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Cooling Load Analysis of a New Building at PMI Bogor Hospital Using the CLTD Method

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Abstract

Purpose: This study aims to design the cooling load for the new building of the PMI Hospital in Bogor using the Cooling Load Temperature Difference (CLTD) method, focusing on optimizing cooling efficiency in line with temperature and humidity standards.
Research Methodology: The study utilizes the CLTD method to calculate the cooling load for the hospital's new building. It includes assessing the total cooling load, the required air supply, and selecting the VRV (Variable Refrigerant Volume) system for effective cooling. The building's data was used to calculate indoor and outdoor unit requirements.
Results: The cooling load calculation for floors 1 to 3 of the hospital resulted in a total load of 4,956,985.54 Btu/hr, with a required air supply of 100,690.73 CFM. The selected VRV system specifications for both indoor and outdoor units were aligned with the calculated cooling.
Conclusions: The study provides an effective cooling load calculation for the hospital, ensuring optimal air supply and appropriate VRV system selection. This approach guarantees the building meets its cooling requirements for the given environmental conditions.
Limitations: The study is based on available data and does not account for future changes or real-time environmental variations, which could influence the cooling load. Future research may integrate dynamic data for more accurate predictions.
Contributions: This work contributes a practical method for calculating cooling systems in large buildings, such as hospitals, utilizing the CLTD method and VRV system for optimal performance.

Keywords: *Air Supply, CLTD Method, Cooling Load, HVAC Design, VRV System*

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1. Introduction

HVAC (heating, ventilation, and air conditioning) systems function to regulate the temperature and humidity of the air in a room to ensure comfortable indoor environmental conditions. In modern buildings, especially large-scale facilities such as hospitals, offices, and commercial centers, HVAC systems play a crucial role not only in providing thermal comfort but also in maintaining indoor air quality and ensuring the health and safety of occupants (Cao et al., 2020). This is particularly important in tropical countries such as Indonesia, where high ambient temperatures and humidity levels significantly influence indoor thermal conditions (Bahramnia et al., 2019).

In tropical climates, buildings are continuously exposed to high solar radiation, resulting in substantial heat gain through walls, roofs, and windows (Che et al., 2019). In addition to external heat sources, internal heat gains from occupants, lighting systems, and electronic equipment further increase the cooling demand within the building. These combined factors create a cooling load that must be properly calculated to ensure that the HVAC system can maintain the desired indoor conditions effectively and efficiently (Shajahan et al., 2019).

Hospitals, as critical healthcare facilities, have more stringent environmental requirements compared to other types of buildings. The indoor environment in hospitals must be carefully controlled to support patient recovery, ensure the comfort of medical staff and visitors, and minimize the risk of infection. Proper temperature and humidity control are essential, as deviations from recommended conditions can affect patient health, increase the spread of microorganisms, and reduce the effectiveness of medical treatments. Therefore, HVAC systems in hospitals must be designed with high precision and reliability (Che et al., 2019; Saran et al., 2020).

Moreover, HVAC systems in hospital buildings are required to operate continuously, which makes them one of the largest contributors to energy consumption. Inefficient HVAC design can lead to excessive energy usage, increased operational costs, and environmental impacts. Consequently, accurate cooling load estimation is essential to achieve an optimal balance between thermal comfort, energy efficiency, and system performance. An undersized system may fail to meet cooling demands, while an oversized system may result in unnecessary energy consumption and poor humidity control (Cao et al., 2020).

One widely used method for estimating cooling load is the Cooling Load Temperature Difference (CLTD) method. This method takes into account various factors influencing heat gain, such as solar radiation, building orientation, construction materials, occupancy levels, lighting, and equipment usage. The CLTD method is particularly suitable for preliminary HVAC design and is commonly applied in building cooling load analysis due to its practicality and reliability (Enteria et al., 2020).

In addition to technical considerations, HVAC system design must also comply with applicable regulations and standards. In Indonesia, hospital environmental conditions are regulated by the Decree of the Minister of Health No. 1204/Menkes/SK/X/2004, which specifies that indoor temperature should be maintained at approximately 23°C with a relative humidity of around 50%. Compliance with these standards is essential to ensure a safe and comfortable environment for hospital occupants (Li et al., 2018).

