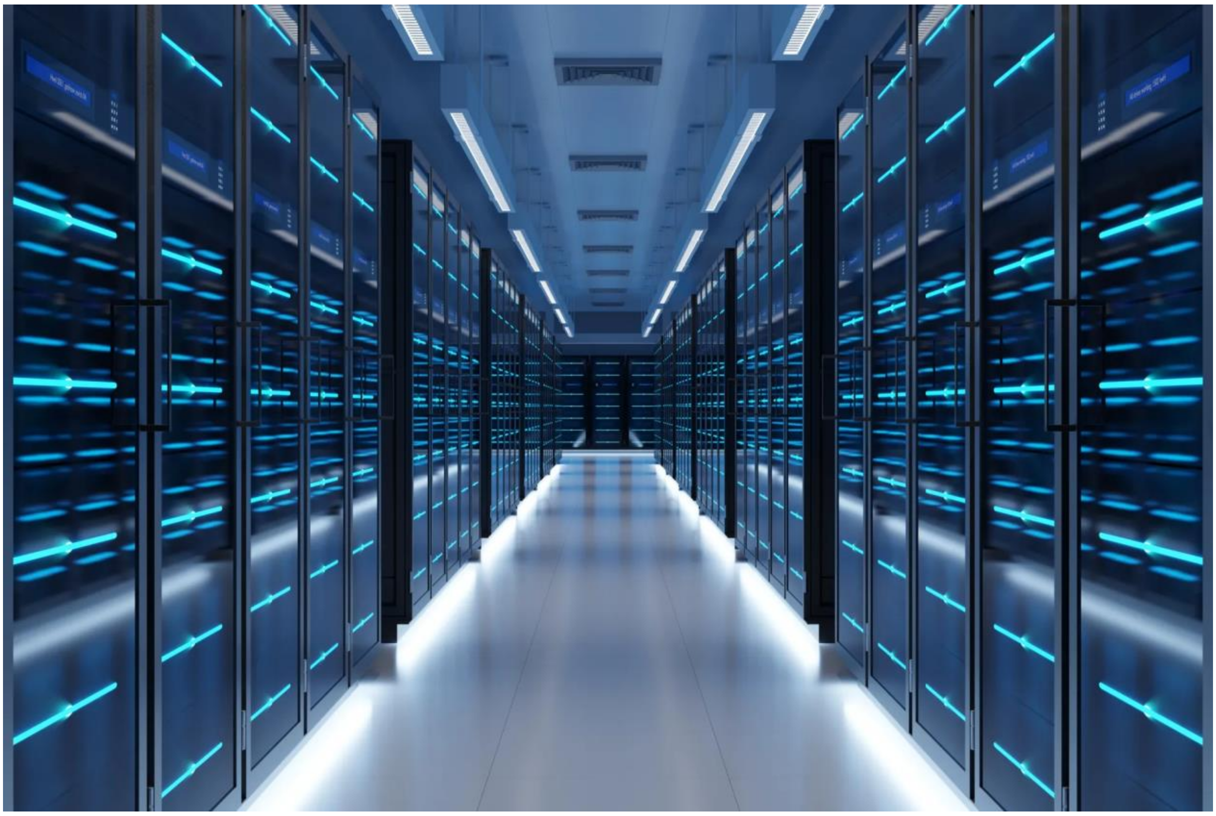
Meeting the energy needs of Data Centres: What role for cogeneration?



November 2024

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1. Executive summary

Trends

Demand for digital services and consequently data is rapidly increasing, with a 25-fold growth in global internet traffic and a doubling of internet users since 2010. This increase has resulted in a significant rise in the number of data centres. As of December 2023, there are approximately 10,978 data centre locations worldwide, with 33% located in the United States (5,388), followed by Germany (522), UK (517), China (449) and Canada (336). Ireland is a popular location to site data centres due to low corporation tax, a highly skilled workforce and access to the EU single market. In the UK, data centres are highly concentrated in West London and the M4 corridor due to the proximity of fibre-optic cables.

Energy supply is the key consideration for data centre operators, specifically in relation to selecting sites to build new data centres. Long waiting times for grid connections and sufficient supply to be available is impacting development of new facilities. Consequently, operators are prioritising locations with available alternative energy sources such as wind, solar and hydro in addition to investing in new technologies such as battery storage and geothermal.

Estimated global data centre electricity consumption in 2022 amounted to 1-1.3% of global final electricity demand or 240-340TWh, excluding energy used for cryptocurrency mining which accounted for 0.4% of annual global electricity demand. According to the USA Department of Energy, data centres account for approximately 2% total USA electricity use and is projected to consume up to 9% by 2030. In Ireland, data centres accounted for 21% total metred electricity consumption, up from 5% in 2015.

Within the European Union (EU), data centre energy use amounts to 40-45TWh, equivalent to 1.4-1.6% of total EU electricity consumption. By 2030, data centres are forecast to account for 3.2% of electricity demand within the EU, and 18.5% increase since 2018.

Data centres and associated transmission networks were responsible for 330MtCO_2 equivalent in 2020, equivalent to 0.9% of energy-related greenhouse gas emissions (GHG) or 0.6% of total GHG emissions. To help achieve net-zero targets, Information and Communication Technology (ICT) companies are investing heavily in renewable energy projects and are major purchasers of renewable energy power purchase agreements (PPAs).

In terms of future trends, the key drivers are seen to be:

- Artificial Intelligence (AI) which is driving unprecedented demand for data centres
- Power and energy – projected doubling of data centre energy demand by 2027
- Sustainability - lack of available grid capacity is driving need for alternative solutions such as alternative generation in the form of renewable technologies, nuclear, CHP, hydrogen etc. Also increase in the need to recover and reuse heat for commercial or residential buildings close by or greenhouses/vertical farming
- Automation – of routine workflows and processes is increasingly being adopted to improve efficiency.

Power requirements

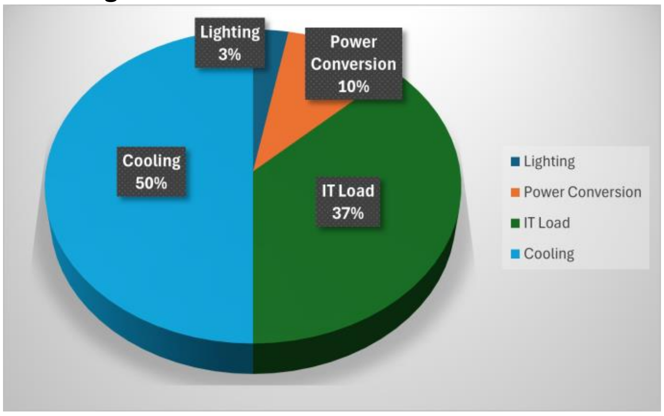
Power requirements vary depending on size and design of the data centre, as depicted in the table below.

Data Centre Power Requirements

Data Centre Size	Small	Medium	Large
Building Size	5,000 – 20,000 sqft	20,000 – 100,000 sqft	>100,000 sqft
Server Count	500 – 2,000 servers	2,000 – 10,000 servers	10,000 – 100,000 servers
Power Capacity	1 – 5 MW	5 20 MW	20 – 100+ MW
Design/Efficiency	Basic power management and cooling	Robust power management, partial efficiency	High efficiency, renewable energy use
Example Company	Equinix	Digital Realty	Amazon Web Services

Typical use of the power is illustrated in the pie chart below, though the use of power for cooling can range from 35%-50% depending on technology being used.

Power usage in a data centre



Source: ieeexplore

Impact on grids

The rapid expansion of data centres presents a significant challenge to the energy utilities. Data centres need a consistent supply of power 24/7/365 which is reliable, consequently, the electricity grid is experiencing increased pressure. Furthermore, there is a substantial lag between the growth in computing power and the grid growth. Whilst data centres take 1-2 years to build, adding new capacity to the grid takes substantially longer.

A major overhaul of the electricity infrastructure is required including reinforcing and upgrading through use of smart grid technologies, upgrading transmission and distribution systems as well as using digital tools for real-time monitoring and maintenance.

In addition, the intermittent nature of renewable energy presents the grid with a bigger problem of matching supply with demand. Data centres can be used to support the grid through shifting non time-critical workloads to match peaks in renewable generation. Furthermore, data centres use of uninterruptible power supply (UPS) can be integrated with the grid to help smooth peaks. An example of this is Fortum Spring which connects flexible assets and batteries to their platform which is then delivered to various energy markets. This can create additional revenue streams for the data centre operator.

Prime Power

There are several main continuous power sources including:

- Electrical Grid: The primary source of power for most data centres, relying on local utility providers. Data centres must ensure a stable connection to the grid to maintain operations.
- Renewable Energy Sources: Increasingly, data centres are integrating solar panels, wind turbines, and other renewable sources to diversify their energy supply
- Alternative sources include CHP, hydrogen Fuel Cells and nuclear in the form of small modular reactors.

Backup power is required to provide a continuous power supply during outages and include UPSs, diesel or gas-powered generators as well as sustainable options such as long-term batteries, CHP and hydrogen.

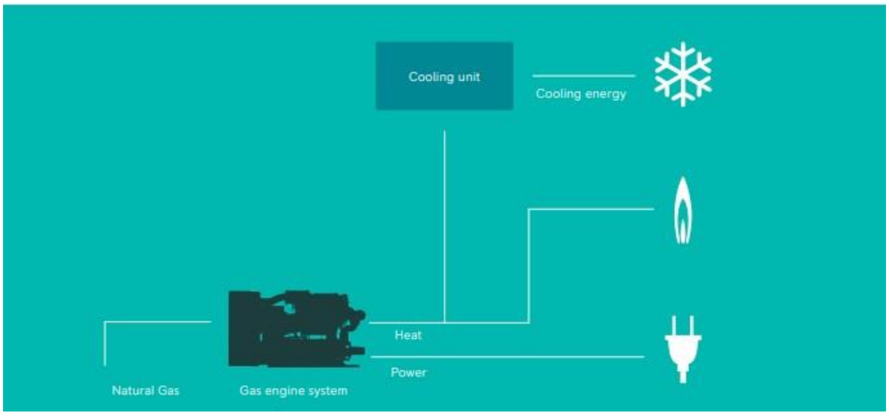
Waste heat recovery

Nearly 97% of the electrical energy consumed by a data centre could be harnessed in the form of heat which can be used for heating nearby buildings, providing hot water or supporting industrial processes. Benefits include reduction in carbon emissions as well as creating new revenue streams and improving energy efficiency. Several technologies are available including CHP, liquid cooling, heat exchangers and heat pumps.

