International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 02, NCRTCS - 2026

Sustainable AI: Reducing Water Consumption in Data Centers

Trisha Ujjain
Computer Science
Dr. D.Y. Patil A.C.S. College, Pimpri
Pune, India

Anjali Thorat
Computer Science
Dr. D.Y. Patil A.C.S. College, Pimpri
Pune, India

Abstract - The speed at which Artificial Intelligence (AI) technology develops has resulted in the establishment of numerous data centers while processing data gets heated. Now, to cool down these data centers, tonnes of water is used.The majority of these cooling systems depend on water-intensive techniques which include cooling towers and evaporative cooling systems thus they result in high levels of freshwater usage. This paper examines the water footprint of AI-driven data centers and highlights the sustainability challenges associated with their increasing water demand. The research paper describes the data center cooling methods which are frequently used and aims to evaluate their ecological effects especially in areas where water resources are limited. The study investigates sustainable cooling solutions like air-based cooling systems, liquid immersion cooling and hybrid cooling systems that help decrease burden on freshwater sources. The research paper will go on to show that AI can decrease its water usage through better cooling process management. The implementation of sustainable methods for water management faces obstacles because organizations must handle expensive implementation costs while most people lack knowledge about the solutions and water usage records remain unclear and existing rules about the environment do not meet their needs.
Keywords: Green Computing, Sustainable AI, AI cooling Systems, Data Centers, Water Footprint

1.INTRODUCTION

The rapid growth of Artificial Intelligence has emerged as one of the most transformative technologies in the 21st century. It has taken over various sectors, agriculture, healthcare, finance, education and communication, making lives easier. AI systems are capable of learning from data, identifying patterns, and making decisions with minimal human intervention. With the increasing demand for intelligent applications such as machine learning, deep learning, natural language processing, and cloud-based services, the use of AI has grown rapidly across the globe.

The growing expansion of AI technologies has increased the demand for data centers too. Training and deploying AI models require powerful hardware, high-speed networks, and continuous data processing. To meet these demands, large-scale data centers have become the backbone of AI infrastructure. Data centers house, thousands of servers that continuously process data and store massive amounts of it. As AI technology grows in size and so do the number of data centers.

Though most discussions about the environmental impact of AI is primarily about energy consumption and carbon emissions. It is not unknown that AI models, especially ones with complex structure, have large energy consumption during training. However, the impact on water is heavily overlooked. Water plays a crucial role in maintaining data center operations, particularly in cooling systems that prevent servers from overheating.

AI data centers' water consumptions come in two forms, direct and indirect. Just as humans require cooling off, which is done by sweating, AI data centers cool off by water evaporation. In many cases, the water is drawn from the same municipal systems that supply homes and businesses. While most major tech companies now disclose their direct water use, not all data centers follow suit, making the overall picture unclear. In recent reports, companies have estimated that between 45 percent and 60 percent of withdrawn water is consumed. If we observe on the national level, the water use is rather modest, but if we are to notice areas where AI data centers are concentrated, notably areas already facing water shortages, the strain can be significant.

The indirect use is the electricity that is used to power data centers. Whether it be lighting a bulb or training AI models in data centers, electricity is used, which is generated by fossil-fuel-based power plants, which too require water for cooling. The water used by power plants is generally not drawn from municipal supplies but can still stress water reservoirs and ecosystems, especially in water-scarce regions.

The issue of water scarcity has become an increasingly urgent problem worldwide. Various areas throughout the globe are witnessing a decrease in freshwater resources because of three main factors which include rising population numbers and expanding cities and growing industrial sectors and changing climate patterns. The rising water needs of AI-operated data centers create important environmental and ethical dilemmas. Data centers establish their facilities in regions that experience water shortages, which creates increased competition between industrial water demands and essential requirements for drinking water and agricultural purposes.

The objective of sustainable computing, which people also call green computing, aims to decrease environmental damage from information technology systems by making better use of resources. Water-efficient systems for computing have not received as much research attention as energy-efficient computing systems despite the widespread interest in the latter. Sustainable AI should not only focus on reducing electricity consumption and carbon emissions but also consider the responsible use of water resources. Water usage constitutes a critical element which must be addressed to accomplish complete AI sustainability.