The planned construction of a new building to function as a PMI hospital in the Bogor area necessitates the development of adequate supporting utilities, including a well-designed HVAC system. Given the climatic conditions of Bogor and the specific requirements of hospital facilities, it is essential to perform a detailed cooling load analysis based on the building design parameters. This analysis will serve as the foundation for selecting appropriate HVAC equipment and ensuring that the system can meet the required thermal comfort and air quality standards (Pryazhnikov et al., 2017).

Furthermore, the integration of efficient HVAC design with sustainable building practices is becoming increasingly important in modern construction. Energy-efficient HVAC systems not only reduce operational costs but also contribute to environmental sustainability by lowering greenhouse gas emissions. Therefore, incorporating accurate cooling load calculations and appropriate system design strategies is a key step toward achieving both functional and sustainable hospital infrastructure (Bahramnia et al., 2019; Cao et al., 2020; Kumanek & Janas, 2019; Li et al., 2018).

Based on these considerations, this study focuses on the design of an HVAC system for the new PMI Bogor Hospital building using the CLTD method. The objective is to determine the cooling load requirements and to ensure that the designed system can provide optimal thermal comfort, maintain indoor air quality, and comply with applicable health standards.

2. Literature Review

2.1 Air Freshener

Air conditioning is the process of cooling air to achieve the desired temperature and humidity in a given room. It also regulates airflow and cleanliness (Sekhar, 2016; Xu et al., 2018). Air-conditioning systems are generally divided into two main categories:

1. Air freshener for comfort
   Refreshing the air in the room to provide working comfort for people who carry out certain activities.

2. Air freshener for industry
   Refreshing the air in a room as required by the processes, materials, equipment or items in it (Asif et al., 2018; Lim et al., 2018).

2.2 Vapor Compression Refrigeration System

In principle, a vapor compression refrigeration system, as the name suggests, is a system that uses a compressor to compress the refrigerant. This system exploits the properties of the refrigerant (Rhee et al., 2017; Zsembinszki et al., 2017). At low pressures and low saturation temperatures, the refrigerant phase changes to vapor by absorbing heat from the cooled area. At high pressures and saturation temperatures, the refrigerant phase changes to liquid by releasing heat to the surrounding environment (Hu et al., 2017). Of course, to create the high-pressure side, a compression device (commonly called a compressor) is required, and on the low-pressure side, an expansion valve is installed, which will result in a decrease in refrigerant pressure (Algarni et al., 2018; Fekadu & Subudhi, 2018; Ni & Bai, 2017).

Based on the above, this vapor compression system consists of several working steps, namely

1. Compression Process
   This process occurs in the compressor where the refrigerant vapor with low pressure and temperature that enters the compressor through the suction line is compressed in the compressor cylinder so that the temperature and pressure of the refrigerant vapor exiting the compressor through the discharge line increased (Hu et al., 2017; Yee & Hermes, 2019).

2. Condensation Process
   Superheated steam from the discharge line (compressor outlet) enters the condenser, where it undergoes a process called condensation. The heat from the condenser is released into the environment, causing the refrigerant to gradually change from vapor to liquid. This condensation process occurs at a constant pressure and temperature (McLinden et al., 2020).

3. Expansion Process
   The refrigerant that has undergone condensation in the condenser will flow to the capillary tube, where the pressure decreases followed by a decrease in temperature in an isoenthalpy manner, or there is no change in enthalpy, and the refrigerant is partly in the liquid phase and partly in the gas phase gas (Baakeem et al., 2018; Bentrcia et al., 2017).

4. Evaporation Process
   The refrigerant whose pressure and temperature have been reduced undergoes a change in its composition. In this process, vapor is added to the refrigerant, resulting in a liquid-vapor mixture. By drawing even a small amount of heat from the cooled area, the refrigerant will completely change to vapor until it reaches a saturated vapor state. This process is called evaporation. Similar to condensation, this process occurs at a constant pressure and temperature (Nkwetta & Sandercock, 2016; Satrio et al., 2019; Zhang et al., 2017).