Role of CHP

CHP use in data centres is currently limited but has significant potential for growth as the industry seeks more efficient and sustainable power solutions. The image below illustrates the role CHP can play in a data centre through delivery of power, heat and cooling via an absorption chiller.

Role of CHP



Source: mtu

Benefits include:

- Significant increase in energy efficiency
- Significant cost savings when CHP is used as the primary source of power, with waste heat recovered and used for cooling
- CHP offers flexibility in the design and operation of a data centre, facilitating expansion and development without depending on the grid
- Reliability is improved with increased resilience and energy security
- Reduction in emissions through increase efficiency of fuel use and recovery of waste heat

Main challenges include:

- High upfront costs
- Regulatory barriers in some regions can hinder adoption of CHP
- Reliability – seen as a barrier if the fuel supply is not located onsite
- Lack of awareness of the technology by data centre operators
- Higher need for maintenance.

Market opportunities

Current use of CHP in data centres is limited, however there is excellent potential for growth driven by the increasing focus on sustainability and energy efficiency.

EU Legislation

There is currently no EU directive that applies exclusively to data centres, but the Energy Efficiency Directive contains some important provisions applicable to data centres. Under Article 12 of the Energy Efficiency Directive, data centre operators are obliged to monitor and report on the energy performance of data centres. Regardless of the transposition status of the EED, the reporting obligation is directly applicable in all Member States.

The European Commission adopted a new delegated regulation, (EU) 2024/1364 in March 2024, on the first phase for establishing and EU-wide scheme to rate the sustainability of EU data centres. As foreseen under the recast Energy Efficient Directive, this secondary legislation requires data centre operators to report key performance indicators (KPIs) to the European database on a yearly basis. The first reporting date was 15 September 2024, with the second reporting date set as 15 May 2025, and then by 15 May thereafter.

In addition, the European Code of Conduct for Data Centres (EU DC CoC) launched in 2008, is a voluntary initiative set up by the Joint Research Centre (JRC) to encourage and guide data centre operators and owners in cost-effective reductions in energy consumption.

2. Introduction

The COGEN World Coalition has commissioned this study to understand the role that Combined Heat and Power (CHP) can play in meeting the energy needs of data centres.

A data centre is a physical building that houses critical applications and data through a network of computing and storage resources. The key components include routers, switches, servers, storage systems, application delivery controllers and firewalls. Network infrastructure connects servers, data centre services, storage and external connectivity to end-user locations. Computing resources provide the processing, memory, local storage and network connectivity that drive the applications.

Data centres need significant infrastructure to support their 24/7/365 activity in the form of power subsystems, uninterruptible power supplies, ventilation, cooling, backup generators, fire suppression and connections to external networks.

Classification of data centres is determined by their ownership structure:

- **Enterprise data centres** are built, owned and operated by companies and often located onsite
- **Managed service data centres** are managed by a third party on behalf of a company through leasing
- **Colocation data centres** enable companies to rent space within a data centre owned by another entity
- **Hyperscale or Cloud data centres** are hosted by a cloud service provider such as Amazon Web
- **Edge data centres** host applications closer to end users, either in smaller edge data centres or on the customer premises.

The considerable need for energy brings opportunities for the use of CHP systems within this sector as they can provide many benefits to data centres, including:

- Cost savings: CHP can reduce energy-related costs by lowering the need for fuel and electricity purchases.
- Reliability: CHP can increase reliability and reduce the risk of outages by providing a reliable onsite power supply.
- Sustainability: CHP can increase system efficiencies and sustainability.
- Environmental impact: CHP can reduce carbon footprints by using natural gas fuelled power generation.
- Energy security: CHP can provide increased energy security for data centres.
- Revenue streams: Surplus energy produced on site can be sold back to the grid.
- Efficiency: CHP can increase energy efficiency at data centres by continuously supplying them with both thermal energy and electricity.
- Flexibility: CHP can provide flexible power, with thermal energy that can be stored for use and electricity that can be fed into the public grid.

This study provides a full analysis of the current state of play in the data centre sector including their energy usage, impact on networks, operational requirements and potential for CHP.

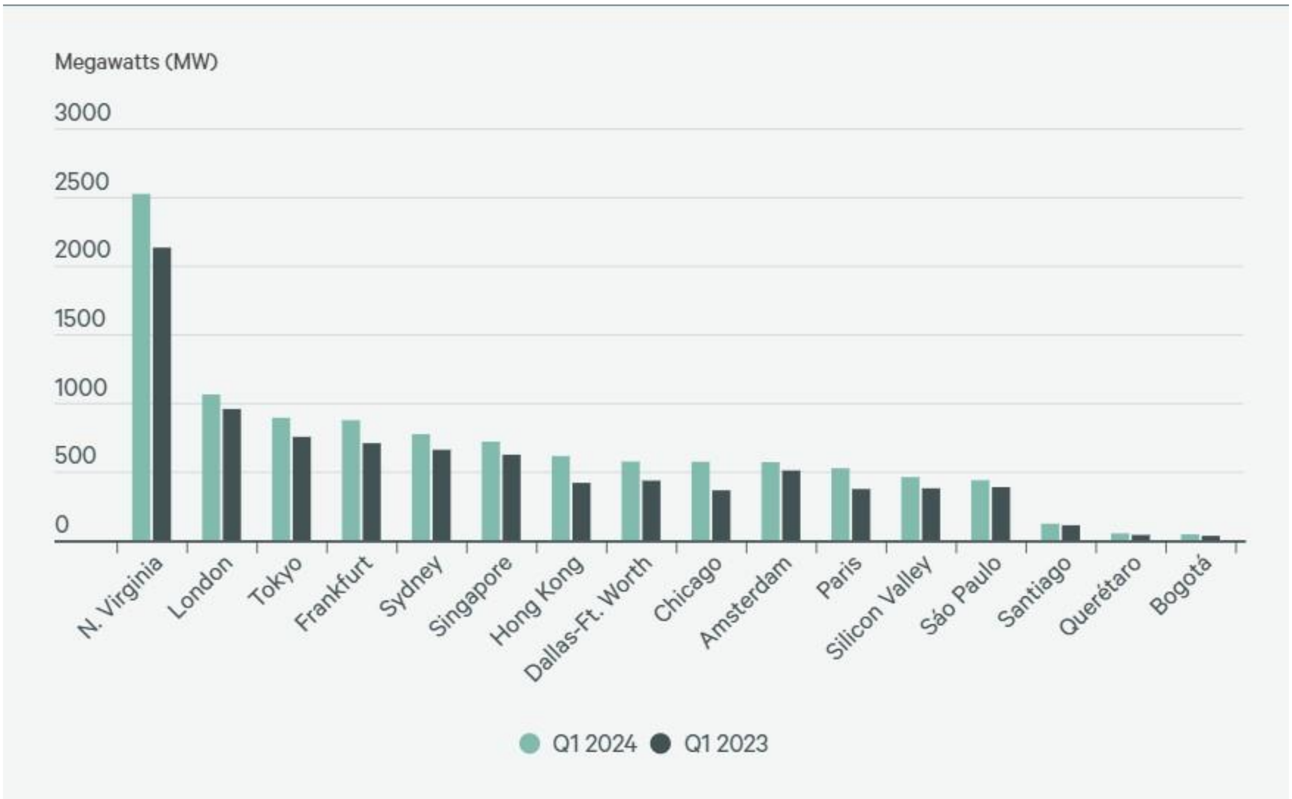
3. Key Trends in Data Centres

3.1. Current Status

Demand for digital services and consequently data is rapidly increasing, with a 25-fold growth in global internet traffic and a doubling of internet users since 2010. This increase has resulted in a significant rise in the number of data centres. As of December 2023, there are approximately 10,978 data centre locations worldwide, with 33% located in the United States (5,388), followed by Germany (522), UK (517), China (449) and Canada (336). Ireland is a popular location to site data centres due to low corporation tax, a highly skilled workforce and access to the EU single market. In the UK, data centres are highly concentrated in West London and the M4 corridor due to the proximity of fibre-optic cables.

In terms of data centre inventory (includes all assets – both physical and virtual – measured in MW), the North American data centre inventory grew by 24.4% between Q1 2023 – Q1 2024 whilst the European inventory grew by nearly 20% over the same period. Figure 1 illustrates the growth in data centre inventory across key markets.

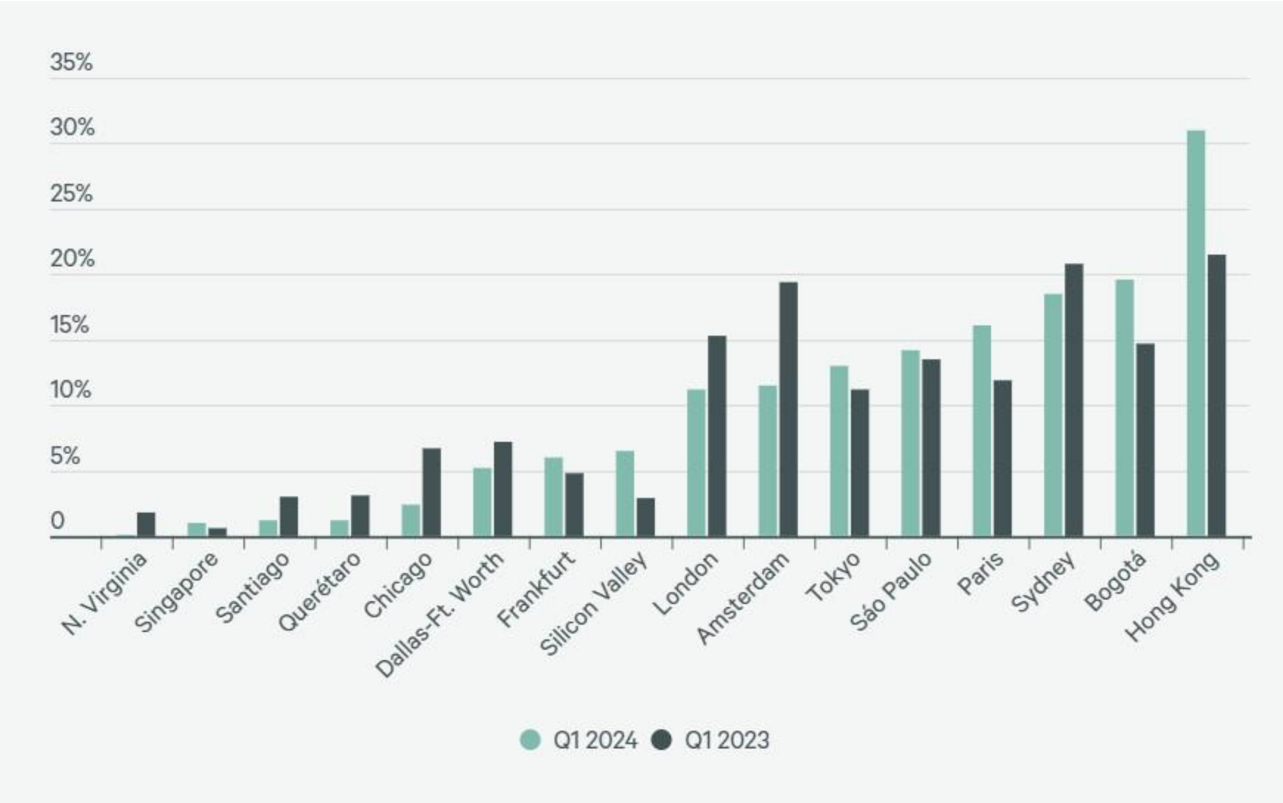
Figure 1: Data Centre Inventory by Market



Source: CBRE Research, Q1 2024.

