Jurnal Arsitektur Zonasi 9(1) (2026) 143-152

Jurnal Arsitektur Zonasi

Journal homepage: https://ejournal.upi.edu/index.php/jaz

Comparison of Energy Load Between Chiller Water System and Dx System in High-Rise Hotel Buildings

Muhammad Fadly Saleh[1], Nurul Inayah[2]*

[1]Universitas Teknologi Sulawesi, Kota Makassar, Indonesia
[2]Institut Seni Indonesia Surakarta, Kota Surakarta, Indonesia

*Correspondence: Email: mfadly.uts@gmail.com

ABSTRACT

The building sector is the largest energy consumer in Indonesia. Approximately 50% of total energy is consumed by buildings. Most of the energy consumption in buildings is used to provide thermal comfort. The taller and larger the building, the more difficult it is to meet its thermal comfort needs solely through natural ventilation. Air conditioning (AC) becomes a necessity to acomodate these thermal needs in buildings. This study aims to compare the energy load of two central air conditioning systems commonly used in high-rise buildings: the chiller water system and the Direct Expansion (DX) system with ducting. The DX system does not use pumps in its process. Thus, in the DX system, the energy load is reduced when using pumps. However, it is not known for certain whether the DX system is more energy-efficient overall than the chiller water system. That is why this research was conducted. The research method used was quantitative, with an experimental approach using the eQUEST computer simulation. The research object focused on one floor of a high-rise hotel in Makassar City. The research focused on the 10th floor, where most rooms served as guest rooms. The results show that the chiller water system consumes 338,020 kWh/year of energy, while the DX system consumes 366,400 kWh/year. This indicates that the chiller water system is preferred for high-rise hotels over the DX system, as it is 7.75% more energy-efficient.

ARTICLE INFO

Article History:
Submitted/Received 15 Nov 2025
First Revised 5 December 2025
Accepted 9 January 2026
First Available online 2 Feb 2026
Publication Date 2 February 2026

Keywords:
Energy Saving,
Chiller Water System,
DX System,
eQUEST

1. INTRODUCTION

In recent years, Cities around the world have experienced a steady increase in energy consumption. For example, due to population growth and increased industrial and commercial activity, Jakarta experienced 6% annual increase between 2017 and 2019 (Muzayanah et al., 2022). Jakarta consumed 28 TWh in 2017, equivalent to Bangladesh (Arifin et al., 2024). Meanwhile, Makassar consumed approximately 2.1 TWh annually from 2018 to 2022 (Wahyuni et al., 2024). Superficially, Makassar's energy consumption may not be comparable to Jakarta's, but this must also be considered due to its size and population density.

Population growth and economic development worldwide are accompanied by an increase in the number of buildings (Lachheb et al., 2024). The massive development is not only occurring in developed countries but also in developing countries. Development is also occurring not only in cities but also in villages. The increase in population, the complexity of community activities, and the rate of economic growth are the factors contributing to increasing construction needs. The increasing growth in the construction sector is also accompanied by an increasing need for energy. Energy is used in the construction sector not only during construction but also well before construction begins. Energy consumption in the construction sector begins with mining, production, and transportation. All of these processes require significant energy and produce significant emissions. The Global Alliance for Building and Construction indicates that by 2025, the construction sector will consume 32% of the world's total energy(UCL, BPIE, UNEP CCC, 2025) .

Besides a significant energy burden, the construction industry is also responsible for approximately 40% of global carbon emissions, contributing to environmental degradation primarily through high resource consumption and waste production (Firoozi et al., 2024). Numerous approaches have been developed to improve the energy performance of buildings, including passive design techniques, renewable energy sources, efficient building services, and promoting reasonable consumption. Consequently, in developed countries, the energy consumption indicators for buildings are gradually decreasing (González-Torres et al., 2022). In some countries around the world, the energy performance of buildings has been systematically improved towards zero energy (Merema et al., 2018).

The current energy and environmental crises are fueled by the human inability to manage energy effectively. The Indiscriminate use of energy without regard for its source, purpose, or quantity has driven global warming and triggered numerous climate problems today.

