

# Evolution of Data Center Designs

12.09.2025



# Objectives

- Discuss the progression of data center design criteria from the 2000s through today and into the future.
- Discuss data center performance criteria
  - Rack Density
  - Cooling Technologies
  - Data Center Usage Cases



# Types of Data Centers



**Enterprise Data Centers:**  
Typically, Corporate owned  
single-use facility



**Wholesale Colocation Provider:**  
Lease large amounts of space or  
entire centers to single tenants.



**Retail Colocation Data Center  
Providers:**  
“Carve” up the space to allow for a  
variety and multitude of tenants.



**Hyperscale Data Centers:**  
AWS, Microsoft, Google, Facebook,  
Apple, etc.



**Modular Data Centers:**  
Used to create building blocks of  
colocation, hyper-scale and  
standalone data centers.



# Types of Data Centers by Usage

## Enterprise

- Hosting of client applications and machines for a single corporate entity. Examples: Financial, Health Care, Smaller Private Businesses

## Cloud

- Hosting of Applications by others. Typically spread between data centers. This is the main product of many Hyperscalers but can also be hosted in Colocation Data Centers.
- Includes Public Cloud, Private Cloud, and Hybrid Cloud.

## Edge (Traditional)

- Concentrating data centers at high usage areas
- A main usage of Colocation Data Centers.

## Edge (New)

- Extending the Internet to Remote Areas. Associated with 5G and self-driving cars
- Usually a combination of Colocation and Modular Data centers

## AI

- Used for the development and training of Large Language Models
- Inference – use models to respond to queries

