



WP6 – Exploitation and Standardisation 1

Task 6.1 Watch activities, market landscaping and market analysis

D6.1 Tertiary buildings cooling market landscaping and market analysis



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Terms and Abbreviations

Acronym	Description
AI	Artificial intelligence
AFCOM	Professional association that is dedicated to advancing the careers of data centre and IT infrastructure professionals
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
CAGR	Compound Annual Growth Rate
CRAC	Computer Room Air Conditioning
CNDCP	Climate Neutral Data Centre Pact
DCIM	Data Centre Infrastructure Management
DIGITALEUROPE	Trade association representing digitally transforming industries in Europe
DDA	The Dutch Data Centre Association
DCA	Data Centre Alliance
EED	EU Energy Efficiency Directive
EUDCA	European Data Centre Association
EMEA	Europe, the Middle East, and Africa
FDCA	Finnish Data Centre Association
GWP	Global Warming Potential
GDPR	General Data Protection Regulation
GPP	Green Public Procurement
GDA	German Datacentre Association
PUE	Power Usage Effectiveness
REHVA	Federation of European Heating, Ventilation and Air Conditioning Associations
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals
SDIA	Swedish Data Centre Industry Association
TCO	Total Cost of Ownership
TWh	Terawatt-hours

Executive Summary

The goal of HYCOOL-IT project is to propose a standardised comprehensive set of processes, digital tools and advanced adsorption equipment to achieve a replicable cost-effective thermal management and energy optimisation of tertiary buildings with high energy demand IT Rooms¹².

This report presents a comprehensive PESTLE analysis and market assessment supporting the exploitation strategy of HYCOOL-IT's innovations. The PESTLE framework enables a structured examination of Political, Economic, Social, Technological, Legal, and Environmental factors shaping the regulatory and business environment, understanding market drivers and challenges, identifying forces influencing demand and barriers to adoption for advanced HVAC and digital technologies for server rooms and data centres across Europe. In parallel, the market analysis provides targeted insights into market overview and size and demand drivers and challenges, emerging technological trends, competitive landscape, and key stakeholders across the value chain. The analysis benchmarks HYCOOL-IT innovations — particularly the rack-integrated adsorption chiller and digital twin-supported design and operations processes — against existing market offerings, identifying key differentiators and market gaps.

Recognizing that HYCOOL-IT project introduces innovations that extend beyond a single use-case or product, the PESTLE analysis and market assessment is structured around four interconnected exploitation spaces. These exploitation spaces include Energy Efficiency (EE), Targeted Cooling Solutions for IT Server Rooms (ITSR), Building Digital Twin (BDT), and Smart Building Management Systems (SBMS). Further details on the rationale, scope, and specific elements covered within each exploitation space are provided in the Table 1. For each exploitation space, this report presents a PESTLE analysis alongside a comprehensive market analysis, covering the market landscape and size, key drivers and challenges, key market players, and summary findings. Detailed discussions are provided in the respective sections for ease of reference, while concise one-page summaries of the market analysis results for each exploitation space are included in the Appendixes.

The results of PESTLE analysis and market assessment identifies strong market drivers arising from the increasing power demands of AI and HPC related workloads, combined with rising environmental and regulatory pressures, and increasing energy costs pushing data centres and IT server rooms toward energy efficiency, hybrid cooling, and intelligent management systems. HYCOOL-IT's solutions directly address these market trends and needs. The market analysis confirms that HYCOOL-IT is well-positioned to lead in a fast-evolving market by tackling urgent industry challenges with scalable, compliant, and easy-to-replicate solutions. It targets decentralised and underserved segments—where innovation is most needed—and directly aligns with the EU's dual green and digital transitions. As data centres and server rooms become critical infrastructure for Europe's future, HYCOOL-IT delivers what the sector demands: energy efficiency, reliability, and readiness for real-world deployment.

¹ [HYCOOL-IT R2M SOLUTION](#)

² [HYCOOL-IT project - IDP - ingeniería · medio ambiente · arquitectura](#)

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1. Introduction

The International Energy Agency (IEA)³ estimated that data centres and server rooms amounted to around 1.5% of the world's electricity consumption in 2024, that will be 415 terawatt-hours (TWh). Further segmented and granular analysis from IEA's report shows that the United States was responsible for the largest share of global data centres and server rooms electricity consumption in 2024 (45%), followed by China (25%) and Europe (15%). Furthermore, in IEA's recently published report 'Energy and AI'⁴, the IEA asserts that data centres and server rooms electricity consumption is projected to more than double to around 945 terawatt-hours (TWh) by 2030. This is slightly higher than Japan's present total electricity consumption. Artificial intelligence (AI) is the most significant driver and factor of this growth, alongside growing demand for other HPC and digital services. In the last few years, AI has gone from a purely scientific academic activity to an industry with trillions of dollars of market capitalisation and potential. While there are numerous uncertainties about its adoption and impact, AI's rapid advancement and huge potential have made it cardinal to corporate strategies, economic policies and geopolitics.

More AI means a greater need for data centres and server rooms capable of supporting GPU-intensive AI/HPC workloads. This transformation is fundamentally reshaping their design and operations. Unlike traditional IT workloads, AI requires GPU-intensive computing and servers, substantial data storage, and high-speed connectivity, ensuing in higher power densities and greater cooling needs. This is pushing data centres and server rooms operators to adopt advanced solutions like liquid or hybrid cooling technologies, DCIM solutions, digital twins, or AI-powered infrastructure management solutions.

According to newest McKinsey & Company publication "the cost of compute: A \$7 trillion race to scale data centres"⁵, centred on their second scenario (seen in Figure below), data centres and server rooms will need nearly \$6.7 trillion in capital investments worldwide by 2030 to meet the mounting demand for computing power—including the hardware, processors, memory, storage, and energy needed to operate data centres and server rooms facilities. Out of this, \$5.2 trillion will be required for data centres and server rooms capable to handle AI processing workloads, whereas \$1.5 trillion will go toward data centres and server rooms facilities supporting traditional IT applications. Altogether, this signifies a astonishing capital expense—emphasising the scale of investment necessary to support the digital infrastructure of the future.

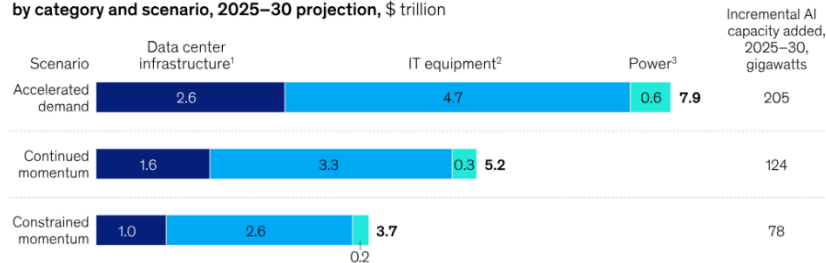
³ [Executive summary – Energy and AI](#)

⁴ [Energy and AI – IEA](#)

⁵ [The cost of compute power: A \\$7 trillion race | McKinsey](#)

Capital investments to support AI-related data center capacity demand could range from about \$3 trillion to \$8 trillion by 2030.

Global data center total capital expenditures driven by AI, by category and scenario, 2025–30 projection, \$ trillion



Note: Figures may not sum to totals, because of rounding.

¹Excludes IT services and software (eg, operating system, data center infrastructure management), since they require relatively low capex compared with other components.

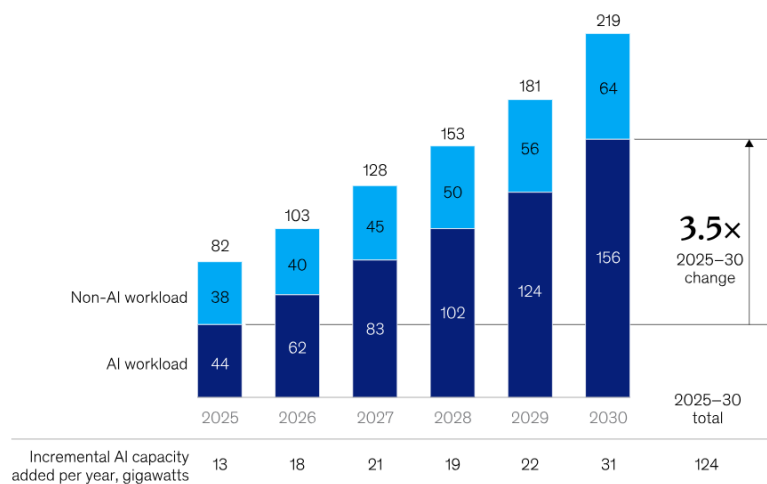
²Includes server, storage, and network infrastructure. IT capex also accounts for replacing AI accelerators every 4 years.

³Assumes \$2.2 billion–\$3.2 billion/gigawatt (including power generation and transmission cost) to account for a range of power generation scenarios (eg, fully powered by gas, a combination of gas power and storage, and solar) and regional cost differences. Distribution cost is neglected, as most AI centers are expected to be >50 megawatt scale and connected to a transmission grid.

Source: McKinsey Data Center Capex TAM Model; McKinsey Data Center Demand Model

Figure 1 McKinsey forecast on the capital investments to support global data centre capacity demand from 2025 to 2030 (Source: McKinsey & Company)

Furthermore, the \$6.7 trillion in capital investments globally by 2030, based on the second scenario, include a anticipated demand of 156 gigawatts (GW) for AI-related data centre capacity by 2030, with 125 incremental gigawatts (GW) expected to be added between 2025 and 2030 (Figure 2).



Note: Figures may not sum to totals, because of rounding.

Source: McKinsey Data Center Demand Model; Gartner reports; IDC reports; Nvidia capital markets reports

Figure 2 McKinsey forecast on the global data centre capacity demand from 2025 to 2030 (Source: McKinsey & Company)

The analysis of McKinsey & Company report suggest that this trend is contributing to a two-speed data infrastructure landscape: data centres and server rooms equipped to handle AI and HPC processing workloads, and those supporting traditional IT applications. These two types of data centre infrastructure will differ significantly in their design and operational requirements.

The forecast growth by McKinsey & Company in global data centres and server rooms capacity by 2030, driven by AI/HPC and traditional IT workloads, is creating pressing demand for energy-efficient and high-performance server rooms and data centres. The projected global growth in data centre and

server room capacity by 2030, as outlined by McKinsey & Company, is not only a worldwide trend—it is also a key market driver within Europe, where demand for decentralized and sustainably operated IT infrastructure is rapidly increasing. This growth is driven by the dual rise of AI and HPC workloads and traditional IT services, urging a shift toward localized, high-performance server rooms in tertiary buildings such as offices, hospitals, schools, and public institutions.

According to 451 Research's (unit of S&P Global Market Intelligence⁶) surveys and Datacentre Market Monitor⁷, in Europe, the Middle East, and Africa (EMEA) region, there are as many as 1.22 million enterprise server rooms, micro-datacentres, datacentres with less than 100 Kilowatt (kW) of IT power, and telecom/network hubs, as compared with an estimated 16,000 enterprise datacentres with more than 100 Kilowatt (kW). Many of these small IT deployments exist for a specific reason (e.g., location requirements, latency) and cannot easily be moved to public cloud. Decreasing the total amount of energy used by these servers could make a significant change to an enterprise's carbon footprint.

The European Data Centre Association (EUDCA)⁸ asserts in their latest report “State of European Data Centres 2025”⁹, that the European data centre market is experiencing substantial expansion, motivated by the swelling demand for digital and cloud services, AI/HPC driven applications, and edge computing requirements and solutions. Data centres are vital to Europe’s digital infrastructure, supporting a wide range of important services. The growth of data centres sector is also contributing to Europe’s GDP, employment, and overall economic development. Although colocation and hyperscale data centres now dominate in terms of overall IT power capacity in Europe—especially in core markets like FLAPD (Frankfurt, London, Amsterdam, Paris, Dublin)—enterprise data centres and server rooms still represent more than 50% of IT power in many European regions outside these hubs.

Based on the State of European Data Centres 2025 report by the EUDCA, enterprise-owned data centres remain the most numerous in Europe, with 9,000 facilities exceeding 50 Kilowatt (kW) of IT power capacity. These on-premises facilities—built by businesses to meet their immediate IT needs—represent a core target market segment for the HYCOOL-IT project. More specifically, HYCOOL-IT targets users and customers who own tertiary buildings equipped with in-house server rooms.

1.1 Scope

This report captures a clear and strategic analysis of the market conditions for the HYCOOL-IT project, focusing on: PESTLE analysis and market assessment to explore the external and market-specific factors and conditions influencing the uptake, replication, and commercialization of the HYCOOL-IT project's innovations.

⁶ [Market Intelligence | S&P Global](#)

⁷ [Improving datacentre efficiency in Europe: The role of PUE](#)

⁸ [Home | eudca.org](#)

⁹ [EUDCA State of European Data Centres 2025](#)

1.2 Audience

This deliverable is designed for:

- **HYCOOL-IT Partners** – Keeping project technical partners informed about market trends, regulatory environment, industry developments, and emerging opportunities relevant to HYCOOL-IT’s innovations.
- **The European Commission** – Providing a clear overview of key stakeholders, project outcomes, and impact management, ensuring alignment with economic, social, and environmental goals.
- **IT and Data Centre Industry Stakeholders:** Operators and managers of data Centres and IT server rooms; IT infrastructure and facility managers to inform them about the emerging trends, technologies, and best practices that directly affect the operational efficiency, sustainability, and resilience of their infrastructures.

1.3 Relation to other activities in WP

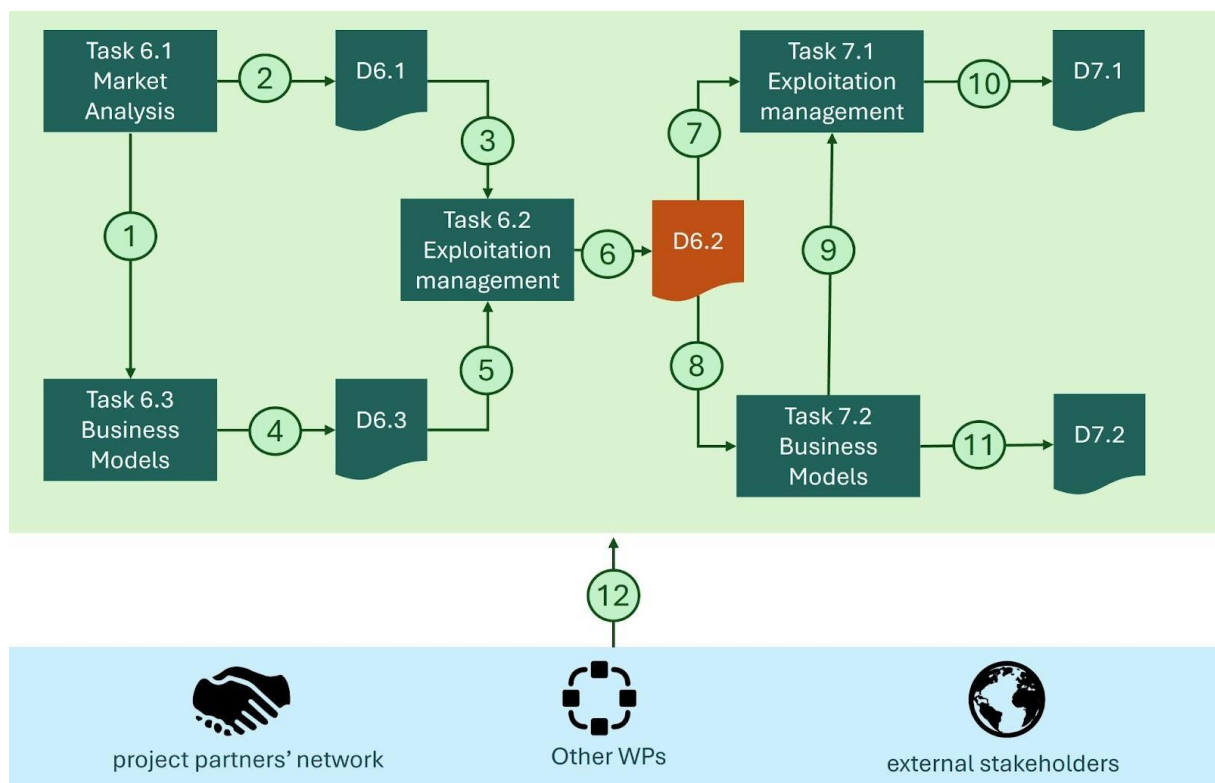


Figure 3 Relationship of D6.1 with other activities and deliverables

Figure 3 illustrates the relationship of this deliverable to other activities and deliverables in the HYCOOL-IT project. These relationships are represented as links numbered from 1 to 12 and are described as follows:

- **Link 1:** Task 6.1 conducts a market analysis, focussing on the relevant market segments for HYCOOL-IT covering building digital twin, cooling solutions for IT server rooms, DCIM solutions, and energy efficiency. The selected target markets set the scope for the analysis of relevant business models.
- **Link 2:** The results of the market analysis, including an overview of the key actors in the HYCOOL-IT business ecosystem, drivers and barriers, and a PESTEL analysis, are presented D6.1.
- **Link 3:** The results of the market analysis set the business context for the project results for which the draft exploitation plans will be developed in Task 6.2.
- **Link 4:** Based on the selected target markets, Task 6.3 conducts an analysis of the dominant business models in the HYCOOL-IT business ecosystem and drafts an initial business model for the HYCOOL-IT solution.
- **Link 5:** The overview of the business models of key actors in the HYCOOL-IT ecosystem and the initial business model for the HYCOOL-IT solution, as presented in D6.3, will be input for the preparation of the exploitation plans for the project results as developed in the other WPs.
- **Link 6:** Based on the market research performed in Task 6.1 and the business model analysis from Task 6.3, the initial exploitation plans and IPR strategies for the project results are described in this report, D6.2.
- **Link 7:** The draft exploitation plans as described in D6.2 are a starting point for Task 7.1 which will finalise the exploitation plans for the project results.
- **Link 8:** The draft exploitation plans as described in D6.2 are a starting point Task 7.2 which will validate and finalise the business model for the HYCOOL-IT solution.
- **Link 9:** The results of the business model validation activities as conducted in Task 7.2 are input for the Task 7.1 which will develop the final exploitation plans for the project's results.
- **Link 10:** The final exploitation plans for the project's results, including IPR measures, will be presented in D7.1.
- **Link 11:** The final business model for the HYCOOL-IT solution, including an overview of the validation results will be presented in D7.2.
- **Link 12:** The input from the project partners and external stakeholders, together with the solutions developed in the other workpackages, are used as input for the market analysis and definition of the HYCOOL-IT business model and exploitation plans.

1.4 Structure

This report is organized into five key chapters, each providing critical insights into the HYCOOL-IT project:

- **Chapter 1 – Introduction:** Outlines the goals, scope, targeted audience for this report, and relevance of this report within the broader project context.
- **Chapter 2 – Methodology:** Explains the approach used for landscaping and market analysis of HYCOOL-IT innovations, with a focus on IT server rooms.
- **Chapter 3 – PESTLE Analysis:** Presents the findings of HYCOOL-IT's PESTLE analysis, identifying key external factors influencing its success.

- **Chapter 4 – Market Characteristics:** Examines the HYCOOL-IT market landscape, including demand drivers, competition, and commercialization potential.
- **Chapter 5 – Conclusion:** Summarizes the key takeaways.
- **Appendixes:** Includes one-page summaries of the market analysis results for each exploitation space, providing a concise overview of market size and growth, key trends, driving factors and challenges, technologies, stakeholders, and opportunities identified throughout the report.

2. Methodology and Implementation

The Chapter 2 presents the methodology and approach used for the HYCOOL-IT Market Landscaping and Analysis.

The methodology for this report follows a structured approach to evaluate the external environment, regulatory landscape, market and business potential, and strategic pathways for the successful deployment of HYCOOL-IT solutions. This is achieved through a combination of PESTLE analysis and market assessment method, with a specific focus on four key exploitation spaces that align with the project's technological scope and objectives.

2.1 HYCOOL-IT Exploitation Spaces

The HYCOOL-IT project introduces innovations that go beyond a single product or use case. Therefore, the project's PESTLE analysis and market assessment is structured around four interlinked exploitation spaces. These exploitation spaces include Energy Efficiency (EE), Targeted Cooling Solutions for IT Server Rooms (ITSR), Building Digital Twin (BDT), and Smart Building Management Systems (SBMS). Further details on the rationale, scope, and specific elements covered within each exploitation space are provided in the Table 1.

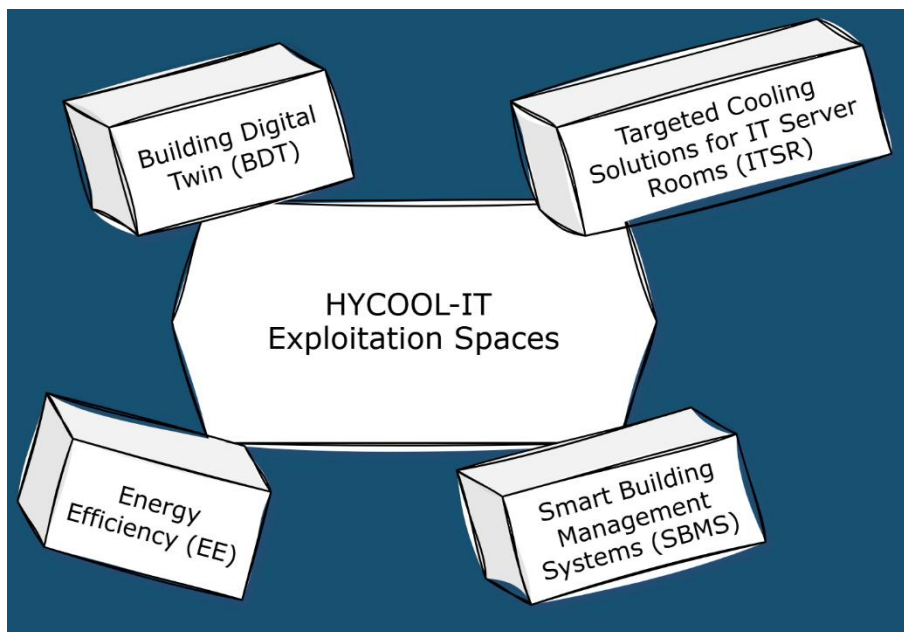


Figure 4 HYCOOL-IT Exploitation Spaces

Scope and Mapping of HYCOOL-IT Exploitation Spaces with HYCOOL-IT Innovations

The table below summaries the scope of each exploitation space, highlighting its relevance to HYCOOL-IT innovations, the specific elements addressed within each space, and the mapping of each exploitation space to the corresponding HYCOOL-IT innovation components. For each identified exploitation space, the report presents a structured and comparative analysis based on the following key dimensions: **Market Overview and Size**, highlighting the economic market size and growth potential; **Market Drivers and Challenges**, identifying forces influencing demand and barriers to adoption; **Market Segmentation**, outlining the relevant market segment and application contexts with a focus on IT server rooms; **State-of-the-Art and Emerging Technologies**, showcasing current solutions and innovation trends; **Competitive Landscape Analysis**, profiling key market players and technology providers; and a **Summary of Findings**, capturing critical insights and implications for further exploitation and business model development.