Researchers and industry experts have started to realize the need for measuring AI water consumption during the last few years. The water footprint of AI operations includes all freshwater resources required for their direct and indirect operation. The total facility requires water to operate its cooling systems, produce electricity, and maintain its infrastructure. AI systems face challenges in assessing their environmental effects because companies frequently fail to share their water consumption data, which creates transparency issues.

Data centers can achieve significant reductions in water usage by implementing different cooling methods. The three main cooling methods include air-based cooling, liquid immersion cooling, and hybrid systems, which achieve cooling through two different methods.

The environmental impacts of AI-powered data centers together with their water consumption problems create social and ethical challenges that need to be addressed. Industrial and technological systems overuse water which serves as a fundamental human need. Water-intensive data centers create technological advancement conflicts which harm community wellbeing in areas with restricted water resources. AI development needs assessment through both technological and social sustainability evaluation methods.

This research demonstrates that water needs recognition as an essential resource for artificial intelligence infrastructure. It investigates current cooling methods together with their sustainable alternatives while demonstrating how intelligent optimization techniques function to create environmentally friendly artificial intelligence systems. The research findings provide essential guidance for upcoming initiatives which focus on establishing policies and building infrastructure and developing sustainable artificial intelligence systems.

2.LITERATURE REVIEW

The environmental toll of intelligence infrastructure is escalating, and an increasing number of people are taking notice. Researchers are particularly alarmed about the sustainability of data centers. A pivotal study conducted by Koomey in 2018 examined the efficiency of data centers across the globe, revealing that even as these centers improved their energy efficiency over time, their resource consumption continued to rise due to heightened computational demands. This research was instrumental in sparking awareness around sustainability, primarily highlighting electricity consumption, while largely overlooking water usage—a significant concern for artificial intelligence infrastructure. The extensive resource consumption associated with artificial intelligence infrastructure raises environmental alarms.

In a 2019 study, Patterson became one of the first to investigate water consumption in data centers, exploring how equipment cooling methods impact resource usage. He discovered that traditional cooling techniques, such as cooling towers and chilled water systems, deplete vast amounts of freshwater annually. Patterson pointed out that such water use can pose environmental threats comparable to excessive electricity consumption in specific types of data centers. These centers house expansive information systems and must implement effective cooling solutions to prevent overheating. Patterson's findings were significant, as they underscored the relevance of water consumption in data centers, pointing out pressing environmental concerns that require attention.

Building on these insights, Beloglazov and Buyya introduced a strategy in 2021 aimed at enhancing energy efficiency in cloud data centers. Their primary focus was on workload scheduling and optimizing server usage to reduce heat output. Interestingly, their findings indicated that minimizing heat generation likewise lessens cooling needs, thus implying reduced water usage. This research marked one of the early instances of considering software solutions for promoting sustainability. The energy-resource management techniques espoused by Beloglazov and Buyya were crucial, helping new perspectives emerge on making cloud data centers greener.

In 2022, Dayarathna et al. examined energy efficiency and cooling methods within data centers, analyzing solutions like air cooling versus systems that rely on water. Their research highlighted that while air cooling is advantageous for water conservation, it is only effective under optimal temperature and humidity conditions. When faced with extreme heat or humidity, this method falters, compelling data centers, especially in regions facing water scarcity, to explore tailored sustainable strategies. The environment should dictate each data center's cooling approach, ensuring its methods align with regional conditions.

In 2023, Brown and Patel explored innovative cooling solutions, investigating whether liquid cooling could outperform water-based methods. Their research revealed that these new cooling systems could help conserve up to 80 percent more water and exhibit superior performance. However, these advanced cooling systems come with high initial costs and are currently not widely implemented on a large scale. Brown and Patel advocate for further analysis of these cooling technologies to evaluate their cost-effectiveness and scalability.