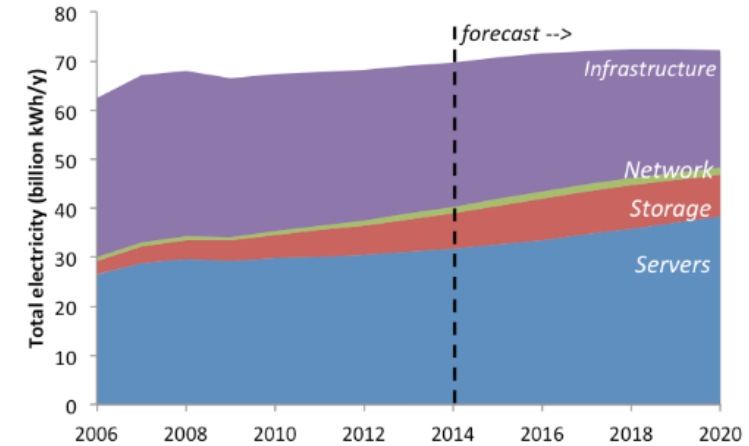


# United States Data Center Energy Usage Report June 2016

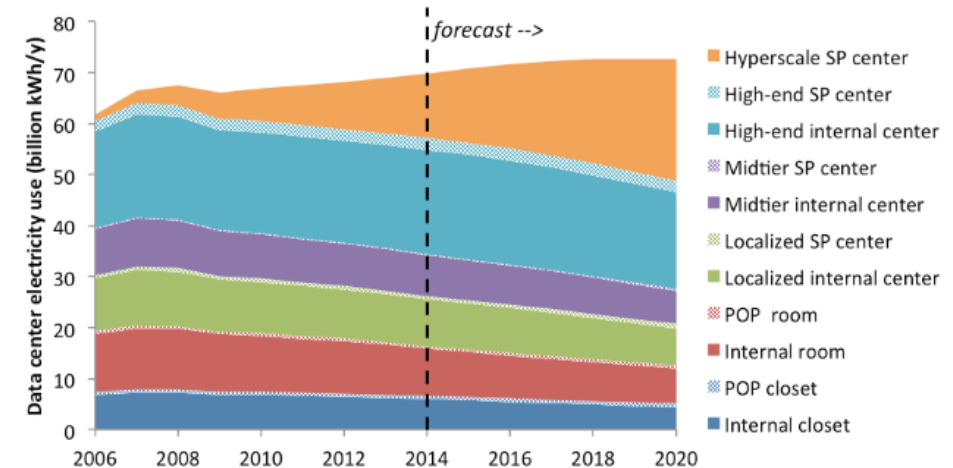


**Table 2. Typical IT Equipment and Site Infrastructure System Characteristics by Space Type**

Space type	Typical size	Typical infrastructure system characteristics
Internal server closet	< 100 ft <sup>2</sup>	Often outside of central IT control (often at a remote location) that has little to no dedicated cooling.
Internal server room	100-999 ft <sup>2</sup>	Usually under IT control, may have some dedicated power and cooling capabilities.
Localized internal datacenter	500-1,999 ft <sup>2</sup>	Has some power and cooling redundancy to ensure constant temperature and humidity settings.
Midtier internal datacenter	2,000-19,999 ft <sup>2</sup>	Superior cooling systems that are probably redundant.
High-end internal datacenter	> 20,000 ft <sup>2</sup>	Has advanced cooling systems and redundant power.
Point-of-presence server closet	< 100 ft <sup>2</sup>	At local points of presence for OSS and BSS services. Typically leverages POP power and cooling. Space is often a premium.
Point-of-presence server room	100-999 ft <sup>2</sup>	Secondary computer point of presence for OSS and BSS services. Typically leverages POP power and cooling.
Localized service provider datacenter Including subsegment: containerized datacenter	500-1,999 ft <sup>2</sup>	Has some power or cooling redundancy to ensure constant temperature and humidity settings. These are typically facilities set up by VARs to provide managed services for clients.
Midtier service provider datacenter Including subsegment: prefabricated datacenter	2,000-19,999 ft <sup>2</sup>	Location for small or midsize collocation/hosting provider. Also includes regional facilities for multinational communications service providers. Has superior cooling systems that are probably redundant.
High-end service provider datacenter	> 20,000 ft <sup>2</sup>	Primary server location for a service provider. May be subdivided into modules for greater flexibility in expansion/refresh. Has advanced cooling systems and redundant power.
Hyperscale datacenter	Up to over 400,000 ft <sup>2</sup>	Primary server location for large collocation and cloud service providers. Based on modular designs, with individual modules of 50,000 sq ft on average in up to 8 modules. Employs advanced cooling systems and redundant power.



**Figure 21. Total Electricity Consumption by Technology Type**



**Figure 22. Total Electricity Consumption by Space Type**

# 2024 United States Data Center Energy Usage Report

## Server Electricity Use

The total annual server energy use from 2014 to 2023 is presented in Figure 5.1, along with a future scenario range of server energy use through 2028. Server energy usage grew from about 30 terawatt-hours (TWh) in 2014 to nearly 100 TWh in 2023, more than tripling during that period. A large portion of this increase came from GPU-accelerated AI servers, which grew in energy usage from less than 2 TWh in 2017 to more than 40 TWh in 2023. Conventional servers, primarily dual processor servers, increased significantly during the same period as well, doubling from about 30 TWh to nearly 60 TWh.