Table 1 Scope and Mapping of HYCOOL-IT Exploitation Spaces with HYCOOL-IT Innovations

Exploitation Space	Scope Description	HYCOOL-IT Innovation Fit
Energy Efficiency (EE)	<p>Scope: This exploitation space targets the expanding energy efficiency (EE) market within the data centre and server room sector, covering both State-of-the-art digital and hardware innovations that enable smarter and low-carbon operations of data centres and server rooms. It encompasses solutions such as efficient cooling technologies, AI powered O&M software solutions, Real-time monitoring and analytics tools, advanced simulation and modelling tools.</p> <p>Relevance with HYCOOL-IT Innovations: HYCOOL-IT addresses this space by delivering system-level EE improvements in the often-overlooked segment of small-to-medium server rooms in tertiary buildings. The project's solution integrates a waste-heat-driven, rack-integrated adsorption chiller with a Building Digital Twin Environment (BDTE), supported by a suite of digital tools—including SIMBOTs, Software-in-the-Loop (SiL) environments, and the Simulation Model Tracking System</p>	<p>HYCOOL-IT Solution</p> <p>Rack-integrated adsorption chiller</p>

	(SMTS)—to enable predictive control, lifecycle optimisation, and data-driven energy performance management.	
Targeted Cooling Solutions for IT Server Rooms (ITSR)	<p>Scope: This exploitation space targets the global data centre and server room cooling market, with a focus on the transition from traditional air-based cooling systems to emerging liquid-based cooling solutions. As computing density increases—driven by AI workloads, edge computing, and rising digitalization of buildings—the limitations of conventional air cooling have become evident.</p> <p>Relevance with HYCOOL-IT Innovations: HYCOOL-IT's flagship hardware innovation, the rack-integrated adsorption chiller, directly addresses this need. It introduces a compact, energy-efficient, and waste-heat-powered cooling solution designed specifically for localized server rooms in tertiary buildings. By integrating cooling directly into the server rack and enabling the simultaneous cooling of both servers and the surrounding room, the HYCOOL-IT system significantly improves thermal management while reducing energy demand.</p>	<p>Rack-integrated adsorption chiller</p> <p>Specific SIMBot of Rack-integrated adsorption chiller system libraries</p> <p>Tool for waste heat reuse for IT server rooms</p> <p>Innovative engineering guidelines for ICT Server's Room design</p>
Building Digital Twin (BDT)	<p>Scope: This exploitation space targets the growing market for Digital Twin technologies in building and IT infrastructure management, with a focus on IT server rooms in tertiary buildings such as offices, schools, hospitals, and public institutions. As AI workloads drive higher power densities and more complex thermal profiles, data centres and server rooms require smarter, more adaptive management solutions that go beyond conventional monitoring tools.</p> <p>Relevance with HYCOOL-IT Innovations: HYCOOL-IT directly addresses this need through its Building Digital Twin Environment (BDTE), powered by SimBOTs (interactive simulation models). The system enables the creation of high-fidelity digital replicas of server rooms and their thermal systems, supported by standardised and reusable SimBOT libraries. The integration of a Simulation Model Tracking System (SMTS) allows real-time data to be</p>	<p>Methodology for SIMBots creation</p> <p>Methodology for predicting and optimizing building performance using SiL</p> <p>SiL Predictive Control Module</p> <p>Simulation Model Tracking System (SMTS) Module</p> <p>Generic SIMBot libraries for IT rooms</p> <p>Specific SIMBot of Rack-integrated adsorption chiller system libraries</p> <p>CEN TC442/WG9 new working item or CWA aggregating HYCOOL-It's ICT tools and methods</p>

	merged with the simulation environment, enabling software-in-the-loop testing, lifecycle optimisation, predictive control, and performance evaluation.	
Smart Building Management Systems (SBMS)	<p>Scope: This exploitation space targets the Smart Building Management System (SBMS) market, including DCIM (Data Centre Infrastructure Management), DCM (Data Centre Management), and BMS (Building Management Systems) platforms.</p> <p>Relevance with HYCOOL-IT Innovations: The SBMS exploitation space focuses on the integration of HYCOOL-IT's digital and thermal control components into existing or new building management environments to enable real-time, intelligent, and energy-optimised operations.</p>	Doesn't cover specific HYCOOL-IT results but insights can be used for connecting the Building Digital Twin (BDT), Simulation Model Tracking System (SMTS), SiL Predictive Control Module, and the cooling hardware into a coordinated, smart building ecosystem, helping optimize energy use and control equipment in real time.

2.2 HYCOOL-IT Market Landscaping and Analysis

The HYCOOL-IT project market landscaping and analysis follows a two-step approach (shown in figure below), combining PESTLE analysis to assess the broader macro-environment and market analysis to examine specific industry dynamics. The **First step** is to perform PESTLE analysis to identify external factors and conditions that the HYCOOL-IT solution and services can leverage to seize existing opportunities or overcome/reduce barriers. The **Second step** is to perform the market analysis for targeted insights into market overview and size, demand drivers, challenges to adoption, emerging technological trends, competitive landscape, market gaps, and key stakeholders across the value chain. By integrating these methods and approaches, HYCOOL-IT delivers a comprehensive market perspective, enabling HYCOOL-IT consortium to make informed strategic decisions and gain a competitive edge.

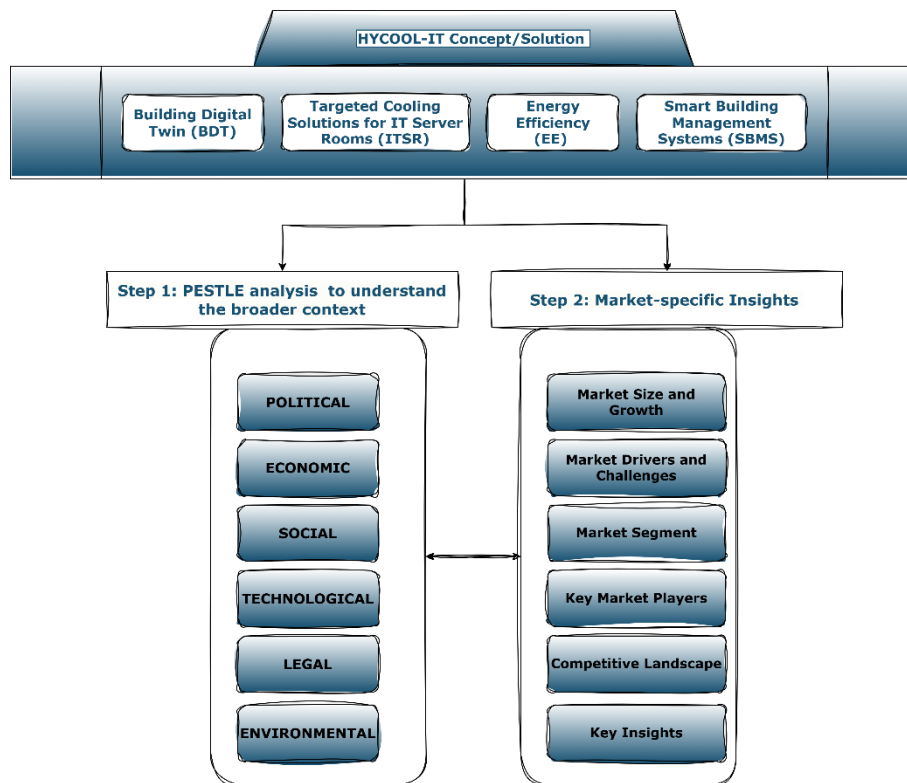


Figure 5 HYCOOL-IT Landscaping and market analysis Methodology

HYCOOL-IT Approach to PESTLE Analysis

HYCOOL-IT PESTLE analysis followed a three-step process to systematically assess the external factors shaping the adoption and impact of HYCOOL-IT's innovations. The **First step started with the Data Collection**: We started with an in-depth literature review, gathering insights on political, economic, social, technological, legal, and environmental factors affecting energy-efficient IT Server rooms. The **Second step involved Key Factor Identification & Prioritization**: From the collected data, we identified

the most critical factors for each PESTLE category. We then prioritized them based on their potential impact on HYCOOL-IT's deployment and scalability. The **Third and final step covered Expert Evaluation & Rating**: In the final step, with the support of HYCOOL-IT technical partners we assessed the identified factors. Each was classified as either a barrier or an opportunity, providing a clear roadmap for overcoming challenges and leveraging growth drivers.

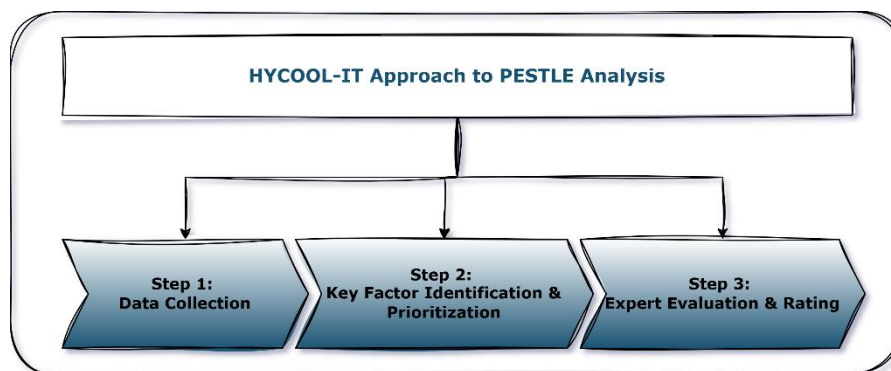


Figure 6 HYCOOL-IT Approach to PESTLE Analysis

HYCOOL-IT Approach to Market Analysis

The market analysis for the HYCOOL-IT project is based primarily on desk research, supported by targeted enquiries and expert insights to ensure a comprehensive understanding of the project's four exploitation spaces. The analysis draws on a wide range of credible sources, including **market research reports** from organisations such as McKinsey & Company¹⁰, Uptime Institute¹¹, International Data Corporation (IDC)¹², and Gartner¹³, which provide market related insights about global and European trends in data centres and server rooms, AI-driven infrastructure, and emerging cooling technologies. Additionally, publications and data from **industry associations** such as the European Data Centre Association (EUDCA)¹⁴ and The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA)¹⁵ were consulted to capture sector-specific technical and regulatory developments. Regular monitoring of **sector-specific newsletters and magazines**—including Data Centre Dispatch¹⁶—helped track recent innovations, use cases, and industry sentiment. To benchmark current technologies and identify market gaps, **information from company websites, product sheets, and case studies** was also reviewed. Where relevant, direct consultation with stakeholders and project partners was used to validate findings and gather context-specific insights. This multi-source approach ensures the market analysis is well-grounded, up-to-date, and aligned with the strategic goals of HYCOOL-IT.

¹⁰ [Why invest in the data centre economy | McKinsey](#)

¹¹ [Digital Infrastructure Authority | Tier Certification & Training - Uptime Institute](#)

¹² [IDC: The premier global market intelligence firm.](#)

¹³ [Gartner | Delivering Actionable, Objective Insight to Executives and Their Teams](#)

¹⁴ [European Data Centre Association \(EUDCA\)](#)

¹⁵ [The Federation of European Heating, Ventilation and Air Conditioning Associations \(REHVA\)](#)

¹⁶ [DVL Group: Mission Critical Data Centre Power and Cooling Experts](#)

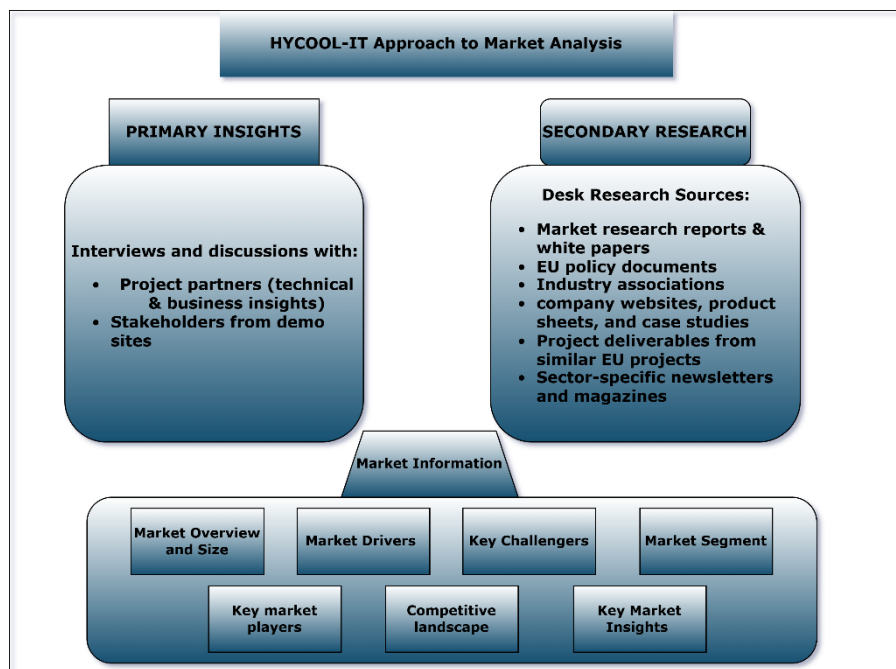


Figure 7 HYCOOL-IT Approach to Market Analysis

3. HYCOOL-IT PESTLE Analysis

HYCOOL-IT's integrated approach—combining advanced thermal management technology, digital simulation environments, predictive control, and smart building integration—aims to reduce energy consumption, optimise performance, and enable low-carbon IT infrastructure management and operation in tertiary buildings. Each of the project's exploitation spaces (EE, ITSR, BDT, SBMS) contributes to this overarching goal by addressing different technical layers and market segments.

The Chapter 3 specifies PESTLE analysis for each of HYCOOL-IT's key exploitation spaces, inspecting the political, economic, social, technological, legal, and environmental factors shaping their market potential and business environment. Among these, the **PESTLE analysis conducted for the Energy Efficiency (EE) exploitation space** can be considered broadly representative of the entire HYCOOL-IT solution, as energy efficiency is the core driver and cross-cutting objective across all the project's innovation components. The political, economic, social, technological, legal, and environmental factors affecting energy efficiency—such as the EU Energy Efficiency Directive¹⁷, the European Green Deal¹⁸, increasing energy costs, and growing sustainability pressure to decarbonise the built environment—also apply to the other exploitation spaces. As a result, the EE-focused PESTLE analysis captures the key systemic enablers, constraints, and trends that influence the full HYCOOL-IT value proposition and its market relevance. More information about HYCOOL-IT innovations and results can be found in **“D6.2 Exploitable Results table V1”**

3.1 PESTLE: A tool to study the environment

The PESTLE analysis¹⁹ is a widespread tool that is extensively utilized to investigate the external factors that influence organisations, operations, and socio-economic processes. The word PESTLE stands for Political, Economic, Sociological, Technological, Legal, and Environmental factors. The PESTLE analysis is designed to help organisations identify and investigate external factors and mega trends that could influence organisation's opportunities and threats, supporting exploitation strategies. This section presents the overview of PESTLE analysis and its relevance to the HYCOOL-IT project.

Over time, PESTLE analysis evolved to reflect changes in the external environment and the growing recognition of the importance of environmental sustainability and legal compliance. Figure below summarizes the PESTLE analysis concept.

¹⁷ [Energy Efficiency Directive](#)

¹⁸ [The European Green Deal - European Commission](#)

¹⁹ [What is a PESTLE Analysis? A Complete PESTLE Analysis Guide](#)

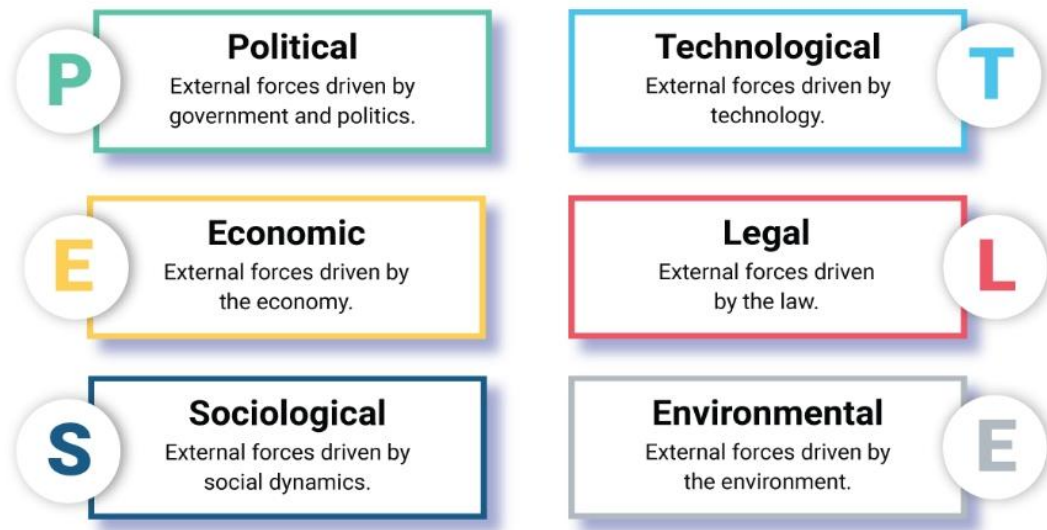


Figure 8 PESTLE Analysis Overview²⁰

²⁰ [What is a PESTLE Analysis? A Complete PESTLE Analysis Guide](#)

3.2 PESTLE analysis Energy Efficiency (EE)

Scope: This exploitation space targets the expanding energy efficiency (EE) market within the data centre and server room sector, covering both State-of-the-art digital and hardware innovations that enable smarter and low-carbon operations of data centres and server rooms. It encompasses solutions such as efficient cooling technologies, AI powered O&M software solutions, Real-time monitoring and analytics tools, advanced simulation and modelling tools.

Relevance with HYCOOL-IT Innovations: HYCOOL-IT addresses this space by delivering system-level EE improvements in the often-overlooked segment of small-to-medium server rooms in tertiary buildings. The project's solution integrates a waste-heat-driven, rack-integrated adsorption chiller with a Building Digital Twin Environment (BDTE), supported by a suite of digital tools—including SIMBOTs, Software-in-the-Loop (SiL) environments, and the Simulation Model Tracking System (SMTS)—to enable predictive control, lifecycle optimisation, and data-driven energy performance management.

Table 2 PESTLE analysis Energy Efficiency (EE)

Energy Efficiency (EE)			
P	Political		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
EU Green Deal ²¹ and Digital Decade ²²	Opportunity	Data centres and server rooms are at the centre of the EU's green and digital transitions. The European Commission explicitly aims for "climate-neutral, highly energy efficient and sustainable data centres by 2030" as part of its goals for Green Deal and Digital Decade.	Strong alignment with EU policy priorities creates a favourable business environment for HYCOOL-IT's innovations.
EU Energy Efficiency Directive for Data Centres ²³	Opportunity	The EU Energy Efficiency Directive (EED) which was adopted in 2012 and amended several times, targets to realize substantial energy savings within various sectors. One of its essential goals is a 32.5% improvement in energy efficiency by 2030. The EED assigns energy	The EED strengthens the regulatory push for energy-efficient and sustainable data centre operations, creating a demand driver for innovations like HYCOOL-IT's rack-integrated waste-heat-powered adsorption chiller. It also enhances the relevance of HYCOOL-IT's

²¹ [The European Green Deal - European Commission](#)

²² [Europe's digital decade: 2030 targets | European Commission](#)

²³ [Energy Efficiency Directive](#)

		audits, reporting, and efficiency measures for large energy consumers, including data centres. In its latest updates, the directive has progressively concentrated on data centres due to their fast growth and significant energy demands. Article 12 of revised EED (adopted on 13 September 2023) establishes an annual reporting requirement for datacentres placed in the EU, with a power demand of installed IT above 500kW. The data will be circulated in an accumulated manner at EU and Member States levels and will be evaluated regularly. Following the evaluation, the European Commission may suggest further procedures to enhance the sustainable development of the EU data centres industry, such as minimum performance standards, or a labelling scheme. On top of the reporting requirements, the EED also establishes further measures which will impact datacentre operators, with new provisions on the reuse of waste heat, and provisions on energy management systems.	digital twin-based control and management systems for monitoring, reporting, and compliance, positioning the project as a solution to meet upcoming regulatory requirements and future-proof data centres.
Delegated Regulation (Art. 3.1 §2) establishing the reporting scheme for Data Centres ²⁴	Opportunity	The delegated regulation establishes up the reporting obligations and requirements and the reporting scheme and registers the data points to be gathered and associated KPIs. Furthermore, the delegated regulation officially sets up the European database which will gather the information and data and publish some of it at two levels of aggregation: EU level and country levels. The delegated regulation adopted into action 20 days after its publication (6 June 2024). Reporting requirements on ICT equipment capacity: The requirement and obligation to report on ICT equipment	The delegated regulation strengthens the regulatory push for energy-efficient and sustainable data centre operations, creating a demand driver for innovations like HYCOOL-IT's rack-integrated waste-heat-powered adsorption chiller. It also enhances the relevance of HYCOOL-IT's digital twin-based control and management systems for monitoring, reporting, and compliance, positioning the project as a solution to meet upcoming regulatory requirements and future-proof data centres.

²⁴ [Commission takes first step towards establishing an EU-wide scheme for rating sustainability of data centres - European Commission](#)

		only relates to the equipment that is installed in data centres after the entry into force of the delegated regulation (6 June 2024).	
National Transposition of the Art. 12 of the EED	Barrier & Opportunity (mixed)	<p>EU Member States are anticipated to transpose the EED into their domestic legal framework. On the other hand, the Delegated Regulation completely employs and is not subject to transposition procedures.</p> <p>The Art. 12 of the EED is essential to be transposed by all Member States into their national legal systems, via the legal instruments of their choosing. Upon transposing the Art. 12 of the EED, Member States might also modify several portions of the reporting proposal, such as addition of new data and information points, extending the scope of reporting entities, or establishing up their own national reporting platform for instance.</p>	The varied pace and approach of national transpositions may create uncertainties and fragmented compliance landscapes across EU markets, posing a barrier for rapid and uniform adoption.
German Energy Efficiency Act ²⁵	Opportunity	Require all data centres that start operations before July 2026 to sustain a PUE of 1.5 or lower by 2027, and eventually 1.3 PUE or lower by 2030.	Germany's ambitious PUE requirements create a strong market pull for highly efficient cooling and energy management solutions. HYCOOL-IT's rack-integrated adsorption chiller and digital tools can directly support operators in meeting these targets, making Germany an early adopter and key pilot market for HYCOOL-IT.
Energy Performance of Buildings Directive ²⁶	Opportunity	The Energy Performance of Buildings Directive plays a key role in advancing the EU's energy and climate objectives, with the overarching goal of fully decarbonising the building stock by 2050 — including data centres.	Strong alignment with EU policy priorities creates a favourable business environment for HYCOOL-IT's innovations.