However, whilst data centre inventory is increasing, demand for space or vacancy rates are declining (Figure 2) with large corporations facing difficulties in securing data centre capacity.

Figure 2: Data Centre Vacancy Rate by Market



Source: CBRE Research, Q1 2024.

3.2. Energy Use

Energy supply is the key consideration for data centre operators, specifically in relation to selecting sites to build new data centres. Long waiting times for grid connections and sufficient supply to be available is impacting development of new facilities. Consequently, operators are prioritising locations with available alternative energy sources such as wind, solar and hydro in addition to investing in new technologies such as battery storage and geothermal.

Estimated global data centre electricity consumption in 2022 amounted to 1-1.3% of global final electricity demand or 240-340TWh, excluding energy used for cryptocurrency mining which accounted for 0.4% of annual global electricity demand. According to the USA Department of Energy, data centres account for approximately 2% total USA electricity use and is projected to consume up to 9% by 2030. In Ireland, data centres accounted for 21% total metred electricity consumption, up from 5% in 2015.

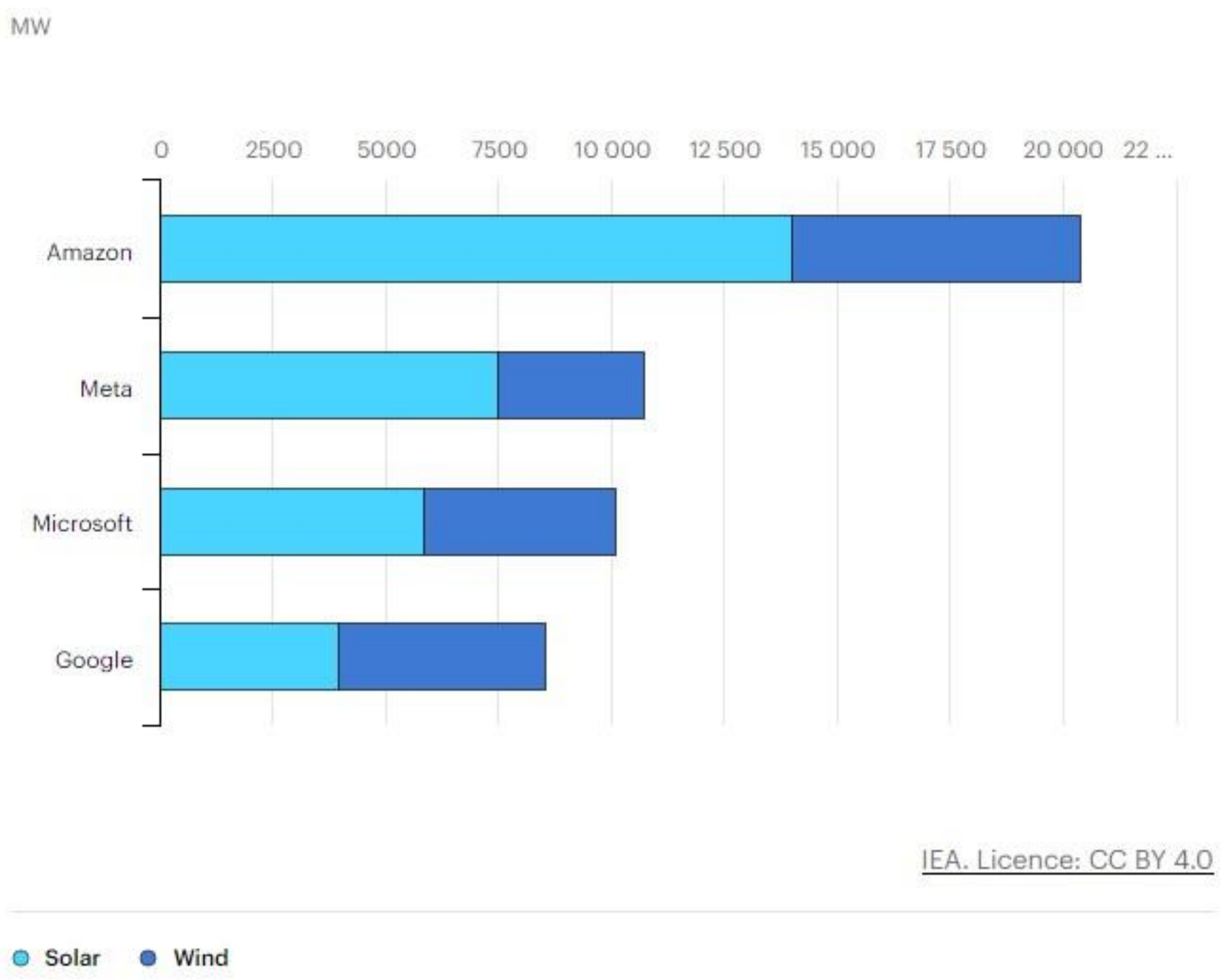
Within the European Union (EU), data centre energy use amounts to 40-45TWh, equivalent to 1.4-1.6% of total EU electricity consumption. By 2030, data centres are forecast to account for 3.2% of electricity demand within the EU, and 18.5% increase since 2018. The European data centre market was forecast to generate nearly 78 billion euros in revenue in 2024, with the majority of this realised in Central and Western Europe, driven by the markets of Frankfurt, London, Amsterdam, Paris, and Dublin (FLAPD). The financial powerhouses of London and Frankfurt are the two leading FLAPD hubs, with total estimated inventory of around 1,000MW and 700MW, respectively.

Whilst improvements in efficiency in IT hardware and cooling in addition to economies of scale have minimised demands within a data centre, rapid growth in workloads handled by large data centres has resulted in an increase in energy use of 20-40% per year.

Data centres and associated transmission networks were responsible for 330MtCO_2 equivalent in 2020, equivalent to 0.9% of energy-related greenhouse gas emissions (GHG) or 0.6% of total GHG emissions. Due to energy efficiency improvements, renewable energy purchases and wider decarbonisation of electricity grids, emissions have only increased modestly since 2010, however, to meet net-zero targets, emissions must halve by 2030.

To help achieve net-zero targets, Information and Communication Technology (ICT) companies are investing heavily in renewable energy projects and are major purchasers of renewable energy power purchase agreements (PPAs). Not only does this help mitigate against GHG emissions, but it also protects them from price volatility in the market and improves their brand image. Amazon, Microsoft, Meta and Google are the four largest purchasers of corporate renewable energy PPAs, having contracted almost 50GW to date as depicted in Figure 3. However, matching total annual demand with renewable energy PPAs or certificates does not mean data centres are powered 100% of the time by renewable sources due to mismatches between variability of supply and data centre demand profiles. Several of the larger corporates have set targets to source and match zero-carbon electricity on a 24/7 basis where demand is located, with a growing number of companies working towards matching their electricity demand on an hourly basis.

Figure 3: Top Corporate Off-takers of Renewable Energy PPAs, 2010 - 2022



Source: IEA (2023)

3.3. Future Trends

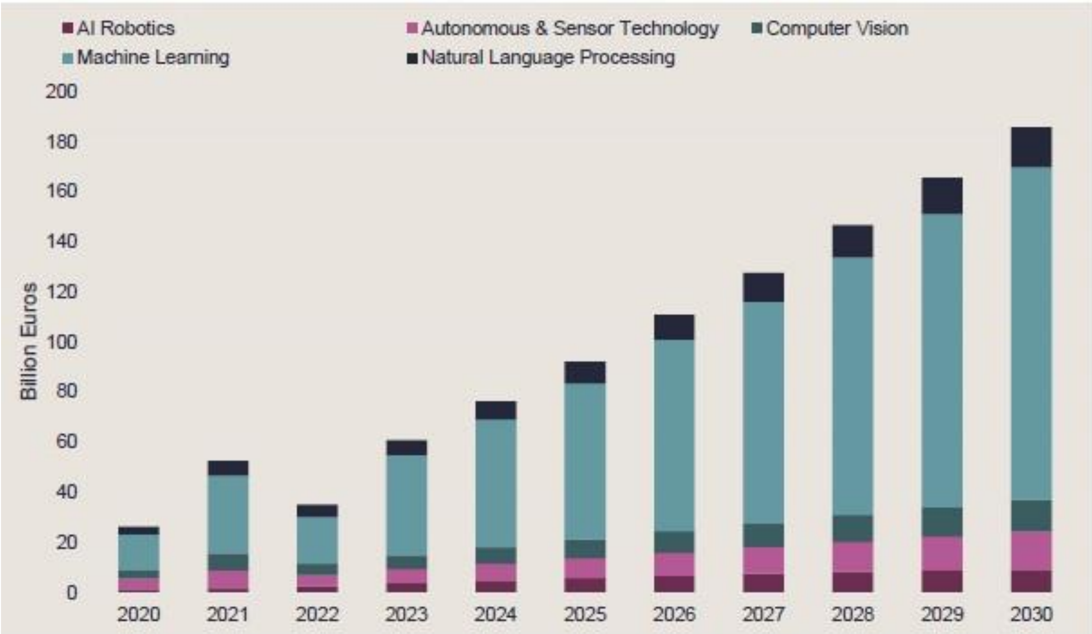
There are a number of trends shaping the data centre industry, with strong growth for data network services expected.