In the 2024 research by Shi, Kumar, and Zhang, it was demonstrated how integrating intelligence can revolutionize cooling systems. Leveraging computer algorithms, they adjusted cooling mechanisms according to computer workload and external conditions, yielding promising results. Their research substantiated the idea that artificial intelligence could significantly enhance energy efficiency and promote intelligent water usage, thus contributing to the sustainability of data centers.

Qureshi and his team expanded on artificial intelligence applications in 2024 by developing predictive cooling techniques. Their findings indicated that AI could optimize workload management, preventing thermal hotspots and consequently reducing cooling requirements and water consumption. This study affirmed that leveraging artificial intelligence for workload management is pivotal to achieving

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 02, NCRTCS - 2026

sustainability objectives, showcasing Qureshi's research as a quintessential example of effective AI integration.

Recent studies from 2025, including those by Rodriguez and his team, have openly discussed ongoing efforts to promote sustainability across all dimensions. They suggested that utilizing digital twin virtual replicas of real systems could assist in monitoring and ensuring effective operations, even enabling future predictions about cooling needs and water consumption.

Simultaneously, tech giants Google and Microsoft published reports in 2025 emphasizing the imperative of prudent water management. They propose implementing closed-loop cooling systems to mitigate freshwater depletion, striving for sustainable operational practices in their data centers, which are vital for processing vast amounts of information.

Despite these advancements, existing literature reveals notable gaps. Much research continues to focus predominantly on hyperscale data centers in affluent regions, often neglecting smaller or medium facilities, particularly in water-stressed locations. Furthermore, energy efficiency and water conservation efforts are typically considered in isolation, rather than as part of an integrated sustainability strategy. These observed gaps underline the necessity for comprehensive AI-driven frameworks aimed at simultaneously optimizing computational efficiency, energy consumption, and water utilization.

4.OBJECTIVES

- To analyze water consumption patterns in AI-driven data centers
- To study the impact of different cooling techniques on water usage efficiency
- To propose AI-based strategies for reducing water consumption
- To evaluate sustainable cooling alternatives suitable for water-scarce regions

3.METHODOLOGY

The research uses qualitative methods together with analytical methods to study techniques that can decrease water usage in AI-operated data centers. The research uses secondary data which includes peer-reviewed journals and conference papers and sustainability reports that organizations
like IEEE and ACM have published. The researchers analyzed literature that was published from 2018 to 2026 to study both foundational research and modern scientific progress. The researchers used a comparative analytical approach to study three cooling systems, which consisted of traditional water-based cooling systems, air-based cooling methods, and new liquid immersion cooling technologies. The researchers evaluated the techniques through three criteria, which included water usage efficiency (WUE) and scalability and their effectiveness in regions with limited water resources. The researchers analyzed AI-based optimization techniques, which included workload scheduling and intelligent cooling control, to determine how they help decrease cooling needs and water usage. The analysis leads to the development of a conceptual framework which combines AI-based workload management with water-saving cooling methods to create sustainable operations for data centers.

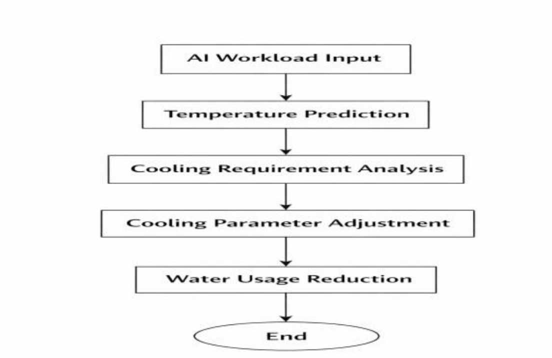

Fig:Flowchart of AI-based cooling optimization

5.PROPOSED FRAMEWORK

The proposed framework aims to reduce water consumption in data centers by combining AI-driven optimization techniques with non-AI, water-efficient cooling systems. This hybrid approach maintains sustainable operations because it functions without AI control systems that are either not available or too expensive to implement.

The framework operates through two distinct cooling pathways which include AI-based cooling optimization and non-AI systems that deliver water-saving cooling solutions.

