

Introduction to Datacenters

Explore the Heart of the Digital World!



Supported by **Microsoft Datacenter Academy**

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Welcome to the Datacenter Academy!

Explore the essential infrastructure powering the digital world

Learn about:

- Datacenter evolution, design, and operations
- Key hardware: Servers, storage, and networks
- Sustainability and innovation in the industry

Discover career pathways in a growing, high-demand field

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1. Introduction to Datacenters

1.1 Overview

1.2 History of Datacenters

Summary

Overview: This module covers the basics of datacenters—what they are, why they exist, and their critical role in modern IT infrastructure.

01

Explore

The evolution of datacenters from mainframes to the cloud.

02

Look

At different types of datacenters, such as enterprise, colocation, cloud, and edge datacenters.

03

Discover

The core components that make up a datacenter, including power supply, cooling, and security.

By the end, you'll have a clear understanding of the purpose and structure of datacenters.

Learning Objectives

Understand what data and a datacenter are, why data matters, and why datacenters exist.

Identify the historical evolution of datacenters from mainframes to the cloud.

Recognize the different types of datacenters and their use cases.

Understand the core components of a datacenter.



1.1 Overview of datacenters

- What are datacenters?
- Why do datacenters exist?
- What are the types of datacenters?
- What are the main components of a datacenter?

Understanding data and datacenters

What is data?

Data refers to information in a structured, unstructured, or semi-structured format that can be stored, processed, and transmitted digitally.

What is a datacenter?

A datacenter is a specialized facility designed to house computers, servers, storage systems, and networking equipment. Its purpose is to provide a secure, reliable, and efficient environment for storing, managing, and processing large amounts of data.



Why do datacenters exist (their role and objectives)?

Without datacenters, many of the services, technologies, and operations we rely on daily would not be possible.

Without datacenters, we would lose access to cloud computing, e-commerce, communication platforms, real-time media streaming, financial services, and many other critical technologies that define our connected world.

Some of the major areas supported by datacenters

Cloud Computing Services

Communication Platforms and Social Media (Including Email)

Online Gaming

Big Data Analytics and Artificial Intelligence (AI)

Web Hosting and Websites

IoT (Internet of Things) Ecosystem

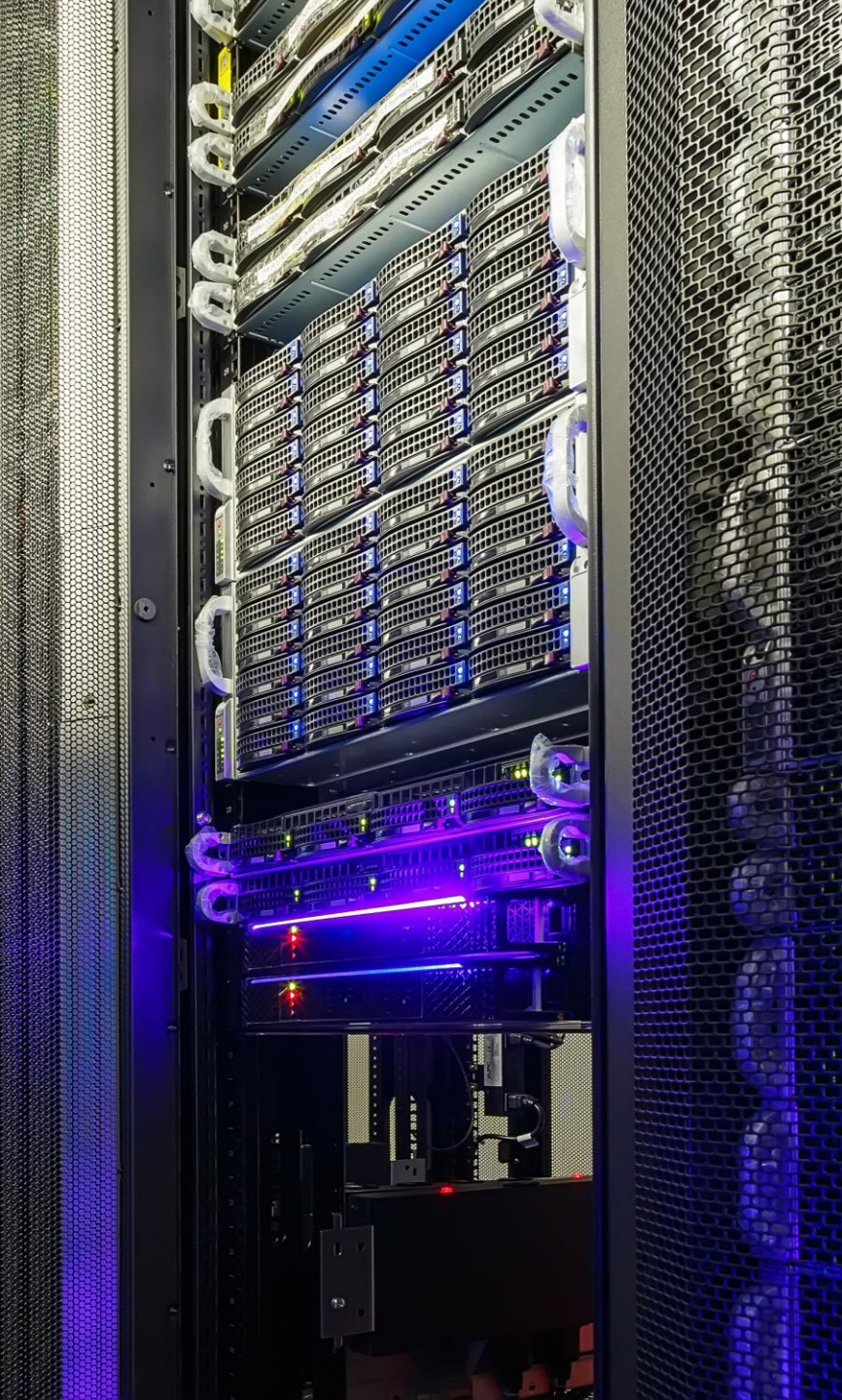
Streaming Services

Online Education and Remote Work

Online Banking and Financial Transactions

Healthcare and Telemedicine

E-Commerce and Online Retail



Types of datacenters

Datacenters come in various forms, each designed to meet specific needs and requirements.

Datacenter types we'll explore:

- Enterprise datacenter
- Colocation datacenter
- Cloud datacenter
- Edge datacenter
- Hyperscale datacenter
- Managed services datacenter
- Software-defined datacenter (SDDC)

Enterprise datacenter



These are privately owned and operated by a single organization to support its business operations. Designed for internal use, offering high customization and control over infrastructure and security.

Example: A corporate datacenter that supports a bank's online transactions:
JPMorgan Chase Data Center

Colocation datacenter



These facilities lease (rent out) space, power, cooling, and networking to multiple organizations. Ideal for businesses that want to avoid building and maintaining their own datacenters but still need reliable infrastructure.

Example: Companies renting server racks in a third-party facility such as Equinix, Digital Realty, NTT Global Data Centers.

Cloud datacenter



These are operated by cloud service providers and deliver services like computing, storage, and applications over the internet. Designed for scalability and flexibility, enabling organizations to pay only for the resources they use.

Example: Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform

Edge datacenter



Smaller, distributed datacenters located close to users or devices to reduce latency and improve performance. They support real-time applications like IoT, autonomous vehicles, and streaming.

Example: Amazon Web Services (AWS) Wavelength

Hyperscale datacenter



Massive facilities operated by tech giants to handle extremely high levels of data and compute capacity. They are optimized for cloud computing and big data analytics with thousands of servers working together. A hyperscale datacenter is much larger in terms of both physical size and computing capacity than a usual datacenter.