3.3.1. Artificial Intelligence (AI) and Other Technical Innovations

AI is essential in data centres as they automate complex processes, increase operational efficiency and enhance digital infrastructure performance whilst managing vast amounts of data and ensuring seamless operation. Consequently, AI is driving unprecedented demand for data centre capacity and capabilities.

In addition, other technical innovations such as cloud computing, the Internet of Things and 5G are also driving data centre demand. 5G's share of mobile data traffic is projected to rise to nearly 70% in 2028, from around 17% in 2022. AI has brought profound changes to the data centre industry, bringing great opportunities but also significant challenges. Statista projects that the size of the European AI market will reach €76.5bn this year, up by 25.9% compared to 2023 as illustrated in Figure 4.

Figure 4: Market size of European AI



Source: Savills Research based on Statista

Key impacts include:

- Increased spending on hyperscale data centres to handle AI processing requirements including Machine Learning (ML).
- Amount of computing power needed to train the largest ML models is growing rapidly.
- Need for liquid cooling solutions to manage heat from AI hardware.
- Use of AI for predictive analytics and automation of data centre operations is rapidly increasing.

3.3.2. Power and Energy

Data centres are facing significant power challenges with increasing demand to power to operate efficiently. Key impacts include:

- Projected doubling of data centre energy demand by 2027.
- Grid modernisation efforts needed to meet surging power needs due to current lack of capacity – currently leading to delays in construction of new centres.
- Increased focus on renewable energy and sustainability will be key to reducing carbon footprint, including 'behind the meter' solutions.
- Exploration of new power sources like nuclear and natural gas – both Google and Amazon have just announced forays into nuclear power. Google has ordered up to 7 small modular nuclear reactors (SMRs) to meet its energy needs whilst Amazon is buying a stake in US nuclear developer X-energy as part of a collaboration to deploy SMRs to power its data centres.

3.3.3. Sustainability

Environmental concerns are driving several trends including:

- Increased focus on renewable energy usage including co-locating data centres with renewable energy generation.
- Heat reuse initiatives to repurpose excess heat such as redirecting excess heat to commercial or residential heating as well as other options including greenhouses or vertical farming.
- Efforts to reduce material waste and improve energy efficiency
- Use of liquid cooling technologies to lower the temperature of computer processor units and graphics processer units will improve energy efficiency.
- Several regions including Dublin in Ireland, the Netherlands and Singapore have placed a moratorium on construction of new data centres to prioritise sustainability.

3.3.4. Automation

Data centres are increasingly adopting automation of routine workflows and processes to:

- Improve agility and operational efficiency.
- Reduce human labour requirements.
- Handle routine tasks like scheduling, monitoring, and maintenance.

By focusing on these key areas, the data centre industry is adapting to meet growing demand while addressing challenges around energy, sustainability, and technological advancement.

4. Functional requirements of data centre electricity supply

To ensure efficient operation there are several functional requirements to be met including reliability and redundancy, power quality and capacity, distribution, efficiency and sustainability as well as safety and compliance.

4.1. Power Requirements

Power requirements for a data centre vary significantly depending on the size and design of the facility as well as the efficiency of the equipment installed. Table 1 indicates power requirements for different size data centres.

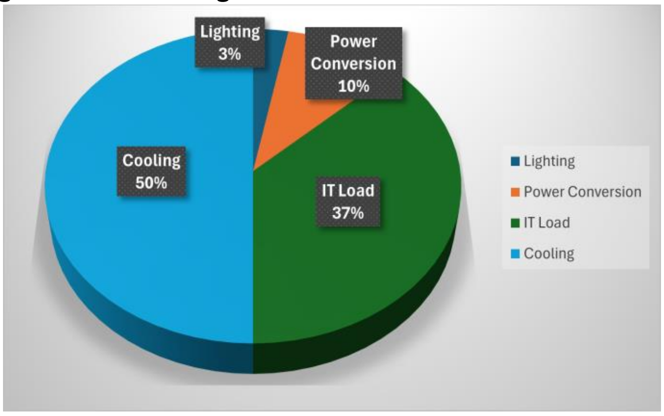
Table 1: Data Centre Power Requirements

Data Centre Size	Small	Medium	Large
Building Size	5,000 – 20,000 sqft	20,000 – 100,000 sqft	>100,000 sqft
Server Count	500 – 2,000 servers	2,000 – 10,000 servers	10,000 – 100,000 servers
Power Capacity	1 – 5 MW	5 20 MW	20 – 100+ MW
Design/Efficiency	Basic power management and cooling	Robust power management, partial efficiency	High efficiency, renewable energy use
Example Company	Equinix	Digital Realty	Amazon Web Services

Source: Dgtl Infra

The power is used to run IT equipment, cooling systems and supporting infrastructure. Figure 5 illustrates a typical breakdown of power use. The percentage of power attributed to cooling can vary between 35-50% with more modern data centres requiring lower percentages resulting from improvements in cooling technologies.

Figure 5: Power usage in a data centre



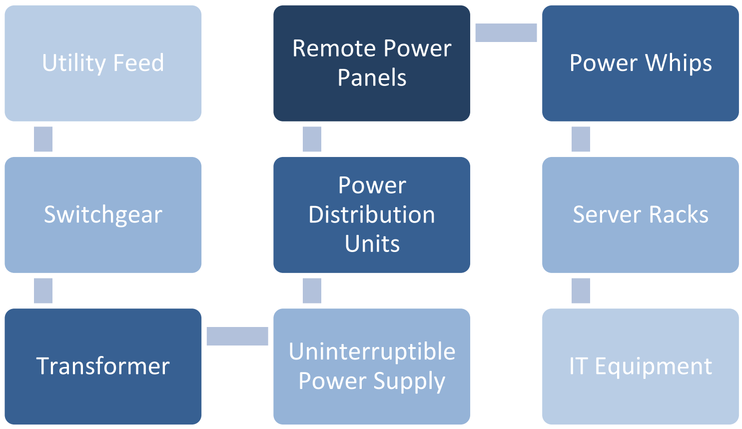
Source: ieeexplore

Within the data centre, power is distributed according to a specific hierarchy as illustrated in Figure 6 and explained below:

- **Utility Feed:** power initially comes from the local power grid. To prevent a single point of failure, data centres often have multiple feeds from different grids for redundancy.
- **Switchgear:** the initial point of contact for utility power, it divides incoming power into smaller circuits.
- **Transformer:** transformers adjust the voltage to levels suitable for data centre infrastructure through either stepping up or stepping down voltage as required.

- **Uninterruptable Power Supply (UPS):** stores energy and provide emergency power during an outage until back-up generators start. They can also be used to smooth out power quality issues and can support the grid, specifically balancing intermittent supply from renewable generation and demand.
- **Power Distribution Units (PDUs):** convert power into a suitable voltage for equipment before distributing it to individual server racks, switches etc. Most data centres operate multiple PDUs to ensure redundancy.
- **Remote Power Panels (RPPs):** smaller protective enclosures containing fuses, circuit breaker panels and ground fault protection devices which function as localised distribution point.
- **Power Whips:** conduit systems comprising flexible cables distribute power from a PDU or RPP to server racks and other IT equipment.
- **Server Racks:** each rack has its own power strip. From here, power is provided to the IT equipment including individual servers, storage systems and networking devices within the rack.

Figure 6: Data Centre Power Distribution Hierarchy



Source: Dgtl Infra

4.2. Reliability and Redundancy

- **Multiple utility feeds**: Data centres often connect to two or more independent power grids to ensure continuous power supply if one grid fails
- **N+1 or 2N redundancy**: Provide backup systems that can take over if primary systems fail, ensuring uninterrupted operation
- **Backup generators**: On-site diesel generators typically start within 10-15 seconds of a power outage, providing long-term emergency power
- **Uninterruptible Power Supply (UPS)**: UPS systems provide immediate backup power during the brief period before generators activate, ensuring no interruption in power supply
- **Automatic Transfer Switches (ATS)**: These devices automatically switch between utility power and backup generators, minimizing downtime during outages
- **Redundant power paths**: Critical equipment is often connected to two separate power distribution paths for added reliability.
- **Fault tolerance**: Systems are designed to continue functioning even if individual components fail, enhancing overall reliability

4.3. Power Quality and Capacity

- Voltage regulation: Essential for maintaining stable power supply within acceptable ranges for IT equipment. The input dependency of a UPS falls into:
  - Voltage and Frequency Dependent (VFD)
  - Voltage Independent (VI)
  - Voltage and Frequency Independent (VFI)

  Table 2 outlines the different types of power problem and if they are addressed.

Table 2: Summary of UPS capabilities for protecting the load by input dependency performance

7 types of power problems	Problems addressed by classification VFD	VI	VFI
Power interruptions	✓	✓	✓
Voltage sags and swells	✓	✓	✓
Voltage transients	*	✓	✓
Sustained over- and under-voltages	×	✓	✓
Voltage waveform distortion	×	**	✓
Voltage fluctuations	×	**	✓
Frequency variations	×	×	✓

Source: Schneider Electric

- Power conditioning: Ensures clean power by filtering out electrical noise, harmonics, transients.
- Power quality management: Ensures clean power by filtering out electrical noise, harmonics, and transients, while providing surge protection to safeguard sensitive equipment from voltage spikes.
- Scalability and high-capacity infrastructure: Power systems must be designed to accommodate future growth and increased power density, typically connecting to high-voltage networks to meet substantial power demands.

4.4. Distribution, Efficiency, and Sustainability

- Power Distribution Units (PDUs) and monitoring systems: Modern data centres use intelligent PDUs and advanced monitoring systems to optimise power distribution and track energy consumption in real-time.
- Energy efficiency metrics: Power Usage Effectiveness (PUE) determines the energy efficiency of a data centre. A PUE value of 1.0 indicates that all energy consumed by a data centre is used to power the IT infrastructure, therefore, the closer PUE is to 1, the better. The industry average PUE has remained around 1.58 since 2020, while larger data centres achieve a capacity-weighted PUE of 1.47. Despite ongoing industry modernisation, the PUE average has remained almost static, partly because many older and less-efficient legacy facilities have a moderating effect. 30 % of servers are 'Comatose', indicating that nearly a third of capital in enterprise data centres is wasted.
- Cooling efficiency: Cooling typically accounts for 35-50% of power usage in data centres, making it a critical area for efficiency improvements.
- Sustainability initiatives: Major tech companies are leading the way in sustainable data centre practices:
  - Google's data centres have been carbon neutral since 2007, aiming for zero carbon by 2030. In October 2008, Google's data centre was noted to have a ratio of 1.21 PUE across all 6 of its centres, which at the time was considered as close to perfect as possible.
  - Microsoft plans to be carbon negative by 2030, with data centres supported by over 2 GW of renewable energy projects.