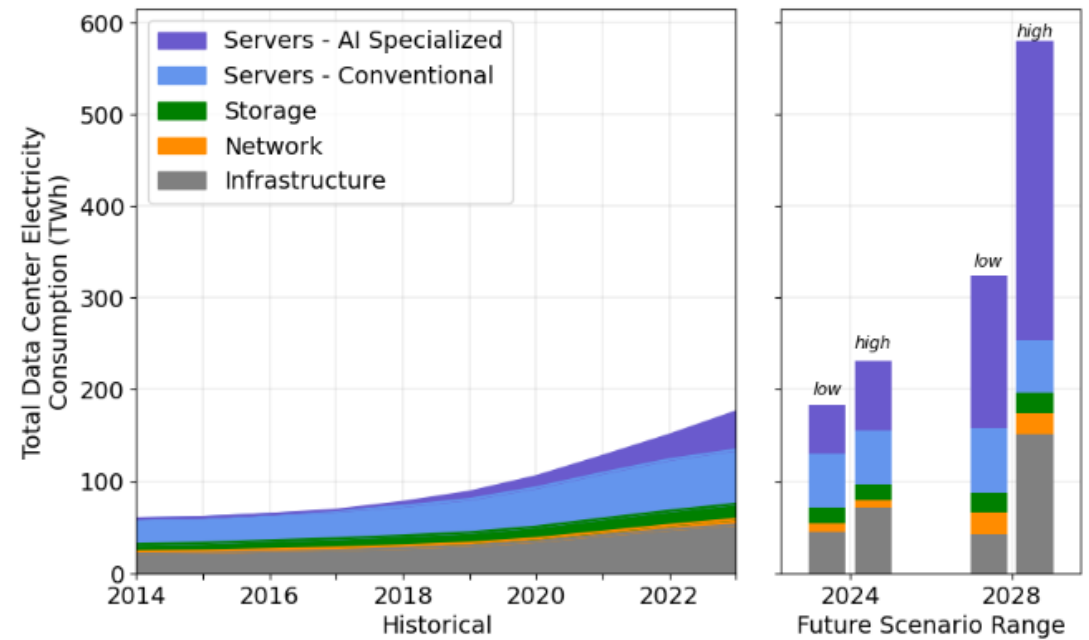
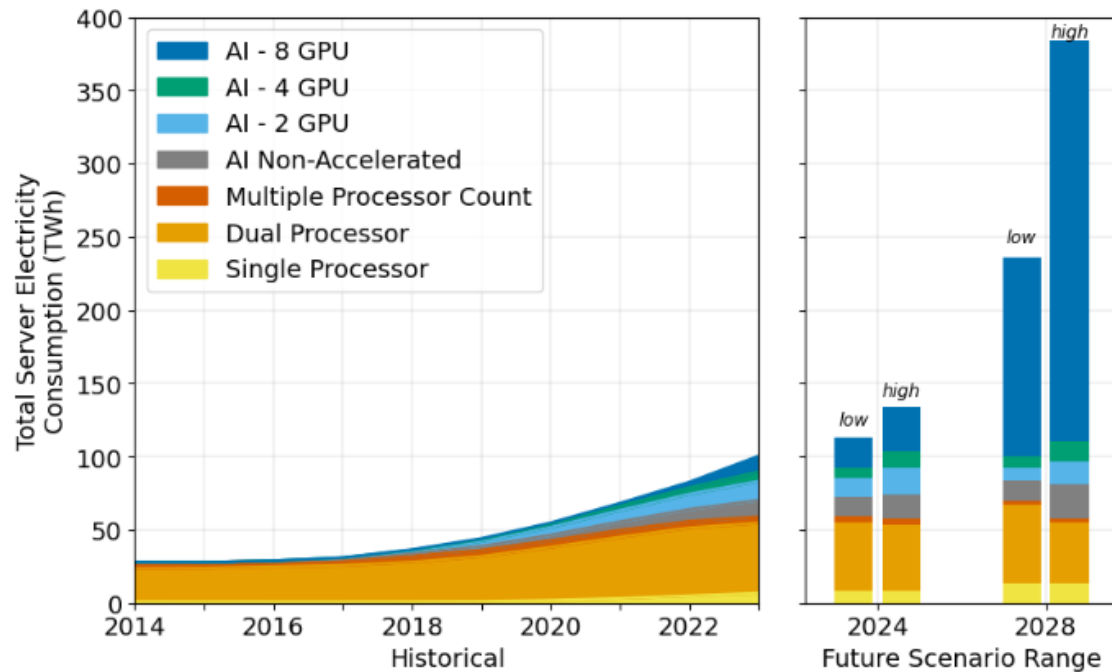


Figure 5.6. Total data center electricity use from 2014 through 2028 by equipment type.