²⁵ [Dentons - How Germany's Energy Efficiency Act will impact data Centre operators](#)

²⁶ [Energy Performance of Buildings Directive](#)

Smart Readiness Indicator (SRI) ²⁷	Opportunity	The smart readiness indicator (SRI) is a European Commission programme underneath the Energy Performance of Buildings Directive that evaluates a building's capability to utilize smart technologies. For example, from 2027, the Smart Readiness Indicator (SRI)—which assesses the smart capabilities of a building based on several criteria—will become mandatory for non-residential buildings.	The mandatory SRI creates new drivers for integrating smart, energy-efficient, and responsive technologies into buildings, including data centres and server rooms in tertiary buildings.
Climate Neutral and Energy-Efficient Industry Goals ²⁸	Opportunity	The EU's Green Deal sets a political (non-binding) target for data centres to become climate-neutral and highly energy-efficient by 2030. The European data centre industry, through initiatives like the Climate Neutral Data Centre Pact (CNDCP) ²⁹ , has voluntarily committed to these targets.	The HYCOOL-IT's combined solution that includes adsorption chiller and Building digital twin environment (BDTE) can help facilities meet these commitments while providing verification capabilities.
EU Code of Conduct for Data Centre Efficiency ³⁰	Opportunity	This voluntary program promotes energy efficiency best practices and provides a framework for monitoring and improvement.	The Code of Conduct provides recognised guidelines and frameworks that can support HYCOOL-IT's alignment with industry best practices.
Corporate Sustainability Reporting Directive (CSRD) ³¹	Opportunity	The CSRD introduces extensive sustainability reporting requirements that include energy usage, GHG emissions, and other metrics relevant to data centres.	The CSRD increases pressure on data centre operators to measure, report, and improve their sustainability performance, creating market demand for solutions that support data tracking, reporting, and efficiency improvements.
EU Taxonomy ³²	Opportunity	The EU Taxonomy legislation expects that a passing organization get their data centre "externally examined	The EU Taxonomy creates strong incentives for data centre operators to adopt highly efficient, low-carbon

²⁷ [Smart readiness indicator - European Commission](#)

²⁸ [The European Green Deal - European Commission](#)

²⁹ [Climate Neutral Data Centre Pact – The Green Deal need Green Infrastructure](#)

³⁰ [European Code of Conduct for Energy Efficiency in Data Centres - European Commission](#)

³¹ [Corporate sustainability reporting - European Commission](#)

³² [EU taxonomy for sustainable activities - European Commission](#)

		every three years" to "expected best practices", which can be reviewed on the EU Taxonomy compass ³³ .	technologies to maintain or achieve green finance eligibility and ESG compliance.
Data centre specific Green Public Procurement (GPP) criteria ³⁴	Opportunity	The EU has developed GPP criteria specifically for data centres to guide public sector purchases toward sustainable digital solutions.	HYCOOL-IT innovations align with several GPP criteria areas, potentially opening access to public procurement opportunities.
EU F-Gas Regulation 2024/573 ³⁵	Opportunity	The renewed EU F-Gas Regulation 2024/573 establishes rigorous legal obligations on refrigerants with high global warming potential (GWP) and includes significant implications for data centre cooling infrastructure. These changes concern equipment phase-outs and more leak detection requirements, urging operators to adjust their repairs strategies and plan for sustainable new builds.	The regulation accelerates the market shift toward low-GWP or refrigerant-free cooling solutions, creating an opportunity for HYCOOL-IT's adsorption chiller technology, which uses water as a working fluid with no GWP impact.
E	ECONOMIC		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Expanding Data Centre Capacity and Market	Opportunity	The global data centre market continues to grow rapidly, driven by digitalisation, AI/HPC, cloud computing, and edge computing expansion.	The expanding data centre market increases the demand for energy-efficient, scalable, and sustainable infrastructure solutions. This growth offers a favourable business environment for HYCOOL-IT's innovations, opening opportunities in both new builds and retrofits of localized server rooms and enterprise data centres.
Rising Operating Costs	Opportunity	Power costs account for a significant and growing portion of data centre operational expenses, particularly with increasing workloads and AI-driven demand.	Rising energy costs create strong economic incentives for data centre operators to invest in energy-efficient cooling and smart management solutions.
Focus on Lowering the Total Cost of Ownership (TCO)	Opportunity	Data centre operators are increasingly prioritising solutions that reduce both capital and operational expenses over the facility lifecycle.	This strengthens the demand for solutions like HYCOOL-IT's rack-integrated adsorption chiller and digital twin, which offer energy savings, operational efficiency, and

³³ [EU Taxonomy Navigator](#)

³⁴ [Green Public Procurement \(GPP\) criteria for data centres - Lexology](#)

³⁵ [F-gas Legislation - Fluorinated Greenhouse Gases – Climate Action](#)

			reduced maintenance costs, contributing directly to lowering the TCO for both new and existing data centre and server room infrastructure.
S	SOCIAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Industry Skills Shortage	Barrier	A shortage of skilled technical personnel poses significant challenges for the design, construction, and operation of data centres, with intense competition for talent across industries.	The skills gap can slow adoption of complex or resource-intensive technologies, making simplicity, automation, and ease of integration key value propositions.
Industry Awareness	Barrier	While awareness of sustainability is growing, knowledge about advanced technologies such as adsorption chillers or digital twins is still limited among data centre operators and designers.	Limited market awareness poses a barrier to adoption, requiring HYCOOL-IT to invest in targeted dissemination, demonstration, training, and awareness-building efforts to educate stakeholders on the benefits, performance, and applications of adsorption cooling and digital twins, supporting market acceptance and uptake.
T	TECHNOLOGICAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Compliance Automation	Opportunity	Automated capacity and ESG reporting to free up valuable data centre operations resource to focus on added value activities.	This trend creates an opportunity for HYCOOL-IT's digital twin and monitoring tools to integrate automated compliance and reporting functionalities.
AI-powered Cooling Advisory and Anomaly Detection tools ³⁶	Opportunity	To help operations teams unlock cooling energy savings from their systems and identify M&E cooling equipment performance anomalies ahead of a potential equipment failure.	This trend enhances the market readiness for HYCOOL-IT's integrated digital twin and AI-driven predictive control capabilities, positioning the project's solutions as part of the next generation of smart, autonomous, and efficient data centre cooling and maintenance systems that reduce risks and unlock energy savings.
Efficiency Plateauing	Opportunity	After a decade of easy efficiency gains (e.g., airflow management, virtualization), further efficiency improvements in data centres and server rooms now	This creates a clear opening for HYCOOL-IT's advanced digital twin, AI-driven control, and innovative rack-integrated adsorption cooling system, which provide

³⁶ [Data Centre liquid cooling advice - EkkoSense](#)

		require advanced digital tools, deep system optimization, and innovative cooling solutions.	new levers for optimization where traditional methods have reached their limits.
Standards Development	Opportunity	Both liquid cooling and digital twin technologies currently lack fully established and universally adopted standards, creating uncertainty in interoperability and scalability.	The lack of standards can slow adoption and create market hesitancy but also provides an opportunity for HYCOOL-IT to contribute to and influence emerging standards.
L	LEGAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Regulatory Compliance and Permitting	Barrier	Compliance with evolving EU and national regulations (e.g., EED reporting, EU Taxonomy, F-Gas) is becoming increasingly complex, especially for older and smaller data centres.	Compliance can pose a barrier for data centre operators due to added complexity and costs, but it also creates an opportunity for HYCOOL-IT to position its integrated digital twin, monitoring, and low-GWP cooling solutions as enablers of regulatory compliance, reporting automation, and sustainable permitting readiness.
Data Privacy and Security	Barrier	Digital twins collect and process operational data that may be sensitive for facility operators.	Data privacy and cybersecurity concerns can pose a barrier to adoption, especially in highly regulated or risk-averse environments. HYCOOL-IT must ensure that its digital systems include robust data governance, secure architecture, and GDPR compliance, which are critical to building user trust and enabling deployment in commercial environments.
E	ENVIRONMENTAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Sustainability Pressures	Opportunity	The data centre industry faces continued pressure to reduce its environmental footprint, including improved water efficiency and advanced heat reuse solutions.	These pressures create a favourable environment for HYCOOL-IT's low-impact, water-based adsorption chiller and integrated waste-heat reuse capabilities, positioning the solution as a sustainable alternative that aligns with industry goals for water conservation, carbon reduction, and circular resource use.

Local climate conditions	Opportunity	Colder conditions lead to lower PUE given a reduction in energy needed for cooling systems that account for up to 40% of energy usage.	Local climate conditions should be leveraged for design and operations decisions.
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3.3 PESTLE analysis Targeted Cooling Solutions for IT Server Rooms (ITSR)

Scope: This exploitation space targets the global data centre and server room cooling market, with a focus on the transition from traditional air-based cooling systems to emerging liquid-based cooling solutions. As computing density increases—driven by AI workloads, edge computing, and rising digitalization of buildings—the limitations of conventional air cooling have become evident.

Relevance with HYCOOL-IT Innovations: HYCOOL-IT’s flagship hardware innovation, the rack-integrated adsorption chiller, directly addresses this need. It introduces a compact, energy-efficient, and waste-heat-powered cooling solution designed specifically for localized server rooms in tertiary buildings. By integrating cooling directly into the server rack and enabling the simultaneous cooling of both servers and the surrounding room, the HYCOOL-IT system significantly improves thermal management while reducing energy demand.

Table 3 PESTLE analysis Targeted Cooling Solutions for IT Server Rooms (ITSR)

Targeted Cooling Solutions for IT Server Rooms (ITSR)			
P	Political		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
EU Green Deal ³⁷ and Digital Decade ³⁸	Opportunity	Data centres and server rooms lie at the heart of the EU’s green and digital transitions. The European Commission explicitly aims for "climate-neutral, highly energy efficient and sustainable data centres by 2030" as part of its goals for Green Deal and Digital Decade.	Strong alignment with EU policy priorities creates a favourable business environment for HYCOOL-IT’s innovations.
EU Energy Efficiency Directive for Data Centres ³⁹	Opportunity	Article 12 of revised EED (adopted on 13 September 2023) establishes an annual reporting requirement for datacentres placed in the EU, with a power demand of installed IT above 500kW. The data will be circulated in an accumulated manner at EU and Member States levels and will be evaluated regularly. Following the evaluation, the European Commission may suggest further procedures to	The EED strengthens the regulatory push for energy-efficient and sustainable data centre operations, creating a demand driver for innovations like HYCOOL-IT’s rack-integrated waste-heat-powered adsorption chiller. It also enhances the relevance of HYCOOL-IT’s digital twin-based control systems for monitoring, reporting, and compliance,

³⁷ [The European Green Deal - European Commission](#)

³⁸ [Europe’s digital decade: 2030 targets | European Commission](#)

³⁹ [Energy Efficiency Directive](#)

		enhance the sustainable development of the EU data centres industry, such as minimum performance standards, or a labelling scheme. On top of the reporting requirements, the EED also establishes further measures which will impact datacentre operators, with new provisions on the reuse of waste heat, and provisions on energy management systems.	positioning the project as a solution to meet upcoming regulatory requirements and future-proof data centres.
EU F-Gas Regulation 2024/573 ⁴⁰	Opportunity	The renewed EU F-Gas Regulation 2024/573 establishes rigorous legal obligations on refrigerants with high global warming potential (GWP) and includes significant implications for data centre cooling infrastructure. These changes concern equipment phase-outs and more leak detection requirements, urging operators to adjust their repairs strategies and plan for sustainable new builds.	The regulation accelerates the market shift toward low-GWP or refrigerant-free cooling solutions, creating an opportunity for HYCOOL-IT's adsorption chiller technology, which uses water as a working fluid with no GWP impact.
E	ECONOMIC		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
High upfront and transition Costs	Barrier	The transition to advanced cooling systems such as liquid cooling or adsorption cooling systems represents a significant capital investment, especially for retrofitting existing facilities.	High upfront costs for adopting advanced cooling technologies can slow down market adoption, especially in legacy facilities with budget constraints. investment hesitancy among potential customers.
Focus on Lowering the Total Cost of Ownership (TCO)	Opportunity	Data centre operators are increasingly prioritising solutions that reduce both capital and operational expenses over the facility lifecycle. The capital intensity of data centres has operators focusing heavily on reducing total cost of ownership—especially operational and energy costs that eat into margins.	This strengthens the demand for solutions like HYCOOL-IT's rack-integrated adsorption chiller and digital twin, which offer energy savings, operational efficiency, and reduced maintenance costs, contributing directly to lowering the TCO for both new and existing data centre and server room infrastructure.
Rising cost of IT Equipment	Opportunity	As IT hardware becomes more expensive, there is a growing need to protect these investments and hardware	Rising IT equipment costs increase the business case for advanced cooling and management solutions that ensure

⁴⁰ [F-gas Legislation - Fluorinated Greenhouse Gases – Climate Action](#)

		through more reliable, efficient cooling and intelligent infrastructure management systems.	equipment longevity, prevent failures, and optimize performance.
S	SOCIAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Industry Skills Shortage	Barrier	A shortage of skilled technical personnel poses significant challenges for the design, construction, and operation of data centres, with intense competition for talent across industries.	The skills gap can slow adoption of complex or resource-intensive technologies, making simplicity, automation, and ease of integration key value propositions.
T	TECHNOLOGICAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Reliability Concerns	Barrier	Data Centre operators prioritize reliability above all else, creating hesitancy toward new cooling technologies.	Overcoming reliability concerns is critical for HYCOOL-IT's market entry. Demonstrating robustness, performance validation, and risk mitigation strategies (e.g., pilots, certifications, case studies) will be essential to build operator trust and confidence in the rack-integrated adsorption chiller.
Rising Power Density and AI Adoption	Opportunity	AI and HPC driven workloads are significantly increasing rack power densities, surpassing the cooling capabilities of traditional air-based systems.	This creates a strong driver for innovative, high-efficiency, and rack-integrated cooling technologies like HYCOOL-IT's adsorption chiller, which can effectively manage high-density heat loads while supporting energy-efficient, scalable operations in AI-focused and next-generation data centres and server rooms.
Cooling efficiency	Opportunity	Hardware innovation is increasing the power of chips as well as the heat generated. Software for temperature management is increasingly important to prevent hotspots that can damage equipment and optimize cooling systems based on server load and environment.	This trend Favors integrated hardware and software solutions like HYCOOL-IT's combined rack-integrated adsorption chiller and digital twin-based predictive control, enabling real-time, data-driven cooling optimisation, hotspot prevention, and adaptive energy management, strengthening HYCOOL-IT's market relevance.
AI-powered Cooling Advisory	Opportunity	To help operations teams unlock cooling energy savings from their systems and identify M&E cooling equipment	This trend enhances the market readiness for HYCOOL-IT's integrated digital twin and AI-driven predictive control capabilities, positioning the project's solutions as part of

and Anomaly Detection tools ⁴¹		performance anomalies ahead of a potential equipment failure.	the next generation of smart, autonomous, and efficient data centre cooling and maintenance systems that reduce risks and unlock energy savings.
Power Constraints	Opportunity	Access to reliable and sustainable power remains a critical issue, compounded by grid congestion in high-growth regions.	Power constraints increase the attractiveness of energy-efficient, low-demand, and waste-heat-utilizing cooling solutions like HYCOOL-IT's adsorption chiller, helping data centres reduce power demand, operate more sustainably.
L	LEGAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Regulatory Compliance and Permitting	Barrier	Compliance with evolving EU and national regulations (e.g., EED reporting, EU Taxonomy, F-Gas) is becoming increasingly complex, especially for older and smaller data centres.	Compliance can pose a barrier for data centre operators due to added complexity and costs, but it also creates an opportunity for HYCOOL-IT to position its integrated digital twin, monitoring, and low-GWP cooling solutions as enablers of regulatory compliance, reporting automation, and sustainable permitting readiness.
E	ENVIRONMENTAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Waste Heat Reuse	Opportunity	Growing focus on capturing and reusing waste heat from data centres to improve sustainability, energy efficiency, and contribute to circular economy goals.	HYCOOL-IT's waste-heat-powered adsorption chiller directly supports waste heat reuse strategies.
Use of perfluoroalkyl substances (PFAS) ⁴²	Opportunity	PFAS chemicals are facing bans and restrictions in both the EU and US, with the European Chemicals Agency (ECHA) aiming to restrict all PFAS by 2025 due to environmental and health risks.	The upcoming restrictions on PFAS create market demand for PFAS-free alternatives in cooling systems and data centre operations.
Advanced Thermal Management Fluids	Opportunity	Advanced Thermal Management Fluids (e.g., R-1336mzz(Z)): These fluids have very low GWP and zero ozone depletion potential, making them key enablers for	The shift towards low-GWP thermal fluids enhances the market positioning of HYCOOL-IT's environmentally friendly cooling approach, which uses water as the working fluid in adsorption chillers, offering an even more

⁴¹ [Data Centre liquid cooling advice - EkkoSense](#)

⁴² [Per- and polyfluoroalkyl substances \(PFAS\) - ECHA](#)

		sustainable liquid cooling solutions aligned with net-zero goals.	sustainable and regulation-proof alternative in comparison to synthetic thermal fluids.
Refrigerant transition	Opportunity	Regulations are accelerating the phase-out of high-GWP refrigerants, driving the industry toward eco-friendly, low-GWP, or refrigerant-free alternatives.	HYCOOL-IT's adsorption chiller uses water as a refrigerant, with zero GWP and no environmental risks, providing a future-proof, regulation-compliant alternative.

3.4 PESTLE analysis Building Digital Twin (BDT)

Scope: This exploitation space targets the growing market for Digital Twin technologies in building and IT infrastructure management, with a focus on IT server rooms in tertiary buildings such as offices, schools, hospitals, and public institutions. As AI workloads drive higher power densities and more complex thermal profiles, data centres and server rooms require smarter, more adaptive management solutions that go beyond conventional monitoring tools.

Relevance with HYCOOL-IT Innovations: HYCOOL-IT directly addresses this need through its Building Digital Twin Environment (BDTE), powered by SimBOTS (interactive simulation models). The system enables the creation of high-fidelity digital replicas of server rooms and their thermal systems, supported by standardised and reusable SimBOT libraries. The integration of a Simulation Model Tracking System (SMTS) allows real-time data to be merged with the simulation environment, enabling software-in-the-loop testing, lifecycle optimisation, predictive control, and performance evaluation.

Table 4 PESTLE analysis Building Digital Twin (BDT)

Building Digital Twin (BDT)			
P	Political		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
EU Green Deal ⁴³ and Digital Decade ⁴⁴	Opportunity	Data centres and server rooms lie at the heart of the EU's green and digital transitions. The European Commission explicitly aims for "climate-neutral, highly energy efficient and sustainable data centres by 2030" as part of its goals for Green Deal and Digital Decade.	Strong alignment with EU policy priorities creates a favourable business environment for HYCOOL-IT's innovations.
EU Energy Efficiency Directive for Data Centres ⁴⁵	Opportunity	Article 12 of revised EED (adopted on 13 September 2023) establishes an annual reporting requirement for datacentres placed in the EU, with a power demand of installed IT above 500kW. The data will be circulated in an accumulated manner at EU and Member States levels	The EED strengthens the regulatory push for energy-efficient and sustainable data centre operations, creating a demand driver for innovations like HYCOOL-IT's rack-integrated waste-heat-powered adsorption chiller. It also enhances the relevance of HYCOOL-IT's digital twin-based

⁴³ [The European Green Deal - European Commission](#)

⁴⁴ [Europe's digital decade: 2030 targets | European Commission](#)

⁴⁵ [Energy Efficiency Directive](#)

		and will be evaluated regularly. Following the evaluation, the European Commission may suggest further procedures to enhance the sustainable development of the EU data centres industry, such as minimum performance standards, or a labelling scheme. On top of the reporting requirements, the EED also establishes further measures which will impact datacentre operators, with new provisions on the reuse of waste heat, and provisions on energy management systems.	control systems for monitoring, reporting, and compliance, positioning the project as a solution to meet upcoming regulatory requirements and future-proof data centres.
Smart Readiness Indicator (SRI) ⁴⁶	Opportunity	The smart readiness indicator (SRI) is a European Commission programme underneath the Energy Performance of Buildings Directive that evaluates a building's capability to utilize smart technologies. For example, from 2027, the Smart Readiness Indicator (SRI)—which assesses the smart capabilities of a building based on several criteria—will become mandatory for non-residential buildings.	The mandatory SRI creates new drivers for integrating smart, energy-efficient, and responsive technologies into buildings, including data centres and server rooms in tertiary buildings.
Government Regulations and Initiatives ⁴⁷	Opportunity	Government regulations and initiatives are also driving the growth of the Building Twin Market. Governments around the world are increasingly implementing regulations and initiatives that promote energy efficiency and sustainability in buildings. These regulations and initiatives are creating a demand for solutions that can help organizations to meet these requirements.	This creates a favorable environment for HYCOOL-IT's Building Digital Twin (BDT) solution, as governments encourage or mandate the use of smart, energy-optimised technologies.
E	ECONOMIC		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Increasing Demand for Energy Efficiency	Opportunity	The increasing demand for energy efficiency is another key driver of the Building Digital Twin Market. Buildings are responsible for a significant portion of global energy	This strengthens the market relevance of HYCOOL-IT's integrated digital twin and rack-integrated adsorption chiller, offering energy-efficient, intelligent cooling and

⁴⁶ Smart readiness indicator - European Commission

⁴⁷ Building Twin Market Size, Share & Industry Growth 2032

		consumption, and there is a growing demand for solutions that can help to reduce energy consumption and improve energy efficiency.	facility optimisation tools that help operators meet their energy efficiency targets and reduce operational costs.
Rising cost of IT Equipment	Opportunity	As IT hardware becomes more expensive, there is a growing need to protect these investments and hardware through more reliable, efficient cooling and intelligent infrastructure management.	Rising IT equipment costs increase the business case for advanced cooling and management solutions that ensure equipment longevity, prevent failures, and optimize performance.
Focus on Lowering the Total Cost of Ownership (TCO)	Opportunity	Data centre operators are increasingly prioritising solutions that reduce both capital and operational expenses over the facility lifecycle. The capital intensity of data Centres has operators focusing heavily on reducing total cost of ownership—especially operational and energy costs that eat into margins.	This strengthens the demand for solutions like HYCOOL-IT's rack-integrated adsorption chiller and digital twin, which offer energy savings, operational efficiency, and reduced maintenance costs, contributing directly to lowering the TCO for both new and existing data centre and server room infrastructure.
High Initial Investment	Barrier	Implementing building digital twin technology can be cost-intensive, particularly for smaller projects and firms.	High initial costs can slow adoption in cost-sensitive markets, especially among SMEs and operators of smaller data centres or server rooms.
S	SOCIAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Industry Skills Shortage	Barrier	A shortage of skilled technical personnel poses significant challenges for the design, construction, and operation of data centres, with intense competition for talent across industries.	The skills gap can slow adoption of complex or resource-intensive technologies, making simplicity, automation, and ease of integration key value propositions.
Digital Literacy Gap	Barrier	Effective use of digital twins and advanced analytics requires digital skills that are not yet widely available among building and data centre operators.	The digital skills gap may limit the adoption of complex digital twin platforms in the short term. HYCOOL-IT can mitigate this by offering a user-friendly, modular digital twin system with simplified interfaces, automation, and integration capabilities, reducing the skills barrier and enabling broader market acceptance.
Skill Gap in Workforce	Barrier	There is a shortage of skilled professionals with expertise in designing, implementing, and managing digital twin technologies, which limits widespread adoption.	The skills gap can slow adoption of complex digital twin systems, especially in smaller organisations. HYCOOL-IT can differentiate itself by offering a simplified, modular,

			and user-friendly digital twin solution with integrated automation and decision support, lowering the skill threshold needed for deployment and operation.
T	TECHNOLOGICAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Increasing data generation and volumes	Opportunity	There is an increasing amount of data generated from components of data centres creating a need for tools to utilise the data, conduct continuous monitoring, and develop data driven decisions for better operations.	This trend creates an opportunity for HYCOOL-IT's digital twin, real-time monitoring, and predictive analytics tools, which can turn raw data into actionable intelligence, enabling smarter, more efficient cooling and operational decisions.
Simulation Accuracy	Opportunity	The effectiveness of digital twin technology is highly dependent on the accuracy and reliability of its underlying simulation models.	Ensuring high simulation accuracy is critical for market acceptance of HYCOOL-IT's digital twin platform.
IoT and Sensor Integration	Opportunity	Advanced sensor networks are enabling real-time monitoring, control of cooling systems, and continuous updating of digital twin models.	The growing adoption of IoT and sensor technologies enhances the capabilities of HYCOOL-IT's digital twin.
Facility and system design & age Lower PUE	Opportunity	Facility and System Design & Age: Newer data centres designed with energy efficiency in mind can achieve lower PUE from the start, while older facilities often struggle with outdated infrastructure and inefficient cooling systems.	HYCOOL-IT's solutions can be positioned both for new, energy-efficient data centre designs aiming to achieve low PUE, and for retrofit opportunities in ageing facilities needing to improve efficiency and reduce energy demand.
Cooling efficiency	Opportunity	Hardware innovation is increasing the power of chips as well as the heat generated. Software for temperature management is increasingly important to prevent hotspots that can damage equipment and optimize cooling systems based on server load and environment.	This trend Favors integrated hardware and software solutions like HYCOOL-IT's combined rack-integrated adsorption chiller and digital twin-based predictive control, enabling real-time, data-driven cooling optimisation, hotspot prevention, and adaptive energy management, strengthening HYCOOL-IT's market relevance.
AI-powered Cooling Advisory and	Opportunity	To help operations teams unlock cooling energy savings from their systems and identify M&E cooling equipment	This trend enhances the market readiness for HYCOOL-IT's integrated digital twin and AI-driven predictive control capabilities, positioning the project's solutions as part of

Anomaly Detection tools ⁴⁸		performance anomalies ahead of a potential equipment failure.	the next generation of smart, autonomous, and efficient data centre cooling and maintenance systems that reduce risks and unlock energy savings.
Scalability Issues in Large Data Centres	Barrier	As data Centre infrastructures grow, ensuring seamless scalability and maintaining real-time accuracy in digital twins can be complex and resource intensive.	Scalability challenges in large-scale deployments may limit the adoption of digital twins in hyperscale or complex data centres.
Lack of Standardization & Interoperability	Barrier	The absence of unified industry standards makes it difficult to integrate digital twin O&M systems with existing data centre management tools and platforms.	This hinders seamless integration and interoperability, potentially slowing down adoption.
L	LEGAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Data Privacy and Security	Barrier	Digital twins collect and process operational data that may be sensitive for facility operators.	Data privacy and cybersecurity concerns can pose a barrier to adoption, especially in highly regulated or risk-averse environments. HYCOOL-IT must ensure that its digital systems include robust data governance, secure architecture, and GDPR compliance, which are critical to building user trust and enabling deployment in commercial environments.
E	ENVIRONMENTAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Sustainability Pressures	Opportunity	The data centre industry faces continued pressure to reduce its environmental footprint, including improved water efficiency and advanced heat reuse solutions.	These pressures create a favourable environment for HYCOOL-IT's low-impact, water-based adsorption chiller and integrated waste-heat reuse capabilities, positioning the solution as a sustainable alternative that aligns with industry goals for water conservation, carbon reduction, and circular resource use.

