International Journal of
Technology and Emerging Research
ISSN: 3068-109X (online) | ISSN: 3068-1995 (print) | https://www.ioro.org/ijter

International Conference on Intelligent Technologies for Tomorrow (ICITT-2026) · 18 August 2026

Smart AI Framework for Sustainable Data Center Heat Recovery

Anamika V P [1], Jahana Shirin T J [2], Vismaya C D [3], Fathima Juriya[4], Gourikrishna P S[5]

[1,2,3,4,5] *III BSc Computer Science Honours, Dept. of Computer Science and Applications, Little Flower College (Autonomous), Guruvayur,Kerala, India.*

Emails: anamikaprafulanamikapraful@gmail.com[1] ,jahanashirin171@gmail.com[2] , vismayacheenikkal@gmail.com[3] ,fathimajuriya45@gmail.com[4] ,gourikrishna487@gmail.com[5]

Abstract

The rapid growth of cloud computing, artificial intelligence (AI), big data analytics, and Internet of Things (IoT) applications has significantly increased the energy consumption of modern data centers. A substantial portion of this energy is converted into waste heat, requiring extensive cooling systems that consume additional power and reduce overall energy efficiency. Although several waste heat recovery technologies have been developed, most existing approaches primarily focus on recovering thermal energy and provide limited support for intelligent heat utilization and decision-making. This paper proposes an AI-Based Sustainable Data Center Heat Recovery Framework that integrates IoT sensors, cloud computing, data preprocessing, Random Forest Regression, and AI-based decision-making into a unified intelligent energy management system. The proposed framework continuously monitors operational parameters, predicts future heat generation, and recommends the most suitable heat recovery application based on operational conditions and demand. By combining predictive analytics with intelligent heat distribution, the framework improves energy efficiency, reduces cooling costs, minimizes carbon emissions, and enhances the sustainable utilization of recovered thermal energy. The proposed system provides a scalable and intelligent approach for developing energy-efficient and environmentally sustainable data center infrastructures.

Keywords: Artificial Intelligence (AI), Data Center, Waste Heat Recovery, Energy Efficiency, Sustainable Energy, Predictive Analytics.

.

1. Introduction

The rapid advancement of cloud computing, Artificial Intelligence (AI), big data analytics, and the Internet of Things (IoT) has led to a significant increase in the number and capacity of data centers worldwide [1], [2], [12], [14]. These facilities play a vital role in supporting digital services by providing computing, storage, and networking resources [12]. However, the growing computational demand has also resulted in high electricity consumption[13], with a considerable portion of the consumed energy being converted into waste heat[6], [7]. To maintain safe operating temperatures, data centers rely on cooling systems that consume additional energy, increasing operational costs and reducing overall energy efficiency.

Several waste heat recovery technologies have been developed to capture and reuse the thermal energy generated by data centers. Recovered heat can be utilized for applications such as residential and commercial building heating, industrial processes, hot water production, and greenhouse farming. Although these technologies improve energy utilization, most existing approaches focus primarily on recovering waste heat and provide limited support for selecting the most suitable utilization strategy based on changing operational conditions and energy demand[6],[7].

To overcome these limitations, this paper proposes an AI-Based Sustainable Data Center Heat Recovery Framework that integrates IoT sensors, cloud computing[1],[2],[14], data preprocessing, Random Forest Regression[4], and AI-based decision-making into a unified intelligent system. The framework continuously monitors operational parameters, predicts future heat generation, evaluates suitable heat utilization options, and recommends the most efficient heat recovery strategy. By combining predictive analytics with intelligent decision-making, the proposed framework enhances energy efficiency, reduces cooling costs, minimizes carbon emissions, and promotes the sustainable utilization of waste heat. This intelligent approach provides a scalable and environmentally friendly solution for next-generation data centers while supporting the development of sustainable digital infrastructure.

