LOAD PROFILE AND ENERGY ANALYSIS FOR EDUCATIONAL FACILITIES BUILDING: A CASE STUDY AT SK DURIAN TUNGGAL

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DECLARATION

I declare that this chosen item entitled "Load Profile and Energy Analysis for Educational Facilities Building: A Case Study at SK Durian Tunggal" is the result of my own research except as cited in the references. The Choose an item has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Refrigeration and Air Conditioning Systems) with Honours.

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DEDICATION

This research is dedicated to everyone who has helped and guided me along the way. My foundation has been my parents' love, patience, and encouragement, for which I am incredibly grateful. I appreciate your unwavering understanding and support, family and friends. I would especially like to express my gratitude to Ts. Dr. Amir Abdullah bin Muhamad Damanhuri, my supervisor, for his perceptive criticism, mentorship, and important advice. Finally, I would want to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for giving me the tools and setting I needed to succeed academically and personally.

ABSTRACT

This thesis investigates the thermal comfort and energy efficiency challenges at SK Durian Tunggal, focusing on its meeting room, teacher's room, and classrooms. The thesis objectives were to analyze the cooling load using Autodesk Revit 2025 and compare the energy consumption of Variable Refrigerant Volume (VRV) and Split-Unit systems. The scope of the thesis was limited to analyzing thermal comfort in spaces based on specific occupancy and ambient factors. Utilizing TSI Velocicalc, site data collection recorded airflow, relative humidity, and ambient temperature. Energy analysis was made with Carrier HAP software, while 3D modeling and cooling load calculations were done using Autodesk Revit 2025. With total requirements of 302,602 BTU/hr for the classroom building and 108,331 BTU/hr for the office building, the results show significant cooling load issues. Split-Unit systems provided low-cost alternatives for smaller locations, but VRV systems showed the highest energy efficiency. The results highlight the requirement for optimal HVAC system selection in order to improve energy efficiency and thermal comfort in educational facilities. In order to improve thermal efficiency, this thesis provides a methodical structure for getting modern HVAC design methods providing ideas for future applications in related issues.

ABSTRAK

Tesis ini menyiasat keselesaan terma dan cabaran kecekapan tenaga di SK Durian Tunggal, memfokuskan pada bilik mesyuarat, bilik guru dan bilik darjahnya. Objektif tesis adalah untuk menganalisis beban penyejukan menggunakan Autodesk Revit 2025 dan membandingkan penggunaan tenaga bagi sistem Variable Refrigerant Volume (VRV) dan Split-Unit. Skop tesis adalah terhad kepada menganalisis keselesaan terma dalam ruang berdasarkan penghunian tertentu dan faktor ambien. Menggunakan TSI Velocicalc, pengumpulan data tapak merekodkan aliran udara, kelembapan relatif dan suhu ambien. Analisis tenaga dibuat dengan perisian Carrier HAP, manakala pemodelan 3D dan pengiraan beban penyejukan dilakukan menggunakan Autodesk Revit 2025. Dengan jumlah keperluan 302,602 BTU/jam untuk bangunan bilik darjah dan 108,331 BTU/jam untuk bangunan pejabat, keputusan menunjukkan penyejukan yang ketara masalah beban. Sistem Split-Unit menyediakan alternatif kos rendah untuk lokasi yang lebih kecil, tetapi sistem VRV menunjukkan kecekapan tenaga yang paling tinggi. Hasilnya menyerlahkan keperluan untuk pemilihan sistem HVAC yang optimum untuk meningkatkan kecekapan tenaga dan keselesaan terma dalam kemudahan pendidikan. Untuk meningkatkan kecekapan terma, kajian ini menyediakan struktur berkaedah untuk mendapatkan kaedah reka bentuk HVAC moden yang menyediakan idea untuk aplikasi masa hadapan dalam isu berkaitan.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percentage
BIM	-	Building Information Modelling
kWh	-	Kilowatt-hour
AEC	-	Architecture, engineering, and construction sector
W	-	Watt
N	-	North
E	-	East
“	-	Inch
‘	-	Feet
Cb	-	Interzonal Heat Transfer Coefficient
m	-	Meter
Kc	-	Heat transfer coefficient
£	-	Emissivity
°C	-	Degree Celsius
BTU	-	British Thermal Unit
HP	-	Horsepower
HVAC	-	Heating, Ventilation, Air-Conditioning
SK	-	Sekolah Kebangsaan
HAP	-	Hourly Analysis Program
AC	-	Air-Conditioning
STRAC	-	Stratified air-conditioning
ASHRAE	-	American Society of Heating, Refrigerating and Air Conditioning Engineers
NSWAS	-	Nozzle Sidewall Air Supply
IZHT	-	Interzonal Heat Transfer

MST	-	Mountain Standard Time
PMV	-	Predicted Mean Vote
COP	-	Coefficient of Performance

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CHAPTER 1

INTRODUCTION

1.1 Background

One of the main concerns is the thermal comfort of people in buildings. It may have an impact on employees' productivity and efficiency in business facilities. Thermal comfort in residential buildings can enhance daily living, which has an impact on residents' productivity and efficiency at work. Air conditioners have become a commonplace household addition as a result of this. About 50–60% of the energy used in typical business buildings is contributed by air conditioning. Similar things happen in the transportation industry, where the air conditioner uses the most energy out of all the accessories found in normal land vehicles. Up to 70% of the energy utilized in residential structures is used for space conditioning, which is a substantial percentage, particularly in extremely hot climates and cold temperatures (Salisu, A. O. M., & Akinfaloye 2018).

Heating, Ventilation, Air-Conditioning (HVAC) systems represent between 40 and 60% of energy consumption in Europe and more than 50% in the United States (Solano 2021). Optimal operation control for HVAC systems can help improve the energy performance of the HVAC systems dramatically (Xiao 2022). The initial purchase cost and energy consumption are the factors that most influence the decision of what type of air-conditioning (AC) equipment to use without considering the performance during the life cycle (Balbis - Morejón 2023). The key factors considered in the selection of equipment for different spaces in the building include the space profile, equipment selection, temperature if indoor and outdoor and installation cost per unit (Layeni, 2019).

Operating HVAC systems has a lot of potential to save energy. However, due to a lack of supervisory control and excellent operation management for HVAC systems in many buildings, equipment operating conditions typically do not match optimal performance, which results in higher energy consumption for HVAC systems. It would be preferable to supply the necessary cooling load and modify the HVAC system's dynamic operation parameters beforehand in order to overcome these restrictions. Several variables, including HVAC system operating characteristics (such as operation schemes variation and control deviation), weather variations (such as outdoor dry-bulb temperature and solar radiation), and internal heat disturbances (such as occupancy and lighting power), can limit the amount of cooling load demand at any given time (Fan 2020).

The thermal effect of internal heat gains within a well-insulated building can lead to problems, especially with regard to energy consumption and thermal comfort. Solar radiation, metabolism, and the dissipation of heat from electrical appliances and equipment are the sources of the gains. Several research have focused on the modeling techniques of these developments and their applications to evaluate the impact of these gains on building thermal characteristics (Ruellan, 2016). The conditions that follow are examples of internal heat gains: heat from or to processes and goods; heat from or absorbed by hot water, cold water, and sewage systems; heat from or absorbed by lighting devices; metabolic heat from occupants and dissipated heat from appliances. Internal heat sources from people, appliances, and systems, such as a domestic hot water system, cooking, lighting, and electrical appliances were the primary source of heat increases in the studied house (Firlag, 2013).

One of the important first steps in reaching the accepted yet extremely high carbon targets that our society has established is the wise use of energy in buildings. One of the biggest issues facing the construction industry today is maintaining or increasing occupants' thermal comfort while frequently requiring significant reductions in energy use. When one considers that temperature comfort and energy waste are prevalent problems in today's systems, this becomes much poorer (Marco Picco, 2024). The lack of focus on thermal analysis for electrical appliances can be attributed to their lower power density, unpredictable usage, and minor thermal factors in comparison to building dynamics.

Several representative building energy simulation systems, however, solely used a static model of the thermal gains of electrical appliances based on their power consumption and usage characteristics. However, despite their increased efficiency, the amount of electrical equipment in a building is increasing, and their functions are becoming more varied. Furthermore, the need for more precise building energy analysis necessitates intra-hour building simulations due to quick computing. As a result, thermal parameters must be considered when modeling the heat dissipation of electrical equipment (Ruellan, 2016). The total flow rate from luminaries and other lighting components generates the internal heat flow rate from lighting. Unfortunately, there is no official definition of values for residential properties. The assumption that the electrical power of fluorescent bulbs in houses is $10W^2$ is justified based on standard ISO 15193-1 and statistical data. Only compact fluorescent lights, which consume between 20 and 33 percent less power than comparable incandescent lights, were placed in the passive house. With half of the lamps illuminated throughout the six hours of operation from 17.00 to 23.00, the average internal heat flow rate from lighting was 1.3 W^2 (for the time from 17.00 to 23.00) (Firlag, 2013).

People's heat gain is released into the environment and can be utilized to heat buildings. Despite explicit instructions, the protocols did not provide precise details about the types of activities individuals were engaged in at any given time or their attire, so it was assumed in the computation that an adult's sensible heat gains would equal 80W and a child's sensible heat gains would equal 60W. And also, the necessary meteorological information should comprise the temperature of the sky, the intensity of direct and diffuse radiation on a horizontal surface, and the temperature of the outside air. Measurement of sky temperature enables the calculation of heat transfer by long wave radiation between the exterior environment and the home's walls. Particularly on cloudless winter nights, the temperature of the sky is lower than that of the outside air. Using Berdahl's methods, the sky temperature was determined (Firlag, 2013).

1.2 Problem Statement

In this research, there was a complaint from teachers about the uncomfortable thermal issues in the teacher's room, meeting room and classroom. Based on the site concentration, the insufficient cooling and thermal comfort issue was caused by insufficient load capacity from the existing air-conditioning (AC) system. Proper cooling load estimation is important to achieve thermal comfort in a conditioned space. Improper calculations and design may have a negative impact on occupants in a room in terms of thermal comfort. Revit 2025 was used to analyze the cooling load estimation that seeks thermal comfort in the conditioned area in order to provide sufficient cooling load. The AC systems at Sekolah Kebangsaan Durian Tunggal are subjected to significant amounts of demand due to the tropical climate of Durian Tunggal, which is defined by high temperatures, humidity, seasonal changes, and excessive sun radiation. Under these conditions, an effective and well-functioning AC system is required to ensure sufficient cooling and comfort for every building occupant. To effectively deal with these climatic challenges, research and selection strategies are required, as highlighted by the observed limitations in the current AC setup. The energy efficiency of AC systems can be significantly increased with the aid of modern operation control. In order to achieve the most efficient energy consumption, the selection based on Revit 2025 cooling load analysis was made.

1.3 Research Objectives

a) To investigate load profile at educational building of SK Durian Tunggal using Revit MEP 2025.

b) To compare energy consumption between VRV System and Split-unit System based on load profile recommended.

1.4 Scope of Research

This study focuses on determining the load profile estimation energy analysis for meeting rooms, teacher's room and classrooms in SK Durian Tunggal, Durian Tunggal, Melaka as per longitude & latitude 2.3179° N, 102.2837° E. The study focuses on thermal comfort in eight classrooms with the same dimensions, meeting room and teacher's room. Each of the classrooms has 40 students while 35 occupants are in the meeting room and 37 occupants are in the teacher's room. Data such as ambient temperature, relative humidity and dewpoint temperature were collected by using TSI Velocicalc. The HVAC system design and selection were done based on the load profiling which is done by using Revit 2025 software and the energy analysis was done by using Carrier HAP software.

CHAPTER 2

LITERATURE REVIEW

2.1 Thermal Comfort

Due to its impact on student productivity, performance, and motivation to engage in academic activities, thermal comfort is a crucial component of the indoor quality of classrooms. In many nations, educational buildings account for a significant amount of energy usage, with air conditioning using about 40% of this energy. Understanding how each student's thermal comfort varies from person to person is essential to ensuring academic performance and lowering energy use. Only by understanding the factors affecting people's thermal comfort can energy consumption be reduced by fixed temperature adjustment, air velocity modification, or the application of algorithms for variable temperature adjustment (Custódio 2024).

The main goal of heating, ventilation, and air conditioning (HVAC) systems is to provide thermal comfort for the inhabitants. The thermal comfort index is the formal name for the human thermal comfort indicator. Several thermal comfort indices have been researched for HVAC system design. Nonetheless, the predicted mean vote (PMV) index is the most commonly utilized thermal comfort metric. The mean thermal sensation vote on a standard thermal feeling scale for a large group of people in a specific interior climate is predicted by this traditional PMV model. It depends on four environmental factors and two human factors, namely the occupants' clothing insulation, human activity, air temperature, air relative humidity, air velocity, and mean radiant temperature. The PMV index ranges from 3 to +3, representing the inhabitants' temperature ranges from chilly to hot. A null value of PMV indicates neutrality (Atthajariyakul 2005).