⁴⁸ [Data Centre liquid cooling advice - EkkoSense](#)

3.5 PESTLE analysis Smart Building Management Systems (SBMS)

Scope: This exploitation space targets the Smart Building Management System (SBMS) market, including DCIM (Data Centre Infrastructure Management), DCM (Data Centre Management), and BMS (Building Management Systems) platforms.

Relevance with HYCOOL-IT Innovations: The SBMS exploitation space focuses on the integration of HYCOOL-IT's digital and thermal control components into existing or new building management environments to enable real-time, intelligent, and energy-optimised operations.

Table 5 PESTLE analysis Smart Building Management Systems (SBMS)

Smart Building Management Systems (SBMS)			
P	Political		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
EU Green Deal ⁴⁹ and Digital Decade ⁵⁰	Opportunity	Data centres and server rooms lie at the heart of the EU's green and digital transitions. The European Commission explicitly aims for "climate-neutral, highly energy efficient and sustainable data centres by 2030" as part of its goals for Green Deal and Digital Decade.	Strong alignment with EU policy priorities creates a favourable business environment for HYCOOL-IT's innovations.
EU Energy Efficiency Directive for Data Centres ⁵¹	Opportunity	Article 12 of revised EED (adopted on 13 September 2023) establishes an annual reporting requirement for datacentres placed in the EU, with a power demand of installed IT above 500kW. The data will be circulated in an accumulated manner at EU and Member States levels and will be evaluated regularly. Following the evaluation, the European Commission may suggest further procedures to enhance the sustainable development of the EU data centres industry, such as minimum performance standards, or a labelling scheme. On top of the reporting requirements, the EED also establishes further measures	The EED strengthens the regulatory push for energy-efficient and sustainable data centre operations, creating a demand driver for innovations like HYCOOL-IT's rack-integrated waste-heat-powered adsorption chiller. It also enhances the relevance of HYCOOL-IT's digital twin-based control systems for monitoring, reporting, and compliance, positioning the project as a solution to meet upcoming regulatory requirements and future-proof data centres.

⁴⁹ [The European Green Deal - European Commission](#)

⁵⁰ [Europe's digital decade: 2030 targets | European Commission](#)

⁵¹ [Energy Efficiency Directive](#)

		which will impact datacentre operators, with new provisions on the reuse of waste heat, and provisions on energy management systems.	
Smart Readiness Indicator (SRI) ⁵²	Opportunity	The smart readiness indicator (SRI) is a European Commission programme underneath the Energy Performance of Buildings Directive that evaluates a building's capability to utilize smart technologies. For example, from 2027, the Smart Readiness Indicator (SRI)—which assesses the smart capabilities of a building based on several criteria—will become mandatory for non-residential buildings.	The mandatory SRI creates new drivers for integrating smart, energy-efficient, and responsive technologies into buildings, including data centres and server rooms in tertiary buildings.
E	ECONOMIC		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Increasing Demand for Energy Efficiency	Opportunity	The increasing demand for energy efficiency is another key driver of the DCIM Market.	DCIM Market will have crucial role in improving energy efficiency in data centres.
Rising cost of IT Equipment	Opportunity	As IT hardware becomes more expensive, there is a growing need to protect these investments and hardware through more reliable, efficient cooling and intelligent infrastructure management.	Rising IT equipment costs increase the business case for advanced cooling and management solutions that ensure equipment longevity, prevent failures, and optimize performance.
S	SOCIAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Digital Literacy Gap	Barrier	Effective use of DCIM and advanced analytics requires digital skills that are not yet widely available among building and data centre operators.	The digital skills gap may limit the adoption of complex and sophisticated DCIM software platforms.
T	TECHNOLOGICAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment

⁵² [Smart readiness indicator - European Commission](#)

Increasing data generation and volumes	Opportunity	There is an increasing amount of data generated from components of data Centres creating a for tools to utilise the data, conduct continuous monitoring, and develop data driven decisions for better operations.	This trend creates an opportunity for HYCOOL-IT's digital twin, real-time monitoring, and predictive analytics tools, which can turn raw data into actionable intelligence, enabling smarter, more efficient cooling and operational decisions.
Open Architectures and APIs	Opportunity	Modern DCIM and BMS platforms increasingly adopt open architectures and offer REST APIs and SDKs, facilitating integration with third-party systems	The move toward open, API-driven architectures creates a favourable environment for HYCOOL-IT's digital twin and smart cooling systems to seamlessly integrate into existing DCIM platforms, enabling data exchange, interoperability, and broader adoption across hybrid IT and facility management environments.
Automation and Change Management	Opportunity	Integration of digital twins and smart cooling systems with DCIM can support automated workflows for commissioning, maintenance, and performance evaluation, reducing manual intervention and enhancing operational resilience.	This trend aligns directly with HYCOOL-IT's digital twin and predictive control capabilities, enabling operators to automate key operational processes, reduce human error, and improve resilience while lowering OPEX.
L	LEGAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Data Privacy and Security	Barrier	DCIM solutions collect and process operational data that may be sensitive for facility operators.	Data privacy and cybersecurity concerns can pose a barrier to adoption, especially in highly regulated or risk-averse environments. HYCOOL-IT must ensure that its digital systems include robust data governance, secure architecture, and GDPR compliance, which are critical to building user trust and enabling deployment in commercial environments.
E	ENVIRONMENTAL		
Factor	Classification	Explanation	What It Means for HYCOOL-IT Business Environment
Sustainability Pressures	Opportunity	The data centre industry faces continued pressure to reduce its environmental footprint, including improved water efficiency and advanced heat reuse solutions.	These pressures create a favourable environment for HYCOOL-IT's low-impact, water-based adsorption chiller and integrated waste-heat reuse capabilities, positioning the solution as a sustainable alternative that aligns with

			industry goals for water conservation, carbon reduction, and circular resource use.
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4. HYCOOL-IT Market Characteristics

The chapter 4 stipulates an overview of the market analysis and assessment covering HYCOOL-IT's four exploitation spaces: Energy Efficiency (EE), Targeted Cooling Solutions for IT Server Rooms (ITSR), Building Digital Twins (BDT), and Smart Building Management Systems (SBMS). For each identified exploitation space, this section presents a structured and comparative analysis based on the following key dimensions: **Market Overview and Size**, highlighting the economic market size and growth potential; **Market Drivers and Challenges**, identifying forces influencing demand and barriers to adoption; **Market Segmentation**, outlining the relevant market segment and application contexts with a focus on IT server rooms; **State-of-the-Art and Emerging Technologies**, showcasing current solutions and innovation trends; **Competitive Landscape Analysis**, profiling key market players and technology providers; and a **Summary of Findings**, capturing critical insights and implications for further exploitation and business model development.

The market analysis for the HYCOOL-IT project is based primarily on desk research, supported by targeted enquiries and expert insights to ensure a comprehensive understanding of the project's four exploitation spaces. The analysis draws on a wide range of credible sources, including **market research reports** from organisations such as McKinsey & Company⁵³, Uptime Institute⁵⁴, International Data Corporation (IDC)⁵⁵, and Gartner⁵⁶, which provide insights into global and European trends in data centres and server rooms, AI-driven infrastructure, and emerging cooling technologies. Additionally, publications and data from **industry associations** such as the European Data Centre Association (EUDCA)⁵⁷ and The Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA)⁵⁸ were consulted to capture sector-specific technical and regulatory developments. Regular monitoring of **sector-specific newsletters and magazines**—including Data Centre Dispatch⁵⁹—helped track recent innovations, use cases, and industry sentiment. To benchmark current technologies and identify market gaps, **information from company websites, product sheets, and case studies** was also reviewed. Where relevant, direct consultation with stakeholders and project partners was used to validate findings and gather context-specific insights. This multi-source approach ensures the market analysis is well-grounded, up-to-date, and aligned with the strategic goals of HYCOOL-IT.

⁵³ [Why invest in the data centre economy | McKinsey](#)

⁵⁴ [Digital Infrastructure Authority | Tier Certification & Training - Uptime Institute](#)

⁵⁵ [IDC: The premier global market intelligence firm.](#)

⁵⁶ [Gartner | Delivering Actionable, Objective Insight to Executives and Their Teams](#)

⁵⁷ [European Data Centre Association \(EUDCA\)](#)

⁵⁸ [The Federation of European Heating, Ventilation and Air Conditioning Associations \(REHVA\)](#)

⁵⁹ [DVL Group: Mission Critical Data Centre Power and Cooling Experts](#)

4.1 Energy Efficiency (EE)

Scope: This exploitation space targets the expanding energy efficiency (EE) market within the data centre and server room sector, covering both State-of-the-art digital and hardware innovations that enable smarter and low-carbon operations of data centres and server rooms. It encompasses solutions such as efficient cooling technologies, AI powered O&M software solutions, Real-time monitoring and analytics tools, advanced simulation and modelling tools.

Relevance with HYCOOL-IT Innovations: HYCOOL-IT addresses this space by delivering system-level EE improvements in the often-overlooked segment of small-to-medium server rooms in tertiary buildings. The project's solution integrates a waste-heat-driven, rack-integrated adsorption chiller with a Building Digital Twin Environment (BDTE), supported by a suite of digital tools—including SIMBOTs, Software-in-the-Loop (SiL) environments, and the Simulation Model Tracking System (SMTS)—to enable predictive control, lifecycle optimisation, and data-driven energy performance management.

European Data Centres Overview

Data Centres and server rooms are facilities that comprise computer and IT systems and other components to collect, process, and manage distinct and enormous amounts of data and applications. Such a data centre and server room facility often includes various types of infrastructure, including networked IT systems and computers, data storages, compute infrastructure and servers, cooling and power systems. Companies leverage data centres to manage and process their data and operations, and can select from various data centre types, including Enterprise, Co-located, Edge, and Hyperscale data centres.

Below is a brief definition of the different types of data centres:

- **Enterprise Data Centres** are privately owned and operated by a single organization, typically located on-site or in a dedicated facility.
- **Colocation Data Centres** are shared facilities where companies rent space, power, and cooling infrastructure while managing their own servers.
- **Edge Data Centres** are small, decentralized facilities located close to end-users or devices to minimize latency and support real-time processing.

Hyperscale Data Centres are massive facilities built by tech giants to deliver scalable cloud services and manage large volumes of data.

Figure 9 presents data centres in Europe by type and IT power (50 Kilowatt (kW) or more). Based on the State of European Data Centres 2025 report by the EUDCA and shown in the figure below, whereas colocation and hyperscale data centres now dominate in terms of overall IT power capacity in Europe—especially in core markets like FLAPD (Frankfurt, London, Amsterdam, Paris, Dublin)—enterprise data centres still represent more than 50% of IT power in many European regions outside these hubs.

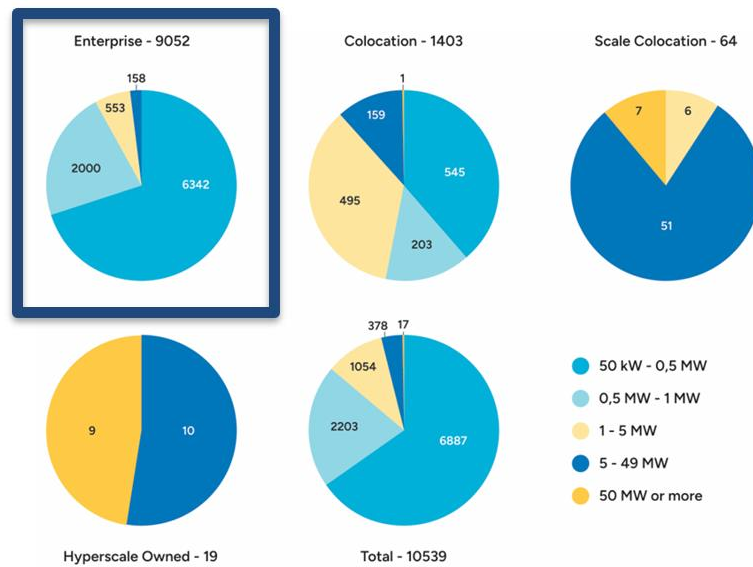


Figure 9 Data centres in Europe by type and IT Power (50kW or more), 2023EY

Market Factors Driving Current and Future Growth

According to the EUDCA State of European Data Centres 2025⁶⁰, the European data centre market is undergoing substantial growth, motivated by the increasing demand for digital and cloud services, AI and HPC driven applications, and edge computing technologies.

Artificial Intelligence: The instant expansion of AI technologies, particularly generative AI, is pushing ample investments in high-density, high-performance data centres.

Digitalisation: Expanding digitalisation among sectors is forcing soaring demand for data storage and processing capabilities.

Cloud and Edge Computing: The move towards hybrid IT environments and the increase of edge computing are meeting low latency requirements and data sovereignty concerns.

Connected Devices: Increase in IoT generating more data that needs to be processed and stored.

Edge Computing: Real time data processing requiring data centres to be closer to where data is generated.

In brief, Data centres are fundamental to Europe's digital infrastructure, supporting a wide range of applications and services. Their growth is also contributing to Europe's GDP, employment, and overall economic development.

⁶⁰ [EUDCA State of European Data Centres 2025](#)

Major Challenges for the European data centres industry

Figure 10 presents key organisational challenges over the next three years for the European datacentres and server rooms industry.

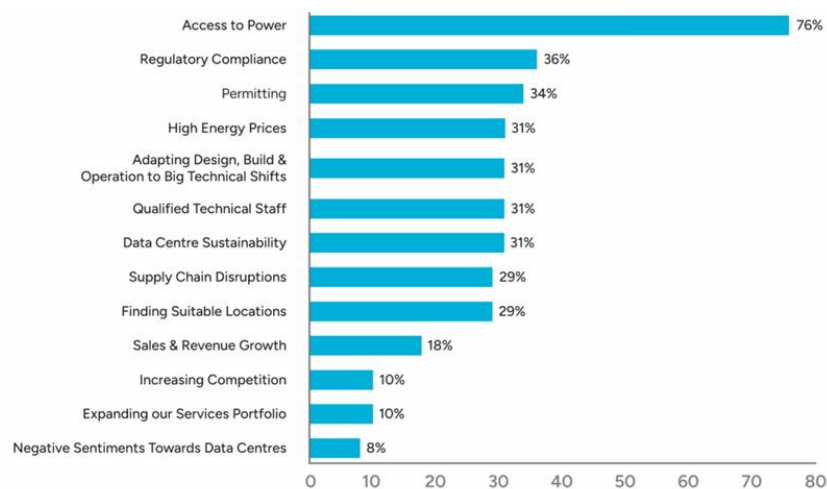


Figure 10 Greatest organisational challenges over the next three years⁶¹

Market for Energy Efficiency in Data Centres

The energy efficiency (EE) market within the data centre and server room sector is a quickly growing segment, guided by surging demand for digital services, AI/HPC workloads, and regulatory pressure for sustainability. Global Sustainable Data Centre Market Size focusing on broad sustainability & EE is valued at USD 85.1 Bn in 2024 and is predicted to reach USD 440.7 Bn by the year 2034 at a 18.0% CAGR during the forecast period for 2025-2034⁶².

Market segment

Based on the State of European Data Centres 2025 report by the EUDCA, enterprise-owned data centres remain the most numerous in Europe (seen in

Figure 9), with 9,000 facilities exceeding 50 kW of IT power. These on-premises facilities—built by businesses to meet their immediate IT needs—represent a core target market segment for the HYCOOL-IT project. More specifically, HYCOOL-IT targets users and customers who own tertiary buildings equipped with in-house server rooms.

According to 451 Research's (unit of S&P Global Market Intelligence⁶³) surveys and Datacentre Market Monitor⁶⁴, in EMEA there are as many as 1.22 million enterprise server rooms, micro-datacentres, datacentres with less than 100 Kilowatt (kW) of IT power, and telecom/network hubs, as compared with an estimated 16,000 enterprise datacentres with more than 100 Kilowatt (kW). Many of these

⁶¹ [EUDCA State of European Data Centres 2025](#)

⁶² [Sustainable Data Centre Market 2025 Latest Report with Forecast to 2034](#)

⁶³ [Market Intelligence | S&P Global](#)

⁶⁴ [Improving datacentre efficiency in Europe: The role of PUE](#)

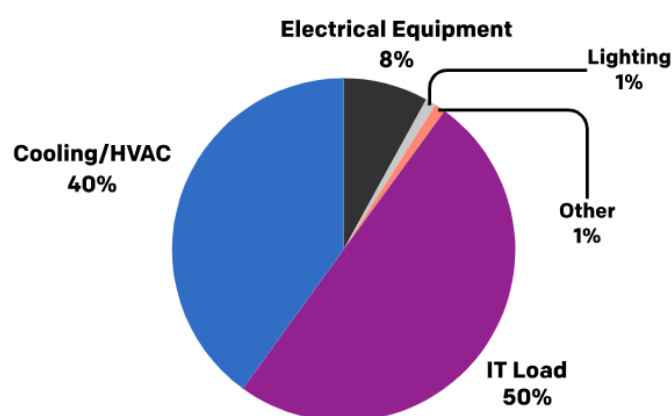
small IT deployments exist for a particular reason (e.g., location requirements, low latency requirements, data sovereignty) and cannot easily be shifted to public cloud. Reducing the amount of energy used by these servers could make a substantial difference to an enterprise's carbon footprint.

The "State of European Data Centres 2025" report⁶⁵ by the EUDCA, together with 451 Research's Datacentre Market Monitor⁶⁶, confirms the widespread presence of enterprise data centres and server rooms across Europe, ranging from small facilities with less than 100 Kilowatt (kW) of IT power to larger setups exceeding 100 Kilowatt (kW). Additionally, research by McKinsey & Company⁶⁷ suggests that global demand for data centre and server rooms capacity could triple by 2030—driven by AI/HPC workloads, which are expected to account for approximately 70% of this growth. These findings indicate that enterprise data centres and server rooms are poised for continued expansion across Europe, as organizations increasingly require on-premises infrastructure to support digital operations, edge computing, and AI-driven workloads.

This trend from market analysis is contributing to the development of a two-speed data infrastructure landscape: data centres and server rooms equipped to handle AI processing workloads, and those supporting traditional IT applications. These two types of infrastructure will differ significantly in their design and operational requirements.

Today's Reality: IT Server Rooms in Europe

Figure 11 presents the standard percentage of data centre and server room energy consumption per component. Whereas energy usage depends on type, size and age of a data centre, there are two major areas that consistently drive the greatest power and water inefficiencies: (1) IT servers and data storage devices responsible for the compute and (2) HVAC and cooling solutions that keep optimal temperatures for those servers to run proficiently. In most cases, these processes are administered through statically programmed controls with human monitoring, but operators are opening to turn to new digital tools that engage cutting edge technology to automate and fine-tune processes.



Source: Mitsubishi Electric

Figure 11 Percentage of data centre energy consumption per component

⁶⁵ [EUDCA State of European Data Centres 2025](#)

⁶⁶ [Improving datacentre efficiency in Europe – the role of PUE | S&P Global](#)

⁶⁷ [The cost of compute power: A \\$7 trillion race | McKinsey](#)

As established and reported in *“D1.1 Processes requirements and building typologies screening”* the small-scale enterprise-owned data centres and server rooms are often older, built by organisations for their own internal needs, and have not scaled to meet the growing performance demands driven by cloud computing, AI, and high-density workloads.

A comparable trend has been confirmed by the EURECA project⁶⁸. The EURECA project⁶⁹ funded under Horizon 2020 research and innovation programme under grant agreement No 649972., examined over 350 public sector data centres across Europe, showed that 80% are small server rooms with less than 25 racks. Additionally, EURECA project found that a significant portion of servers in public sector data centres are aged and inefficient, consuming a disproportionate amount of energy. EURECA emphasized the need for comprehensive solutions that consider both IT and facility-level optimizations. HYCOOL-IT's integrated approach to server room cooling and management reflects this learning, offering a holistic solution that addresses multiple aspects of cost-effective thermal management and energy optimisation of tertiary buildings with high energy demand IT Rooms. HYCOOL-IT addresses this emerging market need through its innovative rack-integrated adsorption chiller and digital twin solutions, offering a cost-effective, replicable, and sustainable approach to cooling and energy optimisation in next-generation of IT server environments.

Datacentres and server rooms efficiency, as measured by Power usage effectiveness (PUE)

PUE is a ratio of the total amount of power required to run the datacentre or server room (which includes cooling and lights), divided by power used to run IT equipment. The smaller the PUE number, the smaller amount of power is used to run the facility beyond what is required for IT servers/networking equipment. This can be thought as a measure of the datacentre's efficiency. Aged data centre and server room facilities can have PUEs of two or higher because the cooling infrastructure and power components are inefficient and outdated and require a lot of additional electricity to run.

In some surveys performed by 451 Research's (unit of S&P Global Market Intelligence⁷⁰) European enterprises cited on average a PUE of 2.1, while most big scale datacentres target for an average PUE of 1.3-1.4 or lower, and leased datacentres can be anywhere in between.

For simple math, a datacentre consuming ten megawatts (MW) of IT power, with a PUE of 2.0, requires 20 megawatts (MW) of power in total to run. Each decimal point advancement in efficiency would save 1 MW of power (or 8,760 annual MW hours). 451 Research's report estimate that enterprise datacentres in Europe (those with >100 kW of utilized power) utilized an average of 34 terawatt hours of electricity in 2021. Reducing their PUE from 2.0 to 1.4 could have saved about eleven terawatt hours of electricity. This is the amount of electricity used by a city the size of Hamburg (1.7 million citizens with per-capita electricity use of 6.8 MW hours per year)⁷¹.

⁶⁸ [DataCentre EURECA Project](#)

⁶⁹ [DataCentre EURECA Project](#)

⁷⁰ [Market Intelligence | S&P Global](#)

⁷¹ [Improving datacentre efficiency in Europe: The role of PUE](#)

Market for Energy Efficiency

Enterprise-owned data centres and server rooms in Europe – on-premises facilities (typically >50 kW IT load) ran by organizations for their own needs – are under increasing pressure to improve energy efficiency and sustainability. These data centres and server rooms consume substantial electricity (on the order of tens of terawatt-hours annually) and traditionally lag behind hyperscale and colocation data centre facilities in efficiency. At present, a blend of rising energy costs, corporate sustainability goals, and robust policy initiatives is driving a major expansion of the energy efficiency (EE) market for enterprise data centres and server rooms. Companies are investing in a spectrum of EE technologies – from advanced cooling and waste-heat recovery to smart energy management and on-site renewables – to cut power usage, reduce costs, and meet stricter environmental standards.

Regulatory Push for Smart and Sustainable Buildings

The revised Energy Performance of Buildings Directive (EPBD)⁷² sets a transformative direction for the tertiary building sector by mandating the Smart Readiness Indicator (SRI)⁷³ for non-residential buildings from 2027, reinforcing the market's move toward digitised, energy-efficient systems. Coupled with the harmonisation of Energy Performance Certificates (EPCs)⁷⁴ and the rising prominence of voluntary green certifications such as Leadership in Energy and Environmental Design (LEED)⁷⁵, The Building Research Establishment Environmental Assessment Method (BREEAM)⁷⁶, and WELL Building Standard (WELL)⁷⁷, this regulatory environment strongly favours innovations like HYCOOL-IT's rack-integrated adsorption chiller and smart server room solutions. These developments also highlight a growing need to skill and upskill professionals in smart HVAC and IT cooling technologies, aligning with HYCOOL-IT's replication and market readiness objectives.