# 2024 United States Data Center Energy Usage Report



**Table 4.1. Data Center Space Types Considered in This Study**

Space Type	Description
<b>Telco Edge</b>	Deployment of small closets/rooms to micro data centers and network infrastructure by communications companies as points of presence throughout their network
<b>Commercial Edge</b>	Network closets, server rooms, and micro-data centers deployed to support modern digital, infrastructure, and software delivery services to edge locations for commercial (focused on customer and business operations) and industrial (focused on supply chain and channel operations)
<b>Small and Medium Businesses (SMB)</b>	SMB deployments in their own internal facilities
<b>Enterprise Branch</b>	Classic remote and branch office (ROBO) deployments for large enterprises in their own internal facilities (network closets, server rooms)
<b>Internal</b>	Data centers run by enterprises, internally, for their own use
<b>Communications Service Providers (Comms SPs)</b>	Data centers run by telecommunications/cable companies to support internal services required to enable provision of communications technology services to their customers
<b>Colocation – Sm/Med Scale</b>	Data centers built by local colocation companies typically providing retail leasing at smaller scale
<b>Colocation – Large Scale</b>	Data centers built by major colocation companies providing wholesale and retail colocation leasing, typically deploying large and mega datacenters
<b>Hyperscale</b>	Data centers built by companies that deploy internet services and platforms at massive scale

# Determining Block Size and PUE

Power usage effectiveness (PUE) is a metric used to determine the energy efficiency of a data center. PUE is determined by dividing the amount of power entering a data center by the power used to run the computer infrastructure within it.

- Example: Input Power to DC is 10MW, Power Measured at Servers is 8 MW.  $PUE = \text{Input}/\text{IT} = 1.25$
- Peak PUE is used for sizing of the power system.
- Average PUE is determined for Mechanical and ROI calculations but would result in undersized utility service for peak conditions.

Table 4. 2014 PUE by Space Type

Space Type	IT	Transformer	UPS	Cooling	Lighting	Total PUE
Closet	1	0.05	-	0.93	0.02	2.0
Room	1	0.05	0.2	1.23	0.02	2.5
Localized	1	0.05	0.2	0.73	0.02	2.0
Midtier	1	0.05	0.2	0.63	0.02	1.9
High-end	1	0.03	0.1	0.55	0.02	1.7
Hyperscale	1	0.02	-	0.16	0.02	1.2