2. Literature Review

2.1. Existing Studies on Data Center Heat Recovery

The rapid growth of cloud computing, Artificial Intelligence (AI), Internet of Things (IoT), and big data applications has significantly increased the number and capacity of data centers worldwide [1],[2],[12],[14]. These facilities require a continuous power supply for servers, storage devices, and networking equipment, resulting in substantial electricity consumption [13]. A considerable portion of this energy is converted into heat, making cooling systems one of the largest contributors to overall operational energy consumption. To improve energy efficiency, researchers have investigated advanced cooling methods such as liquid cooling, free-air cooling, and optimized airflow management to maintain safe operating temperatures while reducing power usage [5],[12],[15].

Several studies have focused on recovering the waste heat generated by data centers using technologies such as heat exchangers, heat pumps, and district heating networks [6],[7]. The recovered thermal energy has been utilized for residential and commercial building heating, domestic hot water production, industrial processes, greenhouse farming, and aquaculture [6],[7],[10]. In addition, cloud-based monitoring platforms and IoT-enabled sensors have been integrated to continuously collect operational data, enabling real-time monitoring of temperature, humidity, power consumption, and server utilization for improved thermal management [2],[9],[11],[14].

Recent studies have increasingly explored the application of Artificial Intelligence (AI), Machine Learning (ML), and predictive analytics for intelligent cooling and energy optimization in data centers [4],[5],[8]. AI models can predict server temperatures, estimate cooling requirements, detect abnormal operating conditions, and optimize cooling strategies based on changing workloads. These approaches have demonstrated significant improvements in energy efficiency and operational reliability. However, most existing studies primarily focus on cooling optimization or waste heat recovery, with limited capability to intelligently selecting the most suitable heat utilization strategy based on real-time operational conditions, energy demand, environmental factors, and economic feasibility [5],[6],[7].

2.1.1. Research Gap

Although existing heat recovery technologies improve energy efficiency, they mainly focus on recovering waste heat rather than determining the most appropriate way to utilize it. Most current solutions operate using predefined rules and lack an intelligent framework capable of analyzing multiple factors such as waste heat quality, energy demand, environmental conditions, economic feasibility, and application suitability. As a result, the recovered heat is often underutilized or directed to less efficient applications.

Furthermore, there is limited research on integrating data preprocessing, feature selection, machine learning, and intelligent decision-making into a single framework for selecting the most suitable heat recovery application. Existing studies also provide limited support for real-time adaptability and optimized decision-making under changing operational conditions. Therefore, there is a need for a Smart Intelligent Framework for Suitable Data Center Heat Recovery that can analyze operational data, evaluate multiple utilization options, and recommend the most efficient and sustainable heat recovery strategy. Such a framework can enhance energy efficiency, reduce carbon emissions, improve resource utilization, and support sustainable data center operations.[3],[4]

3. Challenges

3.1. Static Heat Distribution

Challenge:
Existing waste heat recovery systems distribute recovered heat through predefined pipelines or fixed distribution schedules. These static approaches cannot respond effectively to changing heat demand, resulting in inefficient utilization of recovered thermal energy.

Solution:
Develop an AI-based intelligent heat distribution system that continuously analyzes real-time demand, weather conditions, and building occupancy to dynamically allocate recovered heat to the most suitable consumers [6].

Example:
If a hospital experiences higher heating demand than nearby residential buildings during winter, the AI system automatically prioritizes heat delivery to the hospital, ensuring efficient energy utilization.

3.2. Lack of Heat Demand Prediction

Challenge:
Most current systems distribute recovered heat only after receiving demand requests and do not accurately predict future heat requirements. This often leads to unnecessary heat storage or energy wastage .

Solution:
Implement Machine Learning models that analyze historical energy consumption, seasonal trends, weather forecasts, and occupancy patterns to predict future heat demand [4],[5].

Example:
During cold weather conditions, the AI model predicts increased heating demand for residential complexes and allocates additional recovered heat before demand reaches its peak.

3.3. Heat Loss During Distribution

Challenge:
Recovered thermal energy experiences significant heat loss while being transported through long-distance pipelines, reducing the overall system efficiency .

