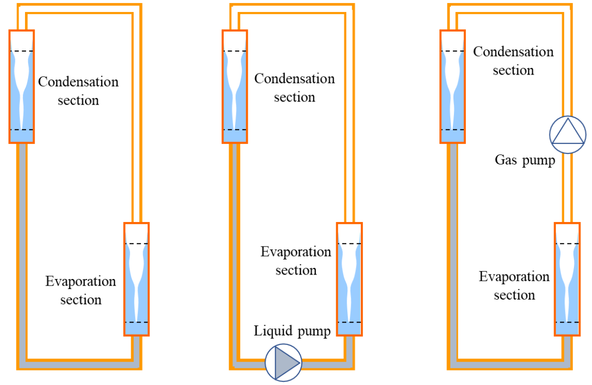
Heat transfer

Coolant choose

Minimal transport power

Environmentally friendly

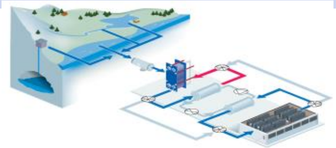
Loop heat pipes
(Base on latent heat)



(a) Gravity-driven(thermosyphon) (b) Liquid pump driven (c) Gas pump driven

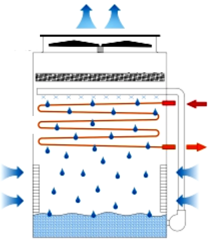
Heat release

Natural cooling



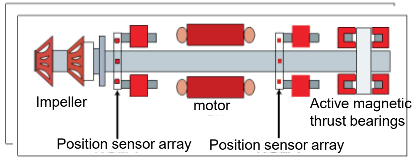
Thermal energy storage

Evaporative cooling

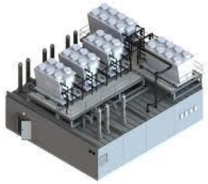


Waste heat recovery

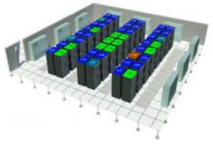
High-efficiency chillers



High-efficiency customized terminal units



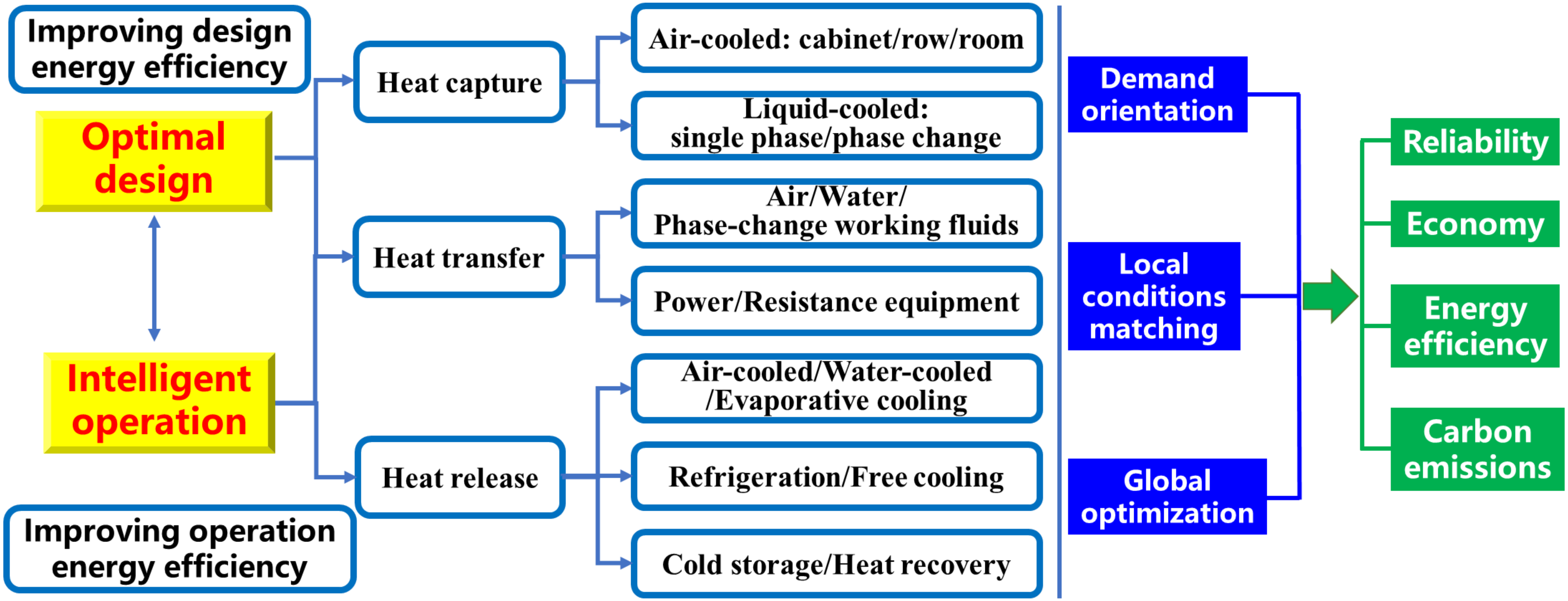
Packaged cooling plant



AI-driven energy man

4 Conclusions

◆Technical development process of a data center cooling system of carbon neutrality



4 Conclusions

- The rapid expansion of data centers drives massive electricity consumption, resulting in significant greenhouse gas (GHG) emissions
- To address the intensified heat generation from super servers, more powerful cooling systems are imperative
- Developing sustainable cooling solutions demands a comprehensive approach — from efficient heat capturing to low-energy heat transport and optimized heat dissipation mechanisms

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One Community for Sustainable Energy

Thank you

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Q&A

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Thank you