Example: Datacenters owned by Meta, Google, Microsoft or Amazon

Software-defined datacenter (SDDC)



A datacenter where all key infrastructure components—compute, storage, networking, and security—are virtualized and managed through software. Physical hardware still exists but is abstracted and controlled programmatically. SDDCs provide greater flexibility, scalability, and automation, enabling organizations to quickly adapt to changing workloads and reduce operational complexity.

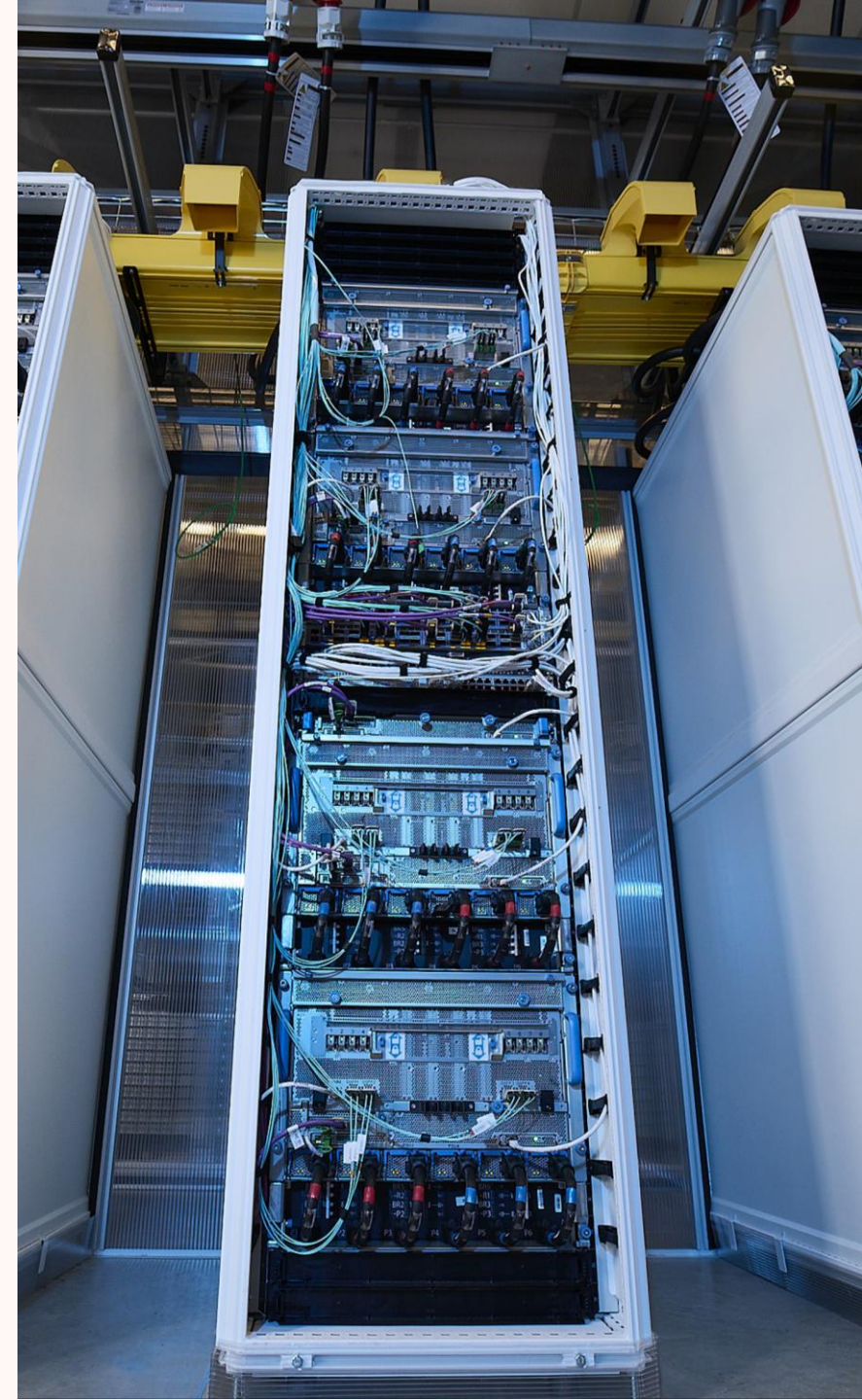
Example: A cloud-based datacenter where virtual machines (VMs), software-defined storage (SDS), and software-defined networking (SDN) are centrally managed through tools like VMware vSphere or Microsoft System Center.

Datacenter components: Computing resources

Servers: The backbone of a datacenter, handling computations, data processing, and application hosting.

Virtual Machines (VMs) and Containers: Software-defined computing units that optimize resource utilization.

High-Performance Computing (HPC) Systems: Advanced servers for handling demanding tasks like AI, simulations, and analytics.



Datacenter components: Storage systems



Hard disk drives (HDDs) and solid-state drives (SSDs): Used for storing data in various formats.

Storage area networks (SANs): High-speed networks that connect storage devices to servers.

Network-attached storage (NAS): Dedicated file storage connected to the datacenter network.

Cloud-based storage: Integrated cloud solutions for scalability and flexibility.

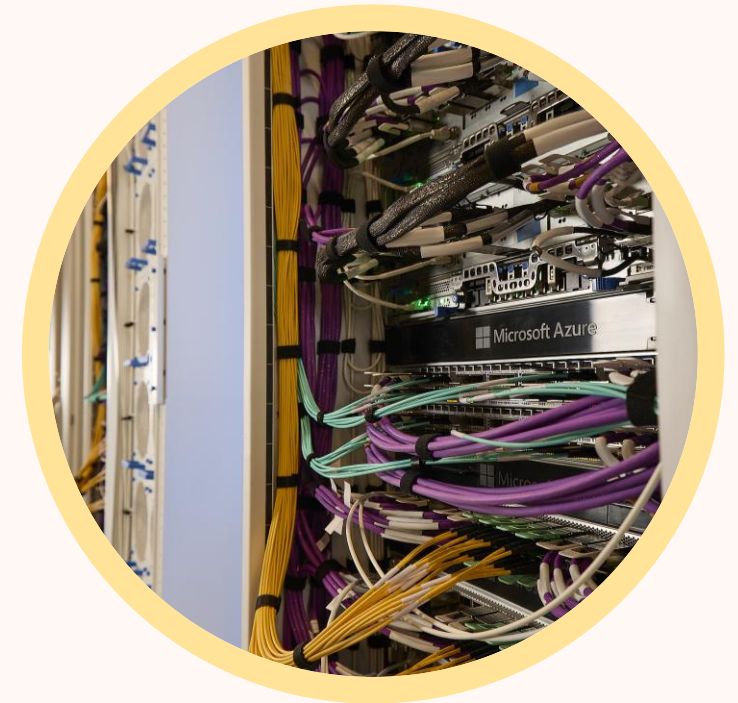
Datacenter components: Networking infrastructure

Switches and routers: Facilitate communication between devices within and outside the datacenter.

Firewalls: Protect the datacenter from unauthorized access and cyber threats.

Load balancers: Distribute network traffic across servers to optimize performance and reliability.

Cabling: High-speed fiber optics and Ethernet cables to connect components.





Datacenter components: Power and cooling systems

Uninterruptible power supplies (UPS): Provide backup power during outages.

Power distribution units (PDUs): Manage and distribute electrical power to datacenter equipment.