Energy Efficiency Directive⁷⁸

Article 12 of revised EED (adopted on 13 September 2023) introduces an annual reporting obligation for datacentres located in the EU, with a power demand of installed IT above 500kW. The data will be circulated in an accumulated manner at EU and Member States levels and will be evaluated regularly. Following the evaluation, the European Commission may suggest further measures to enhance the sustainable development of the EU data centres industry, such as minimum performance standards, or a labelling scheme. On top of the reporting requirements, the EED also proposes further measures which will impact datacentre operators, with new provisions on the reuse of waste heat, and provisions on energy management systems. Although enterprise data centres—on-premises facilities built by businesses to meet their internal IT needs—fall outside the scope of Article 12 EED, they remain a key target segment for the HYCOOL-IT project. Specifically, HYCOOL-IT focuses on tertiary buildings with in-house server rooms, which typically operate below the 500 kW IT load threshold set by the EED for mandatory annual reporting. While not subject to this regulatory obligation, these facilities are still

⁷² [Energy Performance of Buildings Directive](#)

⁷³ [Smart readiness indicator - European Commission](#)

⁷⁴ [How EPCs are shaping new developments in line with the EPBD recast | BUILD UP](#)

⁷⁵ [LEED rating system | U.S. Green Building Council](#)

⁷⁶ [BREEAM | Sustainable Building Certification](#)

⁷⁷ [WELL - International WELL Building Institute | IWBI](#)

⁷⁸ [Energy Efficiency Directive | eudca.org](#)

under growing market and societal pressure to improve energy efficiency and operate more sustainably.

Tackling Efficiency Challenges

Challenge #1: Stationary Cooling Systems: Cooling system amount to 40% of a data centre’s energy consumption on average. Traditional cooling systems warrant intelligence, frequently running with gratuitous redundancy to avoid thermal limits and detector admonitions that might impact tenant service level agreements (SLAs). This results in energy waste and inflates functional costs.

Challenge #2: Lack of Energy Visibility and Predictive Maintenance: Numerous data centres operate with minimum real- time sapience and awareness into their energy operation and consumption, leading to inefficiencies. Without active monitoring and precautionary conservation, equipment frequently consumes further energy than necessary, operating below optimal effectiveness. Over time, this not only drives up energy costs but also increases the threat of untimely equipment failure, leading to unanticipated and expensive replacements.

Challenge #3: Water Use in Cooling Systems: Whilst energy costs are the main worry for data centre operators, water use for cooling is a essential sustainability factor. Some cooling methods can utilize substantial amounts of water, contributing to resource depletion in water-scarce regions.

Key Market Players for EE

Since energy efficiency is the central objective and cross-cutting driver of all HYCOOL-IT innovations—including innovative and sustainable cooling technology, digital twins, and integration with DCIM and smart building systems—the Energy Efficiency (EE) exploitation space can be viewed as broadly representative of the entire HYCOOL-IT solution. As such, the key market players relevant to energy efficiency are already comprehensively covered in other dedicated exploitation spaces:

- Cooling Technologies (air-cooled and liquid-cooled systems)
- Digital Twin and Simulation Platforms
- Smart Building and DCIM Integration

The next sections on three exploitation spaces of the project includes detailed market analysis tables, highlighting players whose technologies and offerings also significantly contribute to the energy efficiency landscape. Therefore, to avoid duplication and maintain clarity, these players are not repeated here, check relevant exploitation space key market player tables for full insights (Table 7, Table 8, Table 9, Table 10).

Air cooled solutions

Daikin⁷⁹, Mitsubishi Electric⁸⁰, Panasonic⁸¹, Tripp Lite (Eaton)⁸², Vertiv⁸³

⁷⁹ [Daikin Global | A leading air conditioning and refrigeration innovator and provider for residential, commercial and industrial applications](#)

⁸⁰ [Mitsubishi Electric Trane Heating and Air Conditioning](#)

⁸¹ [Panasonic - sistemas de aquecimento e arrefecimento - Portugal](#)

⁸² [Eaton - Power and Connectivity Solutions](#)

⁸³ [Data Centre Air Conditioning Systems | Vertiv Room Cooling](#)

Liquid cooled solutions	SorCool ⁸⁴ , ZutaCore ⁸⁵ , CoolIT Systems ⁸⁶ , LiquidStack ⁸⁷ , Submer ⁸⁸ .
Building Digital Twin	EkkoSense ⁸⁹ , New Generation SR ⁹⁰ , Cadence ⁹¹ , Sunbird ⁹² , AKCP ⁹³
DCIM Software	Schneider Electric ⁹⁴ , Sunbird ⁹⁵ , Nlyte ⁹⁶ , Vertiv ⁹⁷ , Hyperview ⁹⁸

⁸⁴ [Produkte - FAHRENHEIT](#)

⁸⁵ [Direct-to-Chip Liquid Cooling Company | ZutaCore](#)

⁸⁶ [CoolIT Systems | Liquid Cooling Technology](#)

⁸⁷ [Home - LiquidStack](#)

⁸⁸ [Immersion Cooling at Scale | SmartPod Platform | Submer | Immersion](#)

⁸⁹ [AI Data Centre Optimization Software - EkkoSense](#)

⁹⁰ [NuveaPaaS | New Generation SR](#)

⁹¹ [Cadence | Computational Software for Intelligent System Design | Cadence](#)

⁹² [DCIM - Data Centre Infrastructure Management Software System, Cable Management, Infrastructure Design & Optimization Companies - Sunbird DCIM](#)

⁹³ [About AKCP: Your Partner in Monitoring Technology](#)

⁹⁴ [What Is Data Centre Management and How Has it Evolved?](#)

⁹⁵ [DCIM - Data Centre Infrastructure Management Software System, Cable Management, Infrastructure Design & Optimization Companies - Sunbird DCIM](#)

⁹⁶ [DCIM Software, Hybrid Cloud Infrastructure and BMS Data Centre | Nlyte](#)

⁹⁷ [DCIM & IT Management](#)

⁹⁸ [Cloud-based Data Centre Infrastructure Management \(DCIM\) Software](#)

4.2 Targeted Cooling Solutions for IT Server Rooms (ITSR)

Scope: This exploitation space targets the global data centre and server room cooling market, with a focus on the transition from traditional air-based cooling systems to emerging liquid-based cooling solutions. As computing density increases—driven by AI workloads, edge computing, and rising digitalization of buildings—the limitations of conventional air cooling have become evident.

Relevance with HYCOOL-IT Innovations: HYCOOL-IT's flagship hardware innovation, the rack-integrated adsorption chiller, directly addresses this need. It introduces a compact, energy-efficient, and waste-heat-powered cooling solution designed specifically for localized server rooms in tertiary buildings. By integrating cooling directly into the server rack and enabling the simultaneous cooling of both servers and the surrounding room, the HYCOOL-IT system significantly improves thermal management while reducing energy demand.

Market Overview and Size

Data centre and IT server room cooling methods can be broadly classified into air cooling and liquid cooling, depending on the cooling medium used to remove heat from IT equipment. While liquid cooling is rapidly gaining attention due to its efficiency advantages in managing high-density, AI-driven workloads, air cooling remains a dominant and evolving technology, particularly for conventional IT applications and legacy data centre environments.

The Uptime Institute⁹⁹ is a globally recognized authority in data centre research and intelligence, performance, reliability, and sustainability. The Uptime Institute's research reports and annual surveys, such as the Uptime Institute Global Data Centre Survey 2024¹⁰⁰ and Uptime Institute 2024 Cooling Systems Survey¹⁰¹, are esteemed for their comprehensive analysis and insights of data centres and IT server rooms industry. According to the Uptime Institute Data Centre Cooling Systems Survey 2024¹⁰², conducted with over 964 data centre industry respondents, there is a consensus in the industry that while air-cooling solutions remains dominant for now, the shift toward more advanced cooling solutions like liquid cooling for most new IT infrastructure deployments is fast approaching.

As data centres and IT server rooms evolve to support higher rack densities and compute-intensive workloads—driven by AI, HPC, and next-gen chip architectures—the demand for advanced cooling technologies is accelerating. While air cooling has long been the industry standard¹⁰³, it is rapidly reaching its limits. New processors like the NVIDIA Blackwell Superchip¹⁰⁴ can exceed 2,800W per server, far beyond what traditional air systems can efficiently handle. Additionally, air cooling systems require significant energy, space, and infrastructure and often struggles to manage the heat generated

⁹⁹ [Digital Infrastructure Authority | Tier Certification & Training - Uptime Institute](#)

¹⁰⁰ [Uptime Institute Global Data Centre Survey 2024](#)

¹⁰¹ [Uptime Institute 2024 Cooling Systems Survey](#)

¹⁰² [Uptime Institute Cooling Systems Survey 2024: Direct liquid cooling](#)

¹⁰³ [Air Cooled vs Liquid Cooled Server Racks & Data Centre ROI | ZutaCore](#)

¹⁰⁴ [Introduction to NVIDIA GB200 Superchip and Liquid-Cooled Servers and Cabinets - fibermall.com](#)

by today's powerful servers¹⁰⁵. This shift underscores the growing necessity of direct liquid cooling as a more efficient and scalable solution¹⁰⁶.

Figure 12 illustrates the range of feasible cooling solutions in relation to the maximum power density of IT equipment per unit area of server rack or white space.

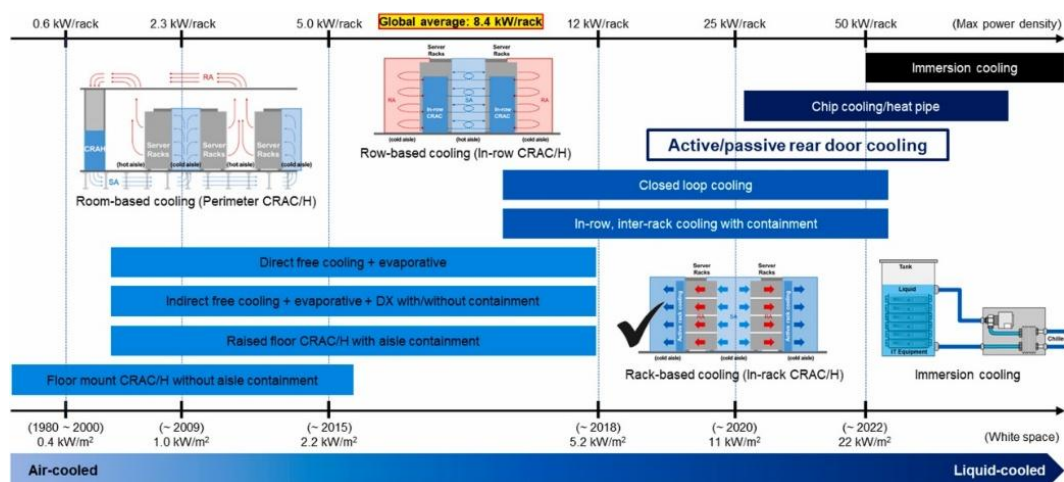


Figure 12 Range of feasible cooling solutions in relation to the maximum power density of IT equipment [1]

A detailed review of IT cooling system technologies is presented in the “**D3.2 Waste heat integration with new gen thermal grids**”. The “**D3.2 Waste heat integration with new gen thermal grids**” discusses various cooling technologies for data centres and server rooms, including air-based, liquid-based, and innovative adsorption-based cooling systems. The characteristics of each technology are analysed, highlighting their working principles, advantages and disadvantages, as well as relevant case studies demonstrating significant results. Therefore, this report will not describe the IT cooling system technologies and their working principles but rather focuses on the market related aspects of the data centre cooling industry. However, high level comparison of air cooled and liquid cooled approaches is presented below.

Table 6 Comparison of Air-cooled vs Liquid cooled approaches

Feature	Air Cooled	Liquid Cooled
Energy Efficiency	Low (high power consumption for fans)	High (reduces energy use by up to 80%)
Space Requirements	High (requires large fans, airflow systems)	Low (compact, no need for bulky infrastructure)
Maintenance	Frequent (dust, wear on fans)	Minimal (closed-loop system, low maintenance)
Risk of Leaks	None (air-based system)	Water-based systems: high; Waterless: none
Environmental Impact	High (energy-intensive, carbon emissions)	Low (sustainable cooling, reduces footprint)

¹⁰⁵ Thermal Management for Data Centres 2025-2035: Technologies, Markets, and Opportunities: IDTechEx

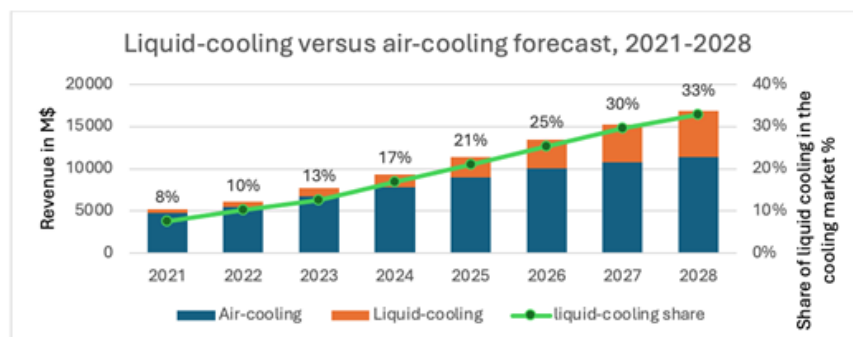
¹⁰⁶ Liquid Cooling Strategies: Meeting the AI Demand in Data Centres

Initial Cost	Lower	Higher, but provides long-term savings
Longevity/Scalability	Limited (struggles with newer tech)	High (scalable for high-powered GPUs and AI)

Omdia's¹⁰⁷ most recent market research indicates that the global data centre cooling market is experiencing rapid growth, driven by the proliferation of AI workloads, high-density infrastructure, and sustainability requirements. The overall data centre thermal management market reached \$7.67 billion in 2023 and is projected to grow at a compound annual growth rate (CAGR) of 18.4% to reach approximately \$16.8 billion by 2028¹⁰⁸.

Liquid Cooling Segment Growth

The graph below illustrates the forecasted evolution of air-cooling versus liquid-cooling revenues in the data centre market from 2021 to 2028, based on research by Omdia¹⁰⁹. It shows that while both cooling technologies are experiencing significant revenue growth, liquid cooling is rapidly gaining market share. Initiating from just 8% of the cooling market in 2021, liquid cooling is envisioned to expand to 33% by 2028. This trend reflects the increasing demand for more efficient thermal management solutions, driven by the rise of ultra-high-density racks and the deployment of AI superchips operating at unprecedented power levels. As traditional air-cooling methods struggle to handle rack power densities beyond 20–30 kW, liquid cooling is emerging as a critical enabler for the next generation of AI-driven, high-performance data centres.



Source: Omdia

Figure 13 Data centre cooling market growth forecast¹¹⁰

Key trends identified by the Omdia market research¹¹¹ include the rapid adoption of Rear Door Heat Exchangers (RDHx) combined with 1-P direct-to-chip cooling, achieving an impressive 65% year-over-year growth, frequently integrating heat reuse applications. This period also sees a strategic blend of air and liquid cooling technologies, creating a balanced and efficient thermal management.

¹⁰⁷ [Cloud and Data Centre | Omdia](#)

¹⁰⁸ [Omdia research predicts data Centre cooling market to reach \\$16.87 billion in 2028](#)

¹⁰⁹ [Cloud and Data Centre | Omdia](#)

¹¹⁰ [Omdia research predicts data Centre cooling market to reach \\$16.87 billion in 2028](#)

¹¹¹ [Omdia research predicts data Centre cooling market to reach \\$16.87 billion in 2028](#)

Other analyst firms, such as Precedence Research¹¹², estimate the global data centre liquid cooling market at \$3.93 billion in 2024, projecting growth to \$22.57 billion by 2034.

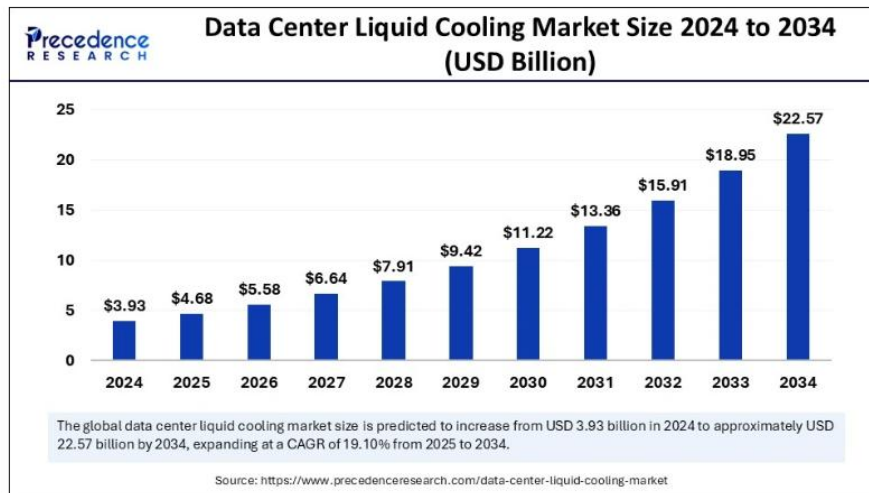


Figure 14 Data centre liquid cooling market growth forecast¹¹³

According to the Research and Markets report, Data Centre Liquid Cooling Market Report 2025 report¹¹⁴, the data centre liquid cooling market size has grown exponentially in recent years. It will grow from \$4.18 billion in 2024 to \$5.17 billion in 2025 at a compound annual growth rate (CAGR) of 23.7%. The evolution in the historical period can be credited to expanded data collection, development of data centre, energy efficiency demands, cloud computing expansion, increase of hyperscale data centres.

In the fast expanding market of liquid cooling, direct-to-chip vendor CoolIT¹¹⁵ remain the top leader in liquid cooling market, followed by immersion cooling leader Sugon.

Figure 15 highlights the broad ecosystem of advanced liquid cooling technologies, covering both chip-level cooling, immersion cooling, and rear door heat exchangers (both passive and active). It shows that several players, like Vertiv¹¹⁶, LiquidStack¹¹⁷, GIGABYTE¹¹⁸, and WiWynn¹¹⁹, offer solutions across multiple technologies, indicating strong diversification in the market.

¹¹² [Data Center Liquid Cooling Market Size to Worth USD 22.57 Bn by 2034](#)

¹¹³ [Data Center Liquid Cooling Market Size to Worth USD 22.57 Bn by 2034](#)

¹¹⁴ [Data Centre Liquid Cooling Market Report 2025](#)

¹¹⁵ [CoolIT Systems | Liquid Cooling Technology](#)

¹¹⁶ [Data Centre Air Conditioning Systems | Vertiv Room Cooling](#)

¹¹⁷ [Home - LiquidStack](#)

¹¹⁸ [Cooling | Solution - GIGABYTE Global](#)

¹¹⁹ [Wiwynn - Data Centre Solutions, Cooling, and AI](#)



Figure 15 Advanced Liquid Cooling Technology Mapping

Additionally, the latest research by McKinsey & Company shows that global demand for data centre capacity could almost triple by 2030, with about 70 percent of that demand coming from AI workloads¹²⁰. This research validates the trend of evolution of a two-speed data infrastructure landscape in future: data centres and server rooms equipped to handle AI processing workloads, and those supporting traditional IT applications. These two types of infrastructure will diverge significantly in their design and operational requirements, including how they are cooled.

Market Factors Driving Current and Future Growth

This chart (Figure 16) from the Uptime Institute Data Centre Cooling Systems Survey 2021¹²¹ illustrates the current and anticipated primary drivers for the adoption of advanced liquid cooling solutions like immersion and/or direct-to-chip liquid cooling technologies in data centres.

Current Drivers (Blue Bars, n=450)

Higher rack densities (70%) – The dominant driver today. As computing demands increase, especially due to AI and HPC, traditional air-cooling systems struggle with the thermal load.

Cost of electricity (37%) and Environmental sustainability (34%) – These also weigh heavily, reflecting operational efficiency and ESG pressures.

Application/workload performance (24%) – Less dominant but notable, especially in performance-critical computing environments.

Expected Future Drivers (Orange Bars, n=448)

Higher rack densities (60%) – Still leading, though slightly reduced, indicating continued concern over thermal management.

Environmental sustainability (42%) – A marked rise, reflecting increasing regulatory and stakeholder focus on green IT.

¹²⁰ [The cost of compute power: A \\$7 trillion race | McKinsey](#)

¹²¹ [Uptime Institute Data Centre Cooling Systems Survey 2021.pdf](#)

Cost of electricity (38%) – Continues to be a top factor, showing economic efficiency remains central.

Limited power availability (18%) – Expected to grow in influence, as energy constraints in urban data centres become more common.

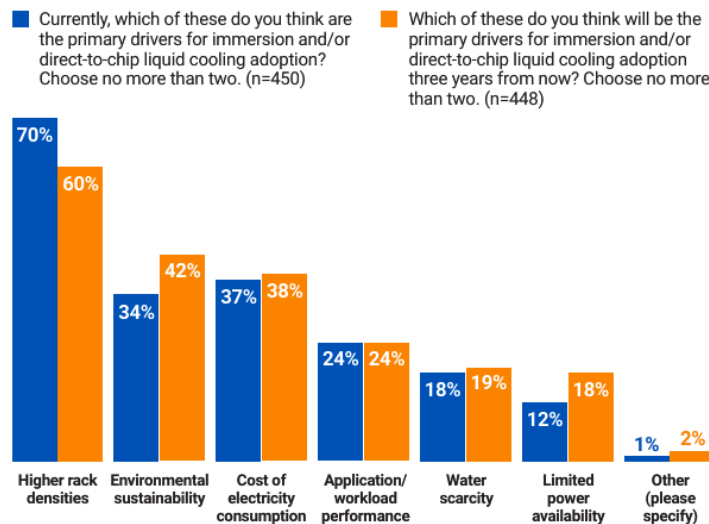


Figure 16 Current and anticipated primary drivers for the adoption of liquid cooling technologies¹²²

Major Challenges for the adoption of DLC

This chart (Figure 17) from the Uptime Institute Data Centre Cooling Systems Survey 2024¹²³ presents the top barriers faced by organizations currently using direct liquid cooling (DLC) in their data centres. Respondents (n=86) were asked to select up to three key concerns.

Increased Cost (41%) – The most cited concern, highlighting that upfront investment and operational costs remain a major hurdle for DLC adoption.

Reliability Concerns (38%) – As significant as cost, suggesting that users are cautious about the long-term performance and system dependability of DLC technologies.

Limited Choice of Equipment or Vendors (30%) – A sign that the DLC market is still maturing, with fewer standardized or widely supported options compared to traditional air cooling.

Maintenance Issues (29%) – Indicates operational complexity and a potential lack of in-house expertise or robust support infrastructure.

Coolant Leaks (27%) – A serious technical concern that impacts trust and perceived safety of DLC systems.

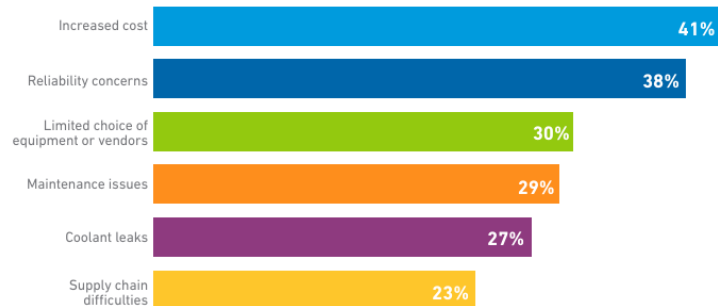
Supply Chain Difficulties (23%) – Points to broader logistical challenges, affected by global disruptions and the specialized nature of DLC components.

¹²² [Uptime Institute Data Centre Cooling Systems Survey 2021.pdf](#)

¹²³ [Uptime Institute Cooling Systems Survey 2024: Direct liquid cooling](#)

DLC users name cost and reliability as top concerns

Which of the following does your organization consider major barriers in deploying direct liquid cooling in your data centers? Choose no more than three. (n=86)



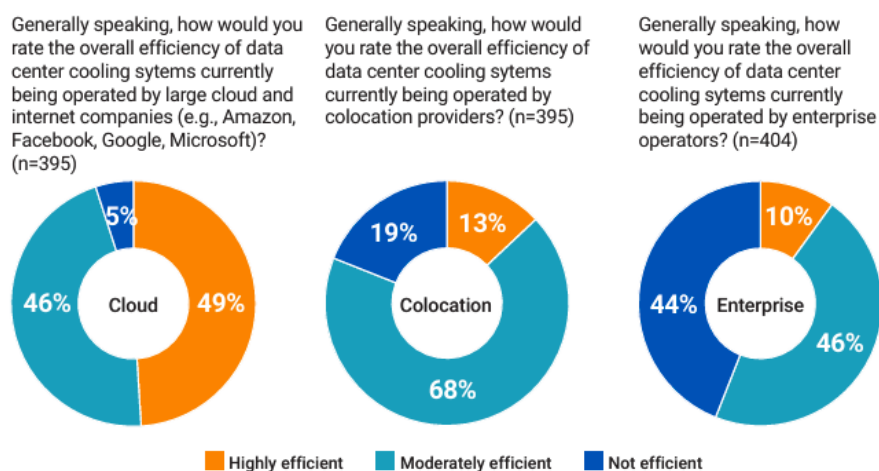
(Only responses from existing users of direct liquid cooling are shown.)