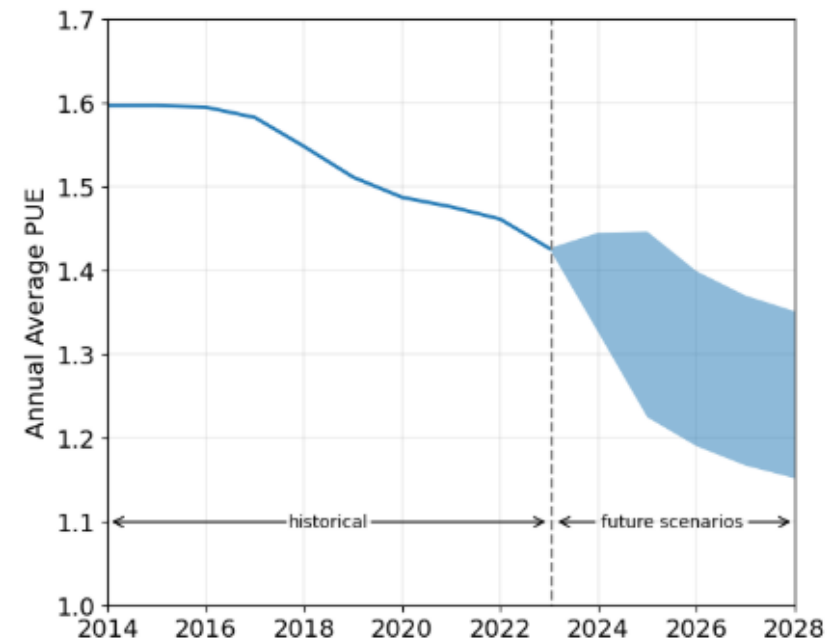


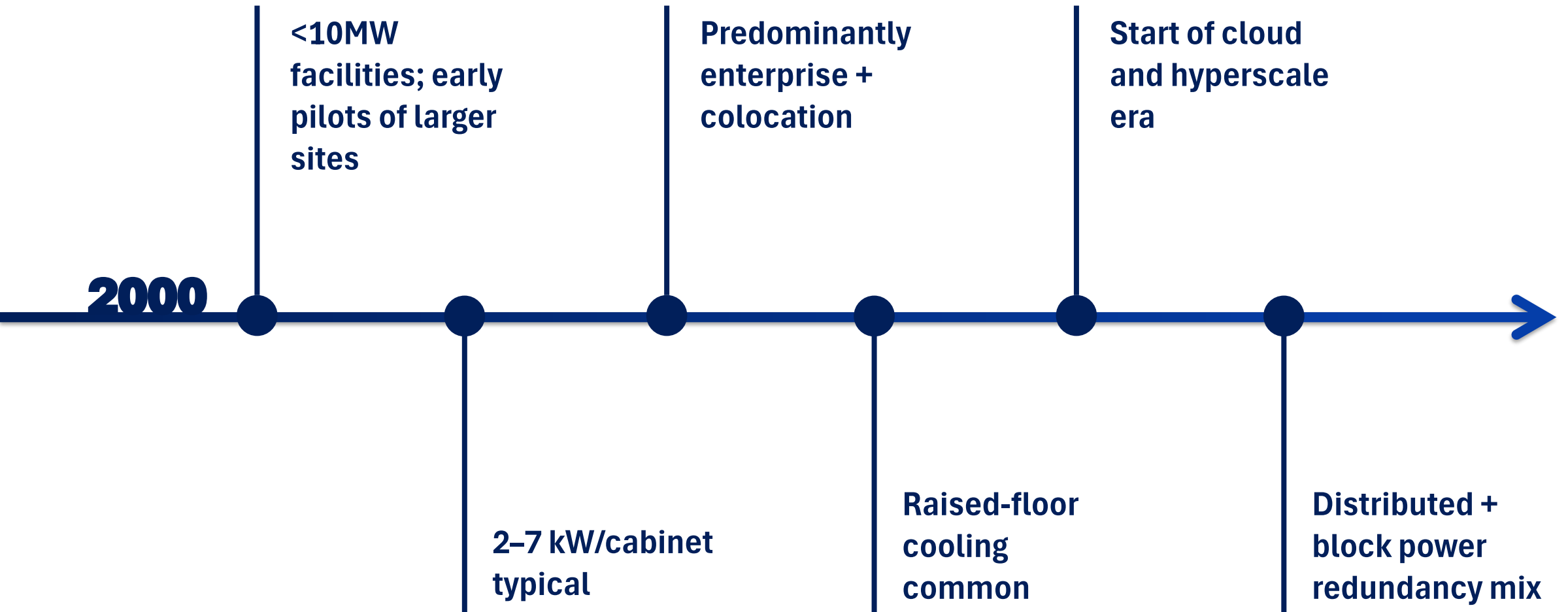
Figure 4.6. Annual average PUE across all U.S. data centers.