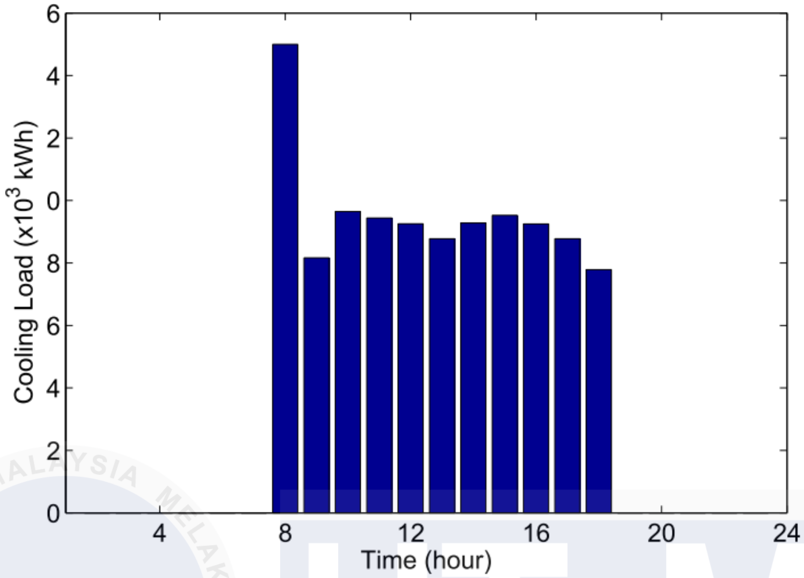

Figure 2.1 Daily Cooling Load of the Multi-storey building

The total cooling load per hour as in Figure 2.1 above is estimated using heat balance method based on the ambient condition stated in weather condition of tropics as in Figure 2.2 below (Thangavelu, S. R., Myat, A., & Khambadkone, A. 2017).

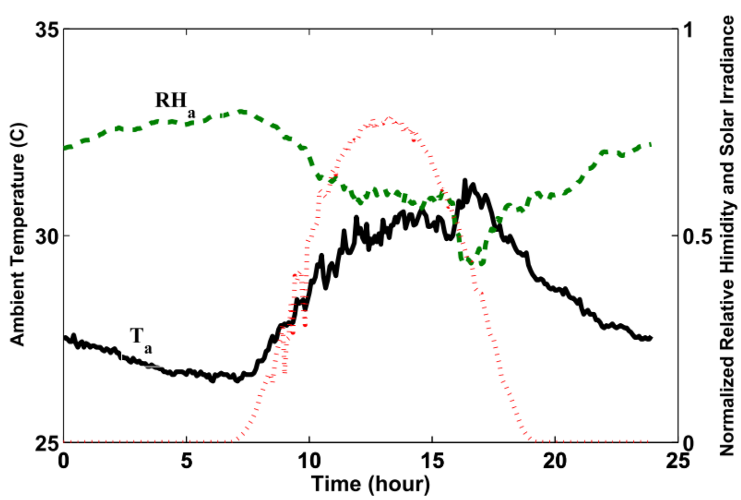

Figure 2.2 Weather Condition of Tropics

The parameter that is selected is relative humidity (RH). The percentage difference between the saturation vapor pressure of water at a given temperature and the partial pressure of water vapor in the air is known as relative humidity (Reda et al., 2022). A study that created a model specifically for Southeast Asia's hot and muggy climate found that the ASHRAE adaptive model and the comfort equation for naturally ventilated structures were comparable (Amaripadath et al., 2023). While some standards, like ASHRAE 55, have no relative humidity requirements, many others, like EN 16798, ISO 7730, BIS NBC, and others, have both an upper and lower threshold value. Despite the absence of humidity signal in the adaptive model equations, the relationship between humidity.

According to Occupational Health and Safety Management, between 40% and 60% of office buildings have this condition (Amaripadath et al., 2023). It can stop the sweat from evaporating from the skin once comfort is attained. Low humidity can cause dryness in your eyes, nose, and throat, while high humidity (over 80%) can cause fatigue and a "stuffy" feeling.

Air velocity was an additional parameter. The average tropical region's quick heat loss is influenced by air velocity. The body is chilled and evaporation is increasing. Accurate air velocity monitoring is essential for comfort, energy economy, and indoor air quality. Increasing air velocity in HVAC systems can improve system performance and save energy. Computer-controlled streams that are colder than the surrounding air temperature can create a refreshing breeze in a hot, muggy setting (Kim Perron, 2022). The ideal air speed range for interior spaces is between 30 and 40 fpm, per ASHRAE Standard 55. An ERV with controls may accomplish high-performance demand control mechanical ventilation, ensuring optimal ventilation and thermal comfort.

Mean radiant temperature (Tmrt) comes next. The emissivity, or ability of a substance to absorb or release heat, determines the radiant temperature, which is a function of the amount of heat radiated from a surface. The mean radiant temperature is influenced by the emissivity, the view factor, and the temperatures of the nearby surfaces. Heat or cold can be released and absorbed by people, windows, floors, walls, radiators, and even other items, especially if the building envelope or insulation is insufficient (Kim Perron, 2022).

One important factor in thermal comfort is air temperature. Air temperature is the average temperature of the air around a person, considering time and place. According to the ASHRAE 55 standard, the spatial average takes into consideration the occupants' head, waist, and ankle levels, which vary based on whether they are seated or standing. Another important element including relative humidity, air velocity, and radiant temperature affected the thermal comfort at the Bandar Bukit Raja Mosque in Klang (Aznan, K., & Saji, N. 2024).

2.1.1 Indoor Air Quality

According to the Journal of Environmental Engineering, maintaining ideal environmental conditions is needed to provide comfort and good air quality in a school. Relative humidity between 40 and 60 percent and a temperature range of 68 to 74°F (20 to 23°C) are ideal for occupant comfort and avoiding problems including respiratory irritation, dry skin, and heat discomfort. Achieving and maintaining these conditions requires sophisticated HVAC systems with controlled capabilities, providing the space's constant efficiency and suitability for any kind of things (ALTINTAŞ, 2016).

In a school environment, good indoor air quality is required for user comfort and health. The entire event experience can be affected by poor air quality, which can cause problems like headaches, exhaustion, and breathing difficulties. The Indoor Air Journal states that proper ventilation systems that remove hazardous substances and supply fresh air are important

(Sadrizadeh et al., 2022). A healthier and more refreshing environment can be created by properly managing pollutants, allergies, and germs through the use of HEPA filters, routine maintenance, and air quality monitoring.

A capable and flexible HVAC system is required for the constant use of classroom and office with changing occupancy levels (Bukhary et al., 2015). Demand-Controlled Ventilation (DCV) and Variable Air Volume (VAV) systems are perfect because they increase energy use and lower expenses while maintaining comfort and air quality by adjusting ventilation and airflow in real-time based on occupancy and activity.

2.2 Introduction to Building Information Modelling

Building Information Modeling (BIM) is a collaborative method for designing, constructing, and managing infrastructure using digital representations of a facility's functional and physical attributes (Mistry, V. 2020). It serves as a shared knowledge repository for stakeholders throughout a building's lifecycle, enabling informed decisions. BIM has been customized for marine applications and is used to innovate HVAC system design for platforms (Stephens, H., & CEng MIMechE, Me.). BIM tools organize fragmented and dispersed information through interoperable databases and software (Bruno, S., de Fino, M., & Fatiguso, F. 2018).

2.2.1 Overview of BIM for HVAC design and analysis

Building Information Modeling (BIM) has emerged as an innovative approach to enhancing communication and project management in the architecture, engineering, and construction (AEC) sectors. By integrating building energy modeling into the digital design process, BIM overcomes the limitations of traditional methods, such as time-consuming model preparation, inconsistencies in data, and high implementation costs. This incorporation streamlines energy analysis and supports more efficient decision-making throughout a building's lifecycle (Gao, H., Koch, C., & Wu, Y. 2019).

The integration of BIM with HVAC systems offers transformative possibilities in the construction industry, enabling paradigm shifts in the design, operation, and management of buildings. This approach allows for enhanced collaboration among stakeholders and more precise control over energy performance and indoor environmental quality (Mistry, V. 2020).

Energy models created through BIM include comprehensive data such as 3D geometry, site location, local weather conditions, building materials, thermal bridges, system characteristics, and occupancy profiles. These energy models can be developed using software like SketchUp or Revit. Tools like the Quick Energy Simulation Tool (eQUEST) integrate various components, including a building development wizard, an energy efficiency measure wizard, and a simulation engine built on the Department of Energy's DOE-2 software. Additionally, Transient System Simulation (TRNSYS) is a widely used simulation program for energy analysis in buildings and HVAC systems, including renewable energy sources like solar and geothermal systems (Patiño-Cambeiro, F., Bastos, G., Armesto, J., & Patiño-Barbeito, F. 2017).

HVAC system modeling plays a crucial role in studying and optimizing energy usage and indoor air quality. It supports the simulation of supervisory and local loop control schemes, which are essential for improving energy efficiency and ensuring that buildings meet performance and environmental standards (Afram, A., & Janabi-Sharifi, F. 2014).

2.2.2 Benefit of using BIM for HVAC design and analysis

Building Information Modelling (BIM) aims to create a centralized and cohesive digital model that integrates both geometric and non-geometric data relevant to a building project. This model serves as a unified point of reference for all stakeholders, ensuring consistency and collaboration throughout the project lifecycle. BIM fosters collaboration and coordination among various disciplines involved in building projects, including engineers, architects, contractors, and facility managers. By providing a shared model, BIM reduces errors caused by miscommunication and supports real-time collaboration. BIM integrates diverse data formats and types, such as schedules, cost estimates, performance data, specifications, and 3D geometric models. This comprehensive integration provides a holistic understanding of a building's features, enabling informed decision-making throughout its lifecycle. (Mistry, V. 2020).

BIM operates on the concept of an integrated digital archive, consolidating geometric, semantic, and topological data in diverse formats within parametric objects. This centralized repository guides workflows and information exchanges, ensuring seamless project execution and efficient data management. BIM solutions, whether proprietary or customized, leverage query operations and automated algorithms to efficiently manage and analyze a wide range of variables. This capability enhances the accuracy and effectiveness of building project management (Bruno, S., de Fino, M., & Fatiguso, F. 2018).

BIM-based technologies are increasingly utilized in the construction industry, especially in developed nations, where they are becoming essential management tools for official projects. Their widespread adoption highlights BIM's value in streamlining processes and ensuring project efficiency (Patiño-Cambeiro, F., Bastos, G., Armesto, J., & Patiño-Barbeito, F. 2017). BIM enhances collaboration and communication among stakeholders by providing a unified platform for information sharing. This reduces the likelihood of misunderstandings and supports more informed decision-making throughout the project lifecycle (Mistry, V. 2020). (5) BIM facilitates effective information sharing and enables the efficient participation of technicians with interdisciplinary skills. Integrating BIM with automation technologies further reduces labor costs and enhances quality control during diagnosis, design, and task execution, streamlining project workflows and improving overall outcomes (Bruno, S., de Fino, M., & Fatiguso, F. 2018).

BIM accelerates design and construction processes by enabling real-time visualization, clash detection, and scenario analysis. This efficiency not only reduces costs but also shortens project timelines, resulting in quicker completion (Mistry, V. 2020). BIM supports accurate evaluations of remaining building performance, which can guide retrofitting and renovation efforts. It ensures effective information sharing and facilitates the participation of technicians with interdisciplinary expertise. When integrated with automation technologies, BIM helps lower labor costs and enhances quality control during diagnosis, design, and task execution (Bruno, S., de Fino, M., & Fatiguso, F. 2018).

BIM technologies have proven to be highly effective for managing construction and restoration projects, offering significant potential for energy optimization and improving overall project efficiency. BIM minimizes mistakes and inconsistencies in project documentation due to its collaborative nature. This reduces the need for rework during construction, ultimately saving time and money (Patiño-Cambeiro, F., Bastos, G., Armesto, J., & Patiño-Barbeito, F. 2017). BIM also enhances facility management by offering a comprehensive digital representation of the building. This model supports maintenance planning, asset tracking, and performance monitoring, ensuring efficient management throughout the building's operational lifespan (Mistry, V. 2020).

2.2.3 Parameters of Energy Simulation

The size and shape of a space are critical factors in designing a multifunctional hall to create an optimal acoustic environment. The room's volume plays a significant role in determining the impact time, which is essential for achieving ideal acoustics. To accommodate the diverse needs of multipurpose venues, a well-balanced acoustic system is necessary to ensure the impact is appropriate for various acoustic requirements.

In a building's energy model, key factors such as 3D geometry, location (topographic orientation), local weather conditions, building materials, thermal bridges, system characteristics, and general data like usage and occupancy profile are included. These elements contribute to a comprehensive model that informs energy performance and efficiency. (Patiño-Cambeiro, F., Bastos, G., Armesto, J., & Patiño-Barbeito, F. 2017)

2.3 Energy Efficiency in Buildings

There are clearly serious issues facing the energy sector, and they get worse every day. According to the International Energy Agency, the "three Es"environment, energy security, and economic prosperity—are seriously threatened by the current energy trends. Since cutting-edge technology and energy-saving strategies are already generally accepted and well-known, the primary challenge is determining which will ultimately prove to be more dependable and effective. With so many suggested actions, the decision-maker must balance environmental, energy, financial, and social considerations to arrive at the best option that will guarantee a building's maximum energy efficiency while simultaneously meeting the needs of the owner, occupant, and final user (Diakaki, C., Grigoroudis, E., & Kolokotsa, D. 2008).

In theory, there are two methods to increase electricity consumption efficiency: either by using more energy-efficient technology or by altering the habits and behavior of consumers. Since awareness of the effects of each alternative is necessary in both situations, information, counsel, and education are crucial components of energy efficiency measures. However, it could be challenging to determine how this information should be designed and how it will reach the consumer. Similar information campaigns can produce significantly different outcomes, as demonstrated by the "Stureplan-project" (SEAB, 1993), which will be discussed later, wherein the potential for achieving power reductions using a straightforward energy efficiency information letter distributed to houses was examined (Henryson, J., Ha, T., & Pyrko, J. 2000).