In Indonesia, buildings account for approximately 50% of total energy consumption (Suamir et al., 2021). It means that buildings, including hotels, are the largest energy consumers in Indonesia. However, currently, the majority of energy used is still derived from fossil fuels, which significantly contribute to the greenhouse effect and global warming (Rahman & Vu, 2021). Therefore, energy use in the construction sector in Indonesia requires a demanding focus.

Although it is known that high energy consumption contributes to global warming and other climate problems, energy consumption cannot be stopped. Due to the enormous demand for comfort, especially indoor comfort, energy use is essential. Visual, audio, and thermal comfort are three essential aspects of building comfort. Unfortunately, the larger and more complex a building, the more difficult it is to achieve these comforts without the aid of energy-consuming equipment or systems. Thermal comfort, in particular, is a concern due to its impact on the building's significant energy load (Jing et al., 2019).

In high-rise buildings and wide-span buildings, it is very difficult to achieve comfortable ventilation with natural ventilation alone. However, thermal comfort is crucial for maintaining

DOI: http://doi.org/10.17509/jaz.v9i1.95696
p- ISSN 2621-1610 e- ISSN 2620-9934

indoor environmental conditions (Lamberti et al., 2021). Uncomfortable thermal conditions can negatively impact human well-being and daily activities (Kim & Jong, 2020). Therefore, air conditioning (AC) systems have become mandatory in buildings to control indoor air quality (Zhao et al., 2023). However, air conditioning use accounts for a large share of building energy consumption, with much of it used solely to maintain indoor thermal comfort (Ni et al., 2023; Zahir et al., 2023).

The high energy load for air conditioning systems is caused by increased internal heat gain from occupants, IT equipment, and lighting, as well as the increasing use of glass facades and longer operating hours (Ahmed et al., 2024; Latif et al., 2022). Not only do internal factors contribute significantly to the air conditioning system, but external factors do as well. For example, (Ahsani et al., 2016) stated that heat transfer from outside into a building through the building envelope, namely walls and roofs, creates a sensible heat load within the building and causes an increase in temperature. Especially in tropical regions such as Indonesia and Makassar, sunlight can be very hot. Furthermore, the widespread use of transparent openings in buildings increases the amount of heat entering the building from sunlight. This heat ultimately becomes a burden on the building's air conditioning (AC) system.

Air conditioning (AC) is a device that regulates room temperature according to comfort needs (Ahyadi & Aghna, 2024). The use of AC as an air conditioning system has long been known and used, and these systems require an electrical supply to operate (Chen et al., 2019). In building utility systems, energy use in heating, ventilation, and air conditioning (HVAC) systems has increased significantly (Deng et al., 2020), while in HVAC, the chiller water coil is a key component (Zhu et al., 2022).

Air conditioning (AC) systems are the largest energy-consuming utility systems in hotels; therefore, energy-saving efforts in AC use are essential to minimize energy consumption in hotel buildings (Suamir et al., 2021). Selecting the type of air conditioning system is a particular challenge for high-rise hotel buildings, as it affects energy consumption.

In Indonesia, high-rise buildings commonly use the chiller water system as their primary air conditioning system. This system is excellent for use in high-rise buildings because it is a centralized air conditioning system distributed through ducting to all rooms whose temperatures are to be controlled. However, the chiller water system is not the only centralized air conditioning system; there is also the Direct Expansion (DX) system that uses ducting.

There are two types of DX systems: unit-based and central-based. Central DX systems use ducting, similar to chiller water systems, to distribute cool air throughout the building. This DX system will be the subject of research and discussed in this article

Chiller Water System

The Chiller Water System is an air conditioning system that uses chilled water to cool the air inside a room. The Chiller Water System has several main components: a chiller, an air handling unit (AHU), a cooling tower, a pump and piping system, a ducting system, and a control and electrical system (Marjianto & Mangindaan, 2020).

The chiller is a cooling device that cools water in its evaporator. The resulting cooled water is then distributed to a heat exchanger, the AHU (Auto-Hydraulic Humidity Unit). The chilled water is distributed from the chiller to the AHU through a piping system and pumped through it.

AHU is a heat exchanger. Hot air from the room is blown through a cooling coil (containing cold water from the chiller) inside the AHU, cooling the air. The cool air is then channelled to the room whose temperature is to be cooled. The cool air from the AHU is distributed through

DOI: http://doi.org/10.17509/jaz.v9i1.95696
p- ISSN 2621-1610 e- ISSN 2620-9934

ducting. A ventilation fan draws the cool air from the AHU and distributes it to the room whose temperature is to be regulated.