Figure 17 Major Challenges for the adoption of liquid cooling technologies¹²⁴

Market segments

Enterprise data centres and server rooms—typically located within tertiary buildings—continue to exist in vast numbers across Europe and globally, forming a substantial share of the IT infrastructure landscape. Despite their prevalence, recent surveys by the Uptime Institute reveal that these facilities are significantly less efficient than those operated by hyperscale cloud or colocation providers.

Below chart (Figure 18) from the Uptime Institute Data Centre Cooling Systems Survey 2021¹²⁵ assesses how respondents regard the general effectiveness of data centre cooling systems across three data centre types: hyperscalers or Cloud providers, Colocation providers, and Enterprise operators. Among the different data centre types, Enterprise data centres and server rooms operators are perceived as having the lowest cooling efficiency among data centre types, with only 10% rated as highly efficient and 44% considered not efficient. Enterprise data centres lag, due to older infrastructure, lack of specialised cooling strategies, and lower investment in energy efficiency. This indicates significant room for improvement and a strong market pull for cost-effective, compact, and sustainable cooling innovations like HyCool-IT's Rack-integrated adsorption chiller.



¹²⁴ Uptime Institute Cooling Systems Survey 2024: Direct liquid cooling

¹²⁵ Uptime Institute Data Centre Cooling Systems Survey 2021.pdf

Figure 18 Efficiency of data centre cooling systems¹²⁶

Looking ahead, the situation is poised to intensify with the growing adoption of AI/ML and HPC, rack power densities are increasing rapidly, often pushing beyond what traditional air-cooling systems can handle. This trend is accelerating the need for advanced, scalable, and cost-effective cooling technologies tailored to smaller, distributed, or retrofitted IT environments.

Below chart (Figure 19) from the Uptime Institute Data Centre Cooling Systems Survey 2024¹²⁷ provides interesting insights into when data centre operators believe direct liquid cooling (DLC) becomes necessary due to the limitations or cost inefficiencies of traditional air cooling systems.

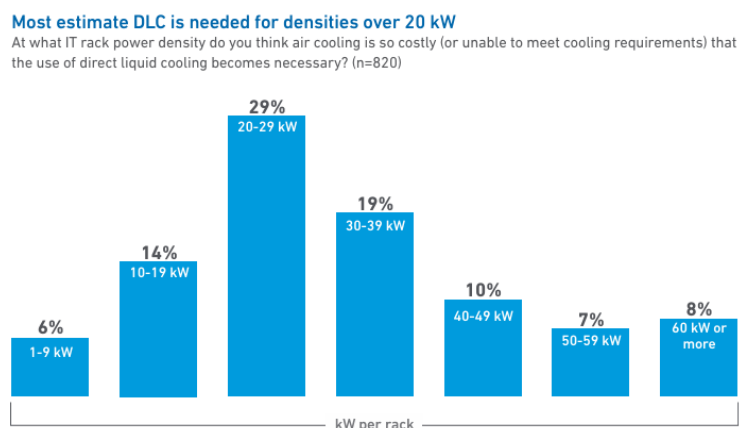


Figure 19 Rack power densities and liquid cooling adoption¹²⁸

While the share and role of liquid cooling and other advanced technologies are expected to grow in the coming years—especially as air cooling reaches its thermal and efficiency limits—a complete shift away from air cooling is unlikely. This is due to several practical considerations, most notably that liquid cooling is economically and technically justified primarily for high-power density applications. A significant number of conventional, lower-power servers continue to be deployed, for which traditional air cooling remains sufficient and cost-effective. As a result, the future of data centre cooling will involve a hybrid model, combining both air and liquid-cooled systems.

The emergence of advanced liquid cooling technologies, such as direct-to-chip (D2C) cooling, immersion cooling (one-phase and two-phase), and rear door heat exchangers, has expanded the industry's capability to handle rising thermal loads. Leading companies—including Vertiv¹²⁹, CoolIT Systems¹³⁰, LiquidStack¹³¹, GIGABYTE¹³², WiWynn¹³³, and others—are innovating across both liquid and air-based cooling segments, offering hybrid solutions that combine the best of both worlds.

¹²⁶ [Uptime Institute Data Centre Cooling Systems Survey 2021.pdf](#)

¹²⁷ [Uptime Institute Cooling Systems Survey 2024: Direct liquid cooling](#)

¹²⁸ [Uptime Institute Cooling Systems Survey 2024: Direct liquid cooling](#)

¹²⁹ <https://www.vertiv.com/en-us/products-catalog/thermal-management/room-cooling/>

¹³⁰ [CoolIT Systems | Liquid Cooling Technology](#)

¹³¹ [Home - LiquidStack](#)

¹³² [GIGABYTE Global](#)

¹³³ [Wiwynn - Data Centre Solutions, Cooling, and AI](#)

Importantly, the adoption of liquid cooling does not signal the end of innovation in air cooling systems. Air-cooled IT hardware will continue to be deployed and operated in data centres for the foreseeable future, often co-existing with liquid-cooled systems in hybrid configurations. Moreover, even liquid cooling systems rely on efficient air-based heat rejection infrastructure, such as rear door heat exchangers and evaporative cooling, to achieve optimal thermal management.

Given this evolving landscape, it is critical for the HYCOOL-IT project's market analysis to consider both air-cooled and liquid-cooled technologies, players, and applications. This inclusive approach ensures that HYCOOL-IT's exploitation strategy reflects the realistic, mixed-use scenarios found in enterprise, colocation, and edge data centres, where hybrid cooling strategies are becoming the new norm.

Key Market Players

The following tables present detailed information on key market players in the data centre cooling industry, encompassing both air-cooled and liquid-cooled technologies. Five companies have been selected from each category based on their technological innovations, market presence, and alignment with sustainability goals. These companies cover a range of cooling technologies (air, direct-to-chip, single-phase immersion, two-phase immersion, adsorption, etc.) to give more depth to our analysis.

Table 7 Air-cooled technology providers

Company Name	Daikin ¹³⁴	Mitsubishi Electric ¹³⁵	Panasonic ¹³⁶	Tripp Lite (Eaton) ¹³⁷	Vertiv ¹³⁸
Product(s)	SkyAir Alpha Series Air Conditioners ¹³⁹	s-MEXT DX Air Conditioning CRAC (Computer Room Air Conditioning) Units ¹⁴⁰	PACi NX Series Standard Air Conditioning Units ¹⁴¹	SmartRack Portable Air Conditioning Unit ¹⁴²	Liebert CRAC (Computer Room Air Conditioning) ¹⁴³
Product highlights	Specifically designed for infrastructure cooling, including IT server rooms and comms rooms. Wide range of installation options: floor	Designed specifically for IT, server rooms, UPS rooms, and technical spaces, providing precise temperature and humidity control,	Designed for commercial environments, including server rooms and IT spaces. 12.5kW nominal cooling capacity, suitable for	Portable, self-contained air conditioning unit specifically designed for small server rooms, network closets, and IT	Purpose-built for data Centres, IT server rooms, and critical infrastructure environments. High-precision temperature and humidity control to protect sensitive IT equipment.

¹³⁴ [Daikin Global | A leading air conditioning and refrigeration innovator and provider for residential, commercial and industrial applications](#)

¹³⁵ [World-leading Supplier of Energy Efficient HVAC Equipment | Mitsubishi Electric](#)

¹³⁶ [Panasonic - Heating and Cooling solutions](#)

¹³⁷ [Rack Cooling Overview | Eaton](#)

¹³⁸ <https://www.vertiv.com/en-us/products-catalog/thermal-management/room-cooling/>

¹³⁹ [FBA-A\(9\) / RZAG-A | Daikin](#)

¹⁴⁰ <https://ies.mitsubishielectric.co.uk/products/it-cooling/mitsubishi-electric-it-cooling-systems/s-mext-dx-close-control-system>

¹⁴¹ [PACi NX Series Standard ceiling Inverter+ - R32](#)

¹⁴² [Portable AC Unit for Server Rooms - 12,000 BTU \(3.5 kW\), 120V](#)

¹⁴³ [Data Centre Air Conditioning Systems | Vertiv Room Cooling](#)

	standing, wall mounted and concealed ducted.		small to medium-sized server rooms.	environments where traditional HVAC is insufficient.	
Key highlights					
Cooling Technology Type	Inverter-driven split system using R-32 refrigerant.	Direct Expansion (DX) split system with inverter scroll compressor	Direct Expansion (DX) split system.	Direct Expansion (DX) portable air conditioner.	Direct Expansion (DX) systems with inverter or digital scroll compressors.
Energy Efficiency	Energy labels up to A++ in both cooling and heating modes.	High efficiency through full inverter technology and EC plug fans	Inverter technology ensures high energy efficiency and lower running costs.	Designed for close-coupled cooling, reducing recirculation and improving efficiency by delivering cold air directly to heat sources	High efficiency at both full and part load, with digital scroll and inverter compressor technology.
Waste Heat Reuse	No explicit waste heat reuse or heat recovery in the SkyAir Alpha Series; these are direct expansion systems focused on cooling and heating only.	No explicit waste heat recovery or reuse features; the system is designed for cooling and humidity control, not for heat reclaim or redistribution	No explicit waste heat recovery or reuse features in the PACi Standard range; the system is focused on cooling only.	No waste heat reuse or heat recovery features; hot air is vented out of the room via an included exhaust kit	Some models (e.g., Liebert PDX) offer hot gas reheat options, which can reuse waste heat for humidity control or re-heating air, improving overall energy efficiency. Chilled water systems (Liebert CW) can be integrated with building systems for potential heat recovery applications.
Scalability	Multiple unit sizes available (e.g., 9.5kW models for server rooms).	Multiple units can be networked (up to 10) for scalable, redundant cooling solutions	Modular design allows for multiple units to be installed for larger or redundant cooling setups. Suitable for	Best suited for small server rooms, network closets, or spot cooling within larger data Centres.	Wide range of capacities, from small server rooms to large data Centres (e.g., Liebert CW up to 181 kW). Modular and networkable units allow for

			scalable server room and IT infrastructure cooling needs.		scalable deployments and redundancy. Flexible installation options (in-row, perimeter, ceiling, upflow, downflow) to fit diverse IT environments.
Maintenance Requirements	Easy front panel access for maintenance on floor standing and wall units	EC fans and inverter compressors are designed for reliability and reduced maintenance.	Standard commercial AC maintenance: periodic filter cleaning, coil checks, and system diagnostics.	Minimal: No external condenser, refrigerant piping, or professional installation required.	Designed for easy access to all components from the front for simplified maintenance. Advanced diagnostics and microprocessor controls for fault detection and proactive maintenance.
Cost Considerations	Cost-effective for small IT server rooms	Premium products with advanced features, typically higher initial investment than standard comfort cooling systems.	Positioned as a cost-effective solution for commercial and IT cooling compared to specialized CRAC units.	Competitive pricing for the portable server room AC segment. Lower installation and maintenance costs compared to fixed or split AC systems.	Premium, mission-critical solutions with higher initial investment than comfort cooling but lower total cost of ownership due to energy efficiency and reliability. Operational savings from reduced energy use, advanced controls, and reduced downtime.
Environmental Impact	Uses R-32 refrigerant, which has a 68% lower Global Warming Potential than R-410A. Quiet operation and advanced filtration contribute to	Uses R32 refrigerant, which offers a significantly lower Global Warming Potential (GWP) compared to R410A (66% reduction)	Uses R32 refrigerant, which has a significantly lower Global Warming Potential (GWP) than R410A. High efficiency reduces overall energy	Uses R410A refrigerant, which is non-ozone depleting and compliant with global standards. No heat recovery, but efficient targeted cooling reduces	Use of R410A or R407C refrigerants (non-ozone depleting); newer models may use lower-GWP refrigerants. Free cooling and hot gas reheat options further reduce environmental impact. Advanced filtration and humidity

	a better indoor environment.		consumption and associated emissions.	unnecessary energy use.	control improve indoor air quality.
Customer type	IT server rooms Computer and comms rooms Small to medium data Centres	Targeted at IT/server rooms, data centres, UPS rooms, and other critical infrastructure environments requiring precise environmental control	IT/server rooms Small to medium data Centres Offices and light commercial spaces	Server rooms Network closets Small IT spaces Hot spots within larger data Centres	Data Centres (all sizes) IT/server rooms Network and telecom facilities. Critical infrastructure environments
Business Models and Pricing	Sold via authorized dealers, distributors, and HVAC contractors. Direct purchase, leasing, and contract options available. Support for installation and ongoing maintenance contracts.	Sold through Mitsubishi Electric's authorized distributors, HVAC contractors, and specialist IT cooling providers. Pricing is project-specific and depends on configuration, options, and installation complexity; consult distributors or partners for quotes. Maintenance contracts and support are available through Mitsubishi's service network.	Sold through Panasonic's authorized distributors and HVAC contractors. Pricing is project-based and depends on configuration and installation requirements. Maintenance and service contracts are available via authorized partners.	Sold through IT and electrical distributors, office supply retailers, and direct from Tripp Lite/Eaton partners. Available for outright purchase; leasing and credit options may be offered by some resellers.	Sold via Vertiv's authorized distributors, system integrators, and direct sales. Project-based pricing, with options for service/maintenance contracts and system integration. Support for design, installation, commissioning, and ongoing maintenance.
Country	Japan (global), Manufactured and distributed by Daikin Europe N.V.	Europe (UK, EMEA), Mitsubishi Electric	Europe (UK, EMEA)	Widely available in North America, UK, and Europe	Global (Europe, North America, Asia-Pacific, EMEA)

Table 8 Liquid-cooled technology providers

Company Name	SorCool ¹⁴⁴	ZutaCore ¹⁴⁵	CoolIT Systems ¹⁴⁶	LiquidStack ¹⁴⁷	Submer ¹⁴⁸
Product(s)	Adsorption Chillers (including new rack-integrated models) ¹⁴⁹	HyperCool® Waterless Direct-to-Chip Liquid Cooling System ¹⁵⁰	Modular Direct Liquid Cooling (DLC) Ecosystem ¹⁵¹	LiquidStack's single phase immersion DataTank™ ¹⁵²	SmartPodX Immersion Cooling System ¹⁵³
Product highlights	Converts waste heat (e.g., from water-cooled CPUs) into chilled water for cooling IT equipment. New rack-integrated chiller can generate up to 16 kW of chilled water from 34 kW of hot water, supporting a total cooling capacity up to 50 kW.	Waterless, two-phase, closed-loop direct-to-chip cooling for CPUs and GPUs, supporting processors up to and beyond 2800W.	Customizable and scalable for any size deployment, from single racks to entire data halls. Supports high-density computing (AI, HPC) workloads.	Single-phase immersion cooling: Entire servers (including CPUs, GPUs, memory, storage) are fully submerged in a thermally conductive, dielectric liquid coolant that remains in the liquid phase	Single-phase immersion cooling: Fully immerses IT hardware (servers, storage, networking) in a proprietary, biodegradable dielectric fluid (SmartCoolant), enabling highly efficient heat removal. Supports both standard 19" and Open Compute Project (OCP) 21" server formats
Key highlights					

¹⁴⁴ [Produkte - FAHRENHEIT](#)

¹⁴⁵ [Direct-to-Chip Liquid Cooling Company | ZutaCore](#)

¹⁴⁶ [CoolIT Systems | Liquid Cooling Technology](#)

¹⁴⁷ [Home - LiquidStack](#)

¹⁴⁸ [Immersion Cooling at Scale | SmartPod Platform | Submer | Immersion](#)

¹⁴⁹ [Fahrenheit Releases Rack-Integrated Adsorption Chillers](#)

¹⁵⁰ [HyperCool: The Data Centre Cooling System for Today's AI Factories](#)

¹⁵¹ [CoolIT Systems | Liquid Cooling Technology](#)

¹⁵² [Immersion Cooling | LiquidStack](#)

¹⁵³ [Immersion Cooling for Generic Workloads | Immersion Applications](#)

Cooling Technology Type	Adsorption cooling, driven by hot water (waste heat) from IT equipment.	Two-phase, direct-to-chip evaporative cooling: heat transfer fluid boils at the chip, vapor is condensed and recirculated in a closed loop.	Single-phase direct liquid cooling (DLC) using water/glycol coolant, centralized pumping, and passive coldplates.	Single-phase immersion cooling: Servers are immersed in a non-conductive liquid that absorbs heat and is circulated through a heat exchanger. The fluid never boils, ensuring stable, uniform, and silent cooling.	Single-phase immersion cooling: Servers are submerged in SmartCoolant, which absorbs heat and circulates it to an integrated Cooling Distribution Unit (CDU) and external heat exchanger. No phase change (no boiling), ensuring stable and uniform cooling.
Energy Efficiency	Reduces electricity consumption by up to 80% compared to traditional electric chillers. Significantly improves data centre Power Usage Effectiveness (PUE).	Up to 80% reduction in cooling power consumption compared to air-based systems.	Up to 50% reduction in cooling energy use compared to air cooling.	Advanced flow technology optimizes heat transfer and rejection, with as low as 1.03 pPUE, by using warmer water temperatures, and minimizing mechanical cooling power consumption.	PUE as low as 1.03: Achieves 25–30x greater efficiency than traditional air cooling.
Waste Heat Reuse	Core feature directly reuses waste heat from CPUs or other hot water sources to drive the cooling cycle.	Designed for 100% heat reuse: captured heat can be redirected to heat offices, other data Centre spaces, or even nearby facilities (schools, pools, etc.).	Supports warm-water loops for integration with facility heat reuse systems.	The system's warm liquid output can be integrated with facility-level heat reuse schemes, supporting sustainability and decarbonization goals.	The system's warm water output can be integrated with facility-level heat reuse schemes, supporting sustainability and decarbonization goals.
Scalability	Modular, rack-integrated design allows for deployment at the rack, row, or room level. Suitable for both small and large installations;	Highly scalable: supports >250kW per rack, suitable for AI factories, high-density data centres, and edge deployments. Can be	Modular architecture allows right-sizing for small server rooms or scaling up to large data Centres.	DataTank™ is available in compact sizes (2U, 4U, 8U) for micro and edge deployments, as well as larger tanks for higher density needs.	Can be deployed as a single unit for a small server room or scaled up by stacking or clustering multiple SmartPodX units for larger needs.

	supports mixed environments with liquid and air-cooled components.	deployed at rack, row, or facility level, and retrofitted to existing data centres.	Compatible with both new builds and retrofits.		
Maintenance Requirements	Fewer moving parts and no synthetic refrigerants, reducing long-term maintenance needs.	Low maintenance: closed-loop, waterless system means no risk of corrosion, bio-growth, or water leaks.	Centralized maintenance at CDU level. Quick disconnects enable easy, hot-swappable server maintenance.	No moving parts in the tank, sealed and dust-free environment, and easy access for hardware swaps.	No moving parts in the immersion tank, sealed and dust-free environment, and easy access for hardware swaps.
Cost Considerations	Potentially higher upfront investment compared to conventional chillers, but lower total cost of ownership due to energy savings and regulatory immunity.	Potentially higher upfront investment but reduces total cost of ownership (TCO) by up to 50% through lower energy use, higher compute density, and reduced infrastructure needs	Lower total cost of ownership (TCO) due to energy savings and reduced infrastructure.	Potentially higher upfront investment but up to 33% improvement in TCO over three years compared to air cooling, with 32% lower CAPEX.	Potentially higher upfront investment but reduces total cost of ownership (TCO)
Environmental Impact	Uses only water as the refrigerant-no synthetic, ozone-depleting, or high-GWP substances. Substantial reduction in CO ₂ emissions due to lower electricity use and elimination of harmful refrigerants.	No water consumption, no synthetic refrigerants-uses dielectric fluid and closed-loop operation. Reduces consumption of energy, water, and land resources.	Significant reduction in energy use and carbon footprint. No refrigerants with high global warming potential.	No refrigerants or water waste: Uses a closed-loop, non-toxic dielectric coolant and eliminates reliance on refrigerants and water.	Biodegradable coolant: SmartCoolant is certified biodegradable, non-toxic, and safe for humans and the environment. Eliminates use of high-GWP gases.

Customer type	Data centres (large and small), supercomputing centres, and IT facilities seeking sustainable, efficient cooling.	Targeted at data centres, AI factories, telecom providers, cloud providers, edge facilities, and enterprises needing high-density, sustainable cooling. Suitable for both new builds and retrofits, including high-performance computing and server hot spots.	Data Centres (AI, HPC, enterprise), cloud providers, research institutions, and high-density IT/server rooms.	IT server rooms, edge data centres, research labs, enterprises, and colocation providers seeking high-density, sustainable, and efficient cooling.	IT server rooms, edge data centres, research labs, enterprises, and colocation providers seeking high-density, sustainable, and efficient cooling.
Business Models and Pricing	Sold directly by SorCool and through specialized data centre integrators. Pricing is project-specific and depends on configuration, cooling capacity, and integration requirements. Service and support contracts available through SorCool.	Sold via direct engagement with ZutaCore and through integration partners. Project-based pricing; includes hardware, software, and optional support/service contracts. Compatible with leading server and rack manufacturers for streamlined deployment.	Sold directly and via OEM/server partners. Project-based pricing, with global design, installation, and service options.	Direct sales, integration, service contracts. Sold via LiquidStack and partners, with support for design, installation, and lifecycle maintenance. Service contracts: Optional for ongoing support and monitoring.	Direct sales, integration, service contracts. Sold via Submer and partners, with support for design, installation, and lifecycle maintenance. Service contracts: Optional for ongoing support and monitoring.
Country	Germany	Israel/USA	Canada	Global	Spain

Summary Findings

The data centre industry is undergoing a profound transformation driven by two major forces:

- Escalating power demands from GPUs powering generative AI, large language models, and HPC workloads.
- Increasing pressure to reduce the environmental impact of data centre operations.

These trends are pushing data centre owners and operators to move beyond traditional air-cooling solutions, embracing hybrid cooling strategies that combine air and liquid cooling technologies. This shift is particularly evident in facilities focusing on AI-intensive applications and energy efficiency improvements.

In this exploitation space, HYCOOL-IT has analysed the data centre and server room cooling market trends, drivers, and challenges, covering a diverse range of cooling technologies including Air cooling Direct-to-chip liquid cooling Single-phase and two-phase immersion cooling, adsorption chillers technology. This comprehensive analysis supports partners and stakeholders in making informed decisions, identifying new opportunities, and reducing operational and investment risks.

HYCOOL-IT's rack-integrated adsorption chiller addresses directly these market needs. It provides a compact, energy-efficient, and waste-heat-powered cooling solution, ideal for localized server rooms in tertiary buildings and hybrid environments. By integrating cooling directly into the server rack and simultaneously managing server and room temperatures, HYCOOL-IT offers an innovative approach to improving thermal management, reducing energy demand, and supporting sustainable data centre operations.

4.3 Building Digital Twin (BDT)

Scope: This exploitation space targets the growing market for Digital Twin technologies in building and IT infrastructure management, with a focus on IT server rooms in tertiary buildings such as offices, schools, hospitals, and public institutions. As AI workloads drive higher power densities and more complex thermal profiles, data centres and server rooms require smarter, more adaptive management solutions that go beyond conventional monitoring tools.

Relevance with HYCOOL-IT Innovations: HYCOOL-IT directly addresses this need through its Building Digital Twin Environment (BDTE), powered by SimBOTs (interactive simulation models). The system enables the creation of high-fidelity digital replicas of server rooms and their thermal systems, supported by standardised and reusable SimBOT libraries. The integration of a Simulation Model Tracking System (SMTS) allows real-time data to be merged with the simulation environment, enabling software-in-the-loop testing, lifecycle optimisation, predictive control, and performance evaluation.