  - Facebook (Meta) aims for zero carbon data centres by 2030, using innovative cooling systems and hyper-efficient servers.
- Renewable energy adoption: The Climate Neutral Data Centre Pact requires data centre electricity demand to be matched by 75% renewable energy by 2025 and 100% by 2030.

4.5. Safety and Compliance

- Electrical Safety Systems:
  - Implement comprehensive grounding, bonding systems, and fire suppression tailored for data centres.
  - Use redundant power supplies, including UPS and generators, to ensure continuous operation.
- Compliance with Regulations:
  - Adhere to national and international standards and regulations.
- Regular Audits and Assessments:
  - Conduct regular audits and arc flash risk assessments to ensure adherence to safety standards.
  - Monitoring and Protection Devices.
  - Utilise insulation monitoring and ground fault protection systems to detect faults early.

5. Impacts on grids

The rapid expansion of data centres presents a significant challenge to the energy utilities. Data centres need a consistent supply of power 24/7/365 which is reliable, consequently, the electricity grid is experiencing increased pressure. Furthermore, there is a substantial lag between the growth in computing power and the grid growth. Whilst data centres take 1-2 years to build, adding new capacity to the grid takes substantially longer.

Increasingly governments are delaying or even refusing permits for new developments. This is particularly high in the FLAPD markets where high population, business and industry density already puts pressure on the national grid. Paris is the exception, largely due to their large nuclear power base.

In 2019, Amsterdam, the authorities imposed temporary bans and new environmental legislation on new data centres. More recently, restrictions were reinforced with new regulation prohibiting construction of any new data centres unless it can be proved that they are a benefit to the community.

In London, a proposal to build a hyperscale server farm and support ancillary buildings was rejected by the government in 2023 because of pressures on energy supply. Even in Ireland, despite easy access to high-capacity subsea cables, in 2021, the decision was taken to limit new connections to the grid. Consequently, data centre operators, Vantage, EdgeConneX and Equinix all had permits for development rejected in 2023.

Additionally, in June 2022, Frankfurt's municipal council passed legislation designating areas where data centres can be developed to control the rise of data centre clusters in the city.

As a result, data centre investors and operators are increasingly exploring alternative locations including the Nordic region where they have an abundant supply of affordable green energy.

5.1. Grid Reinforcement / Upgrade

Energy utilities are under significant pressure to modernise the grid to meet increasing demand as well as evolving sustainability goals. With 40% of Europe's power distribution grids over 40 years old, increasingly constraining demand, governments are being forced to consider the impact of all new projects. Integration of renewable energy generation, the growing needs of new technologies, and the increasing demand for data require a major overhaul of existing electricity infrastructure. This includes reinforcement and upgrading the grid using smart grid technologies, upgrading transmission and distribution systems as well as using digital tools for real-time monitoring and maintenance.

Additionally, utility companies must balance the immediate requirement for increased capacity with the long-term goal of sustainability, thus enabling the grid to support future growth whilst minimising environmental impacts.

Digitised maintenance of the grid is also vital to maintaining operational efficiency of the grid and advanced monitoring tools assessing the physical assets in real-time enable utilities to address issues proactively thus reducing downtime and extending the lifespan of the infrastructure. A comprehensive understanding of the grid's condition will inform decision-making and strategic planning, ensuring the grid can meet current and future demands effectively.

5.2. Grid Balancing / Flexibility Services

Decarbonisation goals mean an increase in renewable energy generation such as wind and solar exported to the grid. The intermittent nature of renewable generation presents the grid with the even bigger problem of matching supply with demand. However, due to the flexible, resilient and highly automated nature of data centres, they can be used to support the grid through balancing intermittent generation with demand, providing reserve power when needed and offering critical load balancing services.

Not all data centre workloads are time-critical or latency-sensitive and can therefore be shifted to times where more energy is available. The high level of automated processes in data centre management systems can be scheduled to match peaks in renewable energy generation and can thus balance supply and demand to stabilise intermittent generation. Workloads can also be shifted geographically. Linking data centres with high-speed, high-capacity data transmission connections enables them to be managed as unified resources that can be moved seamlessly from one location to another. Thus, workloads can move to where the power is which can make the most of renewable generation when and where it is available and improve energy efficiency.

Data centres also utilise uninterruptible power supply (UPS) facilities along with emergency generators to ensure 24/7/365 operation, giving them significant energy storage capability. The UPS can be integrated into the grid to deliver benefits to the utilities, helping them smooth peaks. An example of this is Fortum Spring which connects flexible assets and batteries to their platform which is then delivered to various energy markets. They use existing assets for balancing services and thus, create additional revenue streams for the asset owner as well as supporting increased renewable generation's integration into the grid. Enel X also delivers a solution to allow UPS systems to interact directly with the grid, maintaining system stability in real-time through linking large power consumers such as data centres with others to form a Virtual Power Plant (VPP), integrating power from several sources.

Using a UPS can mitigate voltage spikes lasting seconds to a few minutes; however, data centres also have access to back-up power, normally in the form of generators. Increasingly there has been a move away from the traditional diesel generator to more sustainable options such as long-term batteries or hydrogen. CHP units can also be used to eliminate the need for such backup systems, providing a continuous supply of power, heating and cooling.

6. Prime power and back-up power

6.1. Prime Power Supply in Data Centres

There are several main continuous power sources including:

- Electrical Grid: The primary source of power for most data centres, relying on local utility providers. Data centres must ensure a stable connection to the grid to maintain operations.
- Renewable Energy Sources: Increasingly, data centres are integrating solar panels, wind turbines, and other renewable sources to diversify their energy supply. This shift not only reduces reliance on fossil fuels but also aligns with sustainability goals, including those of the companies investing in their development.

Alternative sources of power which are likely to increase:

- Combined Heat and Power (CHP) Systems: These systems generate electricity and useful heat simultaneously, improving overall energy efficiency. CHP can significantly reduce operational costs and carbon emissions. Use of CHP in data centres appears to be limited, though has a significant potential for growth as the industry seeks more efficient and sustainable power solutions.
- Hydrogen Fuel Cells have been used in pilot projects as both a primary source of power as well as for back-up.
- Nuclear in the form of small modular reactors (SMRs) are expected to become a prime source of power within the next decade.

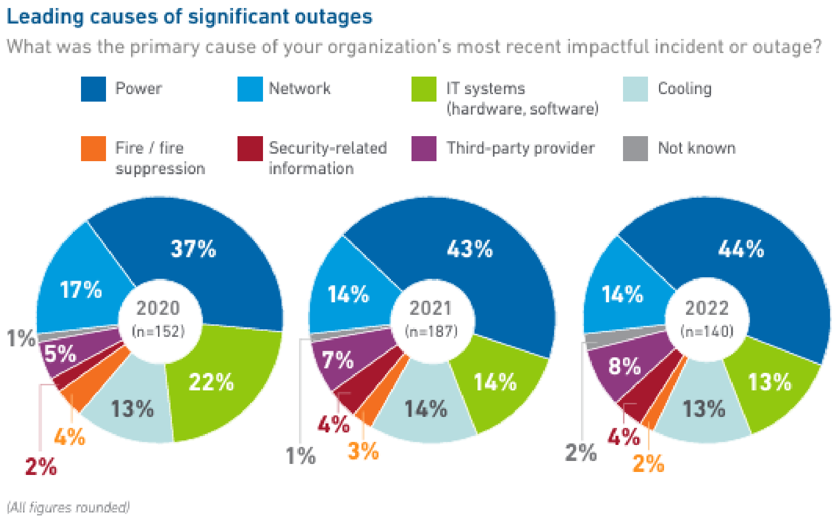
6.2. Backup Power Systems /Redundant Power Systems

Redundant power systems ensure uninterrupted operation by providing a continuous power supply even if there is a failure in the primary power supply. These systems safeguard sensitive equipment from damage due to sudden power loss or surges. They also protect against data corruption or loss, which can occur during outages.

- Uninterruptible Power Supply (UPS) Systems:
  - UPS systems provide immediate backup power during brief outages or fluctuations in the electrical supply. They ensure that critical systems remain operational while backup generators are activated.
  - UPS systems come in various configurations (e.g., online, line-interactive) to meet different load requirements and provide varying levels of protection.
- Diesel or Gas-Powered Generators:
  - These generators serve as a secondary power source during extended outages. They typically start within 10-15 seconds of a power interruption, minimising the risk of downtime.
  - Regular maintenance and testing are essential to ensure that these generators function correctly when needed.
- Sustainable Back-up Solutions
  - Long-term batteries can be used to store excess renewable generation.
  - CHP units can also be used to eliminate the need for such backup systems, providing a continuous supply of power, heating and cooling.
  - Hydrogen produced through electrolysis can be used for energy storage.

Figure 7 emphasises how power outages consistently rank as the leading cause of significant data centre outages, highlighting the critical role of both UPS systems and backup generators in preventing such disruptions. The increasing percentage of outages caused by power issues across the years (from 37% in 2020 to 44% in 2022) directly reinforces the need for reliable backup power solutions in modern data centres, which aligns with the points discussed under backup systems like UPS, diesel generators, and battery storage.

Figure 7: Leading cause of outages



Source: Uptime Institute

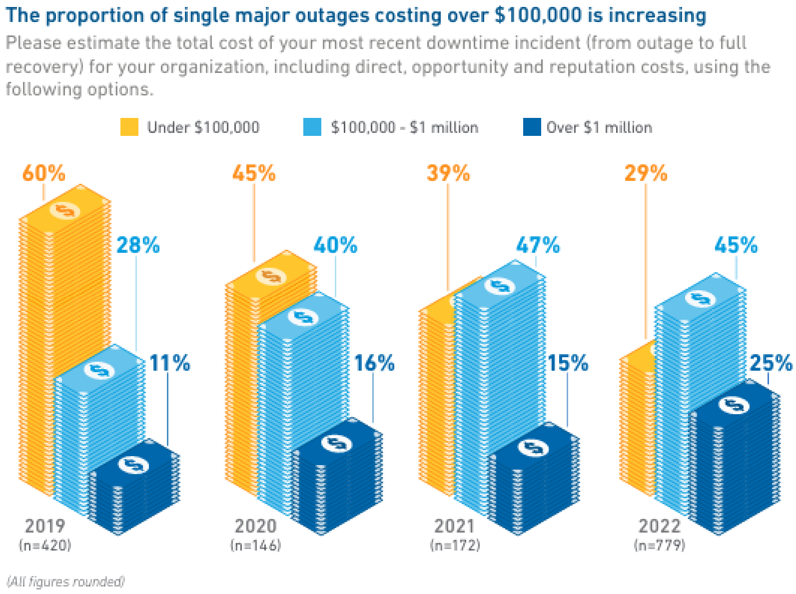
6.3. Redundancy and Resilience Strategies

Redundancy methods are crucial for maintaining system stability with the primary method for power systems known as the 'N' method:

- Redundancy Configurations: N+1, N+2, 2N:
    - These configurations refer to the number of backup units available relative to the primary units. For example, N+1 means one additional unit beyond what is necessary for normal operation.
    - Such configurations enhance reliability by ensuring that if one unit fails, another can take over without disrupting service.
- Multiple Independent Power Feeds:
    - Connecting data centres to multiple independent power sources mitigates the risk of total power loss from a single point of failure. This strategy is crucial for maintaining uptime during grid outages.
- Resilient Power Distribution Paths:
    - Designing robust distribution paths ensures that power can be rerouted in case of a failure in one part of the system. This flexibility is vital for maintaining continuous operations.
- Scalability of Backup Power Solutions:
    - As data centre demands grow, backup power solutions must be scalable to accommodate increased loads without compromising reliability.