DX System with Ducting

The DX system does not use a pump like a chiller water system, as it does not use water. In a chiller water system, cooled water is pumped to the AHU, where it cools the air inside. In a DX system, the air is cooled in the AHU using a cooling coil (Lee, 2025). The air is cooled using a refrigerant (usually Freon) that circulates within the cooling coil.

The ventilation fan draws hot air from the room and directs it into the AHU. In the AHU, the cooling process occurs through a cooling coil. The heat from the hot air is released during this process, leaving only cool air behind. The ventilation fan then distributes the cool air back to the room whose temperature needs to be regulated through ducting.

The DX system is a simple, flexible, energy-efficient air conditioning system widely used (Lin et al., 2021). This air conditioning system is also widely used in Indonesia, including in Makassar. The effectiveness of the DX system has prompted numerous studies to develop it for optimal indoor temperature control (Xu et al., 2018).

A central air conditioning system is one in which the cooling process is centralised in one location and then distributed to all rooms (one outdoor unit with several indoor units) (Saleh et al., 2022). Chiller water systems and DX systems that use ducting are both central air conditioning systems whose energy loads will be studied and compared to determine the best type of air conditioning system for high-rise hotel buildings.

The absence of a pump in the DX system minimizes energy consumption. However, the overall energy load of the DX system can be lower than that of a chilled water system, which is the objective of this research and article.

2. RESEARCH METHODS

2.1 Research Design and Type

The research was conducted to compare the energy load or energy consumption of two types of air conditioning systems commonly used in tall or wide-span buildings: the chiller water system and the DX system

The research was conducted in a high-rise building in Makassar that serves as a hotel. The research was conducted on only one floor of the hotel, the floor where most of the rooms are located. The research took place on the 10th floor of the hotel, where there are no other high-rise buildings nearby. Therefore, the building's exterior walls and windows receive direct sunlight without obstruction.

The research is a quantitative study using experimental methods. The experiment used Building Energy Simulation (BES). The energy simulation software or program used in this study is eQUEST (Quick Energy Simulation Tool).

Building Energy Simulation (BES), such as eQUEST, plays a crucial role in simulating a building's thermal conditions and HVAC systems (Joe et al., 2020). These tools can be used to design energy-efficient technologies and new building designs (Feng et al., 2019). Energy load predictions in residential (Wang et al., 2019) and commercial (Seyedzadeh et al., 2019) buildings can also be performed using these tools.

The eQUEST simulation program is a tool designed to assist in planning energy systems for buildings. The eQUEST program requires physical building data, material types, HVAC systems, and climate data for the building's location to obtain accurate simulation results. All of this data is necessary because the effect of thermal mass on energy consumption varies with climate and design characteristics, such as insulation and window properties (Taki &

DOI: http://doi.org/10.17509/jaz.v9i1.95696
p- ISSN 2621-1610 e- ISSN 2620-9934

Zakharanka, 2023). Replacing windows, lighting fixtures, and office equipment can affect the energy load on air conditioning systems, but the impact can vary depending on the local climate (Ye et al., 2021).

eQUEST is designed to enable users to perform detailed analyses of current building design technologies using state-of-the-art building energy simulation techniques, without requiring extensive experience in building performance modelling. It is an energy modelling software that leverages the DOE-2 simulation tool from the U.S. Department of Energy (Lamichhane et al., 2024).

eQUEST is one of the most popular energy simulation programs, alongside EnergyPlus and TRACE. Compared to other simulation programs, eQUEST is user-friendly, free, and good for LEED compliance modelling. Therefore, eQUEST is well-suited for this research.