# Data Centers Through the Decades



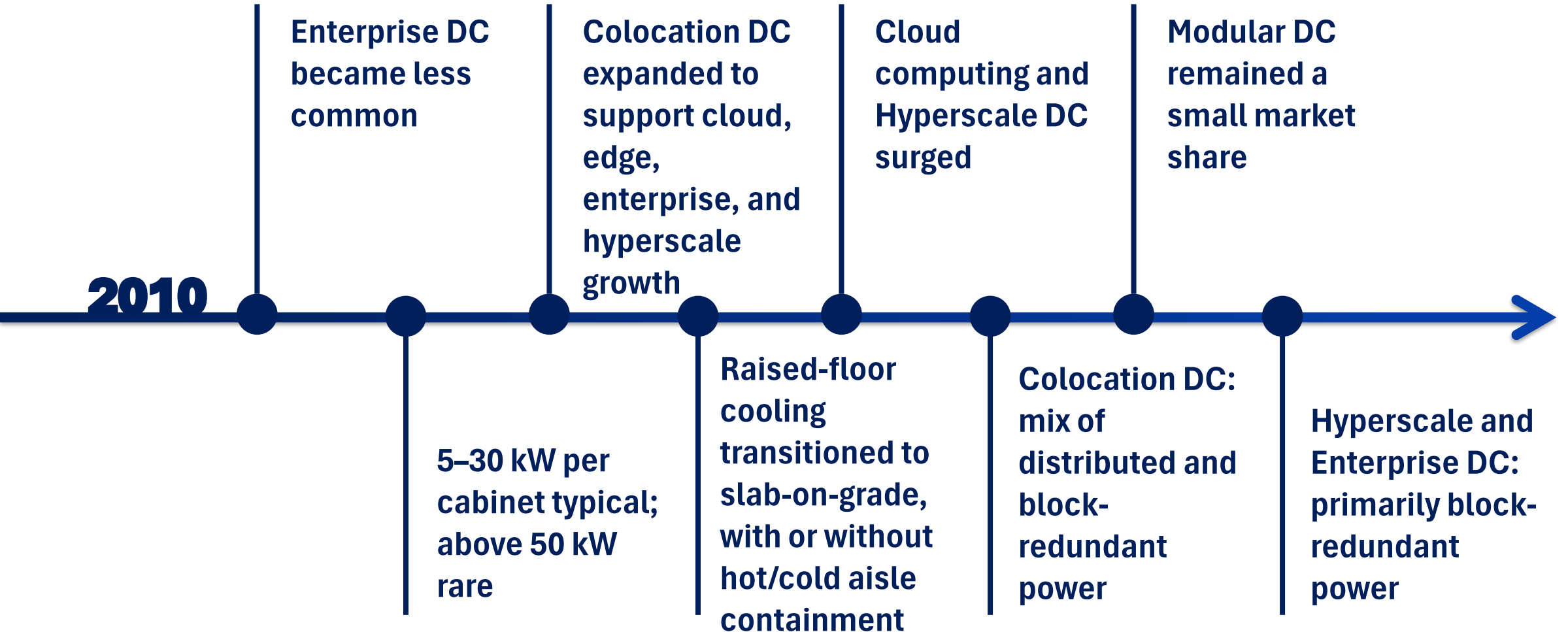
## *2000s: Sub-10MW Data Centers Dominate as Larger Pilots Emerge*



# Data Centers Through the Decades



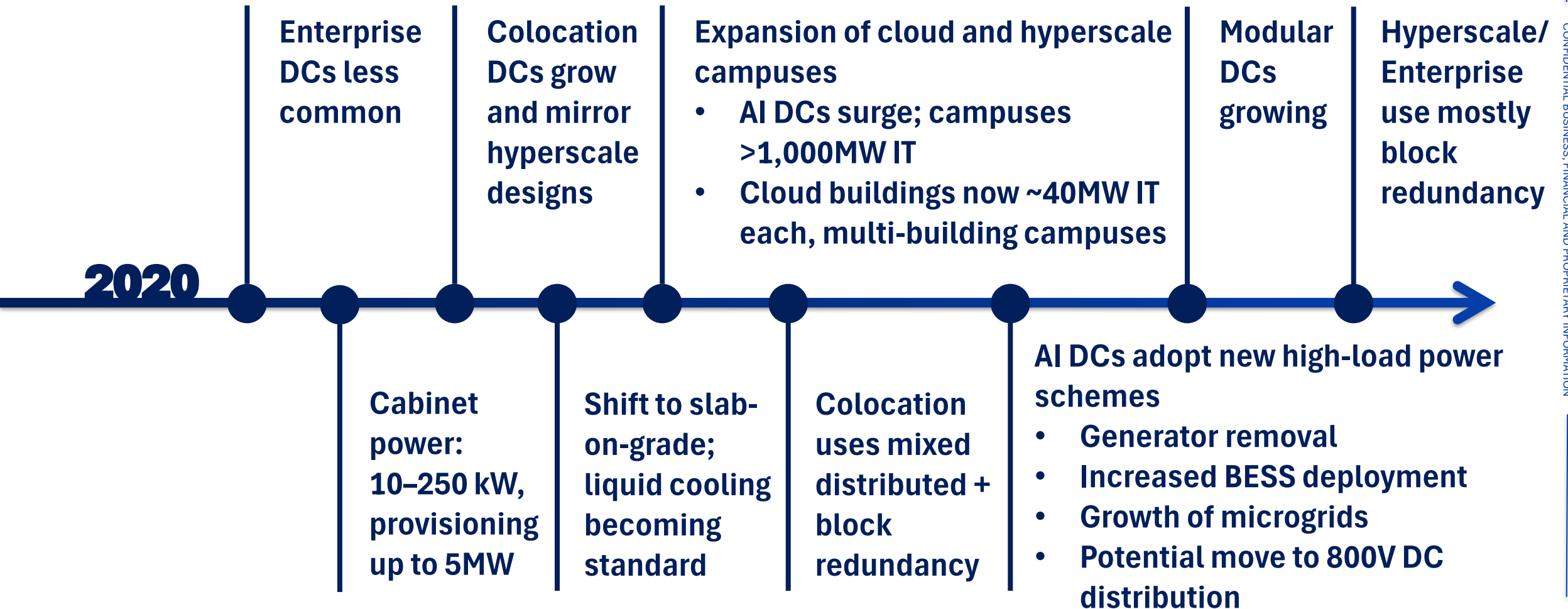
## 2010s: The Rise of Hyperscale Data Centers