Figure 8 demonstrates the financial impact of outages, with more outages costing over $100,000 in recent years. It underscores the importance of redundant power configurations (such as N+1, N+2, or 2N) and resilience strategies in avoiding costly downtime. It provides a strong case for data centres to invest in multiple utility feeds, resilient power distribution paths, and redundant systems to mitigate the risk of prolonged outages, which aligns with the discussion under redundancy strategies.

Figure 8: Financial Impact of Outages



Source: Uptime Institute

7. Waste heat recovery

Waste heat recovery in data centres has become an increasingly important focus for improving energy efficiency and sustainability in the industry. As data centres consume significant amounts of energy and generate high levels of heat, harnessing this waste heat offers numerous benefits. Nearly 97% of the electrical energy consumed by a data centre could be harnessed in the form of heat which can be used for heating nearby buildings, providing hot water or supporting industrial processes.

7.1. Environmental Impact and Sustainability Benefits

- **Carbon Emission Reductions:** Heat recovery can significantly reduce the carbon footprint of data centres. By repurposing the heat generated from operations, data centres can offset energy consumption and emissions associated with heating nearby buildings or facilities.
- **Energy Reuse Effectiveness (ERE)**: By reusing waste heat, data centres improve their energy efficiency metrics, such as Power Usage Effectiveness (PUE) and Energy Reuse Effectiveness (ERE), aiding in the transition toward net-zero emissions.
- **Economic Advantages**: Implementing waste heat recovery systems creates new revenue streams for data centre operators by selling surplus heat to nearby consumers, transforming them from energy-intensive facilities into valuable heat producers for local communities.
- **Regulatory Compliance**: As regulations tighten globally, waste heat recovery is becoming essential for obtaining operational authorisations e.g. Germany has enacted legislation (Energy Efficiency Act) mandating waste heat recovery in data centres and has set a target of data centres achieving 10% heat reuse by 2026 and 20% by 2028.

7.2. Technologies and Methods for Heat Recovery in Data Centres

- Cooling typically accounts for 35-50% of power usage in data centres, consequently harnessing this energy for heat recovery will reduce its impact. There are several different technologies available:
    - Combined Cooling Heat & Power Systems (CCHP), otherwise known as Tri-Generation converts the Low Temperature Hot Water generated into chilled water via an absorption chiller. The chilled water can provide an abundance of cool air that can be used to cool data centre operations.
    - Liquid Cooling Systems can capture heat at higher temperatures (50-60°C)
        - Direct liquid cooling immerses servers in dielectric fluid, enabling high-temperature heat recover
        - Indirect liquid cooling uses liquid-cooled plates attached to components
    - Heat Exchangers transfer heat from the data centre cooling system to external applications either via water-to-water or air-to-water heat exchangers
    - Heat Pumps can elevate low-grade waste heat (e.g., at 30°C-35°C) to higher useful temperatures, such as 70°C to 80°C, for use in heating networks.

7.3. Challenges and Economic Considerations in Implementation

- **Infrastructure Costs**: High upfront costs can be prohibitive, especially without subsidies or supportive policies. Furthermore, a long payback period may not align with the data centre operator’s financial expectations.
- **Proximity to Heat Consumers**: Successful implementation often depends on the presence of nearby heat consumers, such as buildings connected to district heating networks, industrial facilities which may not always be available. Transporting heat over long distances is costly and inefficient.

- **Technical Integration**: Retrofitting existing cooling systems to enable heat recovery can be complex and disruptive. Additionally, space constraints and lack of necessary infrastructure can make it difficult to install new equipment. Furthermore, implementing heat recovery systems may impact the reliability or performance of existing cooling systems and operators may be hesitant to modify systems.
- **Policy Support**: Absence of incentives in many regions reduces motivation along with lack of standardised approaches. Incentives like the UK's **Green Heat Network Fund (GHNF)** help to mitigate some costs, supporting projects that use waste heat from data centres, providing £288 million in capital funding for low and zero carbon heat networks. Furthermore, the EU's recast Energy Efficiency Directive mandates heat recovery where possible and obliges data centre operators to report their efforts to improve efficiency regularly.
- **Business Alignment**: There can be a mismatch between the data centre's supply of heat and the offtaker's requirement for heat, especially in terms of differing business models.

7.4. Applications and Use Cases for Recovered Heat

Waste heat can be used for a variety of different applications including:

- **District Heating**: Examples like the **Stockholm** and **Helsinki** data centres highlight how recovered heat is used in district heating systems, supplying heat to homes and commercial buildings. Telia's data centre in Helsinki will heat more than 20,000 homes in the future.
- **Using CHP**: CHP adoption in data centres is still limited, though interest is growing. One such example is the SoCalGas Data Centre (Monterey Park, California) using a Capstone Hybrid UPS CHP technology which demonstrated significant reductions in energy costs and increased environmental benefits.
- I**ndustrial Processes:** Industries requiring substantial heat, often operating continuously can use waste heat recovered from data centres.
- **Agriculture**: Indoor agriculture in the form of greenhouses, vertical farms, and even fish or insect farms require heat and warm air generated by data centres. Telecity Group's Climate Change Arboretum in Paris uses waste heat from the company's data centre. An experimental project in Sweden suggests that a 1MW data centre may be able to recover up to a third of its electricity costs by attaching a greenhouse to the facility. Another example is the White Data Center on the island of Hokkaido in Japan using water warmed during the cooling process to farm eels.

European countries are leading in waste heat applications with examples seen in Sweden, Norway and Denmark where repurposing waste heat for district heating is prevalent. Furthermore, European data centres are pioneering sustainable energy practices and contributing to the circular economy. Table 3 illustrates the waste heat applications in Europe.

Table 3: Major European data centre waste heat applications

Application	Organisation	Location	Type of data centre
Commercial/Residential heating via district	atNorth	Kista, Sweden	Colocation
	Stack Infrastructure	Oslo, Norway	Colocation
	Amazon Web Services	Dublin, Ireland	Hyperscale
	Meta	Odense, Denmark	Hyperscale
	Yandex	Mantsala, Finland	Hyperscale
	H&M	Stockholm, Sweden	Enterprise
	Volkswagen Financial Services	Braunschweig, Germany	Enterprise
	Nikhef Housing	Amsterdam, Netherlands	High-performance computing
Direct commercial/residential heating	Cloud&Heat	Frankfurt, Germany	Edge
	BIT	Ede, Netherlands	Colocation
Agriculture	Equinix	Paris, France	Colocation
	Microsoft	Middenmeer, Netherlands	Hyperscale
	Google	Middenmeer, Netheralands	Hyperscale
Heating swimming pools	Deep Green	Exmouth, UK	Edge
	Digital Realty	Paris, France	Colocation
	NorthC	Aalsmeer, Netherlands	Colocation
Commodity dehydration: wood pellets	EcoDataCenter	Falun, Sweden	Colocation/High-performance computing
Aquaculture: Trout farming	Green Mountain	Telemark, Norway	Colocation
Lobster farming	Green Mountain	Stavanger, Norway	Colocation
Algae farming	Scale up	Berlin, Germany	Colocation/Cloud
	Windcloud	Enge-Sande, Germany	Colocation

Source: Uptime Institute

8. The Role of CHP

CHP use in data centres is currently limited but has significant potential for growth as the industry seeks more efficient and sustainable power solutions. There does appear to be growing interest in the market, especially considering some of the current access issues relating to obtaining power from the grid. CHP is a proven technology and a reliable power source which is efficient and cost effective as well as delivering significant reductions in greenhouse gas emissions.

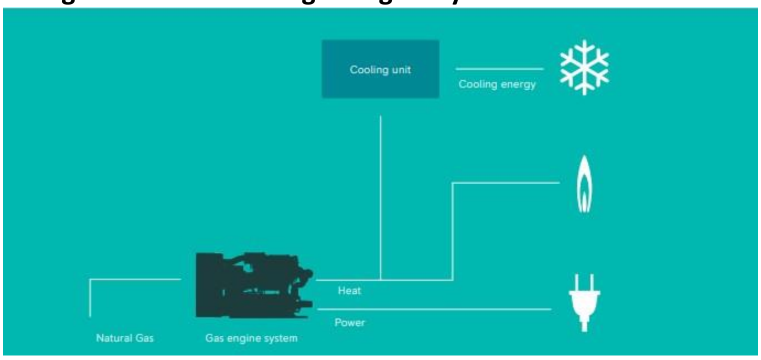
8.1. Key components

The main components of a CHP system used in data centres include:

1. Prime Mover: This is the core of the CHP system, usually one of the following:
   - Gas turbine
   - Reciprocating engine (gas engine)
   - Steam turbine
   - Microturbine
   - Fuel cell
2. Generator: Converts mechanical energy from the prime mover into electricity.
3. Heat Recovery Equipment: Captures waste heat from the prime mover for useful purposes. This may include:
   - Heat exchangers
   - Boilers
   - Steam generators
4. Absorption Chiller: Converts recovered heat into chilled water for cooling the data centre.
5. Electrical Interconnection: Equipment to connect the CHP system to the data centre's electrical distribution system.
6. Control Systems: Manage the operation of the CHP system and integrate it with the data centre's power infrastructure.
7. Fuel Supply System: Typically, natural gas piping and related equipment.
8. Exhaust System: To safely remove exhaust gases from the prime mover.
9. Cooling Tower or Other Heat Rejection Equipment: For dissipating excess heat when not fully utilised.
10. Enclosure: Often used in packaged CHP systems to house the equipment and reduce noise.
11. Piping and Valves: For distributing hot water, steam, or chilled water throughout the facility.