2.2.1 *Mollier Diagram*

This diagram is used to analyze the thermodynamic state of a refrigerant in a refrigeration cycle. The vertical line represents the pressure (P), and the horizontal line represents the enthalpy (h). This diagram is also called a pH diagram, as shown in Figure 1

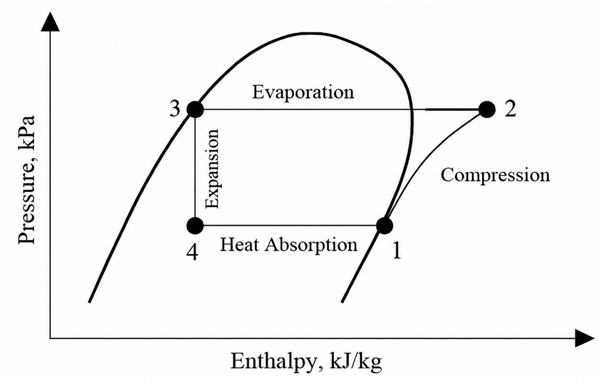

Figure 1. Magnitude of Refrigration Ciirculation in the Mollier Diagram

2.2.2 *Cooling Load Calculation*

Calculating the cooling load is a way to calculate the amount of cooling load for a building as a basis for selecting appropriate equipment, with the aim that the equipment can handle the existing cooling load (Mahmood et al., 2019). The following factors must be considered when determining the cooling load:

1. Characteristics of the building
   (a) Building materials (walls, ceilings, floors, etc.)
   (b) Surface color of the building
   (c) Shape and size of the building
2. Building orientation
   (a) Geographical location
   (b) The effect of sunlight
   (c) The influence of shadows from other buildings
   (d) the effect of heat reflection
3. Heat source from inside the room

1. Heat load from occupants

The heat load from a room must be considered in an air conditioning system. The amount of heat generated by occupants in a room depends on the number and activity of the occupants (Gong et al., 2017; Khammayom et al., 2020), and the heat generated can be either latent or sensible.

- Sensible heat
  Sensible heat is characterized by a change in temperature.

$$Q_s = N \times SHG \times CLF$$

Where :

Qs = Sensible Heat Transfer Rate (BTU/hr)
N = Number of People
SHG = Sensible Heat Gain (BTU)
CLF = Cooling Load Factor

- Latent heat
  Latent heat is not characterized by a change in temperature.

$$Q_1 = N \times LHG$$

Where :

Ql = Latent heat transfer rate (BTU/hr)
N = Number of People (BTU)
LHG = Latent Heat Gain (BTU)

2. Heat load from lighting

$$Q_s = 3.41 \times qi \times F_u \times F_s \times CLF$$

Where : Qs = Sensible heat transfer rate (BTU/hr)
3.41 = Conversion factor
qi = Lamp power (Watt)
Fu = Lamp usage factor
Fs = Ballast factor
CLF = Cooling Load Factor

3. Heat Load from Equipment

$$Q_s = (HG) \times CLF$$

Where : Qs = Sensible heat transfer rate (BTU/hr)
HG = Equipment Heat Gain (BTU/hr)
CLF = Cooling Load Factor

4. Ventilation

The ventilation load is the addition of heat to a room to meet the oxygen needs of the occupants.

- Sensible load

$$Q_s = 1{,}10 \times Q \times \Delta T$$

Where :
Q_s = Sensible heat transfer rate (BTU/hr)
Q = Air flow volume (CFM/person)
ΔT = Temperature difference (°F)

- Latent Load

$$Q_1 = 4840 \times Q \times \Delta W$$

Q_1 = Latent heat transfer rate (BTU/hr)
Q = Air flow volume (CFM/person)
ΔW = Specific humidity difference (lb/lb)

5. Heat Load From Outdoors

Heat conduction through the roof, walls, and glass walls

$$Q_s = U \times A \times CLTD$$

Q_s = Possible heat transfer rate (BTU/hr)
U = Heat transfer coefficient (BTU/hr.ft^2.°F)
A = Cross-sectional area (ft^2)
CLTD = Cooling Load Temperature Difference (°F)

3. Methodology

Research methodology refers to the stages of research that must be established before problem-solving can be undertaken. This allows for focused research and facilitates the analysis of problems. The following flowchart of the research method used is shown in Figure 2.