# Data Centers Through the Decades



## *2020s: Explosive AI-Driven Growth and Mega Hyperscale Development*



# HVAC Deployment

## Types:

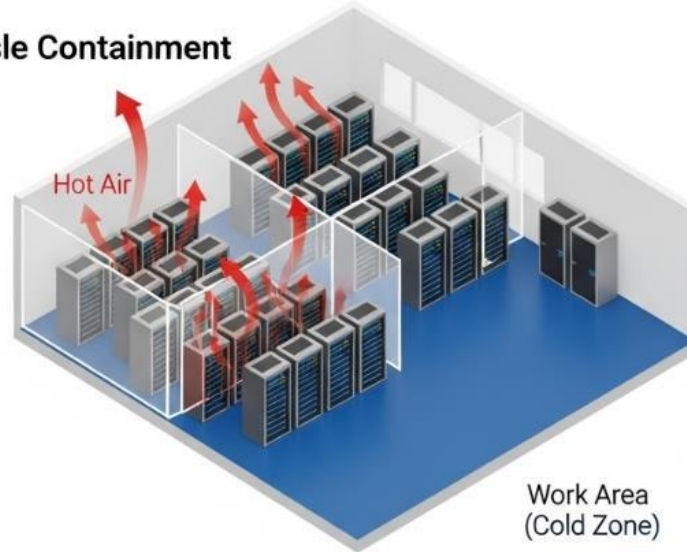
- Raised Floor
- Slab on Grade
- Hot Aisle Containment
- Cold Aisle Containment
- In Row Coolers
- Liquid to Chip
- Immersion Cooling