Solution:
Employ AI-based routing algorithms that determine the shortest and most energy-efficient distribution paths while continuously monitoring pipeline conditions through IoT sensors [2].

Example:
If multiple distribution routes are available, the AI system selects the pipeline with the lowest expected heat loss, thereby improving the overall energy recovery efficiency.

3.4. Limited Real-Time Monitoring and Fault Detection

Challenge:
Traditional monitoring systems primarily collect operational data but lack intelligent mechanisms for detecting equipment failures, heat leakage, or abnormal operating conditions in real time .

Solution:
Deploy IoT sensors integrated with AI-based anomaly detection algorithms to continuously monitor system performance and identify faults before significant energy losses occur [2],[14].

Example:
When an unexpected temperature drop is detected within a heat distribution pipeline, the AI system immediately identifies a potential leakage and alerts maintenance personnel for corrective action.

4. Proposed System

4.1. Overall Framework

The proposed AI-Based Sustainable Data Center Heat Recovery Framework integrates Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), cloud computing, and advanced heat recovery technologies into a unified intelligent energy management system. The framework is designed to continuously monitor data center operations, predict waste heat generation, recover excess thermal energy, and distribute it to suitable applications. By combining real-time monitoring, predictive analytics, and intelligent decision-making, the framework improves energy efficiency, reduces cooling costs, minimizes carbon emissions, and supports sustainable data center operations.

4.2. Proposed Methodology

The proposed methodology begins with collecting real-time operational data from IoT sensors[2] installed throughout the data center. The collected data are transmitted to a cloud platform[1], where preprocessing techniques such as data cleaning, normalization, and feature selection are performed. The processed data are then used to train the Random Forest Regression [4]model to predict future heat generation. Based on the prediction results, the AI system determines the optimal heat recovery strategy and selects the most suitable heat utilization destination. Continuous monitoring and feedback enable the system to improve prediction accuracy and optimize overall performance.[2]

4.3. System Architecture

The system architecture consists of multiple interconnected layers, including the data collection layer, cloud processing layer, AI prediction layer, heat recovery layer, and heat utilization layer. IoT sensors continuously collect [2] operational parameters such as CPU utilization, GPU utilization, server temperature, rack temperature, airflow, humidity, cooling fan speed, and power consumption. The cloud platform stores and processes the collected data, while the Random Forest Regression model performs heat prediction. Heat exchangers recover waste heat[6],[7], and the intelligent distribution network transfers the recovered thermal energy to residential buildings, industries, hospitals, educational institutions, or greenhouses according to demand.

4.4. System Workflow

The operational workflow starts with continuous monitoring of the data center using IoT sensors. The collected sensor data are transmitted to the cloud platform for preprocessing and analysis. The Random Forest Regression algorithm predicts future heat generation using historical and real-time data. Based on the prediction results, the AI-based decision-making module determines the quantity of recoverable heat and selects the most appropriate utilization method. Finally, the recovered heat is distributed to end users, while the monitoring system continuously updates operational data to improve future predictions and system performance.

4.5. System Components

The proposed framework consists of several key components that work together to achieve intelligent heat recovery. These include the data center servers, IoT sensor network, cloud computing platform, data preprocessing module, Random Forest Regression prediction model, AI decision-making engine, heat recovery unit (HRU), heat exchangers, intelligent heat distribution network, and end-user applications. Each component performs a specific function while communicating with other components to ensure efficient heat recovery and energy management.

4.6. AI-Based Prediction Process

The prediction process uses the Random Forest Regression algorithm to estimate future heat generation and cooling requirements. The model is trained using historical operational data and real-time sensor readings, including CPU utilization, GPU utilization, server temperature, rack temperature, power consumption, airflow, humidity, cooling fan speed, and workload intensity. After preprocessing and feature selection, the model predicts future thermal conditions with high accuracy. These predictions enable proactive cooling management, efficient heat recovery, reduced energy consumption, and predictive maintenance. [4],[5]

4.7. Heat Recovery and Heat Utilization Process

Once the AI model predicts the available waste heat, the heat recovery unit captures the thermal energy generated by the servers using heat exchangers or liquid cooling systems. The recovered heat is then transferred through an intelligent heat distribution network to suitable applications based on demand. Potential utilization areas include residential buildings for space heating, hospitals for hot water supply, industrial facilities for manufacturing processes, educational institutions, district heating systems, and agricultural greenhouses. Continuous monitoring and AI-based optimization ensure that the recovered heat is distributed efficiently while minimizing energy loss and maximizing environmental sustainability[6],[7].