2.3.1 Cooling Load

Building cooling load prediction techniques currently fall into two major categories: data-driven methods and physical modeling-based methods. The physical modeling-based approaches primarily use the thermodynamic principle to compute the cooling load and create a building's heat transfer model. This method's modeling procedure is complicated and time- consuming due to the comprehensive building physical information it requires and the high standards for modelers. This causes an inconvenience for real-time cooling load predictions and optimal control. Thus, to produce reliable forecast results, data-driven methods just require building operation data, and their model generation is more flexible and faster (Gao, Z., Yang, S., Yu, J., & Zhao, A. 2024)

In terms of HVAC system use, internal heat gains from people, electric appliances, and lighting are the key factors. Precise prediction of internal heat increases is necessary to lower these systems' energy usage (Ruellan, M., Park, H., & Bennacer, R. 2016).

Revit software makes it simple to cool load items like people's heat gain, lighting's heat gain, infiltration's heat gain, and ventilation's heat gain. Additionally, the application can be used to determine the cooling load caused by roofs and walls. Additionally, the outcomes were contrasted with the standard data provided by CARRIER and ASHRAE. The heat generated in the rooms is determined using the RULE OF THUMB technique. These techniques are employed to reduce capital costs associated with power usage and enhance building aesthetics (Prashanth, I. S. N. V. R., Nikitha, V., Aravind, B., & Mahesh, N. 2019).

2.3.2 Heat Gain Inside and Outside of Buildings

The cooling load of the structure is greatly influenced by indoor conditions, outdoor heat gains from the surrounding environment, and internal heat gains (from lights, equipment, people, etc.). (Thangavelu, S. R., Myat, A., & Khambadkone, A. 2017). Through wall heat conduction, the interior thermal environment also indirectly influences the exterior surface temperature in addition to the external thermal environment. The wall thermal resistance becomes just one factor influencing the outer surface temperature under the identical outdoor and indoor temperature settings: the greater the wall thermal resistance, the less the influence of the internal cooling conditions (Meng 2016).

By considering convective, conductive, and radiative heat transfer, the hypothetical thermal resistance between the occupied and unoccupied zones offers new insight into the process of heat transfer inside a large-space building using stratified air-conditioning (STRAC) systems. Nevertheless, due to the intricacy of the issue this study attempted to solve, numerous factors were left out, including the building's form, the height of the occupied zone, and the internal heat source (all of which have an impact on radiative heat transfer through various internal surface view factors). The type of air distribution system has a noticeable effect on the magnitude of the interzonal heat migration, making it one of the variables determining the interzonal heat transfer (IZHT) coefficient. The nominal thermal resistance varies in magnitude according to the floor-level air supply systems and nozzle sidewall air supply (NSWAS) (Wang 2023).

The IZHT coefficient (Cb), was able to assess the intensity of conductive heat transfer between regions when only a portion of the heat transfer the convective heat transfer caused by the temperature gradient was considered. However, other components of the IZHT, such as the radiative heat transfer and the convective heat transfer caused by the mass exchange, must be calculated independently. A higher heat resistance was indicated by a lower Cb value. The kind of air distribution system was the main factor influencing thermal resistance. For example, the floor level air supply system had a substantially higher thermal resistance value, with a Cb value of about 4 W/m2·, whereas the NSWAS system's Cb value was approximately 12 m2 (Wang 2023).

Furthermore, the exhaust air ratio had little effect on the Cb value of the NSWAS system; when the exhaust ratio was between 0 and 15%, the Cb/m2· value varied from 11.8 to 12.3W. The study's primary contribution is the equivalent heat transfer coefficient Kc, which considers all forms of heat transport and is simple to apply in real-world engineering settings. The table below shows the thermal parameters of envelopes (Wang 2023).

Table 2.1 Heat Transfer Coefficient and Emissivity (Wang 2023)

	Heat Transfer coefficient K (W/m^2. °C	**Emissivity, £**
Roof	1.02	0.88
Wall	2.04	0.92
Window	6.40	0.94
Floor	0.47	0.88

2.3.2.1 Internal Heat Gain

Included in the cooling load must be internal heat. Each internal gain contributor's sensible and latent heat gain components will be considered independently. The number of occupants, their activity levels, and the occupancy schedule must all be considered when evaluating the heat gains from inhabitants. The operation schedules and load factors of internal equipment and lights must be considered when evaluating heat gains from these sources. Heat transmission to the ceiling plenum must be taken into consideration when evaluating the heat gains from lighting equipment (if relevant) (ASHRAE 2017).

The study measurement which carried out in study case house that internal heat gains play an important role in the structure of heat balance of passive buildings. During the two-week period of measurements, the amount of energy delivered to the house by the heating system was lower than the amount of electrical energy consumed by electrical equipment – lighting, ventilation unit, and household appliances as Table 2.2 (Firląg 2013).

Table 2.2 Amount of electrical energy consumed by electrical component (Firląg 2013)

Purpose	Energy delivered, kWh	Average heating capacity, W
Space heating	64	190.5
Household appliances, lighting	79	235.1
Ventilation unit, pre-heater	12	35.7

Internal heat sources from people, systems, and appliances—such as the DHW system, cooking, lighting, and electrical appliances—were the primary sources of heat increases. The sophisticated model specifically featured the following kinds of interior heat sources: the hot water system in the home, electrical equipment and lighting, the users' two adults and visitors' youngsters (Firląg 2013).

2.3.2.2 External Heat

Both solar heat gain and temperature-driven heat gain must be considered in the calculating process. The full fenestration assembly's thermal performance will be used to determine the temperature-driven heat gain. The entire fenestration assembly's solar performance as well as the incident solar flux must be used to compute the solar heat gain. When there are blinds, drapes, or other interior shading devices, their presence must be taken into consideration when calculating the solar heat gain. If there is external shading, it must be taken into consideration when calculating solar heat gain. Additionally, when infiltration occurs, it has an impact on the external load that must be determined independently using both sensible and latent infiltration (ASHRAE 2017).

2.3.2.3 Weather Data

It is common for exposure to hot and muggy weather to result in excessive electricity use for cooling. In institutions and other buildings, heating, ventilation, and air conditioning (HVAC) systems are typically recognized as the biggest energy consumers. This begs the question of how weather conditions affect energy consumption. With the exception of the occasional semester break, the academic building is a prime example of a continuous fixed daily operating characteristic that is measured in hours. As a result, it is reasonable to presume that the HVAC systems on academic buildings will run according to a set schedule every day, year- round. In their experiment, they included several types of parameters, including the mean temperature (°C) and relative humidity (%) during a 24-hour period, as well as the rainfall (mm) between 08 and 08 MST. The Meteorology Department of Malaysia obtained all three parameters from one of the primary automated weather stations located at Batu Berendam, Melaka (2 °16'N, 102 °15'E). The closest main station is the weather station in Batu Berendam, which is roughly 10.90 kilometers from the main university campus. Since there would only be a two-radius difference in the weather every five kilometers, it was assumed that the weather data would be reliable even if there were changes in the weather every five kilometers. As a result, the weather data from this station accurately reflected the conditions on the main campus of the institution (Ngah Nasaruddin 2021).

2.4 HVAC System Selection and Sizing

The needed quality of HVAC systems was established using a number of international quality standards, such as ISO, SASO, and ASHREA. Water chiller, air chiller, variable refrigerant flow, packaged rooftop, and split wall mounted are examples of HVAC systems. The goal of study was to identify the most common criteria and condense them to a manageable size. The writers interacted with experts and quality engineers from a number of reputable businesses during this process (Shahrestani, M., Yao, R., Cook, G. K., & Clements-Croome, D. 2018).

In previous years, load estimates for air conditioning systems were often calculated manually or estimated subjectively using the air conditioning practitioner's experience. Even while manual calculations are time-consuming, estimates based on judgment are subject to inaccuracy since modern architectural plans are enormous, intricate, and dynamic. The dynamic nature of air conditioning applications is likely to benefit from load estimating via computer automation (Kareem, B, 2008).

Choosing HVAC and R systems is a necessary step in the design and construction of a building. Consequently, learning more about the building design and construction process can aid in understanding the HVAC and R systems decision process.

2.4.1 Factor in HVAC System Selection

In the ASHRAE standards, durability is a crucial consideration in the selection of HVAC systems. Designers prioritize climate zones, primary activity, and design cooling/heating loads as the top four criteria when choosing HVAC systems (Tian, Z., Si, B., Shi, X., & Fang, Z. 2019). The selection process generally focuses on key factors like energy consumption, thermal comfort, and air quality. The impact of the HVAC system is significant, as it plays a major role in reducing energy consumption and maintaining appropriate indoor air quality. Additionally, ensuring a low noise level within the building is another important aspect (Al-Ghamdi, M. A., & Al-Gahtani, K. S. 2022). In selecting HVAC and R systems, dependability, life cycle, system cost, occupant satisfaction, health and well-being, and indoor air quality are critical factors to consider (Shahrestani, M., Yao, R., Cook, G. K., & Clements-Croome, D. 2018).

Using the Bayesian Network technique, this study presents a novel method for choosing the HVAC systems with the highest energy efficiency. In order to determine how similar the target building and related buildings are, the first stage in this research process is to cluster them together using Euclidean distance. A poll was done to find out what important considerations designers considered while choosing the primary HVAC system. According to the poll, just 13% of designers give building energy consumption top priority, with climate zone design cooling/heating load, and major activity type ranking as their top three considerations. In order to include all the variables that can affect the HVAC system's energy usage, the study also builds a directed acyclic graph using the Bayesian Network Classifier (Tian, Z., Si, B., Shi, X., & Fang, Z. (2019).

2.4.2 Method for sizing the HVAC System

Because the relationship between a building's thermal mass and radiation heat gain has not been clearly characterized in a zone with a cooling surface, cooling load for a radiant system is hard to forecast. The effect of thermal mass in an exterior wall on the transmission load in an area with an active cooling surface is the goal of one of the earlier studies. Through dynamic simulation using Energy-Plus, they examined the thermal performances in a typical office building under various weather situations (Hu, R., Liu, G., & Niu, J. 2020).

While in this another research, Revit software was used to calculate the building's cooling load provide a suitable PCM to optimize indoor thermal comfort. Using PCM-incorporated wallboards with thicknesses of 0 cm, 1 cm, and 2 cm, the building's cooling demand was compared using Energy Plus software. Applying a 1-centimeter-thick PCM coating to the wall resulted in a 1.1% drop in the overall cooling load, while applying a 2-centimeter-thick layer produced a 1.5% reduction. Additionally, less energy was used because of the decreased cooling loads brought on by the PCM-based gypsum wallboard's impregnation. Finally, a maximum cooling load reduction of 7.6% in total site energy and 4.76% in USD/m2/year was achieved by the 2-centimeter-thickness PCM-based gypsum wallboard (Sangwan, P., Mehdizadeh-Rad, H., Ng, A. W. M., Tariq, M. A. U. R., & Nnachi, R. C. 2022).

2.5 School in Malacca

Out of the 7,780 elementary schools in Malaysia, 238 are located in Malacca, covering both urban and suburban locations, according to the Malaysia Education Ministry (2020). According to Malaysia's national education system, primary school aims to foster critical thinking, a sense of unity and national identity, and a strong foundation in basic literacy and numeracy.

The primary school is essentially situated along a road, in a neighborhood, or even within the school itself. Furthermore, instead of sending their kids to government school, the other parents will send them to a private primary school. A more thorough and often flexible curriculum, smaller class sizes for more individualized attention, improved facilities and resources, and a strong focus on academic performance.

When it comes to education, a classroom's atmosphere and comfort level are crucial components of the teaching and learning process. Additionally, the tropical climate makes many outdoor learning activities feasible and promotes health and environmental awareness. In 2021, there were approximately 98.64 thousand students enrolled in private secondary schools in Malaysia, a slight decrease from the previous year. There are three different kinds of private secondary schools in Malaysia: academic, religious, and Chinese-language institutions.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The selection and installation of HVAC systems were a process aimed at achieving thermal comfort and achieving energy efficiency in buildings. Following the methodology process as in Figure 3.1, the first step is to define the objectives and scope of the thesis, which include cooling capacity requirements, and energy efficiency requirements. Accurate information regarding the project's site, including its dimensions, occupancy trends, and environmental parameters like humidity and temperature outside, must be gathered in the first step, site data gathering. The next step is building modeling, which involves simulating the physical and thermal properties of the building using software like Revit or other Building Information Modeling (BIM) software. This helps visualize the space and get ready for load calculations.

The building's cooling capacity requirements are then determined by cooling load analysis, considering several factors such as occupancy, equipment use, insulation, and external heat gain. The most effective HVAC system is selected in relation to these results. Depending on the specific requirements of the project, it usually is between choosing between a Split Unit system and a Variable Refrigerant Volume (VRV) system. Split-unit systems provide a low-cost choice for smaller spaces with limited funds, whereas VRV systems are perfect for large or complicated structures because of their flexibility and effectiveness.