Cooling systems: Include air conditioning, liquid cooling, and airflow management to maintain optimal operating temperatures.

Generators: Ensure power continuity during extended outages.

Datacenter components: Physical infrastructure



Racks and enclosures: Physical frameworks to house servers and storage devices.

Raised floors: Allow cabling and cooling systems to run beneath equipment.

Buildings and facilities: Purpose-built structures designed for security, scalability, and environmental control.

Datacenter components: Security systems

Physical security: Includes surveillance cameras, biometric access controls, and security personnel.

Cybersecurity tools: Firewalls, intrusion detection systems, encryption, and endpoint security.

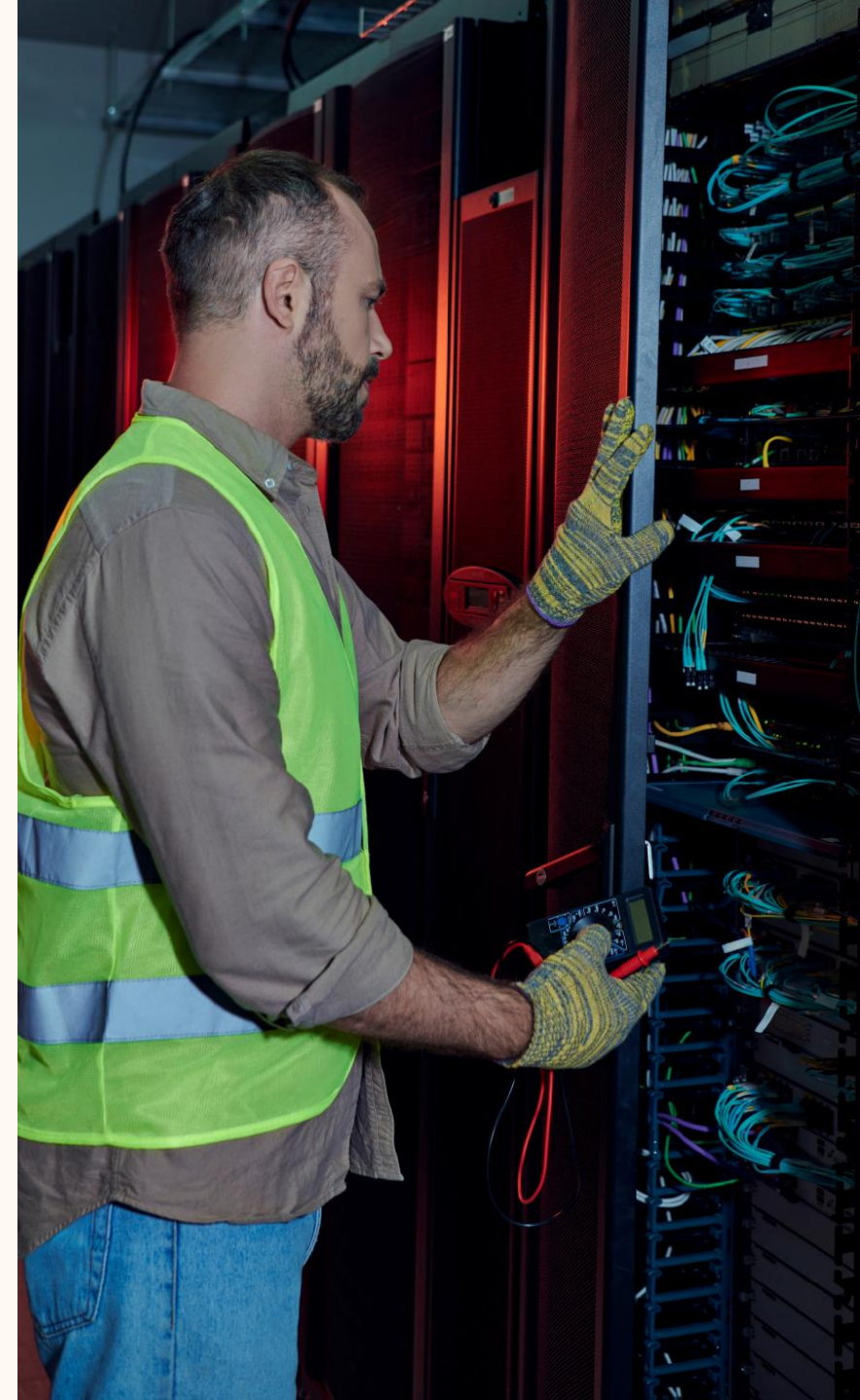


Datacenter components: Management and monitoring tools

Datacenter infrastructure management (DCIM) software: Provide visibility into physical and IT resources.

Monitoring systems: Track performance, power usage, and environmental conditions.

Automation tools: Enable efficient resource management and predictive maintenance.





Datacenter components: Software

Software is a critical component of a datacenter, but its role differs from that of physical infrastructure.

Types of software critical to datacenters:

- Operating systems (OS)
- Virtualization software
- Datacenter infrastructure management (DCIM) software
- Networking software
- Storage management software
- Automation and orchestration tools



1.2 History of datacenters

- What are the major milestones in datacenter history?
- What are the key aspects of the datacenter industry and market?
- What's driving the growth of datacenters?

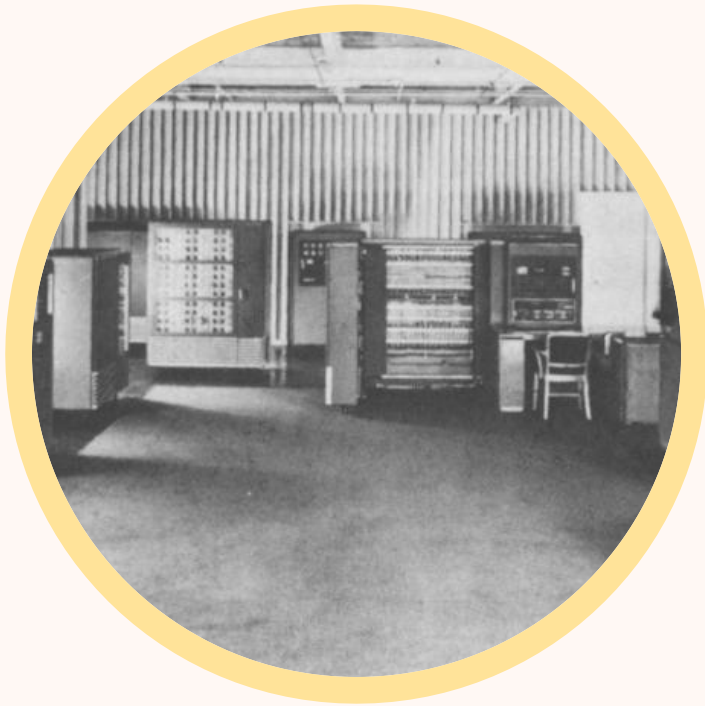


The history of datacenters

The history of datacenters is closely linked to the development of computing technology, the internet, and the increasing demand for data storage and processing.



Early computing (1940s - 1950s)



Mainframes and early computing:

In the 1940s, J. Presper Eckert and John Mauchly were the primary inventors of the world's first data center, the Electronic Numerical Integrator and Computer (ENIAC). Though the first "datacenters" didn't exist in the modern sense, large mainframe computers were housed in controlled environments to handle data processing. These mainframes were typically stored in research facilities or corporate locations.

Challenges:

- Early computing systems were huge, expensive, and required specialized conditions
- Data processing was limited

The birth of modern datacenters (1960s - 1970s)

As computing technology improved, organizations needed better ways to store and manage the growing amount of data.