These components work together to generate electricity onsite and recover waste heat for cooling. The configuration will vary depending on the size of the data centre and its particular needs. Figure 9 illustrates the role CHP can play in a data centre through delivery of power, heat and cooling via an absorption chiller.

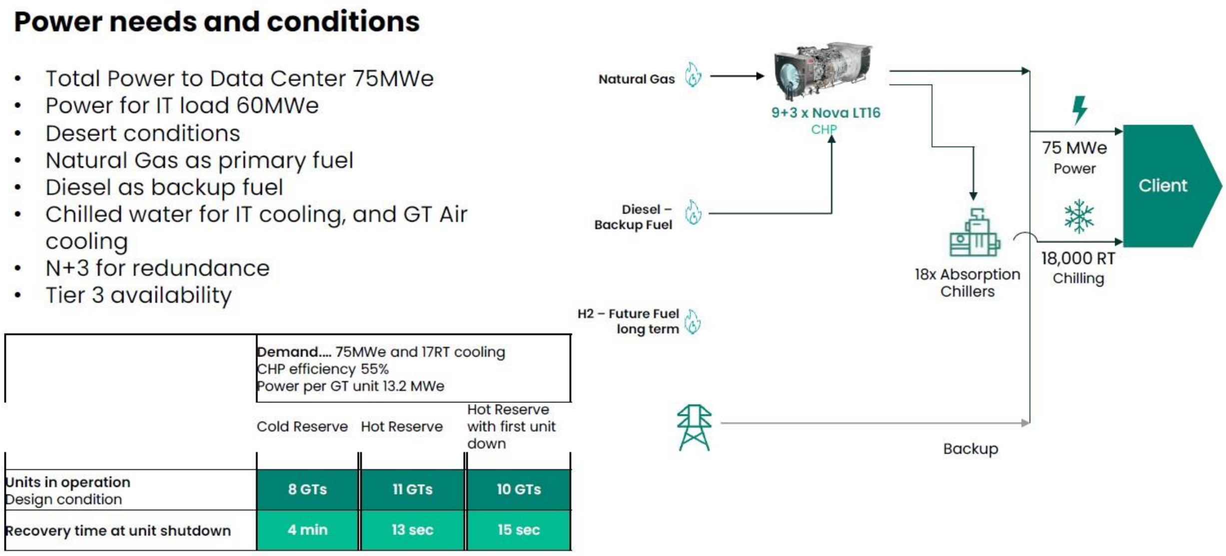
Figure 9: Role of CHP gas engine system in a data centre



Source: mtu

Figure 10 illustrates an example of a gas turbine with absorption chilling demonstrating the level of capacity needed for resilience for the data centre.

Figure 10: Role of CHP gas turbine system in a data centre



Source: Baker Hughes

8.2. Benefits

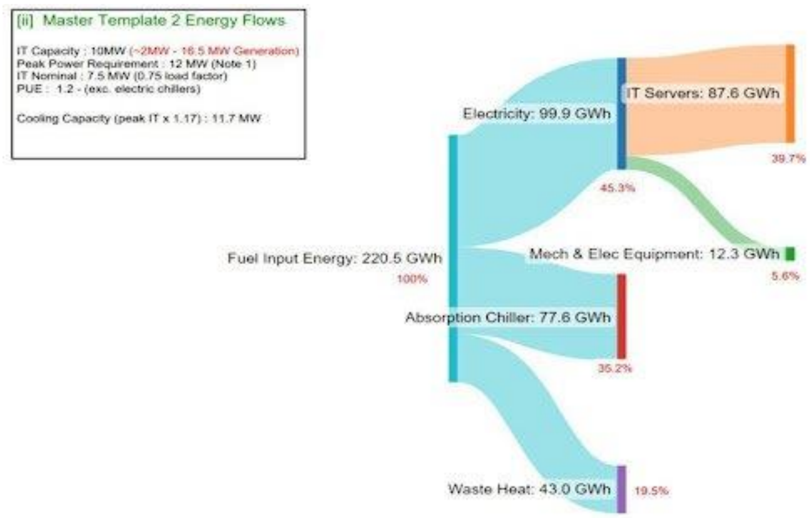
The benefits of incorporating CHP into data centre infrastructure make it an attractive option to improve energy efficiency, reduce costs and minimise environmental impact.

8.2.1. Energy Efficiency

CHP systems significantly increase overall energy efficiency in data centres by:

- Generating electricity onsite eliminates transmission losses associated with grid power:
  Recovering waste heat from power generation for cooling purposes through tri-generation. Mix-fuel gas turbines provide the required power to the data centre, with exhaust fumes at a temperature of around 500°C produced as a by-product. Steam can be supplied via waste heat boilers from the cogeneration sets to two-stage absorption chillers, which provide a highly resilient and highly efficient source of chilled water for data centre cooling. In turn, this also drastically reduces the amount of water needed in the cooling process. Figure 11 illustrates trigeneration energy flows and efficiency. Furthermore, both gas engine and gas turbine generators will be able to accept an increasing blend of renewable fuels such as hydrogen, ammonia and biogas, with the aim of eventually running on 100% renewable fuel as supply chains develop. This approach to recovering waste energy is more efficient than traditional designs using electricity from the grid, backed up by diesel generators, drastically reducing net energy losses to the whole supply chain.

Figure 11: Energy flows and efficiency in a trigeneration solution



Source: Engie

8.2.2. Cost Savings

Cost savings can be significant when CHP is used as the primary source of power, with waste heat recovered and used for cooling. An example produced by Engie and RED in 2023 illustrates this, comparing a 'business as usual' scenario to the CHP onsite power and cooling solution. The CHP scenario comprises installation and operation of a trigeneration system, with mix-fuel gas turbines running on natural gas coupled with two-stage absorption chillers, producing chilled water as a result of waste heat recovery from the gas turbine. The analysis looks at the Total Cost of Ownership (CAPEX and OPEX) over a 15-year lifespan. Table 4 outlines the assumptions whilst Table 5 presents the results.

Table 4: Assumptions

	Business as Usual	On-site CHP Power and Cooling Solution
Location	North California, USA	
Lifetime	15 years	
IT Load ramp-up	Maximum IT load to be 48MW Ramp Up Schedule: Year 1 – 25%, Year 2 – 75%, Year 3 – 100%	
OUE Schedule Includes UPS, Distribution, Building Systems, Cooling Systems	Design PUE at 100% Load: 1.25 Design PUE at 75% Load: 1.35 Design PUE at 25% Load: 1.42 Peak PUE: 1.75	Design PUE at 100% Load: 1.15 Design PUE at 75% Load: 1.17 Design PUE at 25% Load: 1.19 Peak PUE: 1.61
Grid Connection	Electrical PG&E network, Single feeder CAPEX will include all necessary amounts needed to brin power, including substations	Gas PG&E network, Completely isolated from electrical grid CAPEX will include all necessary amounts needed to bring gas, including any substations
Resiliency	Ensured by Diesel gensets in N+2 configuration	Ensured by Gas Turbines in N+2 configuration
On-site power generation schedule	Diesel gensets as back-up (N+2) Year 1 – 9 x 3 MW = 27 MW Year 2 – 14 x 3 MW = 42 MW Year 3 – 7 x 3 MW = 21MW Total – 30 x 3 MW = 90 MW	Gas Turbines as prime power production (N+2) Year 1 – 5 x 3 MW recips + 3 x 12 MW GT = 51 MW Year 2 – 2 x 12 MW GT = 24 MW Year 3 – 1 x 12 MW GT = 12 MW Total = 87 MW
Fuel Storage Tank	48 hours Diesel storage tank for 48 MW IT	48 hours fuel storage tank for 48 MW IT

Cooling assets schedule	IEC units using demineralised water coming from the city (N+2 configuration) Total of 186 units at final build out Year 1: 6 x 500xtons = 3,000 tons Year 2: 4 x 500 tons = 2,000 tons Year 3: 8 x 500 tons = 4,000 tons Total: 34 x 500 tons = 17,000 tons	2-stage Absorptions chillers (N+2 configuration) 1st year includes adiabatic cooling with dry coolers to meet the necessary cooling loads Year 1: 6 x 500 tons (electric) + 3 x 2059 (absorption) = 9,177, tons Year 2: 4 x 2059 tons (absorption) = 8,236 tons Year 3: 2 x 2059 tons (absorption) = 4,118 tons Total = 21,531 tons
Facility Operations	24x7 operations 75% operational electrical and coding load factors	24x7 operations 75% operational power generation load factor
Assumed utility costs	Electric Cost = 21.54 cents/MWh (PG&E) Gas Cost = $13.6 per MMBTUs (future average price)	
Equipment lifecycle replacements	For 15 year lifecycle replacement is expected for major equipment (prime movers, chillers, cooling systems,….) Any costs that may be needed to 'restore' the equipment at the end of the lifetime are excluded	

Source: Engie/RED

Table 5: Results of the TCO analysis

	Business as Usual	On-site CHP Power and Cooling Solution
Power generation and distribution Purchase, Installation works, Cost of Capital	200 488 188 €	308 616 021 €
Cooling generation and distribution Purchase, Installation works, Cost of Capital	295 128 972 €	374 271 753 €
Total CAPEX	**495 617 160 €**	**682 887 774 €**
Fixed and Variable Operations & Maintenance (15 years)	104 050 597 €	219 082 868 €
Electricity supply (15 years)	1 556 694 619 €	• €
Diesel supply (15 years)	23 605 841 €	• €
Natural Gas supply (15 years)	• €	983 298 078 €
Water supply (15 years)	33 084 €	• €
Total OPEX over 15 years of operation	**1 684 384 141 €**	**1 202 380 945 €**
Toral COST OF OWNERSHIP over 15 years of operation	**2 180 001 301 €**	**1 885 268 719 €**

Source: Engie/RED

Despite the higher CAPEX for the CHP solution, the OPEX is significantly lower due to the high energy efficiency of the trigeneration solution (around 80% efficiency), requiring very little electricity compared to the BAU scenario. The study doesn't include revenue from potentially exporting the waste heat or cooling surplus or by participating in any ancillary grid services. Furthermore, the CHP solution is future proofed for the transition to net zero due to its ability to accept alternative renewable fuels. Additionally, an onsite solution such as CHP helps overcome the lack of capacity on the grid.