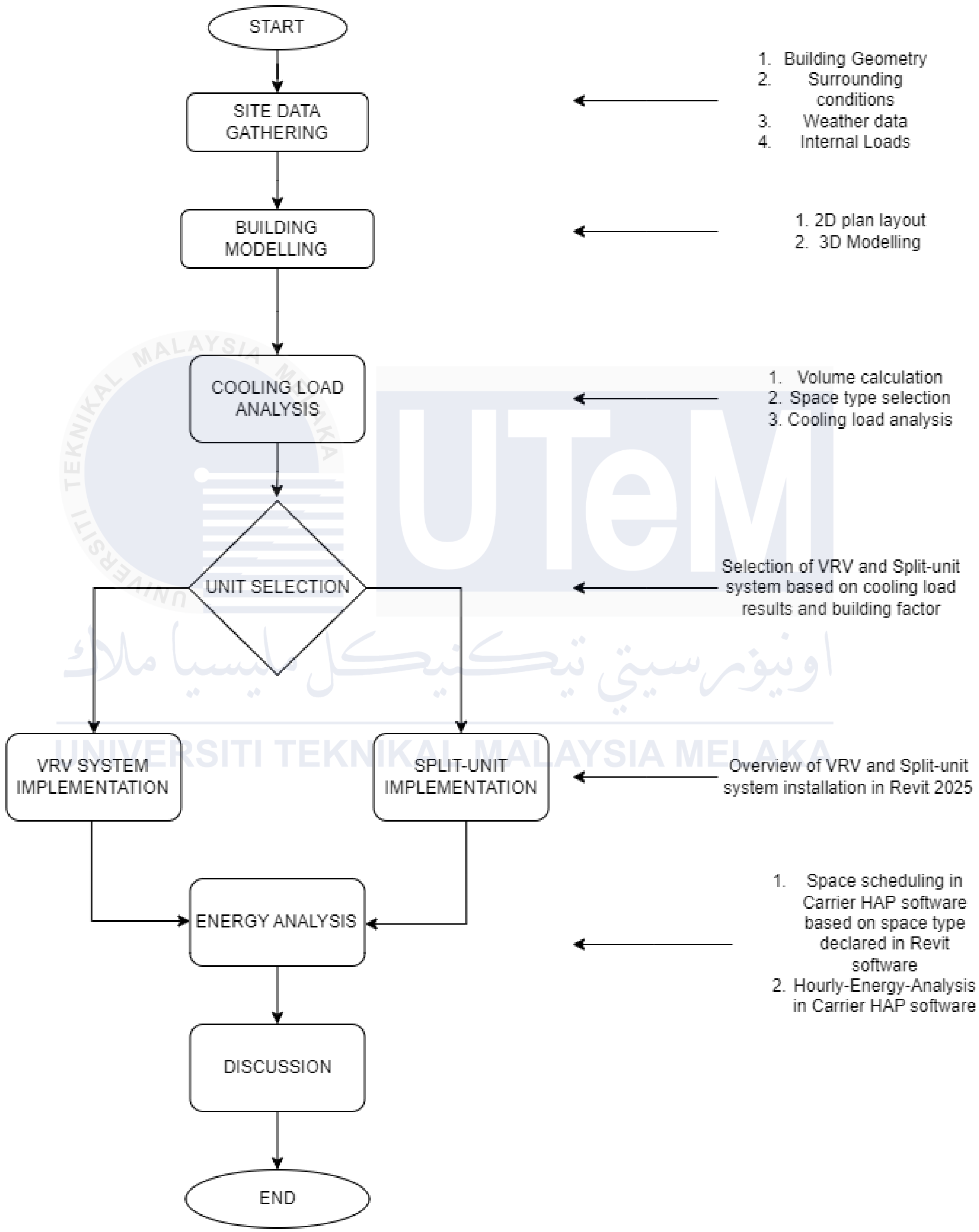

Figure 3.1 Research Flowchart

3.2 Site Selection

The study site selection was decided at SK Durian Tunggal. The school was located in Durian Tunggal town and operates from 7.00am until 1.30pm. After a discussion with the Guru Besar of SK Durian Tunggal, who complaint that the teachers' room and meeting room have insufficient cooling. And she also got complaints among the teachers that the classrooms in IBS building have uncomforted thermal during their teaching process. The school can be found in Google Maps as shown in Figure 3.2 below.

Figure 3.2 Location of SK Durian Tunggal in Malacca

3.2.1 Plan Layout

Figure 3.3 shows the position of both Classroom and Office buildings located in the school.

Figure 3.3 Position of Buildings in SK Durian Tunggal

Classroom buildings facing directly towards the field ground had their air temperature influenced by the environment. These buildings often featured walls made from Precast Concrete Sandwich Panels (PCSPs). While precast concrete products offered numerous advantages, such as excellent quality, proven durability, quick erection, and an aesthetically pleasing architectural look, they were known for having low thermal resistance. Besides, the site visitation on the office building, the study conclude there was unsufficient capacity load in office building.The office building's wall is refering to Jabatan Kerja Raya standards which structured by clay brick with a plaster of Ordinary Portland Cement. Based on the previous study, there are slightly different in thermal conductivity of different length of brick. (Alghamdi, A. A., & Alharthi, H. A. 2017). The thermal conductivity for different length of brick were shown in Table 3.1 below .

Table 3.1 Thermal Conductivity for Different Length of Brick

Brick Length (cm)	Thermal Conductivity (W/m-K)
40	0.43
45	0.4242
50	0.4223
55	0.4207

3.3 Site Data Concentration

Gathering site data to analyze the design, the surrounding environment, and the functionality of the current HVAC system was the beginning phase in resolve the thermal problems at SK Durian Tunggal.

3.3.1 Site Monitoring

In order to investigate the complaint from the teachers, the data collection was taken by using TSI Velocicalc. The data collection was in five days, from 11:00 am to 12:00 pm, all the space zones participated in the data gathering session referring to (Yao, C. Z., Azli, M. N. A. N., Hariri, A., Damanhuri, A. A. M., & Mustafa, M. S. S. 2023) experiment setup in school space. As seen on the classroom speed regulator, the ceiling fan's speed ranged from 3 to 5. Two sets of three-bladed ceiling fans (KDK Regular type K15VC) with 150-cm-long fan blades were utilized in the classroom. The fan speed can be adjusted between 216 and 264 RPM; in the study, it was 18.0 m/s for speed 3, 19.5 m/s for speed 4, and 21.0 m/s for speed 5. While both the teacher’s room and meeting room were in conditioned space. The height of the TSI Velocicalc position set to 100 cm by using tripod and placed at the center of the space and as shown in Figure 3.4 below and the parameter for the TSI Velocicalc is set to air temperature, relative humidity and air movement.

Figure 3.4 TSI Velosicalc Setup in Meeting Room

3.3.2 Existing HVAC System

The meeting room, as in Figure 3.5 and Figure 3.6 also at SK Durian Tunggal is equipped with two units of 2HP air conditioning, providing a combined cooling capacity of approximately 24,000 BTU (British Thermal Units). The teacher's room at SK Durian Tunggal already has two units of 1HP air conditioning, which provides a cooling capacity of approximately 12,000 BTU (British Thermal Units) combined. However, despite this setup, there is still insufficient cooling for the entire room. The site visitation observed that there was none of HVAC system applied in any of the classroom.

Figure 3.5 Site Visitation in Meeting Room

Figure 3.6 Site Visitation in Teachers Room

3.4 Load Profile

An important part for determining the thermal performance and energy needs of the buildings at SK Durian Tunggal is the load profile analysis. In order to achieve maximum HVAC system performance while preserving energy efficiency, this stage involves analyzing the cooling load demands of the office buildings and schools.

3.4.1 3D Modelling Design

Construction improved using Autodesk Revit. In order to maintain structural stability and performance, bridge abutments are essential parts that support the ends of bridge superstructures and transmit loads to the ground. Bridge abutment design has historically depended on 2D drawings and distinct engineering specialties, which frequently led to problems with coordination and inefficiencies during construction. BIM is a collaborative platform that allows contractors, engineers, and architects to collaborate on a single digital model thanks to its integrated 3D modeling capabilities. This method makes real-time visualization possible (Rio Pratama, S., Rifai, A. I., Pamadi, M., & Handayani, S. 2024).

Highly precise and comprehensive models produced by Revit provide better simulation and visualization of the abutment's functioning. Furthermore, the abundance of academic materials available on Google Scholar supported the best practices in the implementation of BIM technology and offered a strong theoretical basis. An efficient method for improving abutment design in civil engineering projects has been found to be the combination of extensive internet research and sophisticated modeling software such as Revit.

The modelling structure of Sekolah Kebangsaan Durian Tunggal begin with structural of beam and wall based on the 2D layout diagram. Wall boundaries were created and determined the dimensions of the wall. The type of wall was declared as table material type. The height of each wall will refer to base constraints which have been decided in the earlier design process.

The constraint was set up to Ground, Level 1, Level 2, Level 3, Stair 1, Stair 2, Stair 3 and Roof. The distance between each level is set to 10 feet in between stair level 5 feet from the level. The dimensions of each level were shown in APPENDIX B part 3 and concluded in Table 3.2 below.

Table 3.2 Elevation of Space from Ground

Level	Height from ground (feet)	Space involved
Ground	0	i. 1 UTM ii. 1 UPM iii. 1 UTEM iv. 3 UTM v. 3 UTEM vi. 3 UPM vii. 1 UKM viii. 1 USM
Level 1	10	Teachers Room Meetings Room
Level 2	20	None
Level 3	30	None
Roof	40	None

Based on the data of materials collected during the site observation, the type of materials for each component such as wall, window, door and ceiling were selected in Revit 2025 as Table 3.3 below. For specific material and component types, family files are required to be uploaded to the software to begin the placing of component. For aluminum naco window in Ground floor at office building, family cannot be found in UK and Malaysia files library. This modeling uses Glazing Bars Window family to be replace which have almost same properties to naco type.

Table 3.3 Type of Component's Material

Space	Components	Type
Teachers room & Meeting room	Wall	Generic 6”
	Window	Window Glass Frame
	Door	Wooden Door
	Ceiling	Generic Concrete 12”
Classroom	Wall	Concrete-Precast Concrete
	Window	Window Glass Frame
	Door	Wooden Door
	Ceiling	Gypsum Board (Drywall)

3.4.2 Load Estimation

The AutoDesk Revit MEP 2012 Student version was installed from AutoDesk website. The "Analyze" tab of the program's main menu has the button for the heating and cooling tool. A preliminary model of the building was made in order to begin using the Revit MEP heating and cooling tool. Only the items that have the potential to affect subsequent energy calculations are included in the model. It is assumed in this example that every room in the building has the same temperature range. For this reason, the inside walls were not included in the model in order to compute it as a single space (Sergey, U. 2012).

An energy analysis of your project may be done right within Revit according to the Heating and Cooling Loads feature in Revit Mep. The precise energy analysis provided by this tool may or may not depend on the specific workflow. Before the selection phase, the cooling load of the selected buildings needs to be done first. For energy analysis, analytical spaces will be produced automatically, as shown in the accompanying picture.

These areas match different rooms, including offices, bathrooms, and classrooms, each with unique lighting, power schedule, and occupancy combinations (Hing Chong, K., & Faiz Mohamad Yusoff, M. 2023). The analysis was performed following the analytical space as shown in Figure 3.7 below. The analytical space needs to be calculated by their volume (ft^3), and space type of each zone. Different uses of space will result in different values of parameters.

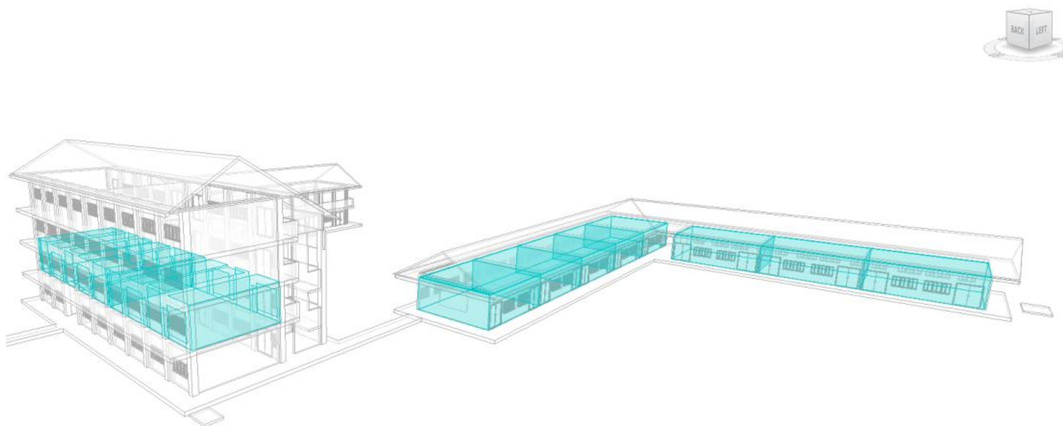

Figure 3.7 Analytical Spaces in Revit 2025

3.4.2.1 Space Volume Calculation

One of the interesting things in Revit 2025 is they can automatically calculate the space zone area in square feet and volume in cube. The software needs an area in area plan view which needs to be defined by wall and boundary lines in the rentable plan. Area rules determine the wall boundary position, such as wall centerline, interior or exterior wall face. The face of the interior walls was selected as boundary lines as Figure 3.8 below. In order to separate the room by their space name, Space Tag command was used to select each of the tag family. The results of the volume calculation in ft³ are shown in Table 3.4 below.