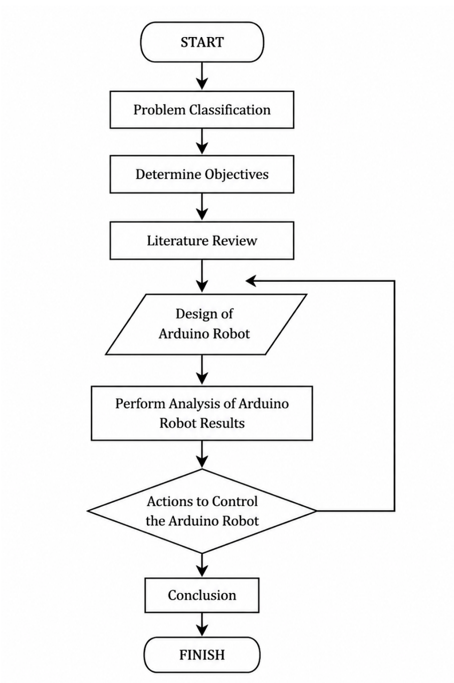

Figure 2. Research Flowchart

"Based on Figure 2, the flowchart illustrates the step-by-step process of designing and controlling an Arduino robot. The process begins with the classification of the problem, followed by determining the objectives, and conducting a literature review. Next, the design of the Arduino robot is carried out, followed by analyzing the results of the robot's construction (Elhelw, 2016; Wei et al., 2019). The flowchart then shows actions taken to control the robot, leading to the conclusion of the process.

The research was conducted at the PMI Bogor Hospital, during the period from October to January 2020.

Data Specifications and Calculations

In HVAC system design, both internal and external building data are required. The following data can be presented:

1. Location and Function of the Building

- Geographic Location : 6°LS – 7°LS and 106°BT – 108°BT
- Building Location : Jl. Padjajaran Indah V No. 97, Bogor, West Java
- Building Function : The building is used as a hospital.
- Building Orientation : The building faces south.

3.1 Building Physical Data

In calculating the required cooling load of a building, it is necessary to know several factors that significantly influence the calculation.

3. Total Cooling Load for Floors 1 to 3

The results of the total calculation of QSensible Heat, QLatent Heat, Room Sensible Heat (RSH), Room Latent Heat (RLH), and Room Total Heat (RTH) for floors 1 to 3 can be seen in Table 1.

Table 1. Total Cooling Load from Floor 1 to 3

No.	Floor	Qs (Btu/hr)	Ql (Btu/hr)	RSH (Btu/hr)	RLH (Btu/hr)	RTH (Btu/hr)
1	One	1066554.24	885598.29	1173209.66	974158.12	2147367.78
2	Two	687987.08	662464.46	756785.79	728710.91	1485496.69
3	Three	668420.32	515332.48	735262.35	588858.72	1324121.07
4	Total	2422961.64	2063395.23	2662577.80	2291727.75	4956985.54

Based on Table 1, the total cooling load from Floor 1 to 3 is presented, including the calculated values for Sensible Heat (Q_s), Latent Heat (Q_1), Room Sensible Heat (RSH), Room Latent Heat (RLH), and Room Total Heat (RTH). For Floor 1, the cooling load values are 1066554.24 Btu/hr for (Q_s), 885598.29 Btu/hr for (Q_1), 1173209.66 Btu/hr for RSH, 974158.12 Btu/hr for RLH, and 2147367.78 Btu/hr for RTH. The second floor shows 687987.08 Btu/hr for (Q_s), 662464.46 Btu/hr for (Q_1), 756785.79 Btu/hr for RSH, 728710.91 Btu/hr for RLH, and 1485496.69 Btu/hr for RTH. For Floor 3, the values are 668420.32 Btu/hr for (Q_s), 515332.48 Btu/hr for (Q_1), 735262.35 Btu/hr for RSH, 588858.72 Btu/hr for RLH, and 1324121.07 Btu/hr for RTH. The total values for all floors combined are 2422961.64 Btu/hr for (Q_s), 2063395.23 Btu/hr for (Q_1), 2662577.80 Btu/hr for RSH, 2291727.75 Btu/hr for RLH, and 4956985.54 Btu/hr for RTH.

4. Results and Discussion

4.1 Cooling Load Calculation Analysis Results

From the results of the cooling load calculations carried out on the new PMI Bogor Hospital building, the cooling load from floors 1 to 3 was calculated, with the load obtained from the design planning results. After calculating the cooling load on the new PMI Bogor Hospital building using the data, the cooling load was obtained as 4956985.54 Btu/hr. This is presented in the figure below.