- **Mainframe storage**
- **Cooling and power management**





Growth and expansion of commercial datacenters (1980s)

First commercial datacenters

As the internet grew, businesses began to see the value of dedicated data storage and processing centers. This marked the rise of commercial datacenters.

Client-server architecture

The shift from mainframe computing to client-server architectures began.

Internet explosion and the dot-com boom (1990s)



Internet and web hosting: As the internet exploded in popularity during the dot-com boom, there was a massive demand for web hosting and storage.

The rise of colocation services: Colocation became popular. In this model, businesses started renting out space within a large facility to house their own servers and IT infrastructure, thus sharing power, cooling, and internet connectivity.

The birth of commercial datacenters: While mainframe computers and client-server architectures were already in use by the late 1980s and early 1990s, the true rise of commercial datacenters came with the explosion of the internet and web hosting services in the mid-to-late 1990s, during the dot-com boom.

Early network connectivity: By the late 1990s, fiber-optic cables and high-speed internet connections started making their way to datacenters, significantly improving the speed and capacity for data transmission.

The Cloud Era and Virtualization (2000s)

Virtualization technology: The introduction of virtualization (by companies like VMware and Microsoft) allowed multiple virtual machines to run on a single physical server, dramatically improving efficiency, scalability, and resource utilization.

Cloud computing emerges: Major players like Amazon (AWS), Microsoft (Azure), and Google began offering cloud computing services, which essentially turned their datacenters into vast, distributed networks of servers that could provide storage, computing power, and software as a service over the internet.



Software-defined datacenters and hyper-scale growth (2010s)

Software-defined infrastructure (SDI): The introduction of software-defined networking (SDN) and software-defined storage (SDS) transformed traditional hardware-based datacenters into software-defined datacenters (SDDCs).

Hyper-scale datacenters: Hyperscale datacenters, operated by companies like Amazon, Google, Meta, and Microsoft, became the backbone of the cloud computing revolution.

Energy efficiency and sustainability: The focus on energy-efficient designs became critical, as massive datacenters consume notable amounts of electricity.



The current state and future trends (2020s and beyond)



Edge computing: Edge datacenters are emerging as the next frontier. These smaller datacenters are located closer to users and devices to reduce latency and provide real-time processing for applications.

AI and automation: Datacenters now use advanced technologies such as artificial intelligence (AI) and machine learning (ML).

Sustainability and green datacenters: With increasing awareness of environmental impact, datacenters are becoming more sustainable.

The datacenter industry and market: Trends, drivers, and size

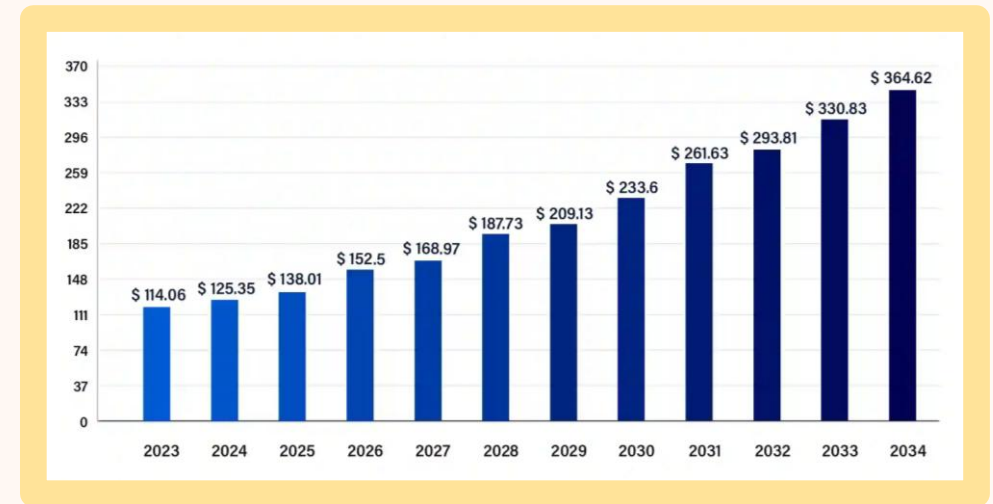


The datacenter industry is growing faster than ever.

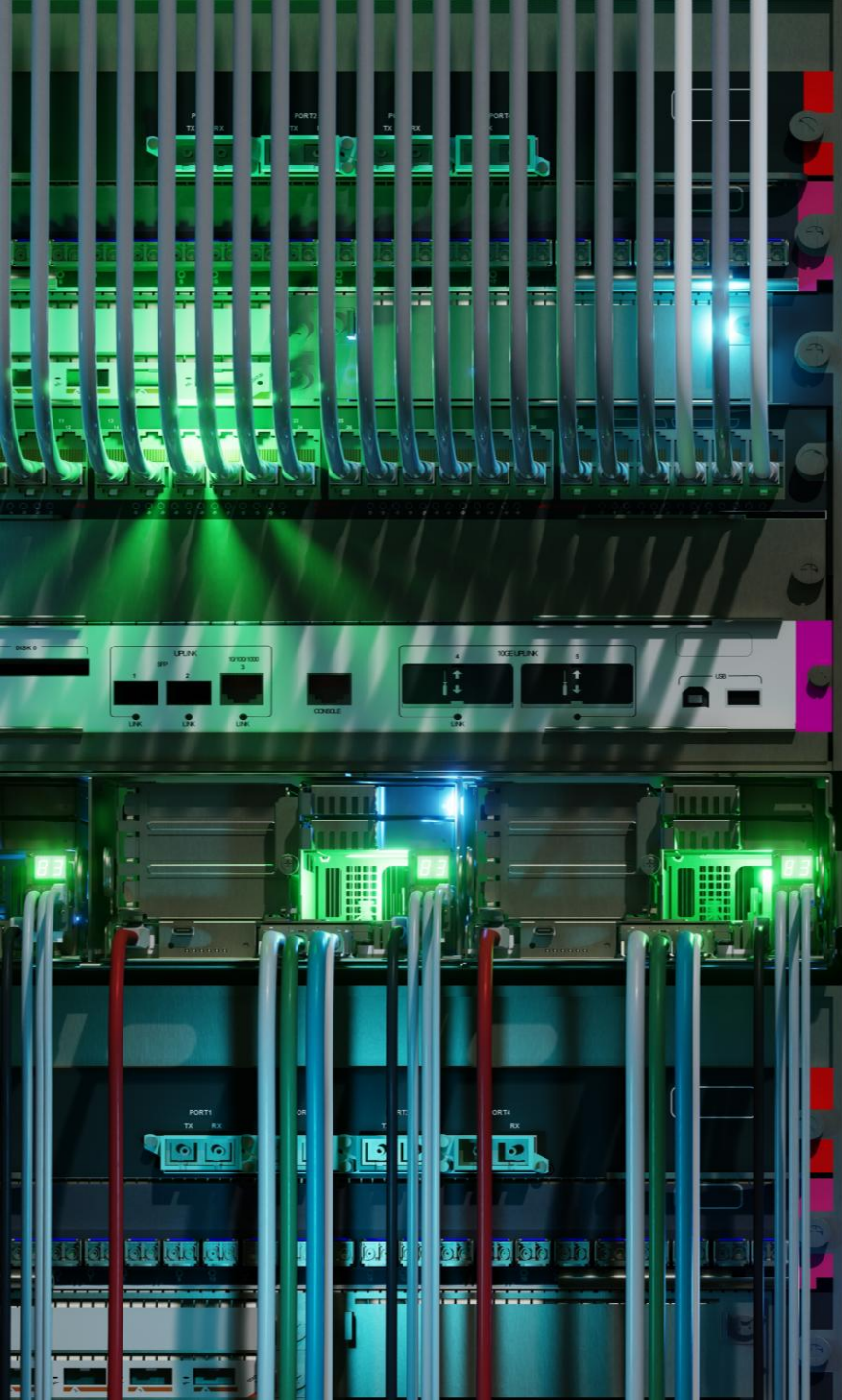
How big is the datacenter market?