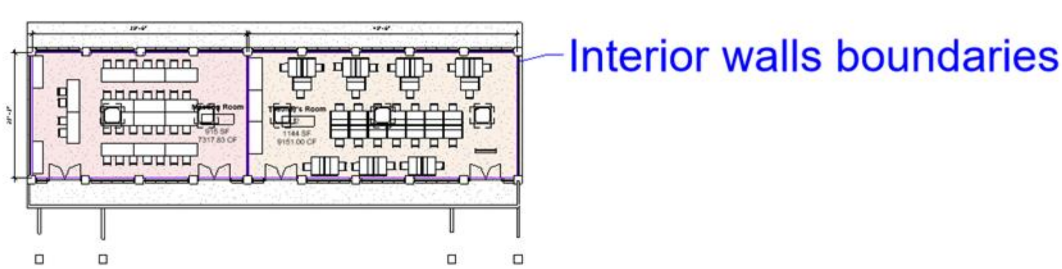

Figure 3.8 Volume Calculation and Space Tagging

Table 3.4 Space Volume

Zone	Volume, ft^3
Meeting Room	912
Teacher's Room	1144
1 UTM	677
1 UPM	677
1 UTEM	677
3 UTM	677
3 UTEM	677
3 UPM	677
1 UKM	677
1 USM	677

3.4.2.2 Space Type

Transmitted, diffuse solar, conductive, occupant, lighting, equipment, radiant, and infiltration heat gains are among the many heats gains that Revit computes and adds up, taking into account the convection component for every hour. To get the daily cooling load result, the system then calculates the peak cooling load for a given hour and multiplies it by the hour set according to space type parameters (Hing Chong, K., & Faiz Mohamad Yusoff, M. 2023).

A space type in Revit is a defined category that is used to demonstrate the purpose and application of a specific area inside a building. Because they define internal loads, ambient conditions, and ventilation needs for space, space types are required for energy modeling and HVAC cooling load analysis. Each space type included several parameters such as sensible heat per person, latent heat per person, lighting load density, power load density, outdoor air per space area. Space properties for each type were selected as Table 3.5 below.

Table 3.5 Space Type Scheduling

Space	Type	Sensible Heat/person (Btu/h)	Latent Heat/person (Btu/h)	Lighting Load Density (W/ft²)	Power Load Density (W/ft²)	Outdoor Air/area (CFM/ft²)
Meeting Room	Conference meeting/multipurpose	250.00	200.00	1.30	1.00	0.06
Teacher’s Room	Office – Open Plan	250.00	200.00	1.10	1.50	0.06
1 UTM	Classroom	250.00	200.00	1.40	1.00	0.06
1 UPM	Classroom	250.00	200.00	1.40	1.00	0.06
1 UTEM	Classroom	250.00	200.00	1.40	1.00	0.06
3 UTM	Classroom	250.00	200.00	1.40	1.00	0.06
3 UTEM	Classroom	250.00	200.00	1.40	1.00	0.06
3 UPM	Classroom	250.00	200.00	1.40	1.00	0.06
1 UKM	Classroom	250.00	200.00	1.40	1.00	0.06
1 USM	Classroom	250.00	200.00	1.40	1.00	0.06

In the space properties, there are several parameters that were set depending on actual situation such as occupancy and electrical loads. The space condition was set to be cooled 24°C which is in range of optimum temperatures ranges based on Ashrae ISO 7730-1984 (Aznan, K., & Saji, N. 2024).

3.5 Unit Selection

Split-unit system was reported to have same more non-compliance of IAQ parameters as VRV system. Also, both systems provide less indoor air quality compared to the centralized system. In this case, the major factor of selection is the structure of buildings which influences the flow of ducting if centralized system is used. The space arrangement of the installation has been discussed. For this study, there was a conflict of 12” beam, offset 8 feet from level 1in both meeting room and teachers’ room which does not give enough space for ductwork. The beam mentioned as shown in the Figure 3.9 below. This issue affected the selection factor of HVAC system. The most suitable system for this case is a VRV or Split-unit system which does not require large space for piping lines.

A number of parameters, including energy consumption, thermal comfort, indoor air quality, and the alternatives' economic and environmental aspects, must be thoroughly evaluated during the decision-making process. Stakeholders may make sure that the chosen strategy supports the project's objectives and provides the best possible performance and sustainability by carefully assessing these elements (David M. Elovitz, PE. 2002).

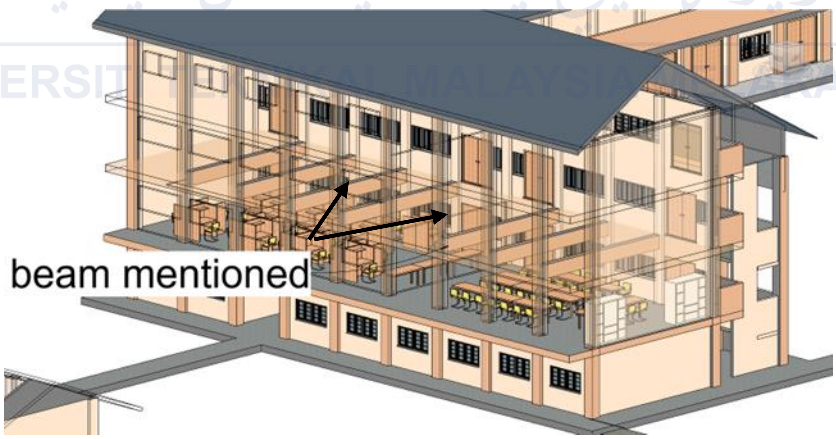

Figure 3.9 North view of Office Building

3.5.1 VRV System Factor

In general, the initial cost for the VRV system is about 50% higher than the split-unit system. The units are not appropriate for 100% outdoor air applications, particularly in hot and humid locations, due to limitations on the inside coil's maximum and lowest entering dry- and wet-bulb temperatures. At lower external temperatures, an indoor section's cooling capacity is less. This restricts the system's application in cold areas to spaces like telecom rooms that need constant cooling. There is a limit to the external static pressure that can be applied to ducted indoor portions. The minimum allowable ducting lengths and fittings for ducted indoor portions must be maintained. Indoor ducts taught to be positioned close to the areas they service (Afify, R. 2008).

3.5.2 Split-unit System Factor

Thermal comfort conditions or specific material or process requirements influence the design of air conditioning systems. This split-unit system is primarily made for home or office use, therefore only thermal comfort should be considered. Therefore, minor variations in humidity and temperature are accepted. One of the most important factors in choosing the right air conditioner is the cooling load calculation. The rate at which heat is extracted from the conditioned area to keep the air space temperature constant is known as the cooling load. It was determined that the surface heat transfer coefficients indoors and outdoors were, respectively, 22.7 and 7.42 w/m2K (Salisu, A. O. M., & Akinfaloye. 2018).

The manufacturer's indicated unit type and model determine the installation costs. In the event both indoor and outdoor units are installed back-to-back, retail sales prices in Malaysia typically encompass both installation costs. Back-to-back installation of interior and outdoor units is seen in Figure 3.10 below (Sukri, M. F., Sukri, M. F., & Jamali, M. K. 2018). The length of the copper piping must exceed 10 feet between the indoor and outdoor. The unit placement of split-unit should follow the Figure 3.10 below.

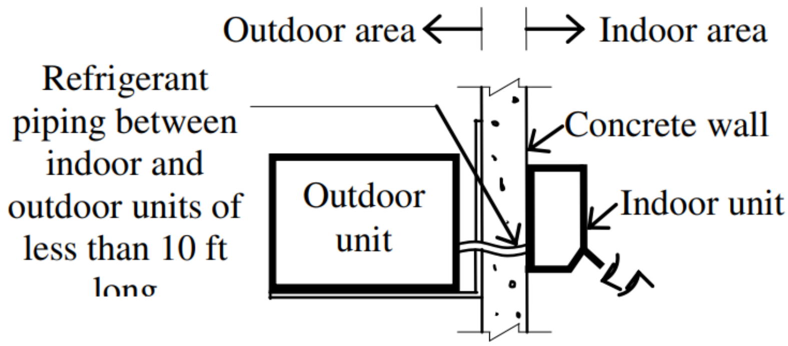

Figure 3.10 Split-unit placement factor

3.6 Energy Analysis

A computer program called Carrier's Hourly Analysis Program (HAP) helps engineers design HVAC systems for commercial buildings. HAP is a multipurpose tool. It is a tool for system design and load estimation, to start. Secondly, it is a tool for estimating energy expenses and simulating building energy use. In this way, it helps with energy cost assessments for LEED®, schematic design, and detailed design. HAP calculates loads using the ASHRAE-approved transfer function approach and analyzes energy using intricate 8,760-hour-by-hour simulation methods. There are two distinct but related goods available for this program. Features for system design and load estimation are offered by the "HAP System Design Load" application. In addition to energy analysis features, the whole "HAP" program has the same system design capabilities (Aaditya, K., & Palaparthy, H. 2011). This study followed the methodology of energy analysis from the previous study.

A project's detailed design phase involves considering one or a limited number of HVAC designs. In this stage of a project, energy analysis aims to thoroughly examine and optimize the design. We can carry out these kinds of energy analyses with the aid of the HAP detailed design interface.

The energy analysis was simulated in Carrier HAP version 6. The building type is Educational-K-12, which relevant type to study consists of conference room, classroom with age 9+, office-enclosed. The 3D model was created based on the Revit plan layout. The components such walls, doors, windows and ceiling properties also refer to original type which included in Revit input. Figure 3.11 shows the 3D model of both buildings created in Carrier HAP.

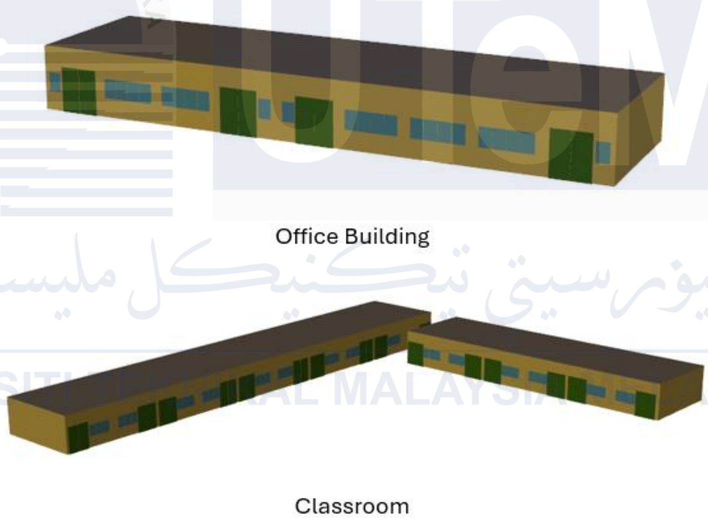

Figure 3.11 3D Model in Carrier HAP version 6

3.6.1 Year Scheduling

To run energy simulations, the schedule properties for both buildings were created as Table 3.6 below. The purpose of this schedule is to illustrate the occupancy rate schedule in the space provided. Carrier HAP provided hourly analysis as the energy data analysis of every hour collected.

This methodology is also conducted with reference to previous study. In the previous study, people at the studios were thought to have a "Medium Work" "Activity Level." The "Electric Equipment," "Overhead Lighting," and "Miscellaneous Sensible - Latent Loads" were presumed to be nonexistent as no specific information was supplied (Aaditya, K., & Palaparthy, H. 2011).

Table 3.6 Space Hour Scheduling

Session	**Rate of Occupancy (0 – 3)**			
	0	**1**	**2**	**3**
Weekday	2pm – 7am	-	-	7am – 2pm
Weekend	12am – 11.59pm	-	-	-
Public Holiday	12am – 11.59pm	-	-	-
School Break	2pm – 8am	8am – 2pm	-	-

3.6.2 Alternative System in Carrier HAP software

As the previous research, they directly import design data to HAP version 4.5 to analyze the system as designed in terms of energy efficiency**.** The various HVAC systems were prepared in the software which need to be declared as an alternative system to be compared. Numerous HVAC designs and equipment types may be considered during a project's preliminary or schematic design phase. In this stage of a project, energy analysis aims to rapidly analyze the energy cost performance of numerous design options in order to select a small number of the best-performing concepts for more, in-depth research. Due to the lack of knowledge about the building and the importance of speed in weighing the options, simplification and approximation may be appropriate in this case. These kinds of energy analyses can be completed more rapidly with the aid of the HAP Wizard interface (Aaditya, K., & Palaparthy, H. 2011).

Also in another previous research, the energy consumption, initial investment costs, operating costs, and ease of operation of six distinct HVAC systems-water-cooled and air-cooled variable flow cooling systems, air handling unit systems, fan coil systems, water source and air source heat pump systems, and split air conditioning systems are examined in the study for a sample office building (Yasin, K., & Yilmaz, D. 2022).In this case, the alternative system selected were both split-air-conditioning but specified in variable-split-system and single-split-system.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The results of the study performed at SK Durian Tunggal are presented in this chapter, with focus to the HVAC system's performance, cooling load requirements, and indoor air quality. The results are based on data gathered through energy analysis, 3D modeling, and on-site monitoring. This chapter's objective is to determine and analyze the data that was gathered in order to solve the school's thermal comfort issues.

4.2 Indoor Data Concentration

The SK Durian Tunggal indoor data concentration was important in figuring out the current thermal conditions and determining the causes of the occupants' discomfort. In order to determine the efficiency of the current HVAC system and recommend improvement, this research includes complete measurements of the space's dimensions, surroundings, and cooling performance.

4.2.1 Space Dimension

Measurement data from the interior and exterior wall was done on all space by using measuring tape. Measurement process also includes the dimension of each component such as door, window and ceiling. Table 4.1 below shows the width and length of the space wall and observation concludes that all the space is the same height as the ceiling. From this data measurement, the 2D plan layout was created in Revit 2025 as in APPENDIX B part 1 for classroom building and office building.

Table 4.1 Space Dimension

Zone	Level	Width x Length (ft)	Ceiling Height (ft)
Meeting Room	Level 1	23’ 3” x 40’	10
Teachers Room		23’ 3” x 50’	10
1 UTM	Ground	23’ 9” x 28’ 6”	10
1 UPM		23’ 9” x 28’ 6”	10
1 UTEM		23’ 9” x 28’ 6”	10
3 UTM		23’ 9” x 28’ 6”	10
3 UTEM		23’ 9” x 28’ 6”	10
3 UPM		23’ 9” x 28’ 6”	10
1 UKM		23’ 9” x 28’ 6”	10
1 USM		23’ 9” x 28’ 6”	10

4.2.2 Site Monitoring

The data of the observation was collected and combined together to make as a comparison between each space zone as shown in the table below. The results showed that there were some slight differences in 0.02% of relative humidity and 0.3°C between the classrooms. The results also show the difference in 0.9°C and 4% RH between the meeting room and the teacher’s room. A full collection of data is shown on Table 4.2 below.