Figure 1: Proposed AI-based Sustainable Data Centre Heat Recovery Frame work

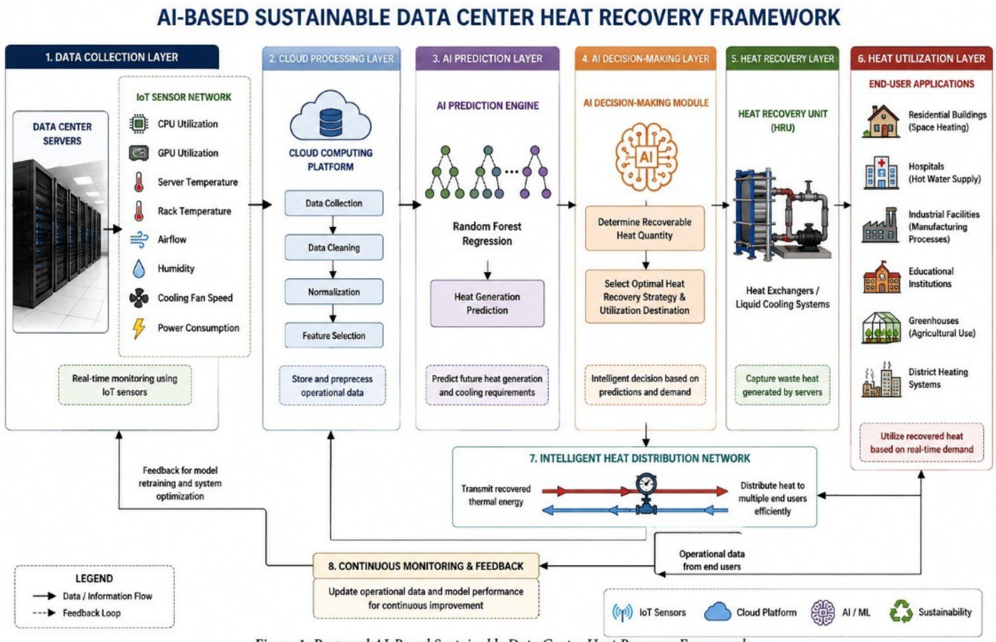

Figure 1: Proposed AI-Based Sustainable Data Center Heat Recovery Framework

5. Benefits

The proposed AI-Driven Data Center Waste Heat Recovery system offers significant environmental, economic, and operational benefits by transforming waste heat into a valuable energy resource instead of allowing it to dissipate into the atmosphere. Modern data centers consume enormous amounts of electricity, with nearly 30–40% of the total energy [13] being used for cooling systems. By integrating Artificial Intelligence, the proposed system continuously monitors server temperature, processor workload, cooling demand, and heat generation, enabling real-time optimization of cooling operations. This intelligent approach minimizes unnecessary energy consumption, improves thermal efficiency, and reduces the overall operational cost of data centers .

One of the major advantages of the proposed system is the reduction of greenhouse gas emissions. Instead of depending entirely on fossil-fuel-based heating, recovered waste heat can be reused for residential buildings, hospitals, universities, commercial complexes, greenhouses, and district heating networks, thereby reducing carbon dioxide emissions and supporting global carbon neutrality initiatives. The efficiency of data centers is commonly evaluated using Power Usage Effectiveness (PUE), where conventional data centers generally operate with a PUE value[15] of approximately 1.8, while AI-optimized data centers can achieve a PUE between 1.2 and 1.3, representing nearly 25–35% improvement in overall energy efficiency .