# Hot Aisle vs. Cold Aisle Containment

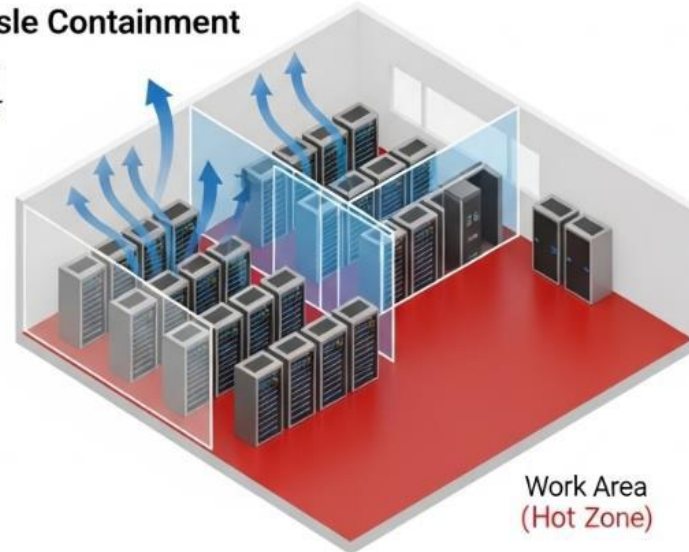


Hot-Aisle Containment



Cold-Aisle Containment

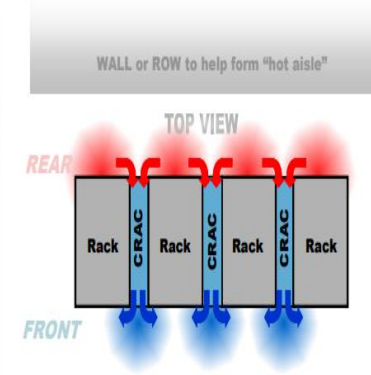
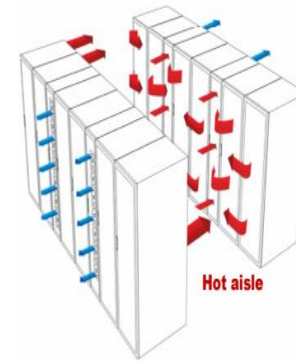
- Hot Air
- Cold Air



# In Row and Cabinet Level Cooling



**Figure 4**  
Illustration of row coolers distributed across a row of racks



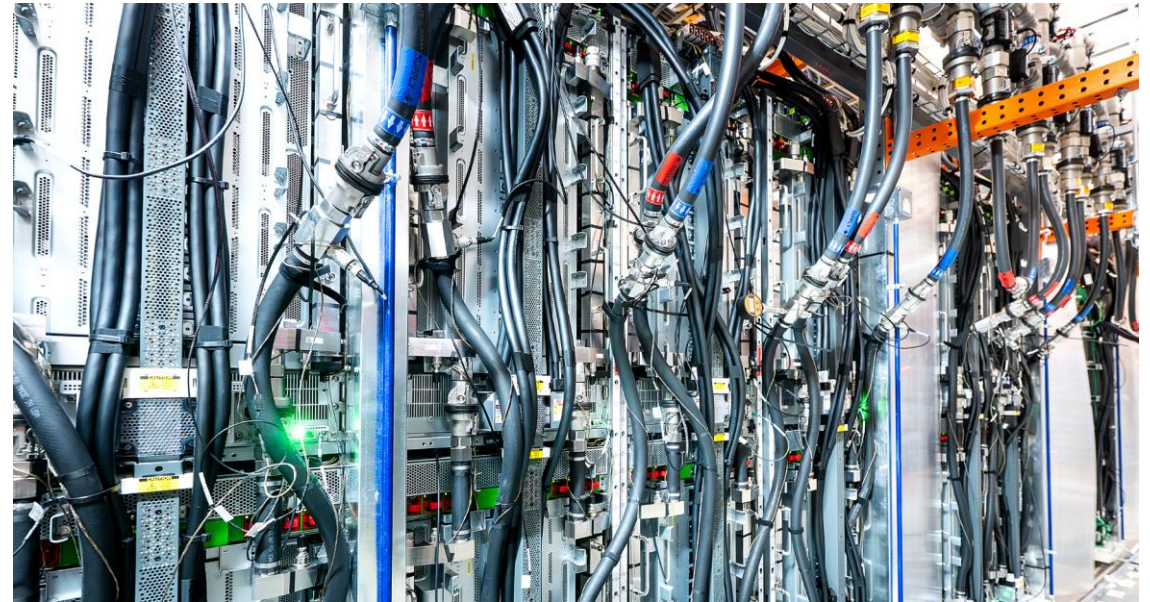
# Liquid to Chip Cooling



Technical Water to CDU (Coolant Distribution Unit)



CDU distributes water to rack for cooling





# Questions