Table 4.2 Data Collection of Site Observation

Space Zone	Ambient Temperature, °C	Relative Humidity, %	Dewpoint Temperature, °C
Meeting Room	29.2	62.4	21.2
Teachers Room	30.3	58.4	21.2
1 UTM	32.2	62.5	24.1
1 UPM	32.1	62.3	24.1
1 UTEM	32	62.1	24.1
3 UTM	32.3	62.3	24.1
3 UTEM	32.1	62.3	24.1
3 UPM	32.2	62.5	24.1
1 UKM	32.2	62.4	24.1
1 USM	32.3	62.5	24.1

Based on the results, the study concludes that the temperature for occupants is not in the recommended range which is shown in Ashrae ISO 7730-1984 Table 4.4 below**.** Also included range for specific physical parameter by DOSH, 2010 as in Table 4.3 below (Zainal Abidin, E., & Atikah Rohizan, N. 2015).

Table 4.3 Acceptable range for specific physical parameter by DOSH

Parameter	Acceptable range
Air temperature	23°C - 26°C
Relative Humidity	40 m/s – 70 m/s
Air Movement	0.15 m/s – 0.5 m/s

Table 4.4 Recommended range by ASHRAE ISO 7730-1984

Season	Clothing Insulation (clo)	Activity level (met)	Optimum operative temp (°C)	Optimum operative temp. range (°C)
Winter	1.0	1.2	22	20-24
Summer	0.5	1.2	24.5	23-26

Differences from the suggested ranges for thermal comfort were found through the monitoring of indoor environmental parameters. The average temperature in the classrooms was 32°C, which was higher than the ASHRAE recommended range of 23°C to 26°C as shown in the graph in Figure 4.1 below. The comfort of the people was also impacted by the higher-than-average relative humidity levels. Optimized HVAC solutions were required due to the old systems' poor cooling performance, particularly in the teacher's room and meeting room.

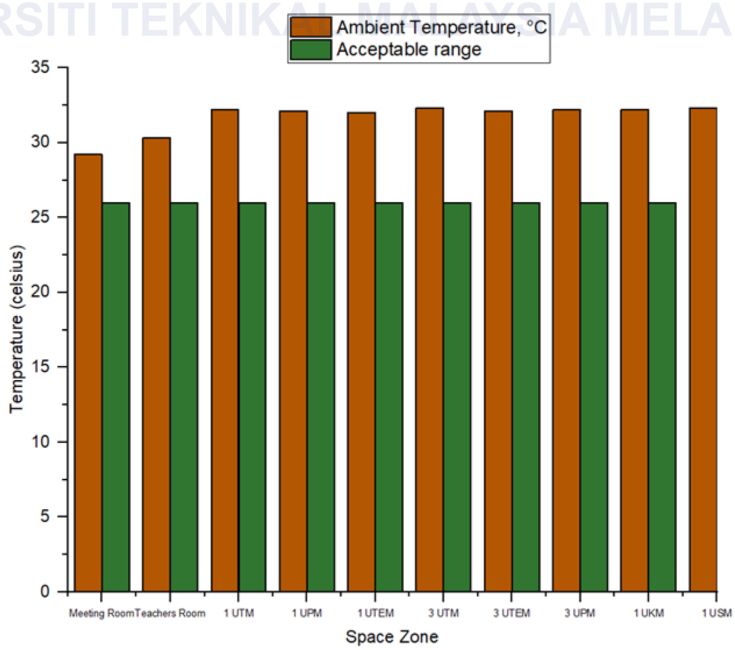

Figure 4.1 Graph of Recommended Temp. and Observation Temp

4.3 Load Profile

It is important to evaluate the HVAC system's capacity to manage peak loads while ensuring energy efficiency during the optimization phase. This requires evaluating how effectively the system reacts to various zoning regulations and how effectively it can sustain constant temperatures and air quality in different areas. The simulation tools provided by Revit 2025 can assist in locating any possible problems, such as equipment that is either over- or undersized, has an uneven temperature distribution, or uses too much energy. Through analysis of these findings, improvements to the system configuration such as equipment resizing, optimization of control tweaks, or zoning plan reassessments can be made to improve overall performance.

4.3.1 3D Design

The main purpose of creating a 3D model of the school is to illustrate the most accurate cooling load and initial costing estimation. 3D model of the office building and classroom building was done as shown in Figure 4.2 below. In order to illustrate the position of space and position of equipment, the transparency of few components was set to 70% in the Specific Element Graphics without changing foreground and background for surface and cut lines pattern. The elements which have changed their transparency were such as walls, beam, floor, ceiling and roof. In order to create accurate energy analysis, the 3D model was created in Revit and exported to Carrier HAP.

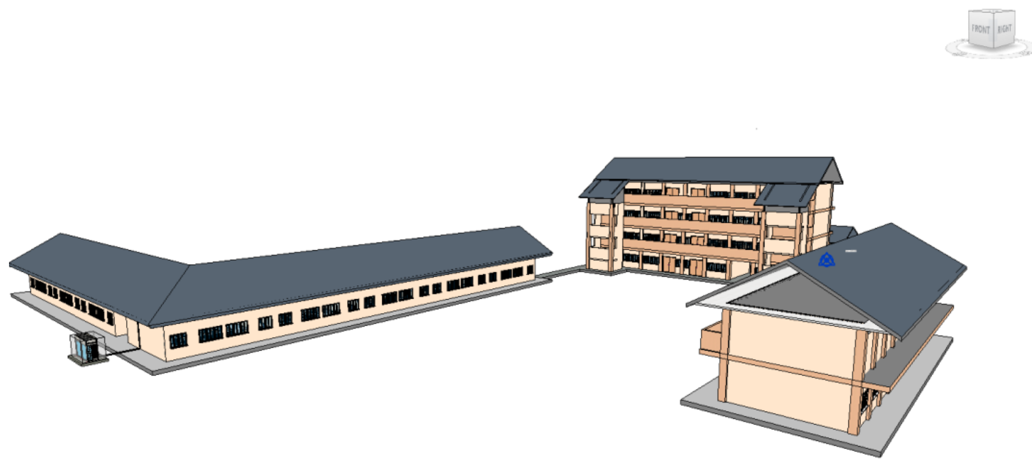

Figure 4.2 3D Modelling in Revit 2025

4.3.2 Cooling Load Analysis

After gathering data in Revit 2025, cooling load analysis was performed following the analytical space and the results as APPENDIX C and concluded as Table 4.5 below. A 12hp system was required for office building while the classroom needs a 32hp system to condition every space. The data of the analysis as the Table 4.5 then were export to selection phase.

Significant load requirements for the office and classroom buildings were found by the cooling load study conducted with Revit 2025. The office building needed a cooling capacity of 108,331 BTU/hr, while the classroom building's total cooling load was predicted to be 302,602 BTU/hr. Given Durian Tunggal's tropical climate, the study showed that better HVAC systems are required to manage the heat loads efficiently.

Table 4.5 Cooling Load Analysis Result from Revit 2025

Space Zone	Building	Instant Sensible (Btu/hr)	Delayed Sensible (Btu/hr)	Latent (Btu/hr)	Grand Total (Btu/hr)	Total Building Load (Btu/hr)
Meeting Room	Office	16,675	15,866	17,584	50,125	108,331
Teachers Room		20,367	18,607	19,232	58,206	
1 UTM	Classroom	19,317	2,808	16,359	38,484	302,602
1 UPM		19,316	2,795	16,357	38,468	
1 UTEM		20,276	1,799	17,239	39,315	
3 UTM		19,319	1,768	16,188	37,275	
3 UTEM		19,319	1,772	16,189	37,280	
3 UPM		19,316	2,757	16,351	38,424	
1 UKM		19,317	2,792	16,357	38,465	
1 USM		18,363	1,443	15,085	34,891	

4.4 Unit Selection

To meet performance expectations, the system must adhere to the stated performance criteria, regardless of how attractive other aspects may be. The specified conditions must be accepted by the owner to ensure satisfaction. The system design must fulfill both indoor and outdoor capacity requirements, as different system types may necessitate varying total building capacities to achieve similar results. Notably, system capacity can be reduced if stringent indoor conditions are relaxed, even partially. However, a decrease in the control zone could result in the area being uncomfortable for thousands of hours each year, and a reduction in peak capacity might lead to discomfort for 100 to 200 hours annually. Lastly, the system must fit within the available space in the building while considering installation costs, operational efficiency, and noise levels to ensure optimal performance and user satisfaction (David M. Elovitz, PE. 2002). For this reason, the specifications of the system were analyzed and properly selected based on requirements.

4.4.1 VRV System

Indoor and outdoor units were selected based on the space CFM and capacity load requirements referring to APPENDIX D part 1. The office building requires a single unit outdoors with 12hp capacity as shown in Table 4.6. While for the outdoor units to be installed in the classroom building, the combination of outdoor was needed and followed as APPENDIX D part 2. The selection of the indoor unit also was decided based on APPENDIX D part 3. Overall, the indoor capacity range selected was between 2hp-3hp based on space requirements. The Figure 4.3 below shows an overview of the location of the unit in VRV system, and the APPENDIX E part 3 and APPENDIX E part 4 provides a detailed location of the unit.

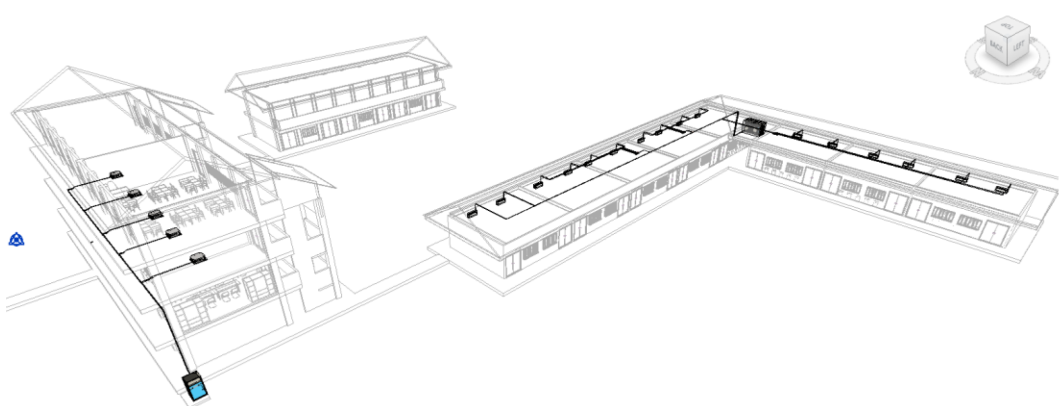

Figure 4.3 VRV System Implementation in Revit 2025

Table 4.6 Unit Selection of VRV System

Building	System	Space	Indoor			Outdoor	
			Model	Capacity	Unit	Model	kW
Office	VRV	Meeting Room	FXFQ-AVM	2hp	1	RXUQ12A	33.5
				3hp	1		
		Teachers Room	FXFQ-AVM	2hp	3		
Classroom	VRV	1 UTM	FXAQ-AVM	2hp	2	RXUQ32AM (RXUQ12A + RXUQ20A)	89.5
		1 UPM	FXAQ-AVM	2hp	2		
		1 UTEM	FXAQ-AVM	2hp	2		
		3 UTM	FXAQ-AVM	2hp	2		
		3 UTEM	FXAQ-AVM	2hp	2		
		3 UPM	FXAQ-AVM	2hp	2		
		1 UKM	FXAQ-AVM	2hp	2		
		1 USM	FXAQ-AVM	2hp	2		

Dimensions of each component such as copper pipe and joint must be followed by specification of selected model. The sizing of pipe was selected based on the specification from manufacturer as Table 4.7 below. For several manufacturer provides refnet header which the piping from indoor unit can be placed separately from the refnet header. This innovation product typically cuts the installation cost from refrigerant amount and sizing of piping factor. The product diagram is shown in the figure below. But there are issues with how much indoor units the refnet header can support and also several manufacturers do not provide the product which will be one of factor in manufacturer selection in order to cut installation cost. There are products differences of connectable indoor unit compared among the manufacturers. The example showing the refnet header installation on 3D model was shown as figure below. This tool is ideal for small-size properties and condominiums and makes fewer piping connections. An easy installation with substantial use of soft copper pipes will be.

Table 4.7 Refrigerant Line Properties of VRV System

Model	RXUQ12AYM	RXUQ32AMYM	FXFQ50AVM	FXFQ80AVM	FXAQ50AVM
Refrigerant type	R-410A				
Liquid Piping Diameter, mm			**2hp**	**3hp**	**2hp**
	12.7	19.1	6.4	9.5	6.4
Gas Piping Diameter, mm	28.6	34.9	12.7	15.9	12.7

4.4.2 Split-unit System

Using APPENDIX D part 4 as a reference, indoor and outdoor units were chosen according to the space CFM and capacity load requirements. For the open space as teachers room and meeting room, the best suit type is selected to cassette type which is located in the center of the space. 3 units of cassette type are required in teachers' room with 2hp capacity each. While the meeting room requires two units of 2hp and 3hp as in Table 4.8. For each classroom, they require a pair of 2.5hp and 2hp to fulfil the requirements of CFM needed. On the principles of APPENDIX D part 4, the indoor unit was also chosen. Based on space considerations, an indoor capacity range of 2 horsepower to 3 horsepower was selected. The overall description to show the installation of the split-unit system was as Figure 4.4 below and the APPENDIX E part 1 and APPENDIX E part 2 shows the detailed position of the unit located.