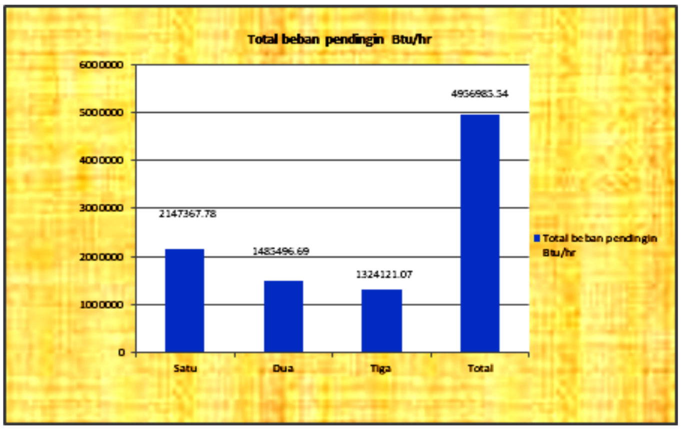

Figure 3. Total Cooling Load Graph

Based on Figure 3, the cooling load for the first floor is 2147367.78 Btu/hr. For the cooling load for the second floor, the cooling load is 1485496.69 Btu/hr. For the third floor, the cooling load was 1324121.07 Btu/hr.

4.2 Air Supply Calculation Analysis Results

The results of the air supply calculations are shown in the graphical image. The air requirements for the building were obtained from the results of the previous calculations in chapter three on air supply.

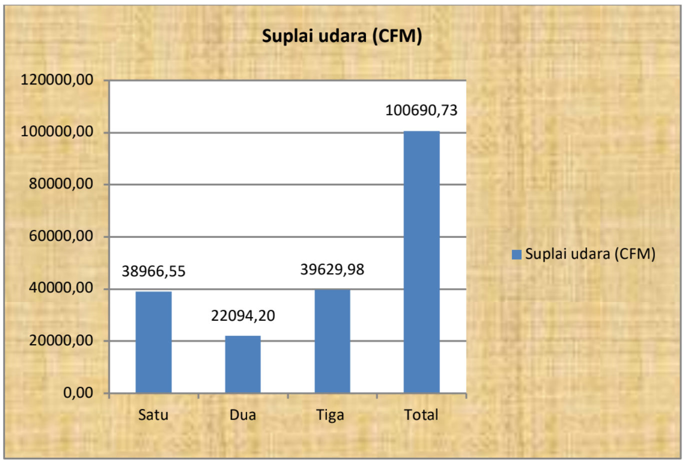

Figure 4. Total Air Supply Graph

Based on Figure 4, the air supply calculations for the first to third floors each have their own total calculation results. The air supply requirements for the first, second, and third floors were 38,966.55, 22, 094.20, and 39, 629.98 CFM, respectively. The total air supply required is 100,690.73 CFM.

5. Conclusions

Several conclusions can be drawn from the discussion in Chapter IV from the results of the cooling load planning for the Variable Refrigerant Volume (VRV) system.

1. The cooling load for floors 1 to 3 has been calculated. The Room Total Heat (RTH) on floor 1 is 2,147,367.78 Btu/hr, on floor 2 is 1,485,496.69 Btu/hr, and on floor 3 is 1,324,121.07 Btu/hr, resulting in a total cooling load of 4,956,985.54 Btu/hr.
2. Based on the air supply calculation, the air capacity on the 1st floor is 38,966.55 CFM, on the 2nd floor is 22,094.20 CFM, and on the 3rd floor is 39,629.98 CFM, with a total air supply of 100,690.73 CFM.
3. The capacity of the VRV system outdoor units is determined as follows:
    - Floor 1: Ou-1.A = 537,196.56 Btu/hr; Ou-1.B = 534,212.32 Btu/hr; Ou-1.C = 538,642.65 Btu/hr; Ou-1.D = 552,941 Btu/hr.
    - Floor 2: Ou-2.A = 492,853.77 Btu/hr; Ou-2.B = 504,365.54 Btu/hr; Ou-2.C = 488,277.38 Btu/hr.
    - Floor 3: Ou-3.A = 505,004.50 Btu/hr; Ou-3.B = 439,181.72 Btu/hr; Ou-3.C = 379,934.85 Btu/hr.

    Overall, the building is supported by 10 VRV outdoor system units.
4. The distribution of indoor units is as follows:
    - Floor 1: Ou.1.A supports 18 ceiling cassette units; Ou.1.B supports 20 units; Ou.1.C supports 27 units; Ou.1.D supports 15 units.
    - Floor 2: Ou.2.A supports 30 units; Ou.2.B supports 20 units; Ou.2.C supports 17 units.
    - Floor 3: Ou.3.A supports 20 units; Ou.3.B supports 30 units; Ou.3.C supports 18 units.
5. Based on the results, the designed VRV system is capable of meeting the cooling load requirements of the building effectively.