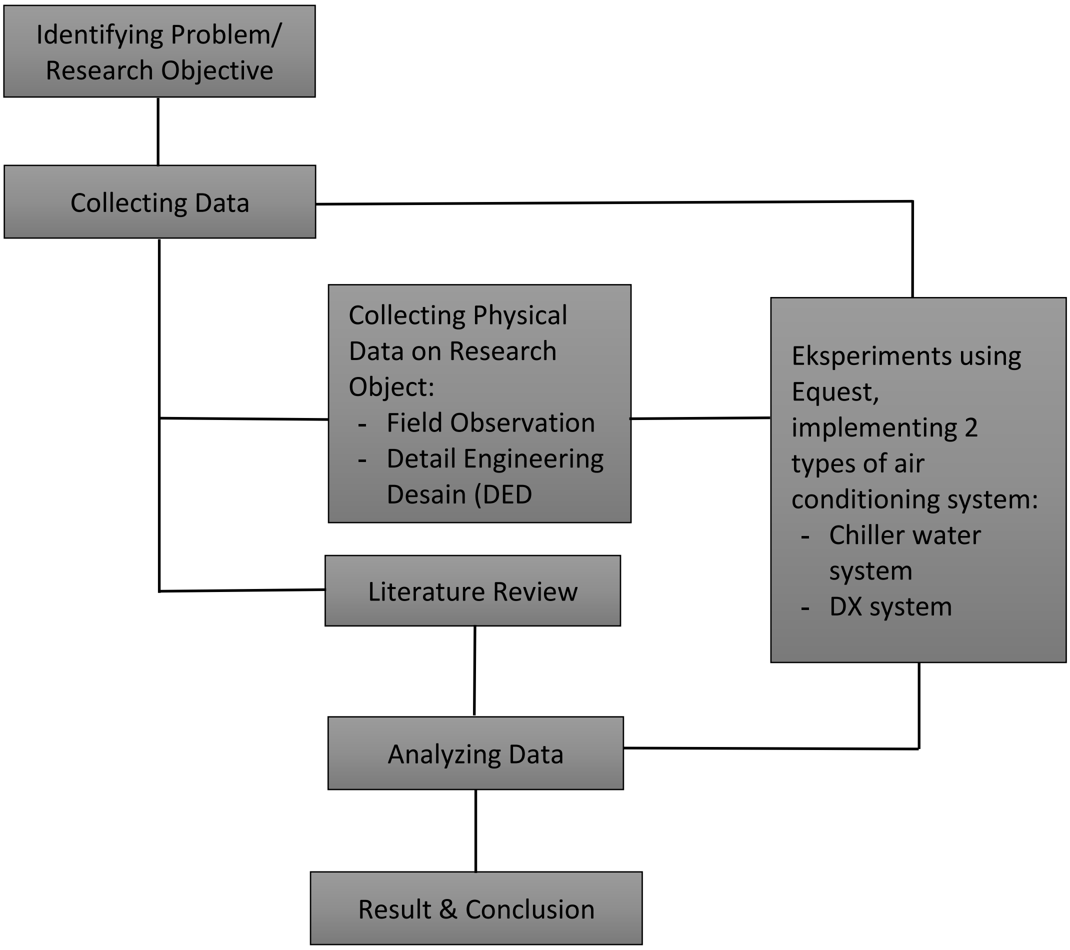

Figure 1. Research Flow
(Source: Author, 2025)

2.2 Data Collection Method

The study aims to compare the energy loads of two types of air conditioning systems. Therefore, by the eQuest computer simulation program, both air conditioning systems will be applied alternately to the building.

The hotel's building, as the research object, will be fully drawn in eQuest, including its shape, materials used, building orientation, window position and size, and other details, all consistent with the building's design, without any changes. After the building data has been entered, local climate data will also be entered into eQUEST. The two air conditioning systems

DOI: http://doi.org/10.17509/jaz.v9i1.95696
p- ISSN 2621-1610 e- ISSN 2620-9934

will then be applied alternately to the building. Energy load simulations will be run after the air conditioning systems are installed.

By operating the eQuest computer simulation, the energy loads of each air conditioning system, namely the chiller water system and the DX system, are obtained. The DX system referred to in this study uses ducting, making it suitable for use as an air conditioning system in high rise buildings

2.3 Data Analysis

Once the energy load of each air conditioning system is known, the energy loads of the two systems can be compared. By comparing the two air conditioning systems, we can determine which air conditioning system has a lower energy load on the building. We can also determine the energy load of each activity in each air conditioning system, thereby understanding why this type of system has a lower energy load.