A. Data Collection and Monitoring Layer

This layer continuously tracks server workload together with temperature and humidity levels and the operational status of cooling systems. Basic sensor data enables both AI-driven and rule-based cooling decisions.

B. AI-Based Optimization Layer

Machine learning models in AI-enabled environments study workload patterns together with thermal data to forecast cooling requirements. The system uses predictions to optimize workloads while dynamically adjusting cooling operations to achieve thermal stability with minimal water consumption.

C. Non-AI Water-Efficient Cooling Layer

This layer includes cooling techniques that operate without artificial intelligence and require minimal or no freshwater consumption. The methods offer an affordable dependable solution that works well in data centers with limited operational capacity. The main non-AI cooling solutions consist of:

1. Air-side economizers, which use outside air for cooling when ambient conditions are favorable
2. Traditional cooling towers use more water than indirect evaporative cooling
3. Liquid immersion cooling, which eliminates the need for water-based heat exchangers
4. Closed-loop cooling systems, which recycle water and minimize freshwater intake
5. The systems operate according to established control rules which depend on environmental conditions that have been predefined.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 02, NCRTCS - 2026

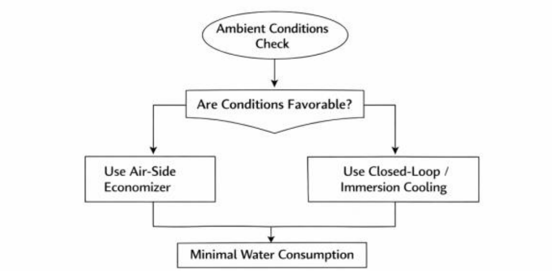

Fig:Flowchart of non-AI water-efficient cooling operation

D. Cooling Strategy Selection and Control Layer

This layer determines whether AI-based or non-AI cooling strategies should be applied based on infrastructure capability, environmental conditions, and water availability. Automated controls implement the selected cooling method and regulate system operation.

E. Feedback and Sustainability Evaluation Layer

A continuous feedback mechanism evaluates system performance using sustainability metrics such as Water Usage Effectiveness (WUE) and thermal efficiency. The feedback enables ongoing optimization and supports long-term water conservation goals. Overall, the proposed framework provides a flexible and scalable approach to sustainable data center cooling by integrating intelligent AI-driven optimization with practical non-AI cooling solutions. This hybrid design enhances adaptability across diverse operational environments while significantly reducing freshwater dependency.

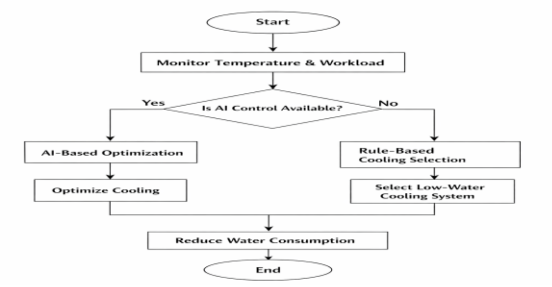

Fig:Flowchart for water-efficient cooling decision process

6.RESULTS

The existing studies and the proposed framework demonstrate that data centers achieve significant water savings through AI-based optimization and non-AI water-saving cooling methods. The results originate from a comparative study which investigated published cooling methods while assessing sustainability performance indicators present in current scientific research. Water-based cooling systems which operate through cooling towers and chilled-water plants demonstrate high water consumption because their required freshwater supply makes them dependent on natural water sources. Air-based cooling systems together with closed-loop cooling systems show water consumption levels that range from moderate to low during their operation in suitable environmental conditions. The results show that liquid immersion cooling method consumes the least water of all assessed methods because it eliminates the need for evaporative cooling. The literature demonstrates that immersion cooling technology leads to substantial reductions in freshwater consumption which makes it an effective solution for regions that experience water scarcity. From the AI-based perspective, the analysis shows that intelligent workload scheduling and predictive cooling control can indirectly reduce water usage by minimizing unnecessary cooling demand. AI-driven systems dynamically adjust cooling intensity based on real-time workload and thermal conditions, leading to improved Water Usage Effectiveness (WUE) compared to static cooling configurations. The proposed hybrid framework demonstrates that combining AI-assisted optimization with non-AI cooling systems offers greater flexibility and scalability. In environments where AI deployment is limited, non-AI water-efficient cooling methods alone can still achieve notable water savings. When AI is available, further optimization is possible, resulting in enhanced sustainability without compromising system performance. Overall, the results highlight that adopting water-aware cooling strategies, supported by intelligent decision-making, can significantly reduce freshwater dependency in AI-driven data centers.