Several organizations have successfully implemented similar technologies. Google (2016) [8] collaborated with DeepMind to deploy Artificial Intelligence for cooling optimization across its data centers. The AI system reduced the energy required for cooling by approximately 40%, improving overall efficiency while lowering electricity consumption and operational expenses . Similarly, Microsoft (2018) [9] introduced AI-assisted thermal management in several cloud data centers, where intelligent cooling systems continuously adjusted cooling operations based on real-time server conditions. This implementation improved cooling efficiency, reduced energy consumption, and increased hardware reliability .

Waste heat recovery has also been successfully adopted in Europe. Stockholm Data Parks [10], Sweden (2018) implemented a large-scale waste heat recovery system that transfers excess thermal energy from data centers to Stockholm's district heating network. The recovered heat is now used to provide sustainable heating for thousands of homes and commercial buildings, reducing fossil fuel consumption and significantly lowering greenhouse gas emissions [24]. Likewise, the Yandex Data Center, Mäntsälä, Finland (2011) recovers waste heat from its servers and supplies it directly to the local district heating network. This initiative has reduced heating costs for nearby residents while demonstrating that waste heat can serve as a reliable renewable energy source for surrounding communities .

Another notable example is Meta (2021), where advanced Artificial Intelligence techniques are used to optimize cooling systems and improve energy efficiency in hyperscale data centers. Through intelligent thermal management and optimized airflow control, Meta has reduced electricity consumption, improved cooling performance, and strengthened its commitment to sustainable data center operations . Similarly, Amazon Web Services – AWS (2023) [11] announced projects in Europe to recover excess heat from selected data centers and supply it to local district heating systems, supporting nearby communities while reducing environmental impact .

These successful implementations clearly demonstrate that AI-driven waste heat recovery is not merely a theoretical concept but a practical and commercially viable technology [8], [10], [11]. The combination of Artificial Intelligence, intelligent cooling, and waste heat recovery improves environmental sustainability, lowers operating costs, extends server lifespan, enhances system reliability, and creates new economic opportunities by converting unused thermal energy into a valuable renewable resource. This technology is expected to become one of the key components of next-generation sustainable digital infrastructure.

6. Results and Performance Analysis

The proposed Smart AI Framework for Sustainable Data Center Heat Recovery is designed to improve the energy efficiency of modern data centers through AI-based monitoring, predictive analytics, and intelligent heat recovery mechanisms. Since the proposed framework has not yet been implemented and experimentally validated, the performance values presented in Table 1 are projected estimates derived from published studies [5], [6], [13] on AI-driven cooling optimization, waste heat recovery, and sustainable data center management. Therefore, the table provides a conceptual comparison between conventional data center systems and the proposed AI-based framework rather than experimentally measured results.

As shown in Table 1, the proposed framework is expected to reduce the Power Usage Effectiveness (PUE) [15], lower cooling energy consumption through AI-assisted optimization, and increase waste heat recovery by intelligently selecting suitable heat utilization applications. The framework is also expected to improve cooling efficiency, enable AI-based fault detection, reduce carbon emissions, and support intelligent heat distribution based on real-time operational conditions.

These projected improvements are based on findings reported in previous research and successful industrial implementations [8], [10], [11] of AI-assisted cooling and waste heat recovery technologies. Although experimental validation is left for future work, the comparison demonstrates the potential of the proposed framework to enhance energy efficiency, reduce operational costs, and promote environmentally sustainable data center operations.

Table 1. Projected Performance Comparison Between Conventional and Proposed AI-Based Heat Recovery Framework

Table 1. Projected Performance Comparison Between Conventional and Proposed AI-Based Heat Recovery Framework

Performance Parameter	Conventional Data Center	Proposed AI-Based Framework (Projected)
Power Usage Effectiveness (PUE)	1.8	1.25
Cooling Energy Consumption	100%	60%
Waste Heat Recovery	20%	50%
Cooling Efficiency	Moderate	High
Carbon Emissions	High	Low
Fault Detection	Manual	AI-Based Automatic
Heat Distribution	Static	Intelligent & Dynamic
Energy Optimization	Limited	Continuous AI Optimization