After comparing the two types of air conditioning systems studied, we can find out which air conditioning system is better to use to minimize energy use in high-rise hotel buildings

3. RESULTS AND DISCUSSION

3.1 Results

The Chiller Water System involves three energy-consuming activities: the cooling process, the ventilation fan, and the pump. The cooling process occurs in the chiller, then the pump distributes the chilled water to the AHU (Air Handling Unit). The ventilation fan (blower) inside the AHU then circulates air across the cold coil surface, transferring heat from the air to the cold water in the coil.

Unlike the chiller water system, there are only two energy-consuming activities in the DX system: the cooling process and the ventilation fan. There is no pump used in the DX system. However, the evidence that energy consumption in the DX system air conditioning is lower than in the chiller water system air conditioning cannot be confirmed.

Table 1. The Results of Energy Consumption Measurement on Chiller Water System

Activity	Electric Consumption (mWh/ year)
Space Cool	259.03
Ventilation Fans	44.78
Pumps & Aux.	34.21

Source: Author, 2025

Energy simulations of the research object using a chiller water system indicate an annual energy consumption of 338.02 mWh/year. Where the cooling activity consumes energy 259.03 kWh/year, ventilation fans consume 44.78 mWh/year, while pumps & auxiliary consume 34.21 kWh/year.

DOI: http://doi.org/10.17509/jaz.v9i1.95696
p- ISSN 2621-1610 e- ISSN 2620-9934

Table 2. The Results of Energy Consumption Measurement on *DX system*

Activity	Electric Consumption (mWh/ year)
Space Cool	266.87
Ventilation Fans	99.53
Pumps & Aux.	0

Source: Author, 2025

The second energy simulation of the research object using the DX air conditioning system showed a high energy consumption of 366.40 mWh/year. The cooling activity consumed 266.87 mWh/year, the ventilation fan 99.53 mWh/year, and the pumps & auxiliary 0 mWh/year.

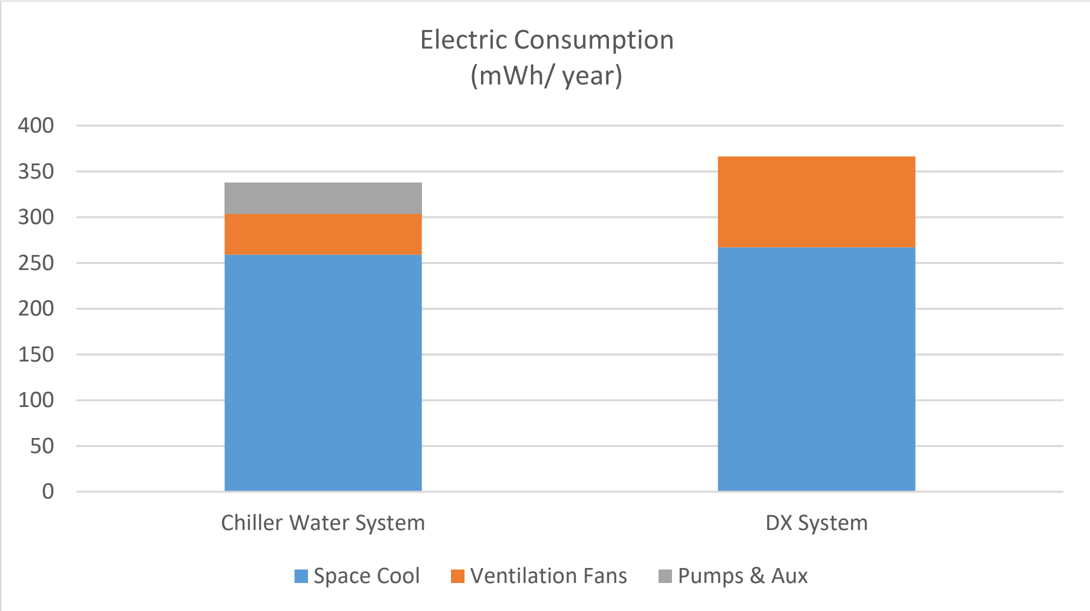

Figure 2. Comparison of Energy Consumption in the Water Chiller System and the DX System (Source: Author, 2025)

The diagram above illustrates the energy consumption of the research object for each type of air conditioning system, the chiller water system, and the DX system. The DX system shows higher energy consumption than the chiller water system. The DX system's energy consumption is 366.40 mWh/year, while the chiller water system is only 338.02 mWh/year. There is a difference in consumption between the two types of air conditioning systems, with the chiller water system consuming 28.38 mWh/year less than the DX system. This shows that the chiller water system is more energy efficient than the DX system, saving 7.75% more energy.