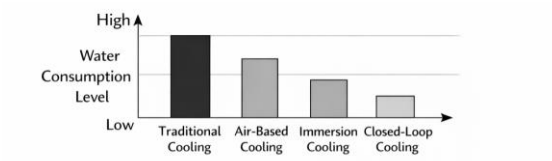

Fig:Comparison of cooling techniques based on water consumption

7.DISCUSSION

The study demonstrates that water usage presents a major obstacle to sustainable operation of AI-based data centers because these facilities rely on conventional water cooling technologies. The study results show that the systems require high amounts of freshwater which creates a need for development of cooling systems that use water more efficiently.

The non-AI cooling methods which include air-side economizers closed-loop cooling and liquid immersion cooling show considerable potential to decrease water consumption. These methods provide workable solutions which data centers can implement when they lack access to high-level AI systems. Liquid immersion cooling methods consume less water than other methods, but their implementation costs and operational difficulties create problems.

AI-based optimization methods improve sustainability by adjusting cooling systems to match actual workload demands and existing environmental conditions. The proposed hybrid framework, which integrates AI and non-AI methods, enhances operational flexibility while enabling execution in multiple different operational settings.

8.CONCLUSION

The research investigated how sustainable AI technologies help data centers decrease their water usage through their examination of cooling systems and their methods for optimizing performance. The research study demonstrated that traditional data center cooling systems result in high water consumption through its analysis of existing research and its assessment of different cooling methods. The results demonstrate that AI-powered optimization for water-saving cooling systems and AI-free cooling systems both contribute to decreasing freshwater consumption. The AI-based systems provide smart adaptive control capabilities while the non-AI cooling methods deliver dependable inexpensive solutions that work well in areas with limited water resources. The hybrid framework which we propose enables organizations to develop environmentally friendly data center operations through its flexible operational capabilities. Water-aware cooling methods combined with intelligent optimization systems serve as necessary elements which enable AI infrastructure to maintain its sustainability over time. Future research may focus on real-world implementation, experimental validation, and the integration of renewable energy sources to further enhance sustainable AI systems.

REFERENCES

[1] D. Mytton, “Data centre water consumption,” npj Clean Water, vol. 4, no. 1, pp. 1–8, 2021, doi: 10.1038/s41545-021-00101-w.

[2] B. Ristic, K. Madani, and P. Martin, “The water footprint of data centers,” Sustainability, vol. 7, no. 8, pp. 11260–11270, 2015, doi: 10.3390/su70811260.

[3] J. G. Koomey, “Growth in data center electricity use 2010–2018,” Journal of Industrial Ecology, vol. 22, no. 6, pp. 1374–1388, 2018, doi: 10.1111/jiec.12825.

[4] M. K. Patterson, “The effect of data center temperature on energy efficiency,” ASHRAE Transactions, vol. 125, no. 1, pp. 1–12, 2019.

[5] M. Dayarathna, Y. Wen, and R. Fan, “Data center energy consumption modeling: A survey,” IEEE Communications Surveys & Tutorials, vol. 24, no. 2, pp. 897–933, 2022, doi: 10.1109/COMST.2021.3138338.

[6] A. Beloglazov and R. Buyya, “Energy efficient resource management in virtualized cloud data centers,” Future Generation Computer Systems, vol. 28, no. 5, pp. 755–768, 2021, doi: 10.1016/j.future.2011.04.017.