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Author Contributions

ES conceptualized the research, designed the system, and wrote the manuscript. RHS contributed to the development and testing of the system, provided data analysis, revised the manuscript, assisted in the research methodology and provided valuable feedback during the manuscript writing process.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this study. This research was conducted independently, and no financial or personal relationships influenced the results or interpretation of the findings.

References

Algarni, S., Saleel, C. A., & Mujeebu, M. A. (2018). Air-conditioning condensate recovery and applications – current developments and challenges ahead. *Sustainable Cities and Society*, *37*, 263–274. https://doi.org/10.1016/j.scs.2017.11.032

Asif, A., Zeeshan, M., & Jahanzaib, M. (2018). Indoor temperature, relative humidity and co2 levels assessment in academic buildings with different heating, ventilation and air-conditioning systems. *Building and Environment*, *133*, 83–90. https://doi.org/10.1016/j.buildenv.2018.01.042

Baakeem, S. S., Orfi, J., & Alabdulkarem, A. (2018). Optimization of a multistage vapor-compression refrigeration system for various refrigerants. *Applied Thermal Engineering*, *136*, 84–96. https://doi.org/10.1016/j.applthermaleng.2018.02.071

Bahramnia, P., Hosseini Rostami, S. M., Wang, J., & Kim, G. J. (2019). Modeling and controlling of temperature and humidity in building heating, ventilating, and air conditioning system using model predictive control. *Energies*, *12*(24), 4805. https://doi.org/10.3390/en12244805

Bentrcia, M., Alshatewi, M., & Omar, H. (2017). Developments of vapor-compression systems for vehicle air-conditioning: A review. *Advances in Mechanical Engineering*, *9*(8), 1687814017717186. https://doi.org/10.1177/1687814017717186

Cao, S. J., Yu, C. W., & Luo, X. (2020). Heating, ventilating and air conditioning system and environmental control for wellbeing. *Indoor and Built Environment*, *29*(9), 1191–1194. https://doi.org/10.1177/1420326X20951967

Che, W. W., Tso, C. Y., Sun, L., Ip, D. Y., Lee, H., Chao, C. Y., & Lau, A. K. (2019). Energy consumption, indoor thermal comfort and air quality in a commercial office with retrofitted heating, ventilation and air conditioning (hvac) system. *Energy and Buildings*, *201*, 202–215. https://doi.org/10.1016/j.enbuild.2019.06.029

Elhelw, M. (2016). Analysis of energy management for heating, ventilating and air-conditioning systems. *Alexandria Engineering Journal*, *55*(2), 811–818. https://doi.org/10.1016/j.aej.2016.01.034

Enteria, N., Cuartero-Enteria, O., & Sawachi, T. (2020). Review of the advances and applications of variable refrigerant flow heating, ventilating, and air-conditioning systems for improving indoor thermal comfort and air quality. *International Journal of Energy and Environmental Engineering*, *11*(4), 459–483. https://doi.org/10.1007/s40095-020-00346-0

Fekadu, G., & Subudhi, S. (2018). Renewable energy for liquid desiccants air conditioning system: A review. *Renewable and Sustainable Energy Reviews*, *93*, 364–379. https://doi.org/10.1016/j.rser.2018.05.016

Gong, G., Liu, J., & Mei, X. (2017). Investigation of heat load calculation for air carrying energy radiant air-conditioning system. *Energy and Buildings*, *138*, 193–205. https://doi.org/10.1016/j.enbuild.2016.12.005

Hu, Z., He, W., Ji, J., & Zhang, S. (2017). A review on the application of trombe wall system in buildings. *Renewable and Sustainable Energy Reviews*, *70*, 976–987. https://doi.org/10.1016/j.rser.2016.12.003

Khammayom, N., Maruyama, N., & Chaichana, C. (2020). Simplified model of cooling/heating load prediction for various air-conditioned room types. *Energy Reports*, *6*, 344–351. https://doi.org/10.1016/j.egyr.2019.11.086

Kumanek, B., & Janas, D. (2019). Thermal conductivity of carbon nanotube networks: A review. *Journal of Materials Science*, *54*(10), 7397–7427. https://doi.org/10.1007/s10853-019-03368-0