3.2 Discussion

The data show that the DX system has no water pump load, assuming its energy load would be lower than the chiller water system. However, the overall energy load on the DX system was 7.75% higher than the chiller water system.

The initial assumption that the DX system is more energy efficient compared to the chiller water system refers to research (Seo et al., 2020), which suggests that the DX system is often superior to the chiller water system in medium- or low-rise buildings. However, the object of this study is a high-rise hotel building; the presence of a water pump does not increase the energy consumption of the chiller water system compared to the DX system; on the contrary, it reduces it. The energy load of the ventilation fan in the DX system exceeds the cooling water

DOI: http://doi.org/10.17509/jaz.v9i1.95696
p- ISSN 2621-1610 e- ISSN 2620-9934

system's energy consumption, resulting in a difference. In the cooling process, although the difference is not significant, the cooling energy load in the DX air conditioning system is higher compared to the chiller water system. The overall energy load in the DX system air conditioning system is 7.75% greater than that in the chiller water system air conditioning system, as shown in the results.

4. CONCLUSION

The chiller-water air conditioning system is preferred over a duct-based DX system for high-rise hotels. Although both are centralized air conditioning systems, the DX system consumes more energy than the chiller water system.

In high-rise buildings such as hotels, the difference in pump usage between the chiller water system and the DX system appears quite significant. The DX system, which was predicted to be more energy efficient because it is pump-less, is unproven. The chiller water system, despite using a pump, actually saves 7.75% more energy than the DX system. Therefore, a chiller water system is preferred in high-rise hotel buildings over a DX system that uses ducting.

This study only compared two types of air conditioning systems. However, there are more than two types of air conditioning systems. Therefore, further research is needed on the energy loads of each type of air conditioning system.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to all parties, especially to the hotel management, which agreed to help us obtain the research dat

REFERENCES

Ahmed, K., Yoon, G., Ukai, M., & Kurnitski, J. (2024). VAV fan coil and demand controlled active chilled beam systems energy efficiency and thermal comfort performance comparison in a Japanese office building. *E3S Web of Conferences*, *562*, 1–12. https://doi.org/10.1051/e3sconf/202456206004

Ahsani, M. S., Mufida, H. N., Aji, M. P., & Sulhadi, S. (2016). *Mengurangi Dampak Panas Matahari Pada Dinding Kaca Dengan "Water Flow." V*, SNF2016-ERE-91-SNF2016-ERE-94. https://doi.org/10.21009/0305020618

Ahyadi, H., & Aghna, T. (2024). PERANCANGAN SISTEM TATA UDARA RUANG ISOLASI RUMAH SAKIT X YOGYAKARTA. In *PRESISI* (Vol. 26, Issue 1).

Arifin, Z., Fachruroji, & Huda, M. (2024). Increasing performance of chiller systems in high-rise buildings by load optimization. *International Journal of Applied Power Engineering*, *13*(1), 113–122. https://doi.org/10.11591/ijape.v13.i1.pp113-122

Chen, X., Zhang, N., Su, Y., Aydin, D., Zheng, H., Bai, H., Georgakis, A., Jarimi, H., & Riffat, S. (2019). Performance analysis and design implementation of a novel polymer hollow fiber liquid desiccant dehumidifier with aqueous potassium formate. *Thermal Science and Engineering Progress*, *13*, 100366. https://doi.org/10.1016/J.TSEP.2019.100366

Deng, J., He, S., Wei, Q., Liang, M., Hao, Z., & Zhang, H. (2020). Research on systematic optimization methods for chilled water systems in a high-rise office building. *Energy and Buildings*, *209*, 109695. https://doi.org/10.1016/J.ENBUILD.2019.109695

Feng, K., Lu, W., & Wang, Y. (2019). Assessing environmental performance in early building design stage: An integrated parametric design and machine learning method. *Sustainable Cities and Society*, *50*, 101596. https://doi.org/10.1016/J.SCS.2019.101596