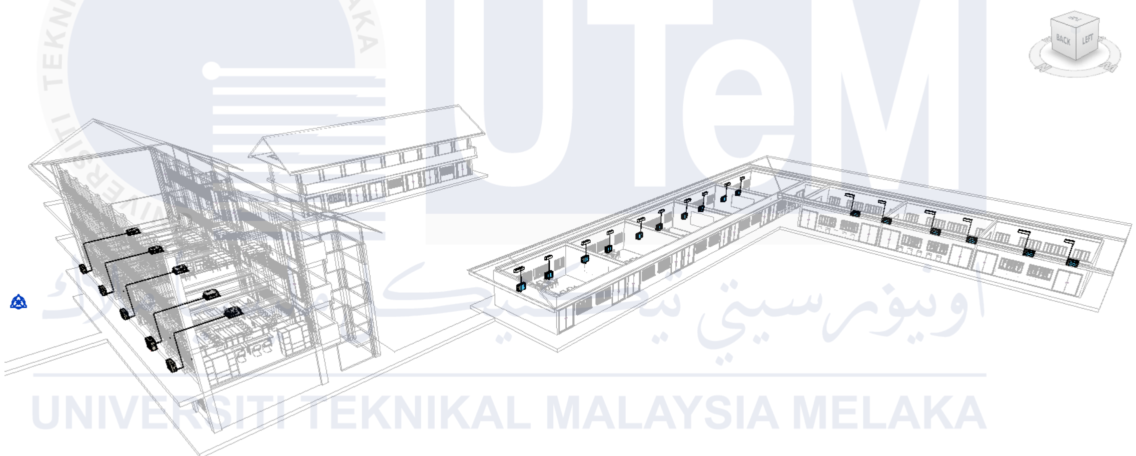

Figure 4.4 Split-unit Implementation in Revit 2025

Table 4.8 Unit Selection of Split-unit System

Building	Space	Indoor			Outdoor		Refrigerant
		Model	Capacity	Unit	Model	kW	
Office	Meeting Room	FCC50AV1MF	2hp	1	RC50BV1M	1.7	R32
		FCC85AV1MF	3hp	1	RC85BV1M	2.7	
	Teachers Room	FCC50AV1MF	2hp	3	RC50BV1M	1.7	
Classroom	1 UTM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	
	1 UPM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	
	1 UTEM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	
	3 UTM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	
	3 UTEM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	
	3 UPM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	
	1 UKM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	
	1 USM	FTKF50CV1MF	2hp	2	RKF50CV1M	1.9	

The specifications of the chosen model need to comply to the dimensions of every component, including copper pipes. The pipe's size was chosen in accordance with the manufacturer's specifications, as shown in Table 4.9 below.

Table 4.9 Refrigerant Line Properties of Split-unit System

Model	FCC50AV1MF	FCC85AV1MF	FTKF50CV1MF	FTKF71CV1MF
Refrigerant type	R32			
Liquid Piping Diameter, inch	¼"	3/8"	¼"	¼"
Gas Piping Diameter, inch	½"	5/8"	½"	½"

4.5 Energy Analysis

An important component of improving a building's sustainability and performance is energy analysis. It involves an analytical examination of a facility's overall energy performance, efficiency, and patterns of energy consumption. The objective of this procedure is to find situations in which energy use can be reduced without affecting functioning or occupant comfort. The graph in Figure 4.5 below shows the energy use from both systems in the year 2024. This study believes that the differences of energy use between each month was influenced by weather factors. This factor was proved by previous research when they discovered four commercial buildings in two distinct temperature zones in the Pacific Northwest to determine how much energy their HVAC systems used in response to various weather conditions (Hadley, D. L. 1993).

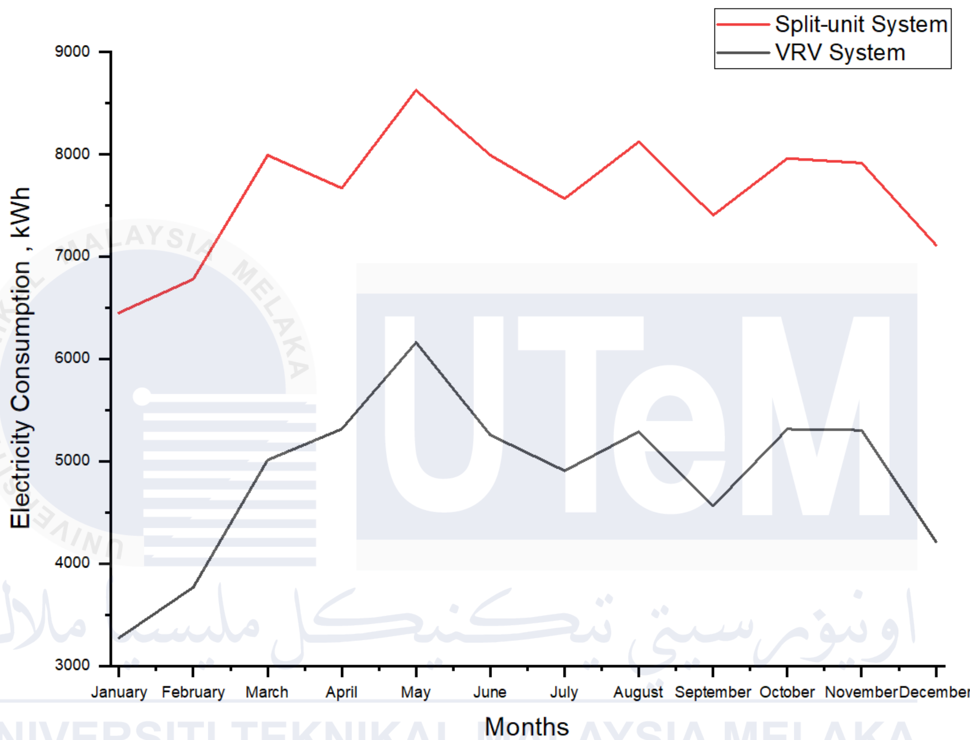

Figure 4.5 Energy Consumption by VRV and Split-unit

The performance of both types of systems was shown by using the Carrier HAP program for energy analysis. The selection of suitable solutions to satisfy cooling demands while maximizing energy use was made easier by the hourly analysis. It was concluded that the VRV system was a practical way to achieve the required cooling capacity while improving indoor environmental management.

The cost, performance, and space efficiency differences between split-unit and VRV systems were highlighted. Despite its higher initial cost, the VRV system has benefits in terms of flexibility and energy efficiency, especially for buildings with limited ducting space. However, the split-unit method was thought to be more appropriate for smaller installations with less financial impact.

4.5.1 VRV System Electricity Consumption

The input results for terminal unit and terminal fan were collected for both buildings to analyze total annual electricity consumption of VRV system components. Table 4.10 below shows the results of electricity consumption each month. The results from Carrier HAP v6 were generated as in APPENDIX F part 3 for classroom and APPENDIX F part 4 for office buildings.

Table 4.10 Monthly Energy Consumption of VRV System

VRV System			
Month	**Terminal Unit Cig Input(kWh)**	**Terminal Fan (kWh)**	**Total (kWh)**
January	3122	152	3274
February	3649	119	3768
March	4841	170	5011
April	5155	160	5315
May	5984	178	6162
June	5089	167	5256
July	4743	164	4907
August	5116	173	5289
September	4404	159	4563
October	5144	170	5314
November	5137	166	5303
December	4055	160	4215
Total Annual Electricity(kWh)			58377

4.5.2 Split-Unit System Electricity Consumption

In order to examine the overall yearly electricity consumption of the split-unit system components, the input results for the terminal unit and terminal fan were gathered for both buildings. The results of monthly electricity consumption are displayed as APPENDIX F part 2 for office buildings and APPENDIX F part 3 for classroom and then concluded in Table 4.11 below.

Table 4.11 Monthly Energy Consumption of Split-unit System

Split Unit System			
Month	**Terminal Unit CIg Input(kWh)**	**Terminal Fan (kWh)**	**Total (kWh)**
January	4921	146	5067
February	5262	135	5397
March	6454	155	6609
April	6149	138	6287
May	7086	157	7243
June	6458	150	6608
July	6040	143	6183
August	6585	156	6741
September	5878	143	6021
October	6426	150	6576
November	6384	149	6533
December	5588	143	5731
Total Annual Electricity (kWh)			74996

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study highlights how important energy analysis and specific HVAC system design are to achieving thermal comfort and energy efficiency in schools. The results highlight the limitations of SK Durian Tunggal's current systems and provide an argument for replacing them with a VRV system in order to effectively manage the cooling demands. Making selection based on data was made possible by the precise analysis of cooling loads and energy performance made possible by the use of advanced tools like Revit 2025 and Carrier HAP. The main objective of the suggestions made here is to improve the thermal environment for occupants while promoting operational effectiveness and energy sustainability.

5.2 Recommendation for Improvement

This study shows how important it is to upgrade SK Durian Tunggal's HVAC systems in order to improve the thermal comfort problems that have been found. To effectively satisfy the cooling load requirements, several recommendations were made such as:

a) Replace the current air-conditioning system with higher-capacity VRV systems.
b) Having along with modern energy-saving techniques like better insulation and smart control systems can maximize HVAC system performance while lowering operating costs.
c) Routine maintenance and monitoring should be done.

d) This thesis did not analyze the financial effects of the suggested improvements, instead concentrating on thermal comfort and energy efficiency. It was recommended that to analyze the cost for both systems. The result of the financial analysis can be compared with energy consumption by both systems.

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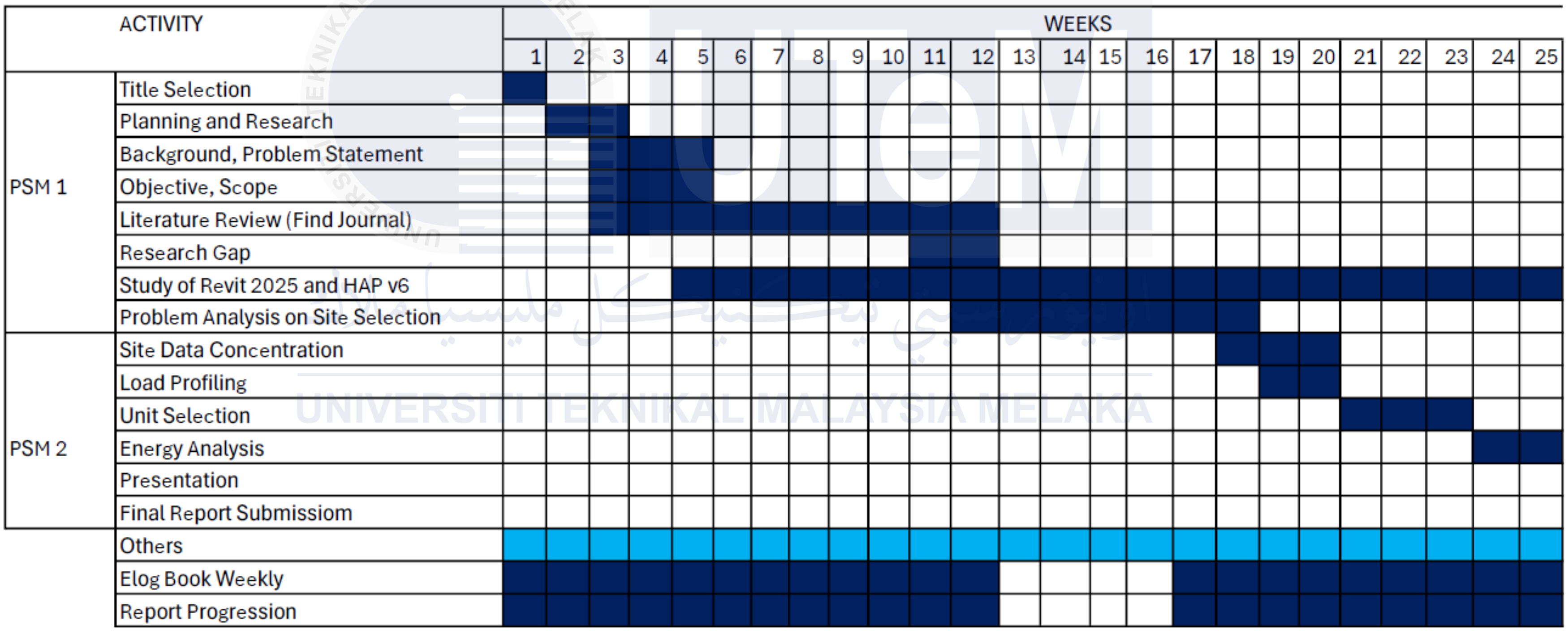
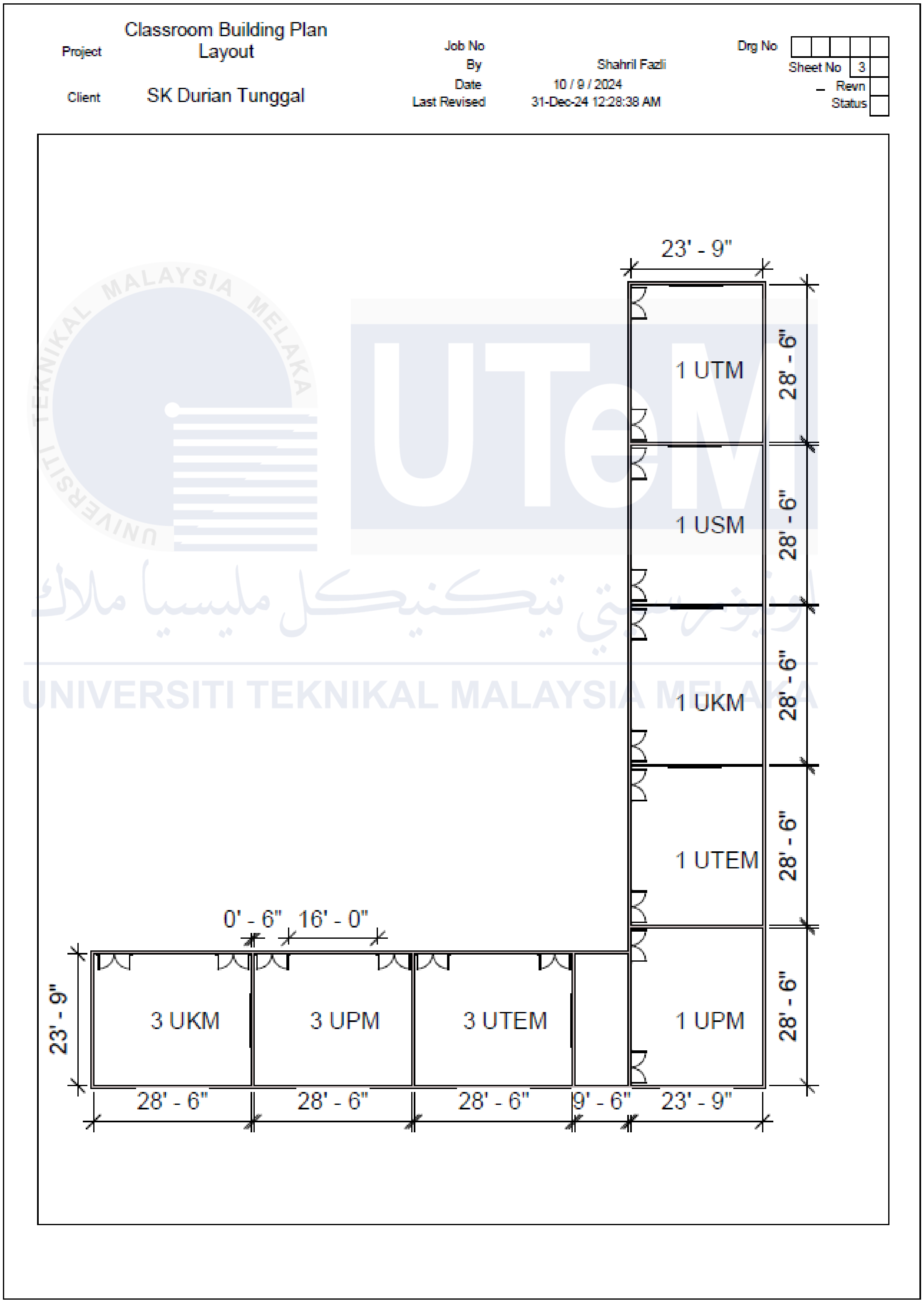
APPENDICES