Market Overview and Size

Digital twin technology is rapidly transforming the way we design, plan, construct, and manage buildings¹⁵⁴. This innovative approach integrates real-time data and intelligent simulations to optimize efficiency, reduce costs, and even increase property values¹⁵⁵.

In easiest terms, a Digital Twin¹⁵⁶ is a virtual illustration of a physical asset, process, or system, supplemented with data harmonised from the object to inform understanding and decision-making upon its performance. For clear interpretation, a digital twin is a virtual model of something that occurs in the real world. It adopts the model of a physical object and data synchronised from that object to make a powerful intelligence model. This allows stakeholders to envision the asset, check status, perform analyses and generate insights to predict and optimise asset performance.

The conception of the digital twin, first introduced in 2003 by Dr. Michael Grieves for the manufacturing sector, was later applied by NASA in 2010 to enhance spacecraft simulations¹⁵⁷. This primitive model of digital twins implicated three core components: the physical product, its virtual counterpart, and the bi-directional connections between them. These connections ensured real-time data flow from the physical asset to its digital replica, enabling informed decision-making in the virtual space, which could then be applied back to the physical system for optimization and control.

¹⁵⁴ [Digital Twins in Built Environments: An Investigation of the Characteristics, Applications, and Challenges](#)

¹⁵⁵ [Digital Twin Market and Benefits for Buildings](#)

¹⁵⁶ [Digital Twins Explained: A Guide for the Built Environment](#)

¹⁵⁷ [Digital Twins Explained: A Guide for the Built Environment](#)

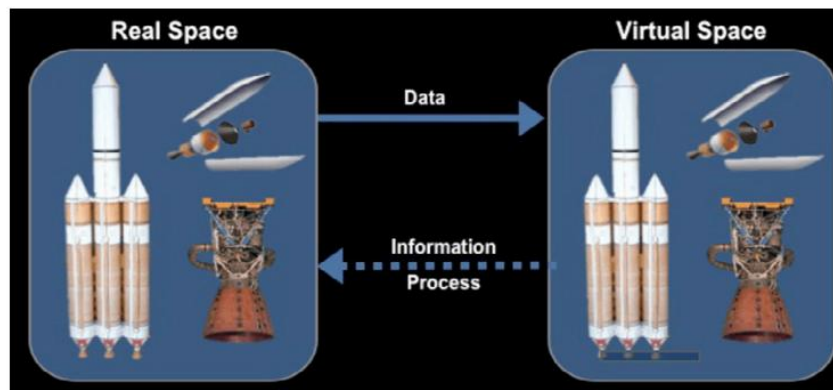


Figure 20 An Early Digital Twin Concept by Grieves and Vickers. Source: Wikipedia

Digital Twins and BIM Models: BIM, brief for Building Information Modeling¹⁵⁸, is a method that concerns creating and managing virtual representations of real and functional features of a construction project. It is like having a digital design that includes all the major information about a building or infrastructure, from its geometry and spatial relationships to its resources and capacities. BIM facilitates cooperation among various stakeholders, such as architects, engineers, and contractors, throughout the project lifecycle.

Digital twins represent an evolution of the industry's ongoing digitalisation journey—from hand-drawn designs to CAD, to 3D BIM models, and now to digital twins¹⁵⁹. The key distinction between a BIM model and a digital twin lies in the connection to the physical asset. While BIM models are static and lack real-time data integration, a digital twin is continuously enriched and updated with data from the actual asset, collected via sensors, monitors, and smart meters. Without this dynamic, bi-directional data flow between the physical and virtual, a model remains just a static representation, not a true digital twin.

Uptime Intelligence¹⁶⁰ regularly tracks the adoption of digital twin solutions for data centre management and control software purposes. While the concept of digital twin is not new, recent developments in precision physics-based models, interactive simulations, and AI/machine learning (ML) have made digital twin a more viable consideration for many data centre operators.

The digital twin for buildings market is quickly developing, forced by demand for efficiency, sustainability, and real-time data insights. Multiple recent market research reports and analyses confirm the rapid expansion of the digital twin for buildings market, with robust forecasts and detailed breakdowns of driving factors:

Astute Analytica¹⁶¹: Projects the global digital twin for buildings market will reach USD 20.2 billion by 2032, up from USD 1.6 billion in 2023, at a CAGR of 32.6%. This growth is attributed to the technology's

¹⁵⁸ [BIM and Digital Twins: How They Differ and Why It Matters](#)

¹⁵⁹ [Digital Twins Explained: A Guide for the Built Environment](#)

¹⁶⁰ [Digital twins: reshaping AI infrastructure planning | Uptime Intelligence](#)

¹⁶¹ [Astute Analytica | Global Industry Analysis Report | Business Consulting and Research](#)

ability to optimize building design, construction, and management, leading to significant reductions in energy usage (up to 20%) and maintenance costs (25–30%), and boosting property values by 7–20%¹⁶².

Market Research Future (MRFR): Estimates the building twin market will increase from USD 2.1 billion in 2024 to USD 13.8 billion by 2032, at a CAGR of 44.6%¹⁶³. Europe is the second-largest developing market, with a market share of approximately 28% in 2023. The region is anticipated to grow at a CAGR of 31.8% from 2024 to 2032. Market Research Future¹⁶⁴ report on building digital twin market is broken down into various industry segments, including Commercial, Residential, and Industrial. Between these, the Commercial segment is projected to dominate the market, amounting for a significant share of the Building Twin Market revenue in 2024. The increase of the Commercial segment can be attributed to the heightening adoption of Building Twin technology in commercial buildings for enhanced energy efficiency, space optimization, and improved occupant comfort.

MarketsandMarkets: Projects the global building twin market to increase from USD 2.1 billion in 2024 to USD 13.3 billion by 2029, at a CAGR of 44.7%¹⁶⁵.

These market research reports and analyses confirm the rapid expansion of the digital twin for buildings market. Focusing on a specific segment, the integration of digital twin technologies in data centres and IT server rooms within tertiary sector buildings—such as offices, educational institutions, healthcare facilities, and public administration buildings—is gaining significant traction.

According to QYResearch Group¹⁶⁶, the international market for Data Centre Digital Twin Operations & Maintenance (O&M) Systems was priced at USD 343 million in 2024 and is anticipated to reach USD 1,796 million by 2031, rising at a CAGR of 25.98% through the estimate period from 2026 to 2031¹⁶⁷. In 2024, Europe amounted for USD 80.67 million, indicating approximately 23.49% of the global market share. This extensive share emphasizes the region's commitment to adopting advanced technologies for efficient data centre and server rooms management.

Leading companies such as Siemens, Bentley Systems, and Autodesk are investing heavily in R&D to enhance their building twin solutions, focusing on improved integration with AI and machine learning capabilities. Collaborations between tech giants and construction firms are also shaping the market landscape, driving further innovation and adoption. The international key companies of Data Centre Digital Twin O&M System consist of Schneider Electric, Siemens, Tencent, IEIT SYSTEMS, FUJITSU, Cadence, EkkoSense etc. In 2024, the worldwide five largest players manage a share approximately 63.43% in terms of revenue.

Market Factors Driving Current and Future Growth

Various key factors are driving the strong expansion in the building digital twin market:

¹⁶² [Digital Twin for Buildings Market Size, 2032](#)

¹⁶³ [Global Building Twin Market Overview](#)

¹⁶⁴ [Building Twin Market Size, Share & Industry Growth 2032](#)

¹⁶⁵ [Building Twin Market Size, Share, Industry Report, Revenue Trends and Growth Drivers](#)

¹⁶⁶ [About Us-QYResearch](#)

¹⁶⁷ [Global Data Centre Digital Twin O&M System Market Size, Manufacturers, Supply Chain, Sales Channel and Clients, 2025-2031](#)

Energy Efficiency Demands and Sustainability Goals: Rising power consumption in data centres and IT server rooms – projected to double by 2030 to 945 TWh¹⁶⁸ according to International Energy Agency forecasts – requires operators to adopt digital twin systems to support energy efficiency. These digital twin systems facilitate real-time simulation of cooling systems, rack and layout configurations, and workload distribution, attaining substantial energy savings in operational trials.

Advancements in IoT and Smart Building Technologies: The incorporation of IoT devices in building structures and environments allows for real-time data collection, which can then be supplied into the digital twin for constant performance evaluation. This IoT interaction is increasing the value proposition of digital twin technology by providing thorough insights into the building's operational parameters.

Operational Complexity of Hybrid Infrastructures: Modern data centres and server rooms combine legacy systems with liquid cooling, AI accelerators, and renewable energy sources, creating multilayered operational challenges. Digital twin solutions for data centres can help address this complexity. These solutions are essential for meeting the growing demands of digital infrastructure, especially as AI and cloud workloads increase operational complexity.

Growing Adoption in Facility Management: Facility managers progressively more rely on building digital twins to improve maintenance schedules, enhance occupant comfort, and guarantee safety. Real-time monitoring of HVAC systems, lighting, and other critical infrastructure has become a standard application within the digital twin framework, reducing unexpected downtime and costs.

Supportive Government Initiatives and Regulations: Governments regulations and initiatives across globe but particularly Europe, are also driving the growth of the building digital twin market. Governments around the world are increasingly implementing regulations and initiatives that promote energy efficiency and sustainability in buildings. These regulations and initiatives are creating a demand for solutions that can help organizations to meet these requirements. In Europe, the EU Energy Efficiency Directive¹⁶⁹ requires data centres to publicly report energy performance metrics and improve their PUE (Power Usage Effectiveness). Compliance costs for retrofitting legacy infrastructure are excessively high, making digital twins economically feasible. For instance, operators in Germany now exploit digital twins to simulate airflow patterns and optimize cooling systems pre-deployment strategies, achieving significant energy savings.

Key Challenges

High Implementation Costs & Complex Integration: Deploying a digital twin system requires significant investment in sensors, AI, and software integration, making adoption challenging for smaller data centres.

Data Security & Privacy Concerns: Digital twin models collect vast amounts of sensitive data, increasing the risk of cybersecurity threats, unauthorized access, and potential breaches.

¹⁶⁸ IEA: Data Centre energy consumption set to double by 2030 to 945TWh - DCD

¹⁶⁹ Energy Efficiency Directive | eudca.org

Scalability Issues in Large Data Centres: As data centre infrastructures grow, ensuring seamless scalability and maintaining real-time accuracy in digital twins can be complex and resource intensive.

Lack of Standardization & Interoperability: The absence of unified industry standards makes it difficult to integrate digital twin systems with existing data centre management tools and platforms.

Limited Technical Expertise & Adoption Barriers: Many enterprises face challenges in adopting digital twin technology due to a lack of skilled professionals and resistance to transitioning from traditional O&M methods.

Market segment

Several Market research reports and analyses confirm the development of two-speed data infrastructure landscape going forward: data centres and server rooms equipped to handle AI processing workloads, and those supporting traditional IT applications. These two types of infrastructure will differ significantly in their design and operational requirements.

Data centres and server rooms embedded within tertiary sector buildings—such as offices, schools, hospitals, and public institutions—constitute a vast but often overlooked market segment. These facilities are typically aging, inefficient, and poorly optimized, consuming a disproportionate amount of energy relative to their size and function. Many were built to meet legacy IT needs and now struggle to accommodate the performance demands and sustainability requirements of modern digital infrastructure. The EURECA project¹⁷⁰ funded under Horizon 2020 research and innovation programme under grant agreement No 649972., checked over 350 public sector data centres across Europe, uncovered that 80% are small server rooms with less than 25 racks. Additionally, EURECA project found that a significant portion of servers in public sector data centres are aged and inefficient, consuming a disproportionate amount of energy.

There are two main challenges facing enterprise IT server rooms today.

- First, how to improve the efficiency of existing data centre and server room infrastructure, which often struggles to meet the performance and sustainability demands of modern digital operations.
- Second, how to effectively manage the future evolution of IT infrastructure as workloads become more intensive and complex. Driven by AI acceleration, high-performance computing (HPC), and real-time data processing, enterprise data centres are transitioning into hybrid infrastructures. These environments increasingly integrate legacy systems with modern technologies such as liquid cooling, powerful GPUs to support AI workloads, renewable energy systems, and advanced processing units. This convergence introduces multilayered operational complexity, requiring smarter, more adaptive management strategies.

Traditional monitoring and thermal mapping techniques are no longer sufficient to handle this complexity. They often lack the precision, real-time responsiveness, and system-level integration needed for efficient system design and analysis. This highlights the need for innovative technologies

¹⁷⁰ [Datacentre EURECA Project](#)

capable of delivering holistic insights. Digital twins represent a pivotal advancement in data centre management, offering a level of analysis, simulation, and efficiency previously unattainable through traditional monitoring and thermal mapping techniques. Their growing adoption signifies a shift towards more sustainable, resilient, and optimized data centre operations.

To better understand the innovation landscape in data centres and server rooms—including the adoption of digital twins, AI, liquid cooling, and sustainability strategies—Cadence¹⁷¹ commissioned a global survey, gathering insights from 400 IT, facility, and business leaders worldwide and reported the results and analysis of the survey in the 2024 report “Data Centre Evolution: The Innovation Imperative”¹⁷². This comprehensive study provides a detailed snapshot of how data centres of all sizes—particularly enterprise facilities and smaller server rooms—are responding to the pressures of rising AI workloads, sustainability regulations, and the need for operational efficiency.

Insights on Digital Twins Cadence Survey and Report¹⁷³

Adoption & Confidence Trends:

- Forty-two percent of respondents are already using digital twins; 21% plan to adopt them in the next 12 months.
- Eighty-one percent are confident in their organization’s ability to use digital twins — but confidence is much lower among enterprise facilities (41%) compared to hyperscalers (58%).

Top Current Use Cases:

- Network planning and management (64%)
- Space planning and management (62%)
- Capacity optimization (61%)
- Managing and introducing AI (58%, 56%)
- Introducing liquid cooling (42%)

Top Future Use Cases:

- Planning site upgrades (45%)
- Managing renewable energy inputs (44%)
- Introducing liquid cooling (43%)
- Managing AI (35%)

According to the Cadence Survey and Report “Enterprise facilities tend to be older, legacy sites, designed for lower density power loads. Consequently, they do not have the infrastructure to accommodate AI. This will drive them to outsource to colocation providers until they have established how to meet the needs of these innovations in-house. When they have done so, we are likely to see a rise in the number of enterprises using digital twins to support the introduction and use of AI.”

¹⁷¹ [Cadence | Computational Software for Intelligent System Design | Cadence](#)

¹⁷² [Data Centre Evolution eBook | Cadence](#)

¹⁷³ [Data Centre Evolution eBook | Cadence](#)

Obstacles to overcome

- **High-quality data availability:** 36% say they cannot provide the data needed for digital twins to operate effectively.
- **Lack of in-house expertise:** Enterprise and small facility operators lack the developers and integration capacity found in hyperscale environments.
- **Cost sensitivity:** Smaller organizations face budget constraints that hinder digital twin adoption despite understanding the benefits.

Opportunities

- Digital twins are seen as a 'game changer' by 73% of respondents, especially among those already using them (81%).
- For enterprise and edge facilities, digital twins can delay costly infrastructure expansions by maximizing existing capacity, improving sustainability, and supporting gradual innovation.

Key Market Players

The following table present detailed information on some interesting market players in the data centre digital twin industry. Five companies have been selected based on their technological innovations, market presence, and alignment with sustainability goals.

Table 9 Data centre digital twin technology providers

Company Name	EkkoSense ¹⁷⁴	Cadence ¹⁷⁵	Sunbird ¹⁷⁶	AKCP ¹⁷⁷	New Generation SR ¹⁷⁸
Product(s)	EkkoSIM ¹⁷⁹	Reality Digital Twin Platform ¹⁸⁰	dcTrack DCIM Operations Solution ¹⁸¹	AKCPro Server software ¹⁸²	NuveaPaaS ¹⁸³
Product highlights	Real-time 3D optimization, rapid room builder, actionable insights, Winner of the ASHRAE 2024 Digital Twins (Data Centres) Award ¹⁸⁴	AI-driven, physics-based simulation, scenario modeling, NVIDIA Omniverse integration ¹⁸⁵	Real-time 3D digital twin, asset/capacity management, 100+ dashboard reports, auto-discovery	Sensor-based monitoring, thermal mapping, CFD airflow simulation, predictive maintenance	One-click monitoring/optimization of Data centre sites, remote management, unified DCMS platform
Key highlights					

¹⁷⁴ [AI Data Centre Optimization Software - EkkoSense](#)

¹⁷⁵ [Cadence | Computational Software for Intelligent System Design | Cadence](#)

¹⁷⁶ [Sunbird DCIM](#)

¹⁷⁷ [AKCP Data Centre Monitoring | Sensor Monitoring Solutions](#)

¹⁷⁸ [Home | New Generation SR](#)

¹⁷⁹ [Unlocking the Potential: Exploring Data Centre Digital Twin - EkkoSense](#)

¹⁸⁰ [Cadence Reality Digital Twin Platform | Data Centre Design, Modelling, Simulation & Optimization | Cadence](#)

¹⁸¹ [DCIM – dcTrack - ITDCIM](#)

¹⁸² [AKCPro Server](#)

¹⁸³ [NuveaPaaS | New Generation SR](#)

¹⁸⁴ [Digital Twin 3D visualization across all your data Centre operations - EkkoSense](#)

¹⁸⁵ [Develop on NVIDIA Omniverse Platform | NVIDIA Developer](#)

Simulation Technology and Accuracy	Real-time, sensor-driven, immersive 3D digital twin	High-fidelity CFD, AI/ML, physics-based, external factors	Real-time 3D visualization, high asset fidelity	Sensor-driven, integrates CFD for airflow/thermal accuracy	Real-time monitoring, optimization; simulation powered by information from the Future Facilities' 6Sigma Digital Twin ¹⁸⁶
Life Cycle Coverage	Full O&M cycle: audit, monitoring, optimization	Design, planning, operational optimization	Full asset lifecycle: planning to decommission	O&M, predictive maintenance, alerting	O&M, monitoring, optimization
Core Functionalities	3D visualization, thermal/cooling optimization, capacity planning, alerting, reporting	Energy optimization, airflow/thermal simulation, predictive analytics, capacity planning	Asset management, capacity planning, power/environment monitoring, workflow/change management, audit trail, reporting	Environmental monitoring, power/energy tracking, water leak/physical security detection, alerting	Centralized monitoring, remote site management, optimization, dashboard reporting
Data Integration Capabilities	Integrates with BMS, DCIM, and environmental sensors; rapid onboarding of new rooms and assets	Data import/export, integrates with design tools and DCIM, supports external environmental data	SNMP, auto-discovery, API, import/export, integrates with CMDB, BMS, change management, Power IQ monitoring	Integrates with wide range of sensors, SNMP, Modbus, BACnet, RESTful APIs, supports third-party integration	Integrates with various Data centre sites, cloud connectivity, supports distributed environments
User Interface and Experience	Intuitive, drag-and-drop, immersive 3D visualization	Web-based, interactive dashboards, scenario modeling tools	Modern web UI, mobile app, 3D rack/floor views, customizable dashboards	Web-based, real-time dashboards, customizable alerts, mobile support	Web-based, user-friendly dashboard, accessible remotely
Business Model and Platform Architecture	SaaS/cloud-based, scalable from server rooms to large DCs	Cloud/SaaS, modular, scalable	SaaS or on-prem, scalable, modular, integrates with other Sunbird tools	Appliance or software, modular, scalable. The business model	PaaS (Platform as a Service), cloud-based, scalable

¹⁸⁶ [Cadence Reality DC Design Product Brief | Cadence](#)

				includes software licensing.	
Customer Type	Edge/IT rooms, server rooms, colocation, enterprise DCs, clear thresholds for liquid cooling compliance	Edge/IT rooms, server rooms, Enterprises, hyperscalers	IT server rooms, distributed sites, enterprise DCs	IT server rooms, containment pods, edge, small DCs	IT server rooms, distributed DCs, remote management
Country	UK	USA	USA	Thailand	France

Summary Findings

Enterprise data centres and server rooms are facing growing complexity due to AI workloads, HPC, and hybrid infrastructures combining legacy and modern technologies. This generates significant obstacles in efficiency, capacity management, and sustainability. Traditional monitoring and thermal mapping tools are no longer sufficient, as they lack real-time precision, integrated system visibility, and decision-support capabilities. Data centre and IT operators also struggle with a lack of end-to-end visibility and unified tools across hybrid IT environments, making capacity and energy management increasingly complex.

Digital twins offer a transformative solution, enabling advanced simulation, predictive control, and holistic visibility. While the concept of digital twins is not new, recent developments in precision physics-based models, interactive simulations, and AI/machine learning (ML) have made digital twin a more viable consideration for many data centre operators. However, current solutions are often:

- Used in isolation, without integration into real-time workflows.
- Too complicated and resource-intensive for big acceptance.
- Lacking standardisation, interoperability, and modularity.

HYCOOL-IT's Building Digital Twin (BDT) directly addresses these gaps by offering a simplified, modular, and standardised approach, using:

- SIMBOTS
- Reusable SIMBOT libraries for IT and thermal systems.
- SMTS for model tracking,
- Software-in-the-loop (SiL) predictive control and performance evaluation

This approach improves accessibility, operational relevance, and capacity management, while supporting standardisation (e.g., CEN TC442/WG9) for interoperability and market replication—making it especially suitable for tertiary sector data centres and localized server rooms aiming for efficient, resilient, and sustainable operations.

4.4 Smart Building Management Systems (SBMS).

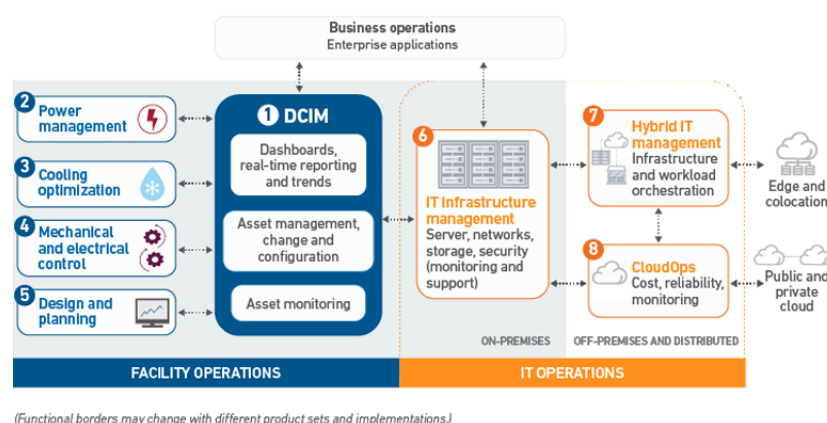
Scope: This exploitation space targets the Smart Building Management System (SBMS) market, including DCIM (Data Centre Infrastructure Management), DCM (Data Centre Management), and BMS (Building Management Systems) platforms.

Relevance with HYCOOL-IT Innovations: The SBMS exploitation space focuses on the integration of HYCOOL-IT's digital and thermal control components into existing or new building management environments to enable real-time, intelligent, and energy-optimised operations.

Market Overview and Size

As data centre and server room operators tackle the increasing complexity of managing both IT and facility infrastructure, data centre management software has become decisive. Data centre operators are tasked with handling a larger number of servers and workloads, often across multiple distributed environments and geographically diverse locations. This complexity is further intensified by the need to support both traditional applications and emerging high-density, AI-driven workloads—each with varying power, latency, and criticality requirements. In response, data centres are adopting new cooling systems, advanced power distribution architectures, and modernised cabling infrastructures to accommodate AI and high-performance computing (HPC). To manage this increasing complexity, tools like Data Centre Infrastructure Management (DCIM) systems are essential. According to Gartner¹⁸⁷, DCIM tools are employed to monitor, measure, manage, and control data centre operation and energy use—covering both IT-related equipment (e.g., servers, storage, network switches) and facility infrastructure components (e.g., power distribution units [PDUs], computer room air conditioners [CRACs]).

Figure 21 presents a data centre management and control software framework, highlighting new capabilities and an expanded range of applications, as outlined in the Uptime Intelligence publication¹⁸⁸.



¹⁸⁷ Definition of DCIM - IT Glossary | Gartner

¹⁸⁸ Data Centre management and control software: an overview | Uptime Intelligence

Figure 21 Data centre management and control software framework¹⁸⁹

The DCIM software market is experiencing robust growth, with a global market size valued at approximately USD 2.02 billion in 2023 and is projected to reach USD 3.63 billion by 2029¹⁹⁰. The broader DCIM market, including services, is even larger and growing at a slightly higher CAGR, reflecting the expanding role of infrastructure management in modern data centres.