Firoozi, A. A., Firoozi, A. A., Oyejobi, D. O., Avudaiappan, S., & Flores, E. S. (2024). Emerging trends in sustainable building materials: Technological innovations, enhanced performance, and future directions. *Results in Engineering*, *24*, 103521. https://doi.org/10.1016/J.RINENG.2024.103521

González-Torres, M., Pérez-Lombard, L., Coronel, J. F., Maestre, I. R., & Yan, D. (2022). A review on buildings energy information: Trends, end-uses, fuels and drivers. *Energy Reports*, *8*, 626–637. https://doi.org/10.1016/J.EGYR.2021.11.280

Jing, S., Lei, Y., Wang, H., Song, C., & Yan, X. (2019). Thermal comfort and energy-saving potential in university classrooms during the heating season. *Energy and Buildings*, *202*, 109390. https://doi.org/10.1016/J.ENBUILD.2019.109390

Joe, J., Im, P., & Dong, J. (2020). Empirical modeling of direct expansion (Dx) cooling system for multiple research use cases. *Sustainability (Switzerland)*, *12*(20), 1–17. https://doi.org/10.3390/su12208738

Kim, H. U., & Jong, S. Il. (2020). Development of a system for evaluating the flow field around a massive stadium: Combining a microclimate model and a CFD model. *Building and Environment*, *172*, 106736. https://doi.org/10.1016/J.BUILDENV.2020.106736

Lachheb, M., Younsi, Z., Youssef, N., & Bouadila, S. (2024). Enhancing building energy efficiency and thermal performance with PCM-Integrated brick walls: A comprehensive review. *Building and Environment*, *256*, 111476. https://doi.org/10.1016/J.BUILDENV.2024.111476

Lamberti, G., Salvadori, G., Leccese, F., Fantozzi, F., & Bluyssen, P. M. (2021). Advancement on thermal comfort in educational buildings: Current issues and way forward. *Sustainability (Switzerland)*, *13*(18). https://doi.org/10.3390/su131810315

Lamichhane, S., Mostafa, R., Gopalakrishnan, B., & Devaru, D. G. (2024). eQUEST Based Building Energy Modeling Analysis for Energy Efficiency of Buildings. *Energy Engineering*, *121*(10), 2743–2767. https://doi.org/10.32604/EE.2024.051035

Latif, H., Hultmark, G., Rahnama, S., Maccarini, A., & Afshari, A. (2022). Performance evaluation of active chilled beam systems for office buildings – A literature review. *Sustainable Energy Technologies and Assessments*, *52*, 101999. https://doi.org/10.1016/J.SETA.2022.101999

Lee, A. (2025, August 29). *Direct Expansion (DX) Type of Central Air Conditioning*. Https://Www.Mytcwgroup.Com/Post/Direct-Expansion-Dx-Type-of-Central-Air-Conditioning.

Lin, Y. H., Lin, M. Der, Tsai, K. T., Deng, M. J., & Ishii, H. (2021). Multi-objective optimization design of green building envelopes and air conditioning systems for energy conservation and CO2 emission reduction. *Sustainable Cities and Society*, *64*, 102555. https://doi.org/10.1016/J.SCS.2020.102555

Marjianto, A., & Mangindaan, D. (2020). *Perancangan Sistem Tata Udara Ditinjau dari Aspek Energi dan Biaya pada Bangunan Hotel di Semarang*.

Merema, B., Delwati, M., Sourbron, M., & Breesch, H. (2018). Demand controlled ventilation (DCV) in school and office buildings: Lessons learnt from case studies. *Energy and Buildings*, *172*, 349–360. https://doi.org/10.1016/J.ENBUILD.2018.04.065

Muzayanah, I. F. U., Lean, H. H., Hartono, D., Indraswari, K. D., & Partama, R. (2022). Population density and energy consumption: A study in Indonesian provinces. *Heliyon*, *8*(9). https://doi.org/10.1016/j.heliyon.2022.e10634

Ni, S., Zhu, N., Hou, Y., & Zhang, Z. (2023). Research on indoor thermal comfort and energy consumption of zero energy wooden structure buildings in severe cold zone. *Journal of Building Engineering*, *67*, 105965. https://doi.org/10.1016/J.JOBE.2023.105965