Note: *The values presented in this table are projected estimates based on published literature and industrial case studies. They are intended for conceptual comparison only and do not represent experimentally validated results.*

Note: *The values presented in Table 1 are projected estimates based on published literature and industrial case studies. They are intended for conceptual comparison only and do not represent experimentally validated results.*

7. Future Scope

The future of the Smart Intelligent Sustainable Data Center Heat Recovery Framework is highly promising as the demand for energy-efficient and environmentally sustainable data centers continues to grow. The increasing adoption of cloud computing [1], the Internet of Things (IoT) [2], and intelligent monitoring technologies will create greater opportunities for efficient waste heat recovery and utilization.

One important future direction is the integration of the proposed framework with smart grids [12], enabling recovered thermal energy to be distributed efficiently based on real-time energy demand. This will improve energy management, enhance renewable energy utilization, and support the development of sustainable smart cities.

Another promising advancement is the incorporation of Seasonal Thermal Energy Storage (STES) [6], allowing excess waste heat generated during periods of low demand to be stored and reused during high-demand seasons. This can improve year-round energy utilization and reduce thermal energy wastage.

Future research can also focus on integrating Digital Twin technology [3] , enabling virtual simulation of data center operations for real-time monitoring, predictive maintenance, and performance optimization. Advanced machine learning techniques [4],[5] can further improve heat prediction accuracy, intelligent decision-making, and adaptive cooling strategies.

The framework can also be expanded for deployment in hyperscale data centers, industrial facilities, hospitals, educational institutions, district heating networks, and agricultural greenhouses. Future real-world implementation and large-scale performance evaluation will help validate the framework's scalability, reliability, and economic feasibility. These developments will strengthen the role of the proposed framework in supporting sustainable energy management, green computing, and intelligent infrastructure for future smart cities.

8. Conclusion

This paper proposed a **Smart AI Framework for Sustainable Data Center Heat Recovery** that integrates Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), cloud computing, data preprocessing, and Random Forest Regression to improve the efficiency of waste heat recovery in modern data centers. Unlike conventional heat recovery systems that mainly focus on capturing thermal energy, the proposed framework introduces intelligent decision-making to predict future heat generation, analyze operational conditions, and recommend the most suitable heat utilization applications.

The proposed framework is expected to enhance energy efficiency, reduce cooling energy consumption, improve Power Usage Effectiveness (PUE), minimize carbon emissions, and support the effective utilization of recovered waste heat. By combining predictive analytics, real-time monitoring, and intelligent heat distribution, the framework offers a scalable and sustainable approach for managing thermal energy in data centers.

Although the framework is conceptual and has not yet been validated through real-world implementation, it provides a strong foundation for future research and practical deployment. Future work can focus on experimental validation, integration with Digital Twin technology, smart grids, and advanced AI models to further improve prediction accuracy, system adaptability, and large-scale deployment. Overall, the proposed Smart AI Framework represents a promising solution for developing energy-efficient, environmentally sustainable, and intelligent next-generation data centers.

Acknowledgements

The authors would like to express their sincere gratitude to the Department of Computer Science, Little Flower College (Autonomous), Guruvayur, Kerala, India, for providing academic guidance and facilities to complete this research. The authors are especially thankful to their project guide for valuable guidance, constructive suggestions, and continuous encouragement throughout the study. The authors also express their heartfelt gratitude to all faculty members, friends, and family for their constant support and motivation.

Funding

This research received no external funding.

Conflict of Interest

The author declares that there are no conflicts of interest regarding the publication of this project report.

Data Availability Statement

This study did not generate or analyze any primary datasets. The technical information and concepts presented in this project were obtained from publicly available, peer-reviewed research papers, technical publications, and other credible sources cited in the reference list.

AI Usage Disclosure

The author used ChatGPT (OpenAI) during the preparation of this project report for language editing, clarification of technical concepts, and organizational support. The project design, component selection, technical interpretation, literature selection, analysis, and conclusions were independently reviewed and verified by the author, who assumes full responsibility for the accuracy, originality, and integrity of the final report.