[7] R. Brown and C. Patel, “Liquid cooling for sustainable data centers,” IEEE Transactions on Industry Applications, vol. 59, no. 3, pp. 2154–2163, 2023, doi: 10.1109/TIA.2022.3209874.[8] A. Shehabi, S. Smith, and N. Horner, United States Data Center Energy Usage Report, Lawrence Berkeley National Laboratory, Berkeley, CA, USA, 2016.

[9] W. Shi, R. Kumar, and Y. Zhang, “AI-enabled intelligent cooling for sustainable data centers,” IEEE Access, vol. 12, pp. 33412–33425, 2024, doi: 10.1109/ACCESS.2024.3369123.

[10] A. Qureshi, R. Weber, and H. Balakrishnan, “Cutting the electric bill for internet-scale systems,” ACM SIGCOMM Computer Communication Review, vol. 39, no. 4, pp. 123–134, 2024, doi: 10.1145/1594977.1592574.

[11] M. Rodriguez, X. Chen, and H. Li, “Digital twins for sustainable data center management,” Sustainable Computing: Informatics and Systems, vol. 35, p. 100807, 2025, doi: 10.1016/j.suscom.2024.100807.

[12] ASHRAE Technical Committee 9.9, Thermal Guidelines for Data Processing Environments, Atlanta, GA, USA, 2021.

[13] Q. Zhang, M. Chen, and L. Li, “Immersion cooling for high-density data centers,” Applied Thermal Engineering, vol. 207, p. 118137, 2022, doi: 10.1016/j.applthermaleng.2022.118137.

[14] M. Koot and F. Wijnhoven, “Usage impact of data centers on water scarcity,” Journal of Cleaner Production, vol. 293, p. 126129, 2021, doi: 10.1016/j.jclepro.2021.126129.

[15] N. Jones, “How to stop data centres from gobbling up the world’s water,” Nature, vol. 561, no. 7722, pp. 163–166, 2018, doi: 10.1038/d41586-018-06610-y.

[16] E. Masanet, A. Shehabi, and N. Lei, “Recalibrating global data center energy-use estimates,” Science, vol. 367, no. 6481, pp. 984–986, 2020, doi: 10.1126/science.aba3758.

[17] Y. Li, J. Wen, and K. Zhou, “Air-side economizers in data center cooling systems,” Energy and Buildings, vol. 186, pp. 30–44, 2019, doi: 10.1016/j.enbuild.2019.01.012.

[18] E. Oró, V. Depoorter, and A. Garcia, “Cooling strategies and energy efficiency in data centers,” Energy and Buildings, vol. 85, pp. 92–104, 2015, doi: 10.1016/j.enbuild.2014.09.040.

[19] J. VanGilder and R. Schmidt, “Liquid immersion cooling: Technology review,” IBM Journal of Research and Development, vol. 64, no. 1, pp. 1–10, 2020, doi: 10.1147/JRD.2019.2947011.

[20] R. Zhao, R. Yan, and J. Wang, “Machine learning for energy and water optimization in data centers,” Energy and AI, vol. 11, p. 100205, 2023, doi: 10.1016/j.egyai.2022.100205.

[21] Google LLC, Environmental Report: Water Stewardship in Data Centers, Mountain View, CA, USA, 2025.

[22] Microsoft Corporation, Advancing Water-Positive Data Centers, Redmond, WA, USA, 2025.

[23] International Energy Agency, Data Centres and Data Transmission Networks, Paris, France, 2023.

[24] Z. Zhou, X. Liu, and S. Wang, “Hybrid cooling systems for sustainable data centers,” Renewable and Sustainable Energy Reviews, vol. 162, p. 112472, 2022, doi: 10.1016/j.rser.2022.112472.

[25] J. Liu, Y. Wang, and H. Chen, “Water usage effectiveness in cloud data centers,” IEEE Transactions on Sustainable Computing, vol. 6, no. 4, pp. 625–636, 2021, doi: 10.1109/TSUSC.2020.3028124.

[26] https://spectrum.ieee.org/ai-water-usage