Rahman, M. M., & Vu, X. B. (2021). Are energy consumption, population density and exports causing environmental damage in china? Autoregressive distributed lag and vector error correction model approaches. *Sustainability (Switzerland)*, *13*(7). https://doi.org/10.3390/su13073749

Saleh, M. F., Helen, Y., & Anita, F. (2022). 826-Article Text-2935-1-10-20221010 (1). *TECNOSCIENZA*, *7*, 176–190. https://doi.org/https://doi.org/10.51158/tecnoscienza.v7i1.826

Seo, B., Yoon, Y. B., Yu, B. H., Cho, S., & Lee, K. H. (2020). Comparative analysis of cooling energy performance between water-cooled VRF and conventional AHU systems in a commercial building. *Applied Thermal Engineering*, *170*, 114992. https://doi.org/10.1016/J.APPLTHERMALENG.2020.114992

Seyedzadeh, S., Pour Rahimian, F., Rastogi, P., & Glesk, I. (2019). Tuning machine learning models for prediction of building energy loads. *Sustainable Cities and Society*, *47*, 101484. https://doi.org/10.1016/J.SCS.2019.101484

Suamir, I. N., Temaja, I. W., Putu, I., & Indra, E. (2021). *Journal of Applied Mechanical Engineering and Green Technology Analisis perbandingan berbagai sistem AC komersial pada aplikasi gedung hotel*. *2*, 128–134.

Taki, A., & Zakharanka, A. (2023). The Impact of Degradation on a Building's Energy Performance in Hot-Humid Climates. *Sustainability (Switzerland)* , *15*(2). https://doi.org/10.3390/su15021145

UCL, BPIE, UNEP CCC, I. (2025). *United Nations Environment Programme*. Https://Globalabc.Org/. https://globalabc.org/index.php/resources/publications/global-status-report-buildings-and-construction-20242025-not-just-another

Wahyuni, M. S., Zaki, A., Hidayat, S., & Pratama, M. I. (2024). Penerapan Metode ARIMA dalam Meramalkan Kebutuhan Energi Listrik di Kota Makassar. *Journal of Mathematics, Computations and Statistics*, *7*(2), 323–331. https://doi.org/10.35580/jmathcos.v7i2.4388

Wang, R., Lu, S., & Li, Q. (2019). Multi-criteria comprehensive study on predictive algorithm of hourly heating energy consumption for residential buildings. *Sustainable Cities and Society*, *49*, 101623. https://doi.org/10.1016/J.SCS.2019.101623

Xu, X., Zhong, Z., Deng, S., & Zhang, X. (2018). A review on temperature and humidity control methods focusing on air-conditioning equipment and control algorithms applied in small-to-medium-sized buildings. *Energy and Buildings*, *162*, 163–176. https://doi.org/10.1016/J.ENBUILD.2017.12.038

Ye, Y., Hinkelman, K., Lou, Y., Zuo, W., Wang, G., & Zhang, J. (2021). Evaluating the energy impact potential of energy efficiency measures for retrofit applications: A case study with U.S. medium office buildings. *Building Simulation*, *14*(5), 1377–1393. https://doi.org/10.1007/s12273-021-0765-z

Zahir, M. H., Irshad, K., Shafiullah, M., Ibrahim, N. I., Kausarul Islam, A. K. M., Mohaisen, K. O., & Sulaiman, F. A. A. (2023). Challenges of the application of PCMs to achieve zero energy buildings under hot weather conditions: A review. *Journal of Energy Storage*, *64*, 107156. https://doi.org/10.1016/J.EST.2023.107156

Zhao, X., Yin, Y., He, Z., & Deng, Z. (2023). State-of-the-art, challenges and new perspectives of thermal comfort demand law for on-demand intelligent control of heating, ventilation, and air conditioning systems. *Energy and Buildings*, *295*, 113325. https://doi.org/10.1016/J.ENBUILD.2023.113325

Zhu, Q., Zhuang, M., Liu, H., & Zhu, Y. (2022). Optimal Control of Chilled Water System Based on Improved Sparrow Search Algorithm. *Buildings*, *12*(3). https://doi.org/10.3390/buildings12030269

DOI: http://doi.org/10.17509/jaz.v9i1.95696
p- ISSN 2621-1610 e- ISSN 2620-9934