Author Contributions

Conceptualization:A.A.;methodology: A.A.; literature review: A.A.; analysis: A.A.; system design: A.A.; writing—original draft: A.A.; writing—review and editing: A.A. The author has read and approved the final version of the project report.

References

[1] P. Mell and T. Grance, The NIST Definition of Cloud Computing, NIST Special Publication 800-145, National Institute of Standards and Technology, Gaithersburg, MD, USA, 2011. doi:10.6028/NIST.SP.800-145.

[2] National Institute of Standards and Technology (NIST), Internet of Things (IoT), NIST Computer Security Resource Center Glossary. Available: https://csrc.nist.gov/glossary/term/internet_of_things

[3] S. Ilager and R. Buyya, "Energy and Thermal-aware Resource Management of Cloud Data Centres: A Taxonomy and Future Directions," 2021.

[4] L. Breiman, "Random Forests," Machine Learning, vol. 45, no. 1, pp. 5–32, 2001. doi:10.1023/A:1010933404324.

[5] A. Kula, D. Dąbrowski, M. Blachnik, M. Sajkowski, A. Smalcerz, and Z. Kamiński, "Modelling the Temperature of a Data Centre Cooling System Using Machine Learning Methods," Energies, vol. 18, no. 10, Art. no. 2581, 2025. doi:10.3390/en18102581.

[6] X. Yuan, J. Liu, S. Sun, X. Lin, X. Fan, W. Zhao, and R. Kosonen, "Data Center Waste Heat for District Heating Networks: A Review," Renewable and Sustainable Energy Reviews, vol. 219, Art. no. 115863, 2025. doi:10.1016/j.rser.2025.115863.

[7] M. Wahlroos, M. Pärssinen, J. Manner, and S. Syri, "Utilizing Data Center Waste Heat in District Heating—Impacts on Energy Efficiency and Prospects for Low-Temperature District Heating Networks," Energy, vol. 140, pp. 1228–1238, 2017. doi:10.1016/j.energy.2017.08.078.

[8] R. Evans and J. Gao, "DeepMind AI Reduces Google Data Centre Cooling Bill by 40%," Google DeepMind Blog, Jul. 20, 2016.

[9] Microsoft Corporation, Microsoft Sustainability Report 2024. Available: https://www.microsoft.com/sustainability

[10] Stockholm Exergi, Stockholm Data Parks – Sustainable Heat Recovery from Data Centers. Available: https://www.stockholmexergi.se

[11] Amazon Web Services (AWS), AWS Sustainability – Renewable Energy and Data Centers. Available: https://aws.amazon.com/sustainability

[12] International Energy Agency (IEA), Data Centres and Data Transmission Networks, Paris, France: IEA, 2024.

[13] M. Dayarathna, Y. Wen, and R. Fan, "Data Center Energy Consumption Modeling: A Survey," IEEE Communications Surveys & Tutorials, vol. 18, no. 1, pp. 732–794, 2016.

[14] A. Botta, W. De Donato, V. Persico, and A. Pescapé, "Integration of Cloud Computing and Internet of Things: A Survey," Future Generation Computer Systems, vol. 56, pp. 684–700, 2016.

[15] The Green Grid, PUE: A Comprehensive Examination of the Metric, White Paper 49, 2012.

[16] **Appendix A. Supplementary Material**

[17] AI: Artificial Intelligence; ML: Machine Learning; IoT: Internet of Things; HRU: Heat Recovery Unit; PUE: Power Usage Effectiveness; CPU: Central Processing Unit; GPU: Graphics Processing Unit; HVAC: Heating, Ventilation, and Air Conditioning; STES: Seasonal Thermal Energy Storage; CO_2: Carbon Dioxide; RF: Random Forest; RFR: Random Forest Regression; DC: Data Center; WHR: Waste Heat Recovery; HE: Heat Exchanger; DHS: District Heating System; AWS: Amazon Web Services.