Li, W., Koo, C., Cha, S. H., Hong, T., & Oh, J. (2018). A novel real-time method for hvac system operation to improve indoor environmental quality in meeting rooms. *Building and Environment*, *144*, 365–385. https://doi.org/10.1016/j.buildenv.2018.08.046

Lim, D. K., Ahn, B. H., & Jeong, J. H. (2018). Method to control an air conditioner by directly measuring the relative humidity of indoor air to improve the comfort and energy efficiency. *Applied Energy*, *215*, 290–299. https://doi.org/10.1016/j.apenergy.2018.02.004

Mahmood, M. H., Sultan, M., & Miyazaki, T. (2019). Significance of temperature and humidity control for agricultural products storage: Overview of conventional and advanced options. *International Journal of Food Engineering*, *15*(10), 20190063. https://doi.org/10.1515/ijfe-2019-0063

McLinden, M. O., Seeton, C. J., & Pearson, A. (2020). New refrigerants and system configurations for vapor-compression refrigeration. *Science*, *370*(6518), 791–796.

Ni, J., & Bai, X. (2017). A review of air conditioning energy performance in data centers. *Renewable and Sustainable Energy Reviews*, *67*, 625–640. https://doi.org/10.1016/j.rser.2016.09.050

Nkwetta, D. N., & Sandercock, J. (2016). A state-of-the-art review of solar air-conditioning systems. *Renewable and Sustainable Energy Reviews*, *60*, 1351–1366. https://doi.org/10.1016/j.rser.2016.03.010

Pryazhnikov, M. I., Minakov, A. V., Rudyak, V. Y., & Guzei, D. V. (2017). Thermal conductivity measurements of nanofluids. *International Journal of Heat and Mass Transfer*, *104*, 1275–1282. https://doi.org/10.1016/j.ijheatmasstransfer.2016.09.080

Rhee, K. N., Olesen, B. W., & Kim, K. W. (2017). Ten questions about radiant heating and cooling systems. *Building and Environment*, *112*, 367–381. https://doi.org/10.1016/j.buildenv.2016.11.030

Saran, S., Gurjar, M., Baronia, A., Sivapurapu, V., Ghosh, P. S., Raju, G. M., & Maurya, I. (2020). Heating, ventilation and air conditioning (hvac) in intensive care unit. *Critical Care*, *24*(1), 194. https://doi.org/10.1186/s13054-020-02907-5

Satrio, P., Mahlia, T. M. I., Giannetti, N., & Saito, K. (2019). Optimization of hvac system energy consumption in a building using artificial neural network and multi-objective genetic algorithm. *Sustainable Energy Technologies and Assessments*, *35*, 48–57. https://doi.org/10.1016/j.seta.2019.06.002

Sekhar, S. C. (2016). Thermal comfort in air-conditioned buildings in hot and humid climates – why are we not getting it right? *Indoor Air*, *26*(1), 138–152. https://doi.org/10.1111/ina.12184

Shajahan, A., Culp, C. H., & Williamson, B. (2019). Effects of indoor environmental parameters related to building heating, ventilation, and air conditioning systems on patients' medical outcomes: A review of scientific research on hospital buildings. *Indoor Air*, *29*(2), 161–176. https://doi.org/10.1111/ina.12531

Wei, T., Ren, S., & Zhu, Q. (2019). Deep reinforcement learning for joint datacenter and hvac load control in distributed mixed-use buildings. *IEEE Transactions on Sustainable Computing*, *6*(3), 370–384. https://doi.org/10.1109/TSUSC.2019.2910533

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

Yee, R. P., & Hermes, C. J. (2019). Thermodynamic design of a mesoscale vapor compression cooling device. *Applied Thermal Engineering*, *147*, 509–520. https://doi.org/10.1016/j.applthermaleng.2018.09.073

Zhang, S., Cheng, Y., Fang, Z., Huan, C., & Lin, Z. (2017). Optimization of room air temperature in stratum-ventilated rooms for both thermal comfort and energy saving. *Applied Energy*, *204*, 420–431. https://doi.org/10.1016/j.apenergy.2017.07.064

Zsembinszki, G., de Gracia, A., Moreno, P., Rovira, R., González, M. Á., & Cabeza, L. F. (2017). A novel numerical methodology for modelling simple vapour compression refrigeration system. *Applied Thermal Engineering*, *115*, 188–200. https://doi.org/10.1016/j.applthermaleng.2016.12.059