In 2023, the global datacenter market was worth about \$123.6 billion. To put that into perspective, that's more than the entire economy of some countries!

By 2030, experts predict the datacenter market will more than double in size to \$354 billion. This is happening because more people are using the internet, and more companies need to store and process tons of data.



Source: Data Center Market Size To Hit Around USD 364.62 Bn by 2034



What's driving the growth of datacenters?

Several key things are making datacenters even more important in 2025:

- AI and heavy computing
- Green and renewable energy
- Cooler, smarter datacenters
- More investment in datacenters
- New locations for datacenters

Why does this matter?

The growth of the datacenter industry is closely tied to almost every digital service you use.

Sustainability is also a big part of the future. As more companies look to reduce their environmental impact, you might see tech companies and cloud services focusing even more on using green energy.

Megawatts (MW)

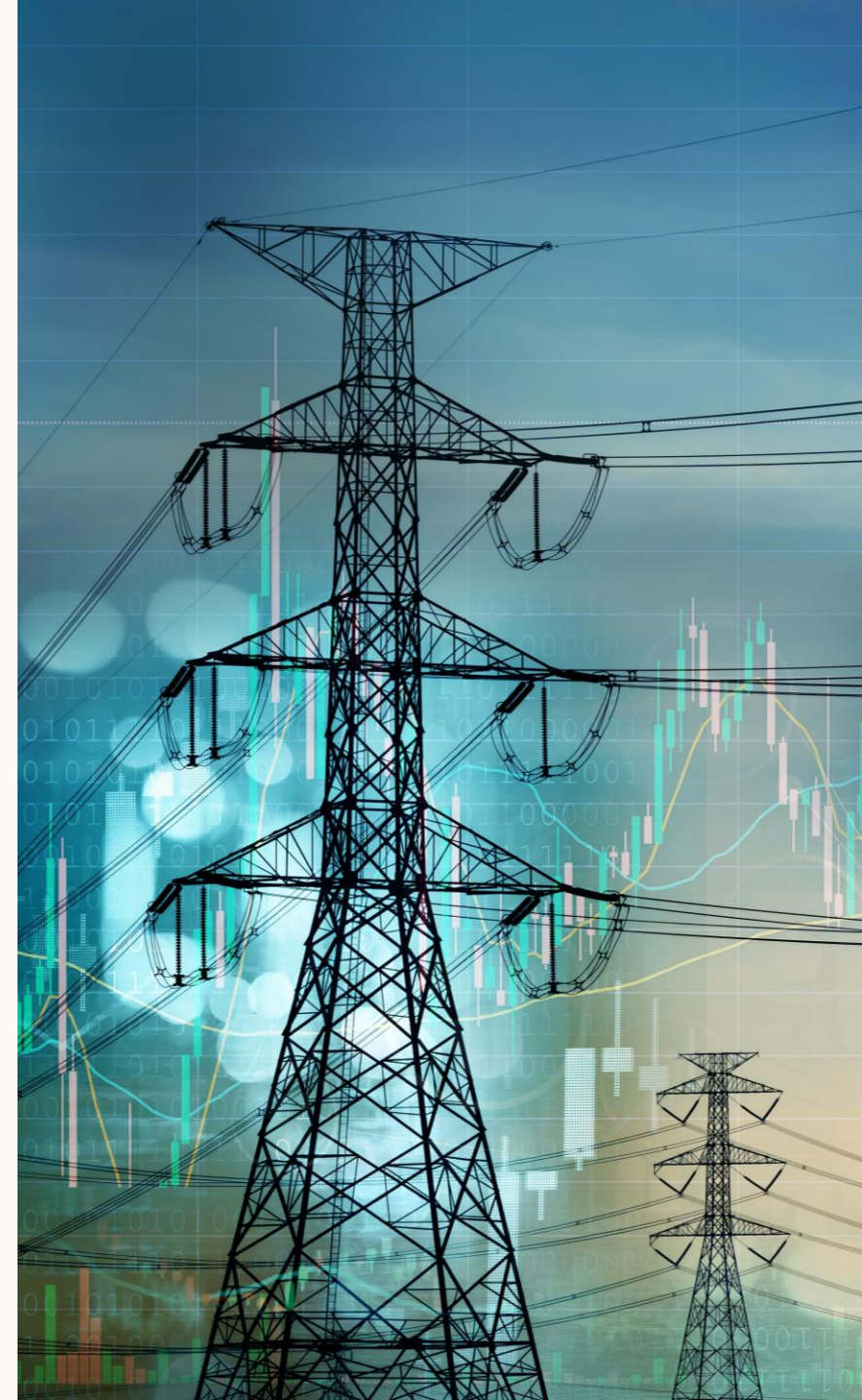


Megawatts measure the power capacity of the datacenter, while square feet measure its physical space.

A typical datacenter can consume hundreds of megawatts per year, with large hyperscale facilities using between 20-50MW annually, meaning a single datacenter can use significantly more energy than thousands of average households combined.

Why megawatts (MW) is the more relevant unit for discussing datacenter size

1. Power consumption is key for datacenters
2. Square feet alone don't tell the full story
3. Efficiency and power density
4. Industry standard for power consumption



Knowledge Check

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Review:

Introduction to datacenters

- ✓ Understand what data and a datacenter are, why data matters, and why datacenters exist.
- ✓ Identify the historical evolution of datacenters from mainframes to the cloud.
- ✓ Recognize the different types of datacenters and their use cases.
- ✓ Understand the core components of a datacenter.

2. Datacenter Design and Architecture

2.1 Site selection and design

2.2 Critical infrastructure

2.3 Network architecture

2.4 Health and safety considerations in datacenters



Summary

Overview: This module covers the key factors of datacenter design, delving into why they are crucial for building a reliable, scalable, and efficient infrastructure.

01

Learn

About site selection considerations such as power availability, climate, and risks from natural disasters

02

Look

At the layout of a datacenter, covering important elements like topologies, IT infrastructure, and space allocation

03

Gain

An understanding of critical infrastructure such as power systems, cooling, and cabling design

By the end, you'll understand the importance of a well-designed datacenter.