8.2.3. Flexibility and Scalability

CHP systems can offer flexibility in the design and operation of a data centre, facilitating expansion and development without depending on the grid. They can also be sized according to the data centre's needs, taking into consideration the thermal and electrical demands of the facility and how they vary throughout the day and year with the aim of running the CHP at as high a load as possible for as much time as possible. Furthermore, they can be integrated with renewable energy generation, providing continuous power despite the intermittent nature of wind and solar generation.

8.2.4. Reliability

Reliability is vital for data centres due to the requirement for them to operate continuously, 24/7/365. CHP systems support this need, providing increased resilience and energy security through their ability to supply both heat and electricity and to maintain continuous operation. As part of a microgrid, CHP enables a data centre to continue operating even during outages, thus protecting critical data.

8.2.5. Environmental Impact

Data centres need for high levels of energy results in high carbon emissions. While CHP systems comprising gas engines or gas turbines run on natural gas, which is not a sustainable resource, CHP systems reduce emissions through increased efficiency of fuel use as well as the recovery of waste heat to use for cooling. The exact level of carbon savings will depend on the size of the data centre, CHP system installed and what its being compared to in terms of grid electricity mix, onsite diesel generators etc.

Case study – how CHP can work to lower data centre emissions (i3solutions)
There follows a sample study of a data centre with an assumed IT power capacity of 10MW (overall electrical capacity of 11.48MW) and associated cooling demand of 3000-Ton (10.5 MW).

A typical installation would include three (3) turbine engines in an (N+1) redundant configuration. All mechanical cooling equipment is also configured in an (N+1) redundant configuration.
Turbine exhaust gas temperature ranges from approximately 340°C to 540°C. Exhaust gases are diverted through a heat exchanger to produce steam which is used in an absorption chiller to produce chilled water. Two (2) 5-megawatt gas turbines have a cumulative exhaust gas flow rate of approximately 150,000 lb/hr., - sufficient to produce over 7000-Ton of cooling (24.6 MW).
In the example, an absorption chiller replaces traditional cooling plant including a centrifugal chiller and cooling towers to reject the heat utilising a reversed Carnot cycle process. Typical cooling plant utilises water cooled chilled water plant with a centrifugal compressor, cooling towers and pumps. The range is 0.8 to 1.0 kilowatt per Ton of cooling.
For a typical 1.0 kilowatt per Ton centrifugal chiller plant, energy usage is approximately 3MW, leading to total site energy usage of 13MW (i.e., IT load plus mechanical load). By comparison, the use of an absorption chiller frees 3MW of power, which is available to provide relief on the electric grid and reduce the overall energy consumption of the facility.
Such a design cuts the carbon footprint of a 11.48MW total connected load data centre by 50%, while fuel consumption is reduced by 553,431 MMBtu. The subsequent reduction in carbon emissions is equivalent to total annual greenhouse gas emissions generated by, e.g., 20,258 cars or 10,818 homes.

8.3. Main Challenges

Despite the benefits of using CHP systems in data centres, their adoption so far has been limited for several reasons.

- **High Upfront Costs:** The initial capital investment required for implementing CHP systems are substantial which deters some data centre operators from adopting this technology.
- **Technical Integration Challenges:** Integrating CHP systems with existing infrastructure and ensuring seamless operation can pose technical challenges, e.g. sizing a CHP system correctly will have an impact on its reliability – facilities often start out at low loads and grow the site gradually, making it more difficult to size CHP on an unknown load. A modular solution would allow for future growth. Integration with UPSs, switching equipment etc can be challenging.
- **Regulatory Barriers:** Complex regulations and permitting processes in some regions can hinder the adoption of CHP systems as they can significantly impact project timelines and feasibility. In addition, regulations and permitting processes will vary for different locations.
- **Reliability:** Although a properly designed CHP system can provide significant benefits in terms of enhancing power reliability for the facility, in terms of gas-fired CHP, because the fuel supply is not located onsite, it is not recognised as an independent form of back-up for these applications.
- **Lack of awareness** of the benefits of using CHP systems in data centres. There are limited number of examples of CHP in data centres, consequently proving reliability and improving operational practices, including cooling are not widely demonstrated. Furthermore, power outage costs are very high, and many data centre operators are reluctant to deviate from the standard design of UPS, battery storage and standby diesel generators.
- **Need for maintenance:** CHP systems run continuously, unlike diesel standby generators, consequently, require more frequent servicing and maintenance at regular intervals.

8.4. Market Opportunities

8.4.1. Key Drivers

CHP for the data centre market, although currently limited, has excellent potential for growth due to its ability to enhance energy efficiency, reduce operational costs and minimise the carbon footprint of data centres. The market is driven by following key drivers:

- Sustainability goals, both of data centre operators and those companies investing in them – CHP offers significantly higher energy efficiency when compared to conventional power generation methods
- Power reliability – the need for uninterrupted power and backup power which can be delivered by a CHP system
- Technological advancements in the form of modular, scalable CHP designs fitting data centre requirements
- Supportive legislation and policies including incentives for CHP adoption and regulation supporting energy efficiency in critical facilities
- Long-term cost stability – offered by CHP reduces dependence on fluctuating utility energy prices.

8.4.2. Market opportunities

The principal opportunities that can be realised are:

- On-site power generation that achieves the following:
    - Align with the power decentralisation strategy of the country (incentivising decentralised power generation) – key role for CHP
    - Path to zero carbon powered by green fuel (i.e. hydrogen) and carbon capture
    - Off-the-grid data centre campus (not drawing major power from the grid) and not requiring additional idle back-up generation infrastructure (i.e. traditional design - back-up generators in addition to grid power)
    - Meeting the sustainability/zero carbon targets & commitment by the large technology firms/hyperscalers
    - Provide peak reserve capacity for the grid (i.e. stabilising the grid)
    - Provide charging stations for large EV vehicles (i.e. trucks)
- Teaming up with energy companies to develop off-the-grid large data centre campuses especially companies playing an active role in the green fuel and sustainable power generation technologies
- Creating two assets through the off-the-grid data centre campus:
    - Energy centre/microgrid (providing mission critical power and cooling to the data centre campus and region around it) – similar returns or better than district cooling
    - Data centre which is optimised and lighter from infra perspective – better returns than traditional data centre
- Emerging markets – untapped markets in developing regions present promising opportunities for the use of CHP in data centres.

8.4.3. Competitive Landscape

There are many established players in the market able to deliver CHP systems for data centres and consequently it is a highly competitive market with established players as well as emerging players competing for market share. Key players are likely to be focussing on product innovation, strategic partnerships and geographical expansion.

9. EU Legislation Governing Data Centres

9.1. Energy Efficiency Directive (EED)

There is no EU directive that applies exclusively to data centres, but the Energy Efficiency Directive contains some important provisions applicable to data centres. The first iteration of the directive was adopted in November 2012 (Directive (EU) 2012/27/EU), while the new recast Energy Efficiency Directive (Directive (EU) 2023/1791) entered into force in October 2023.

The EED aims to ensure that the EU meets its greenhouse gas reduction and energy efficiency targets. The revised EED raises the EU energy efficiency target to a reduction in energy consumption of 11.7% by 2030 compared to projections of the expected 2030 energy use. Member States must set indicative national contributions to identify how they will contribute to reaching this target.

Under Article 12 of the Energy Efficiency Directive, data centre operators are obliged to monitor and report on the energy performance of data centres. Regardless of the transposition status of the EED, the reporting obligation is directly applicable in all Member States.

The European Commission adopted a new delegated regulation, (EU) 2024/1364 in March 2024, on the first phase for establishing and EU-wide scheme to rate the sustainability of EU data centres. As foreseen under the recast Energy Efficient Directive, this secondary legislation requires data centre operators to report key performance indicators (KPIs) to the European database on a yearly basis. The first reporting date was 15 September 2024, with the second reporting date set as 15 May 2025, and then by 15 May thereafter.

The new regulation is intended to increase transparency and potentially to promote new designs and efficiency developments in data centres that reduce energy and water consumption as well as promote use of renewable energy, increased grid efficiency, or the reuse of waste heat in nearby facilities and heat networks.

The delegated act outlines what information and KPIs should be reported as well as defines the first sustainability indicators that will be used for the rating of data centres. They will also be required to publish information on their energy performance and sustainability.

The EED requires the European Commission to establish a European database on data centres to which owners and operators of data centres with a power demand of the installed IT of at least 500kW must report:

i. the contact details of the data centre, its operator and owner
ii. the floor area, installed power, annual incoming and outgoing data traffic, and amount of data stored and processed within the data centre
iii. the KPIs during the last calendar year including energy consumption, power utilisation, temperature set points, waste heat utilisation, water usage and use of renewable energy.

Annex I: details general information to be reported – name of data centre, operator, owner, contact details, location, type).

Annex II: lists more detailed data points that must be reported, some of which are used to calculate the sustainability listed in Annex III (total energy consumption of data centre, total energy consumption of IT equipment, total water input, waste heat reused and total renewable energy consumption).

Annex III: lists sustainability indicators to be calculated (power usage effectiveness, water usage effectiveness, energy reuse factor, renewable energy factor).

Annex IV: outlines which data the European database must make publicly available (number of data centres, distribution per size category, average power usage effectiveness, average water usage effectiveness, average energy reuse factor, and average renewable energy factor).

The EED illustrates the transition the data centre industry is undergoing in terms of policy as this year, for the first time, data centre operators across the EU are required to report data related to their operations. Although this framework is European, the national transpositions will vary. As an example, Germany is imposing additional measures including minimum performance requirements and mandating waste heat recovery within data centres.

9.2. European Code of Conduct for Efficiency in Data Centres

The European Code of Conduct for Data Centres (EU DC CoC) was launched in 2008 as a voluntary initiative set up by the Joint Research Centre (JRC) to encourage and guide data centre operators and owners in cost-effective reductions in energy consumption. Ambitious voluntary standards are set out which identify and focus on key issues and agreed solutions as outlined in the Best Practices document. This document includes the latest technology developments and is updated yearly.

The Best Practices document is accompanied by the Assessment Framework which is more requirement driven and provides auditors with tools to assess if data centres apply the Practices correctly and enables market players to complete disclosures for Taxonomy alignment as part of their non-financial reporting.

More than 500 data centres have joined so far and those that can demonstrate a significant reduction in energy consumption are eligible for the annual EU Data Centres Code of Conduct Awards.

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Ensuring Data Centre Electrical Safety: 10 Essential Best Practices You Should Know (CYCLECT)

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