Market Factors Driving Current and Future Growth

The data centre management software market is influenced by various drivers and challenges that reflect the complexity of modern data centre environments. These factors include technological advancements, economic pressures, and regulatory changes, which collectively shape the growth and evolution of the market. Understanding these drivers and challenges is essential for navigating the competitive landscape and making informed strategic decisions.

The factors responsible for driving the data centre management software market include:

Technological Advancements: Technological advancements, such as AI, machine learning, and cloud computing, are major drivers of growth in the data centre management software market. These innovations enable more efficient data centre operations, predictive maintenance, and advanced analytics. As technology evolves, data centres can leverage these tools to optimize performance, reduce costs, and enhance scalability. The rapid pace of technological change necessitates continuous updates and improvements in data centre management software solutions.

Increasing Data Volumes: The exponential growth in data volumes due to digital transformation, IoT, and big data analytics drives the demand for advanced data centre management software solutions. Data centres need to manage larger and more complex datasets, requiring sophisticated management tools to ensure efficiency and reliability. This increase in data volume fuels the need for enhanced storage, processing, and analysis capabilities within data centre management software platforms.

Demand for Energy Efficiency: Rising energy costs and environmental regulations are pushing organizations to focus on energy efficiency in their data centres. Data centre management software solutions that offer advanced energy management capabilities can help organizations reduce power consumption, lower operational costs, and meet sustainability goals. The emphasis on energy efficiency drives the adoption of data centre management software solutions that incorporate intelligent power management and cooling technologies.

Regulatory Compliance: Stringent regulatory requirements regarding data protection, privacy, and cybersecurity are driving the adoption of advanced data centre management software solutions. Compliance with regulations such as General data protection regulation (GDPR)¹⁹¹ necessitates robust management tools to ensure data security and regulatory adherence. Data centre management

¹⁸⁹ [Data centre management software: the evolving role of DCIM | Uptime Intelligence](#)

¹⁹⁰ [Data Centre Infrastructure Management Software Analysis](#)

¹⁹¹ [General data protection regulation \(GDPR\) | EUR-Lex](#)

software solutions that offer comprehensive compliance features and reporting capabilities are essential for meeting these requirements.

Key Challenges

High Implementation Costs: One of the substantial challenges in the data centre management software market is the high cost of application and integration. Sophisticated data centre management software solutions often require considerable investments in hardware, software, and training. For many organizations, the high early cost can be a barrier to accepting sophisticated management tools, particularly for smaller enterprises with limited budgets.

Complexity of Integration: Integrating data centre management software solutions with existing IT infrastructure can be complicated and burdensome. Data centres frequently have varied and legacy systems that require to be harmonized with new management platforms. The difficulty of integration can lead to interruptions and prolonged implementation timelines, affecting overall efficiency and increasing costs.

Security and Privacy Concerns: As data centres process sensitive and critical information, security and privacy troubles are major challenges. Guaranteeing that data centre management software solutions provide strong protection against cyber threats, data breaches, and unauthorized access is crucial. The advancing nature of cyber threats requires constant updates and improvements to security measures, adding to the complexity and cost of maintaining secure operations.

Key Market Players

The following table present detailed information on some interesting market players in the DCIM software industry. Five companies have been selected based on their technological innovations, market presence, and alignment with sustainability goals.

Table 10 DCIM software providers

Company Name	Schneider Electric ¹⁹²	Sunbird ¹⁹³	Nlyte ¹⁹⁴	Vertiv ¹⁹⁵	Hyperview ¹⁹⁶
Product(s)	EcoStruxure IT ¹⁹⁷ – they sell different modules under the same brand (e.g. energy efficiency, asset planning, etc.)	Energy: Power IQ DCIM Monitoring Asset: dcTrack DCIM Operations Bundle: DCIM Suite	Nlyte Energy Optimizer Nlyte Asset Nlyte DC Monitoring	They provide different software product, all separate: Trellis Enterprise Solutions Vertiv Power Insight Vertiv Environet	Hyperview Asset Tracking Carbon Footprint Reporting Hyperview Control
Product highlights	Vendor-neutral platform Real-time monitoring & management Cloud-based and on-premises options Advanced reporting, including sustainability and regulatory compliance AI-driven insights and	Second-generation, vendor-agnostic DCIM Real-time asset, power, capacity, and environmental monitoring Intuitive, customizable dashboards and reporting	End-to-end asset lifecycle management Robust dashboards and reporting Visual floor planning and CAD-style layouts Intelligent asset placement Automated change management Vendor-neutral integration	Real-time monitoring and management of power, cooling, environment, and IT assets Vendor-neutral integration with third-party devices Centralized monitoring and alarming	Cloud-based, SaaS DCIM Intuitive web interface and quick onboarding Real-time asset, capacity, power, energy, and environmental monitoring

¹⁹² [Soluções DCIM | Schneider Electric Portugal](#)

¹⁹³ [DCIM - Data Centre Infrastructure Management Software System, Cable Management, Infrastructure Design & Optimization Companies - Sunbird DCIM](#)

¹⁹⁴ [DCIM Software, Hybrid Cloud Infrastructure and BMS Data Centre | Nlyte](#)

¹⁹⁵ [DCIM & IT Management](#)

¹⁹⁶ [Cloud-based Data Centre Infrastructure Management \(DCIM\) Software](#)

¹⁹⁷ [What is EcoStruxure IT](#)

	analytics Secure, scalable, and suitable for distributed, hybrid, and colocation environments			Visual infrastructure planning tools	Automated, agentless asset discovery Augmented Reality (AR) integration with DC Vision® Vendor-agnostic, API-first architecture
Key highlights					
Energy monitoring	Digital twin Calculate energy costs Reporting on energy usage	Sensor monitoring Energy billback to customers	Real-time PUE Plan future energy needs	Monitoring and alarms Optionally automates managing devices	Digital twin Calculate energy costs Reporting on energy usage
IT resource capacity management	Assign tenants to specific racks Capacity planning	Capacity Management Identify ghost server candidates Project planning	Capacity Management Identify ghost server candidates Capacity forecasting	Monitoring and management of UPS and rPDU infrastructure Trigger Virtual Machine shutdown or migration	Capacity Management Identify ghost servers Capacity forecasting
Equipment & asset monitoring	Asset visualization	Asset visualization Parts & spares management	Asset visualization	Asset / Inventory visualization	Asset tracking (RFID) Preventative maintenance
Customer type	Small scale Hyperscalers On-premises or cloud Edge	Enterprise (E.g. Comcast, AT&T, United, Akamai, Workday, KPMG, eBay)	Enterprise (Cisco, IBM) Co-location (CompuCentre) Edge	No distinction	No distinction
Business Models and Pricing	Subscription model	From \$5.5/node/month to \$26.65/cabinet/month for a full bundle	Subscription (SaaS) and perpetual license options. Pricing based on number of racks, assets, or total facility power.	Flexible, modular licensing. Pricing based on monitored assets, racks, or data centre size.	Asset tracking: \$24/rack/yr other modules: \$0.5-3/asset/yr
Country	France	USA	USA	USA	Canada

Summary Findings

As data centre and server room operators tackle the increasing difficulty of managing both IT and facility infrastructure, data centre management software—particularly Data Centre Infrastructure Management (DCIM) platforms—has become critical.

DCIM solutions provide a centralized platform that integrates IT, cooling, power, and environmental data, enabling real-time visibility, control, and optimisation of data centre operations.

Modern DCIM platforms are evolving to support:

- **Open architectures and APIs:** Modern DCIM solutions are designed with open architectures and provide REST APIs or SDKs, making them capable of integrating with external systems like HYCOOL-IT's digital platforms. This allows for seamless data exchange, real-time monitoring, and coordinated control between the cooling system and the broader building management environment.
- **Holistic infrastructure monitoring:** DCIM platforms unify data from IT, cooling, power, and environmental systems, displaying it on centralized dashboards. This holistic view enables data-driven decisions and supports the optimization of energy and cooling resources in real time.
- **Advanced energy and environmental analytics:** DCIM tools continuously monitor temperature, humidity, airflow, power usage, and PUE (Power Usage Effectiveness), providing actionable insights for energy optimization and early detection of inefficiencies or failures.
- **Automation and change management:** enabling integration with digital twins and smart cooling systems supports automated workflows for commissioning, maintenance, and performance evaluation, reducing manual intervention and improving operational resilience

Relevance with HYCOOL-IT Innovations

HYCOOL-IT's digital and thermal management components should be designed to integrate seamlessly with existing or new DCIM platforms, enabling real-time data exchange, predictive control, and enhanced operational intelligence.

5. Conclusions

This report provides a comprehensive PESTLE analysis and market assessment to evaluate the external factors and market conditions shaping the uptake, replication, and commercialization of HYCOOL-IT's innovations. By combining regulatory, economic, technological, and environmental insights with a detailed competitive landscape review, the analysis highlights the growing demand for advanced, energy-efficient cooling and digital management solutions in data centres and server rooms.

The data centre industry is at a critical juncture, driven by surging AI and HPC workloads, intensifying sustainability pressures, and increasing energy costs, prompting operators to explore hybrid cooling strategies and adopt digital twin technologies for real-time optimisation and predictive control. In this evolving landscape, HYCOOL-IT's rack-integrated adsorption chiller and digital twin-supported design and operations processes address clear market gaps, offering differentiated, sustainable, and scalable solutions.

These findings reinforce HYCOOL-IT's strong alignment with emerging market needs, regulatory environment, and industry trends, supporting its potential for wide adoption, replication, and contribution to the digital and green transformation of the data centre sector.

6. Appendixes

6.1 HYCOOL-IT Exploitation Space – 1 Pager Summary for Energy Efficiency (EE)

Table 11 HYCOOL-IT Exploitation Space – 1 Pager Summary for Energy Efficiency (EE)

Exploitation Space	Energy efficiency (EE)
Definition and Scope	This exploitation space targets the expanding energy efficiency (EE) market within the data centre and server room sector, covering both State-of-the-art digital and hardware innovations that enable smarter and low-carbon operations of data centres and server rooms. It encompasses solutions such as efficient cooling technologies, AI powered O&M software solutions, Real-time monitoring and analytics tools, advanced simulation and modelling tools.
HYCOOL-IT Innovation Fit	HYCOOL-IT Solution Rack-integrated adsorption chiller
Market Size and CAGR	Global Sustainable Data Centre Market Size focusing on broad sustainability & EE is valued at USD 85.1 Bn in 2024 and is predicted to reach USD 440.7 Bn by the year 2034 at a 18.0% CAGR during the forecast period for 2025-2034 ¹⁹⁸ .
Market Drivers and Challenges	Drivers: Surging demand for digital services, AI workloads, rising energy costs, corporate sustainability goals, and robust policy initiatives. Challenges: Lack of Energy Visibility and Predictive Maintenance, Static and manual cooling controls etc
Key Market Players	Air cooled solutions: Daikin ¹⁹⁹ , Mitsubishi Electric ²⁰⁰ , Panasonic ²⁰¹ , Tripp Lite (Eaton) ²⁰² , Vertiv ²⁰³ Liquid cooled solutions: SorCool ²⁰⁴ , ZutaCore ²⁰⁵ , CoolIT Systems ²⁰⁶ , LiquidStack ²⁰⁷ , Submer ²⁰⁸ .

¹⁹⁸ [Sustainable Data Centre Market 2025 Latest Report with Forecast to 2034](#)

¹⁹⁹ [Daikin Global | A leading air conditioning and refrigeration innovator and provider for residential, commercial and industrial applications](#)

²⁰⁰ [Mitsubishi Electric Trane Heating and Air Conditioning](#)

²⁰¹ [Panasonic - sistemas de aquecimento e arrefecimento - Portugal](#)

²⁰² [Eaton - Power and Connectivity Solutions](#)

²⁰³ [Data Centre Air Conditioning Systems | Vertiv Room Cooling](#)

²⁰⁴ [Produkte - FAHRENHEIT](#)

²⁰⁵ [Direct-to-Chip Liquid Cooling Company | ZutaCore](#)

²⁰⁶ [CoolIT Systems | Liquid Cooling Technology](#)

²⁰⁷ [Home - LiquidStack](#)

²⁰⁸ [Immersion Cooling at Scale | SmartPod Platform | Submer | Immersion](#)

	<p>Building Digital Twin: EkkoSense²⁰⁹, New Generation SR²¹⁰, Cadence²¹¹, Sunbird²¹², AKCP²¹³</p> <p>DCIM Software: Schneider Electric²¹⁴, Sunbird²¹⁵, Nlyte²¹⁶, Vertiv²¹⁷, Hyperview²¹⁸</p>
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²⁰⁹ [AI Data Centre Optimization Software - EkkoSense](#)

²¹⁰ [NuveaPaaS | New Generation SR](#)

²¹¹ [Cadence | Computational Software for Intelligent System Design | Cadence](#)

²¹² [DCIM - Data Centre Infrastructure Management Software System, Cable Management, Infrastructure Design & Optimization Companies - Sunbird DCIM](#)

²¹³ [About AKCP: Your Partner in Monitoring Technology](#)

²¹⁴ [What Is Data Centre Management and How Has it Evolved?](#)

²¹⁵ [DCIM - Data Centre Infrastructure Management Software System, Cable Management, Infrastructure Design & Optimization Companies - Sunbird DCIM](#)

²¹⁶ [DCIM Software, Hybrid Cloud Infrastructure and BMS Data Centre | Nlyte](#)

²¹⁷ [DCIM & IT Management](#)

²¹⁸ [Cloud-based Data Centre Infrastructure Management \(DCIM\) Software](#)

6.2 HYCOOL-IT Exploitation Space – 1 Pager Summary for Targeted Cooling Solutions for IT Server Rooms (ITSR)

Table 12 HYCOOL-IT Exploitation Space – 1 Pager Summary for Targeted Cooling Solutions for IT Server Rooms (ITSR)

Exploitation Space	Targeted Cooling Solutions for IT Server Rooms (ITSR)
Definition and Scope	This exploitation space targets the global data centre and server room cooling market, with a focus on the transition from traditional air-based cooling systems to emerging liquid-based cooling solutions. As computing density increases—driven by AI workloads, edge computing, and rising digitalization of buildings—the limitations of conventional air cooling have become evident.
HYCOOL-IT Innovation Fit	Rack-integrated adsorption chiller Specific SIMBot of Rack-integrated adsorption chiller system libraries Tool for waste heat reuse for IT server rooms Innovative engineering guidelines for ICT Server's Room design
Market Size and CAGR	Global data centre thermal management market reached \$7.67 billion in 2023 and is projected to grow at a compound annual growth rate (CAGR) of 18.4% to reach approximately \$16.8 billion by 2028 ²¹⁹ . Data centre cooling market research shows while both cooling technologies are experiencing significant revenue growth, liquid cooling is rapidly gaining market share. Starting from just 8% of the cooling market in 2021, liquid cooling is projected to grow to 33% by 2028 ²²⁰ . Precedence Research ²²¹ , estimate the global data centre liquid cooling market at \$3.93 billion in 2024, projecting growth to \$22.57 billion by 2034. Global data centre liquid cooling market expected grow from \$4.18 billion in 2024 to \$5.17 billion in 2025 at a compound annual growth rate (CAGR) of 23.7% ²²² .
Market Drivers and Challenges	Drivers: AI workloads, high-density infrastructure, increasing electricity costs, and sustainability requirements. Challenges: Increased Cost, Reliability Concerns, Limited Choice of Equipment or Vendors, Maintenance Issues, Coolant Leaks, Supply Chain Difficulties
Key Market Players	Air cooled solutions: Daikin ²²³ , Mitsubishi Electric ²²⁴ , Panasonic ²²⁵ , Tripp Lite (Eaton) ²²⁶ , Vertiv ²²⁷

²¹⁹ [Omdia research predicts data Centre cooling market to reach \\$16.87 billion in 2028](#)

²²⁰ [Omdia research predicts data Centre cooling market to reach \\$16.87 billion in 2028](#)

²²¹ [Data Centre Liquid Cooling Market Size to Worth USD 22.57 Bn by 2034](#)

²²² [Data Centre Liquid Cooling Market Report 2025](#)

²²³ [Daikin Global | A leading air conditioning and refrigeration innovator and provider for residential, commercial and industrial applications](#)

²²⁴ [Mitsubishi Electric Trane Heating and Air Conditioning](#)

²²⁵ [Panasonic - sistemas de aquecimento e arrefecimento - Portugal](#)

²²⁶ [Eaton - Power and Connectivity Solutions](#)

²²⁷ [Data Centre Air Conditioning Systems | Vertiv Room Cooling](#)

	Liquid cooled solutions: SorCool ²²⁸ , ZutaCore ²²⁹ , CoolIT Systems ²³⁰ , LiquidStack ²³¹ , Submer ²³² .
Summary Findings	Rising AI workloads and environmental pressures are driving the data centre industry toward hybrid cooling solutions, combining air and liquid cooling to meet efficiency and sustainability goals. HYCOOL-IT's market analysis explored trends, drivers, challenges, and technologies across the cooling landscape , providing strategic insights for informed decision-making and risk reduction. HYCOOL-IT's rack-integrated adsorption chiller offers a compact, energy-efficient, and waste-heat-powered solution for localized server rooms, addressing critical market needs for sustainable, scalable cooling.

²²⁸ [Produkte - FAHRENHEIT](#)

²²⁹ [Direct-to-Chip Liquid Cooling Company | ZutaCore](#)

²³⁰ [CoolIT Systems | Liquid Cooling Technology](#)

²³¹ [Home - LiquidStack](#)

²³² [Immersion Cooling at Scale | SmartPod Platform | Submer | Immersion](#)

6.3 HYCOOL-IT Exploitation Space – 1 Pager Summary for Building Digital Twin (BDT)

Table 13 HYCOOL-IT Exploitation Space – 1 Pager Summary for Building Digital Twin (BDT)

Exploitation Space	Building Digital Twin (BDT)
Definition and Scope	This exploitation space targets the growing market for Digital Twin technologies in building and IT infrastructure management, with a focus on IT server rooms in tertiary buildings such as offices, schools, hospitals, and public institutions. As AI workloads drive higher power densities and more complex thermal profiles, data centres and server rooms require smarter, more adaptive management solutions that go beyond conventional monitoring tools.
HYCOOL-IT Innovation Fit	<p>Methodology for SIMBots creation</p> <p>Methodology for predicting and optimizing building performance using SiL</p> <p>SiL Predictive Control Module</p> <p>Simulation Model Tracking System (SMTS) Module</p> <p>Generic SIMBot libraries for IT rooms</p> <p>Specific SIMBot of Rack-integrated adsorption chiller system libraries</p> <p>CEN TC442/WG9 new working item or CWA aggregating HYCOOL-IT's ICT tools and methods.</p>
Market Size and CAGR	<p>Global digital twin for buildings market will reach USD 20.2 billion by 2032, up from USD 1.6 billion in 2023, at a CAGR of 32.6% (Astute Analytica²³³)</p> <p>Global building twin market to grow from USD 2.1 billion in 2024 to USD 13.3 billion by 2029, at a CAGR of 44.7% (MarketsandMarkets²³⁴)</p> <p>Global building twin market will grow from USD 2.1 billion in 2024 to USD 13.8 billion by 2032, at a CAGR of 44.6%. Europe is the second-largest growing market, with a market share of approximately 28% in 2023 (Market Research Future (MRFR)²³⁵)</p> <p>Global market for Data Centre Digital Twin Operations & Maintenance (O&M) Systems was valued at USD 343 million in 2024 and is projected to reach USD 1,796 million by 2031, growing at a CAGR of 25.98% during the forecast period from 2026 to 2031. In 2024, Europe accounted for USD 80.67 million, representing approximately 23.49% of the global market share (QYResearch Group²³⁶)</p>
Market Drivers and Challenges	<p>Drivers: Energy Efficiency Demands and Sustainability Goals, Advancements in IoT and Smart Building Technologies, Operational Complexity of Hybrid Infrastructures, Growing Adoption in Facility Management, Supportive Government Initiatives and Regulations.</p> <p>Challenges: High Implementation Costs & Complex Integration, Data</p>

²³³ [Astute Analytica | Global Industry Analysis Report | Business Consulting and Research](#)

²³⁴ [Building Twin Market Size, Share, Industry Report, Revenue Trends and Growth Drivers](#)

²³⁵ [Global Building Twin Market Overview](#)

²³⁶ [About Us-QYResearch](#)

	Security & Privacy Concerns, Scalability Issues in Large Data Centres, Lack of Standardization & Interoperability, Limited Technical Expertise & Adoption Barriers
Key Market Players	EkkoSense ²³⁷ , New Generation SR ²³⁸ , Cadence ²³⁹ , Sunbird ²⁴⁰ , AKCP ²⁴¹
Summary Findings	<p>Hybrid IT Environments Are Growing Rapidly: AI, HPC, and real-time applications are accelerating the shift to hybrid infrastructures, combining legacy systems with modern, high-density IT setups. Operational Complexity Is Escalating: Traditional monitoring and management tools lack the precision, responsiveness, and integration needed to handle these complex environments. Digital Twins Are Emerging as a Strategic Enabler: There is a growing market demand for digital twin technologies that provide real-time visibility, simulation, and predictive control, particularly in smaller enterprise and edge data centres.</p>

²³⁷ [AI Data Centre Optimization Software - EkkoSense](#)

²³⁸ [NuveaPaaS | New Generation SR](#)

²³⁹ [Cadence | Computational Software for Intelligent System Design | Cadence](#)

²⁴⁰ [DCIM - Data Centre Infrastructure Management Software System, Cable Management, Infrastructure Design & Optimization Companies - Sunbird DCIM](#)

²⁴¹ [About AKCP: Your Partner in Monitoring Technology](#)

6.4 HYCOOL-IT Exploitation Space – 1 Pager Summary for Smart Building Management System (SBMS)

Table 14 HYCOOL-IT Exploitation Space – 1 Pager Summary for Smart Building Management System (SBMS)

Exploitation Space	Smart Building Management System (SBMS)
Definition and Scope	This exploitation space targets the Smart Building Management System (SBMS) market, including DCIM (Data Centre Infrastructure Management), DCM (Data Centre Management), and BMS (Building Management Systems) platforms.
HYCOOL-IT Innovation Fit	Doesn't cover specific HYCOOL-IT results but insights can be used for connecting the Building Digital Twin (BDT), Simulation Model Tracking System (SMTS), SiL Predictive Control Module, and the cooling hardware into a coordinated, smart building ecosystem, helping optimize energy use and control equipment in real time.
Market Size and CAGR	The DCIM software market is experiencing robust growth, with a global market size valued at approximately USD 2.02 billion in 2023 and is projected to reach USD 3.63 billion by 2029 ²⁴² . The broader DCIM market, including services, is even larger and growing at a slightly higher CAGR, reflecting the expanding role of infrastructure management in modern data centres.
Market Drivers and Challenges	Drivers: Technology advancements, increasing data volumes, demand for energy efficiency, regulatory compliance. Challenges: High Implementation Costs, Complex Integration, Data Security & Privacy Concerns.
Key Market Players	Schneider Electric ²⁴³ , Sunbird ²⁴⁴ , Nlyte ²⁴⁵ , Vertiv ²⁴⁶ , Hyperview ²⁴⁷
Summary Findings	Rising infrastructure complexity is driving demand for DCIM platforms that unify IT, facility, and cooling data for real-time, intelligent management of data centres and server rooms. HYCOOL-IT's digital twin and rack-integrated cooling system should be designed to seamlessly integrate with DCIM platforms via open APIs , enabling predictive control, energy optimisation, and automated workflows.

²⁴² [Data Centre Infrastructure Management Software Analysis](#)

²⁴³ [What Is Data Centre Management and How Has it Evolved?](#)

²⁴⁴ [DCIM - Data Centre Infrastructure Management Software System, Cable Management, Infrastructure Design & Optimization Companies - Sunbird DCIM](#)

²⁴⁵ [DCIM Software, Hybrid Cloud Infrastructure and BMS Data Centre | Nlyte](#)

²⁴⁶ [DCIM & IT Management](#)

²⁴⁷ [Cloud-based Data Centre Infrastructure Management \(DCIM\) Software](#)