Learning Objectives

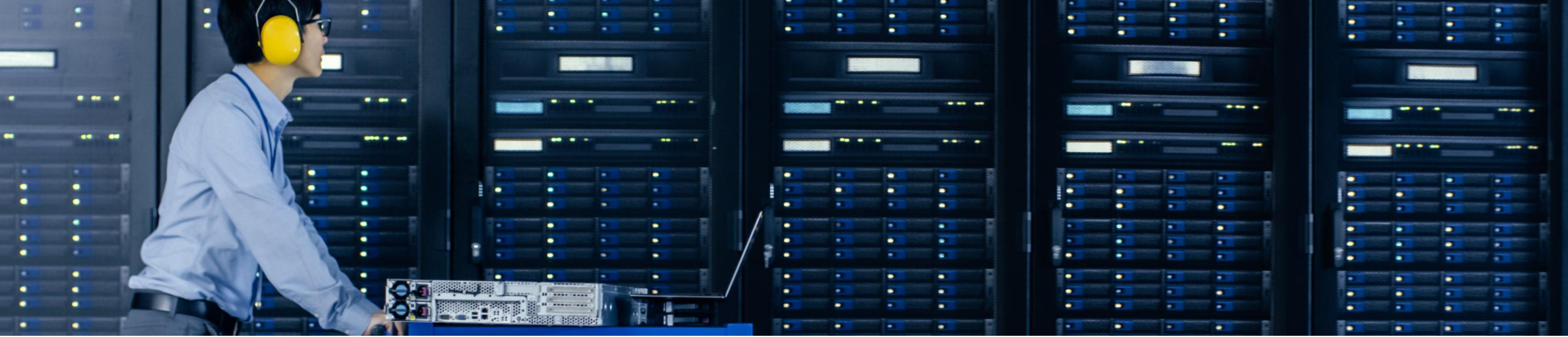
Learn the factors involved in site selection for a datacenter, including power, climate, and natural disaster risks.

Understand the different datacenter topologies and network architecture.

Grasp the importance of critical infrastructure, such as power and cooling systems, in datacenter design.

Learn about Data Center Infrastructure Management (DCIM) and Building Management Systems (BMS) and their role in datacenter monitoring.

Identify key health and safety considerations, including fire protection systems, emergency lighting, and security protocols.



2.1 Site selection and design

- What are key factors in site selection?
- What are subsea cables and their impact?
- What are the key components to datacenter layout and design?
- What are the key zones on the datacenter floor plan?
- What makes up datacenter space?
- What are physical security measures?



Why are datacenters located in specific areas and not others?

A primary reason is whether or not areas have critical datacenter resources like reliable power, stable telecommunications networks, and cooling options.

By carefully selecting the **right location** and **designing the facility thoughtfully**, datacenters can deliver reliable performance, maintain uptime, and scale as needed while minimizing risks and keeping costs manageable.

Key factors in site selection

- Connectivity and proximity
- Infrastructure availability
- Local regulations and permits
- Climate considerations
- Natural disaster risks
- Regulatory compliance and tax incentives
- Security



Subsea cables and its impact on network architecture



Benefits of subsea cables for datacenters can include:

Enhanced performance

Cost efficiency

Scalability

Global reach

Datacenter layout and design



Single-story and multi-story datacenters

Single-story datacenters have been the standard for a long time due to their simpler infrastructure management, easier maintenance, and lower costs.

However, as urban areas face increasing land constraints and higher real estate prices, there's been a shift towards multi-story datacenters.

Datacenter layout and design: Advantages



Single-story datacenters

- Easier layout planning
- Accessibility
- Cooling efficiency
- Cost-effectiveness
- Power distribution
- Scalability
- Security and fire risk management

Multi-story datacenters

- Efficient use of space
- Scalability in tight areas
- Reduced latency in edge deployments
- Energy efficiency opportunities

Datacenter layout and design: Challenges



Single-story datacenters

- Land requirements
- Security perimeter

Multi-story datacenters

- Complex cooling and power systems
- Structural considerations
- Accessibility



Subsea datacenters

Subsea datacenters are an innovative concept that places computing infrastructure under water, usually on the ocean floor.

Subsea datacenters: Advantages and challenges

While subsea datacenters have exciting potential, they typically face more challenges than benefits.

However, this innovative technology is still in early stages and developing, so it may become more feasible in the future with advancements in underwater infrastructure and maintenance capabilities, potentially making it a viable solution in specific situations.



Subsea datacenters: Advantages



Enhanced cooling efficiency

Space utilization

Eco-friendly potential

Proximity to coastal populations

Subsea datacenters: Challenges



Deployment and maintenance

Reliability concerns

Infrastructure longevity

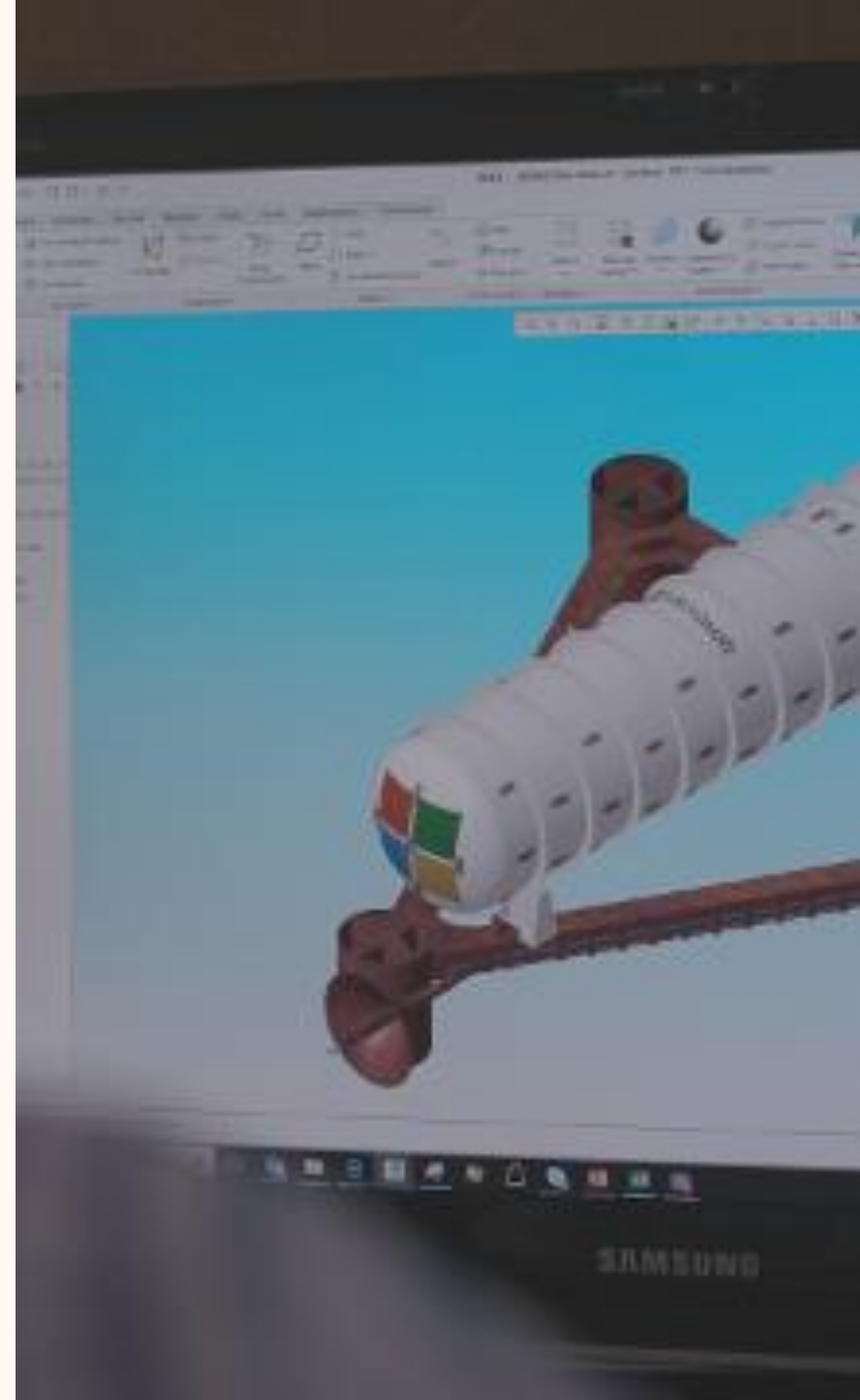
Limited redundancy

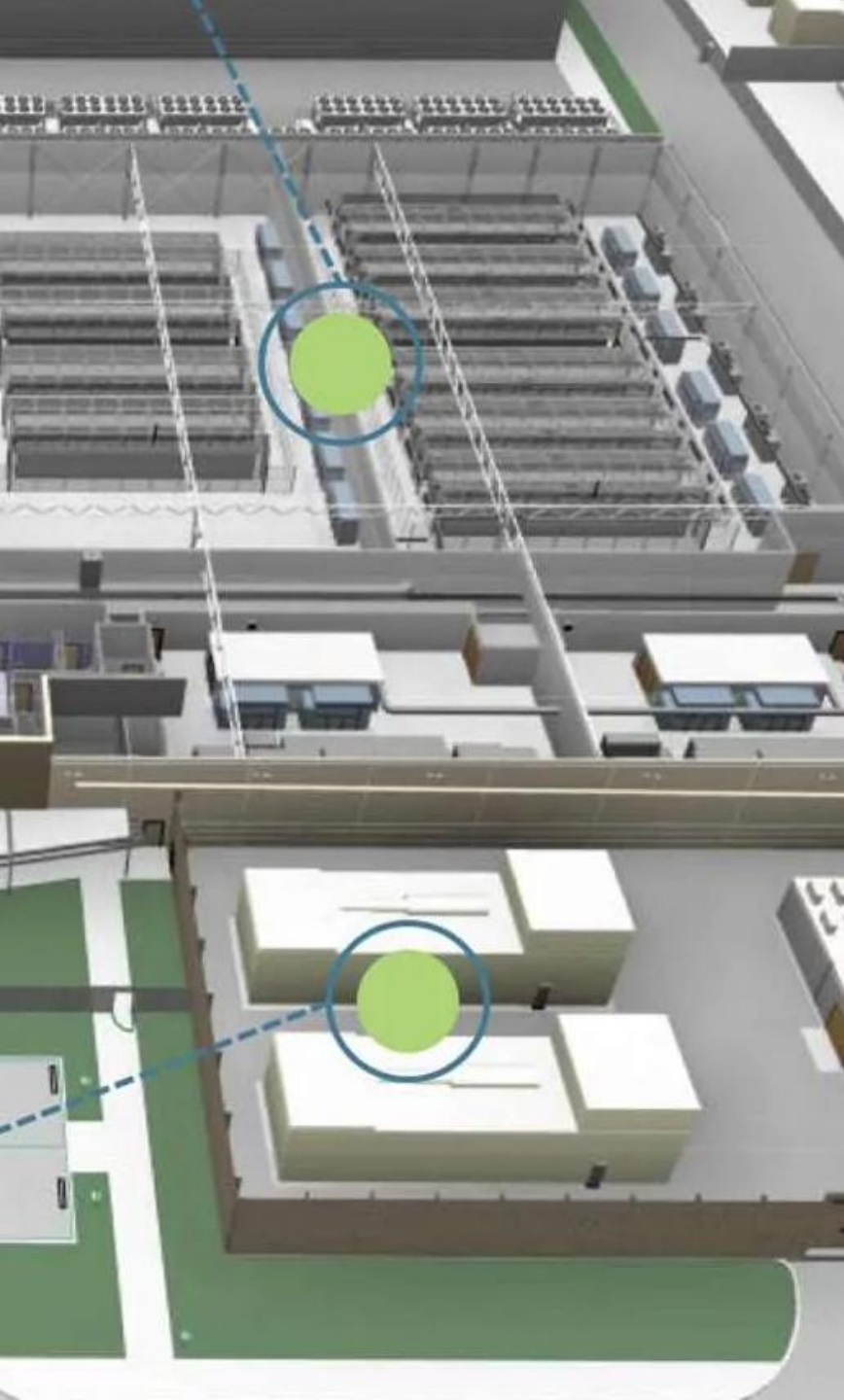
Specialized expertise

Power distribution

Examples of subsea datacenter projects

- Microsoft Project Natick
- Nautilus Data Technologies
- Baidu's Underwater AI Facility





Key zones on the datacenter floor plan

White space: Refers to the areas in a datacenter that are dedicated to IT equipment, such as servers, racks, storage devices, and networking equipment.

Grey space: Refers to areas within a datacenter that are non-IT space but still play a crucial role in supporting the IT infrastructure.

Common datacenter topologies



Centralized Topology

Top-of-Rack (ToR) Topology

Zoned Topology

Multi-Tier Topology

Uptime and tier classification system



There are four levels (Tiers I to IV), each offering different uptime guarantees and redundancy (backup systems).

Tier I: Basic Infrastructure
(Low Reliability)

Tier II: Partial Redundancy
(Moderate Reliability)

Tier III: Concurrently Maintainable
(High Reliability)

Tier IV: Fault-Tolerant (Very High Reliability
Deployment and maintenance)

Datacenter space

A well-thought-out physical infrastructure provides a stable, secure platform for IT equipment, ensuring optimal performance and reliable support for business operations.

- Start with evaluating the **space necessary** to house CE and IT equipment, including servers, storage systems, networking devices, and other essential hardware.
- Efficient **rack layout design** is essential for optimizing space utilization, airflow, and maintenance accessibility.
- The **cabling infrastructure** acts as the backbone of a datacenter, linking all CE and IT equipment and enabling data transfer.



Physical security measures



Establishing strong physical security measures is crucial to safeguarding critical CE and IT infrastructure from unauthorized access. These measures may include security fencing, access control systems, video surveillance, and intrusion detection systems. The specific security protocols implemented will depend on the sensitivity of the data stored in the datacenter and any relevant industry regulations that must be followed.

IT infrastructure design



Identifying key IT infrastructure design requirements

Selecting the right hardware

Optimizing placement for performance & maintenance

Impact on energy consumption & operational costs

Futureproofing for growth



2.2 Critical infrastructure

- What are the key components of critical infrastructure in a datacenter?



Understanding critical infrastructure

Critical infrastructure in a datacenter is designed with redundancy, resilience, and fault tolerance to maintain uptime, even in the event of failures or disasters.

Key component: Power supply systems



Electrical substations

Uninterruptible power supply (UPS)

Backup generators

Power distribution units (PDU)

Power cabling and circuitry

Key component: Cooling systems



- HVAC (heating, ventilation, and air conditioning systems)
- Chillers and cooling towers
- Computer room air conditioning (CRAC) units
- Chilled water systems
- Cooling distribution units (CDU)

Key component: Networking and communication systems

- Data network infrastructure
- Fiber optic cables
- Redundant network paths
- Network security devices



Key component: Security systems



Physical security

Access control systems

Video surveillance

Alarm systems

Key component: Data storage and backup systems

Data storage arrays

Backup solutions

Replication systems





Key component: Fire suppression and environmental monitoring

- Fire suppression systems
- Smoke detectors

Key component: Facility and building infrastructure

Building structural integrity

Raised flooring

Ceiling systems



Key component: Redundancy and resilience systems



N+1, 2N, and 2(N+1) redundancy

Tier classification

Key component: Monitoring and management systems



Building Management Systems (BMS)

Data Center Infrastructure Management (DCIM)



Key component: Disaster recovery systems



Disaster recovery (DR) solutions

Contingency planning



2.3 Network architecture

- What are the layers of datacenter network architecture?



Network architecture: Access layer



What it is	The access layer is the entry point for devices, servers, and end-user systems into the datacenter network. It connects the devices (like servers and storage) to the network infrastructure.
Impact on design	• The access layer must support high-density connectivity with minimal latency and high throughput. • Network switches at this layer often have port redundancy to avoid single points of failure and ensure network reliability. • The design must accommodate high-performance servers, which may require multiple connections for load balancing and fault tolerance.
Performance	Must support high-throughput and low-latency connections to servers and devices.
Redundancy and high availability	Implementing dual-homed servers (multiple network connections to access switches) is common to ensure uptime if one connection fails.
Scalability	Network connections must be easily scalable to handle increasing numbers of devices.
Security	Typically involves VLANs (Virtual Local Area Networks) to segment traffic and limit access to critical resources.

Network architecture: Aggregation layer



What it is	The aggregation layer consolidates traffic from the access layer and routes it to the core layer. It also provides advanced services like firewalling, load balancing, and traffic filtering.
Impact on design	• It serves as a point of control for managing data flows between the access and core layers. • Traffic optimization and redundancy are critical considerations to ensure high performance and availability. Network engineers often design this layer with the capability to scale efficiently. • The aggregation layer might include firewalls and intrusion prevention systems to protect sensitive data.
Performance	Aggregates traffic efficiently without creating bottlenecks, often incorporating load balancing or traffic shaping.
Redundancy and high availability	Must be designed with multiple paths to route traffic in case of a failure, ensuring that the datacenter remains operational.
Scalability	Needs to support adding more access switches and services (like firewalls, load balancing) as more devices and traffic are added.
Security	Firewalls, Intrusion Detection/Prevention Systems (IDS/IPS), and other security appliances are placed here to protect data as it moves through the network.

Network architecture: Core layer



What it is

The core layer is responsible for high-speed, low-latency switching between different parts of the datacenter network or between the datacenter and external networks. It connects the aggregation layer to the outside world.

Impact on design

- The core layer should be highly redundant to ensure continuous operation, often using dual-homed connections to avoid single points of failure.
- High-capacity backbone switches are deployed to support the massive volume of data transfer and ensure that the network can handle large amounts of traffic without bottlenecks.
- Low latency and high bandwidth are key requirements to support real-time data processing, especially for applications like cloud computing, video streaming, or gaming.

Performance

Should support extremely high bandwidth and low latency to avoid congestion and provide a high-speed backbone for data transfer across the entire network.

Redundancy and high availability

Core switches are often deployed in pairs to ensure network continuity even during hardware failures.

Scalability

Should be able to scale to accommodate increased bandwidth demand with minimal impact on performance. Often achieved through modular switches that can be upgraded over time.

Security

Firewalls and traffic encryption help secure data as it exits or enters the datacenter and to prevent attacks targeting external connections.



Basic network design principles

Network topology: Datacenter networks are organized using structures like leaf-spine or three-tier architectures, connecting switches, routers, and servers for performance, scalability, and reliability.

Redundancy and high availability: Backup network paths and failover systems minimize downtime during failures.

Scalability: Networks grow to handle increasing data traffic without losing performance.

Core network components



Switches and routers: Core, aggregation, and edge switches connect servers and external networks, efficiently routing traffic.

Load balancers: Spread network traffic across multiple servers for better performance and uptime.

Virtualization and software-defined networking (SDN)



Virtualized networks: Virtualization separates network functions from physical hardware, making networks more flexible and scalable.

SDN: Software-defined networking uses software to manage and automate networks for faster changes and better control.

Security considerations

Network segmentation: Divides networks into zones (e.g., internal, public) to isolate traffic and protect sensitive data.

Firewalls and intrusion systems: Block unauthorized access and detect cyber threats.

Encryption: Keeps data secure during transmission.



Cloud connectivity



Hybrid/Multi-cloud: Datacenters connect to multiple cloud services to expand resources seamlessly.

Direct Connect: Dedicated, fast connections (e.g. AWS Direct Connect) reduce latency for critical applications.

Performance and monitoring



Quality of Service (QoS): Prioritizes important traffic like video calls to maintain speed and reliability.

Network monitoring: Tracks performance and spots problems early with tools like SNMP and Netflow.

Power and cooling integration



Energy efficiency: Efficient switches reduce power use in large data centers.

Thermal management: Proper cooling keeps equipment stable in high-density environments.



2.4 Health and safety considerations in datacenters

- What are the primary health and safety measures in datacenters?



Fire protection systems

Fire protection systems: Fire safety is critical in datacenters due to the high density of electrical equipment, which poses a risk of fire. Effective fire protection systems minimize damage, protect personnel, and ensure business continuity.

- **Fire detection**
- **Fire suppression**
- **Containment strategies**

Emergency lighting



Emergency lighting: In emergencies like power outages or fires, reliable emergency lighting ensures the safe evacuation of personnel and access to critical systems.

Exit signage

Backup lighting systems

Path marking

Security protocols



Security protocols: Security in datacenters protects against unauthorized access, theft, and physical breaches, ensuring the safety of personnel and data.

- **Access control**
- **Surveillance**
- **Physical security measures**
- **Incident response**

Additional health and safety measures



Additional health and safety measures: While fire protection, emergency lighting, and security protocols are key, other considerations further enhance health and safety in datacenters.

- **Temperature and air quality control**
- **Electrical safety**
- **Ergonomics**
- **Emergency evacuation plans**

Knowledge Check

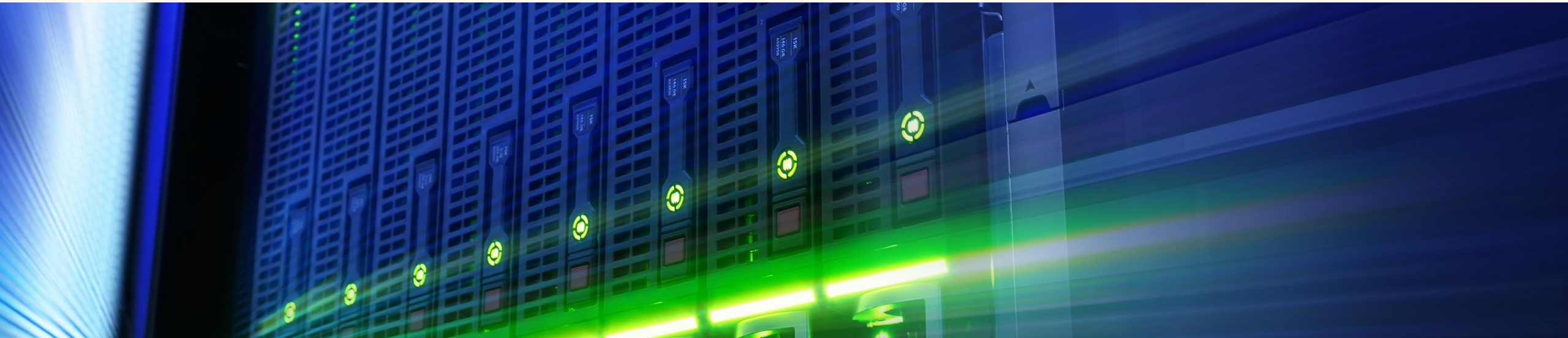
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Review:

Datacenter design and architecture

- ✓ Learn the factors involved in site selection for a datacenter, including power, climate, and natural disaster risks.
- ✓ Understand the different datacenter topologies and network architecture.
- ✓ Grasp the importance of critical infrastructure, such as power and cooling systems, in datacenter design.
- ✓ Learn about Data Center Infrastructure Management (DCIM) and Building Management Systems (BMS) and their role in datacenter monitoring.
- ✓ Identify key health and safety considerations, including fire protection systems, emergency lighting, and security protocols.