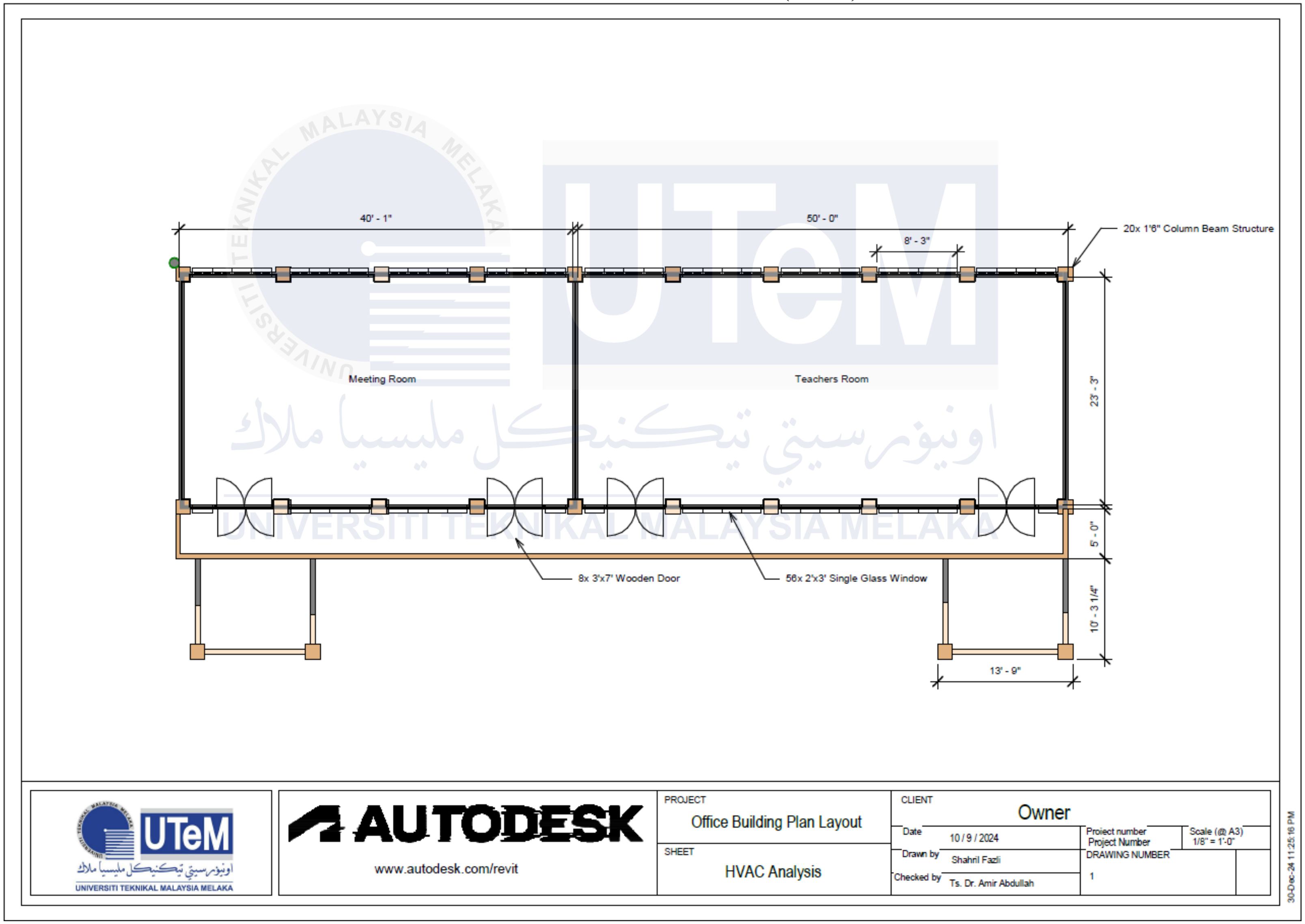
APPENDIX A
GANTT CHART



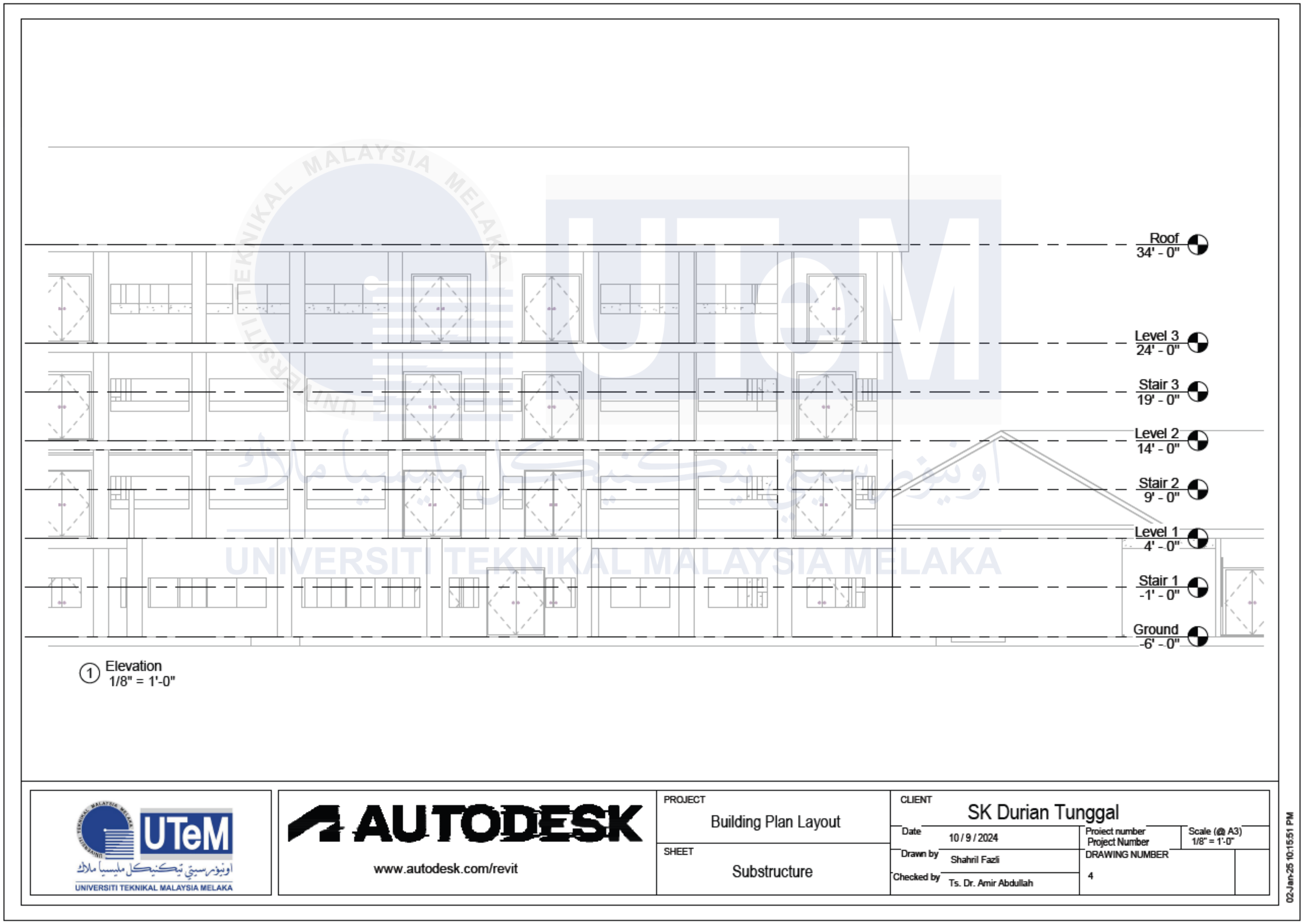
APPENDIX B
CLASSROOM BUILDING LAYOUT (Part 1)



OFFICE BUILDING LAYOUT (Part 2)



LEVEL ELEVATION (Part 3)



APPENDIX C
COOLING LOAD ANALYSIS RESULTS

Zone Load Summary | Zone Meeting Room | COOLING

CONDITIONS AT TIME OF PEAK

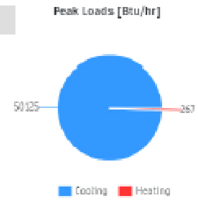
Time at Peak: 5/21 15:45:00

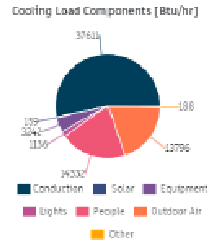
Outside
DB: 92.8 F
HR: 0.0196 lb/lb
WB: 80.3 F

Zone
DB: 74.9 F
HR: 0.0106 lb/lb
RH: 57.5 %

ENGINEERING CHECKS

Capacity per Floor Area: 26.38 Btu/hr-ft2
Floor Area per Capacity: 37.9058 ft2/kBtu-hr
Outdoor Air Percentage: 13.89 %
Airflow per Floor Area: 0.880987 ft3/min-ft2
Airflow per Capacity: 400.735029 ft3/min-ton
Number of People: 35.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	23,488	-	23,488	46.9
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	1,280	-	-	1,280	2.6
Glass - Solar	-	159	-	159	0.3
Door	-	449	-	449	0.9
Wall	-	731	-	731	1.5
Below-grade Wall	-	0	-	0	0.0
Partition	-	3	-	3	0.0
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	-9,981	-	-9,981	-19.9
Slab	-	0	-	0	0.0
Other - Floor	-	0	-	0	0.0
Infiltration	531	-	1,149	1,680	3.4
Subtotal	**1,811**	**14,848**	**1,149**	**17,808**	**35.5**
Internal Gains					
People	6,125	1,207	7,000	14,332	28.6
Lights	1,136	0	-	1,136	2.3
Return Air - Lights	0	-	-	0	0.0
Equipment	3,242	0	0	3,242	6.5
Subtotal	**10,503**	**1,207**	**7,000**	**18,710**	**37.3**
Systems					
Zone Ventilation	4,361	-	9,435	13,796	27.5
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**4,361**	**0**	**9,435**	**13,796**	**27.5**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-188	-	-188	-0.4
Grand Total	**16,675**	**15,866**	**17,584**	**50,125**	**100.0**

Zone Load Summary | Zone 1 UTM | COOLING

CONDITIONS AT TIME OF PEAK

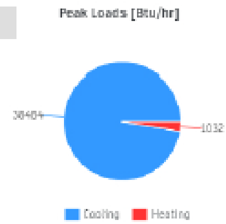
Time at Peak: 3/21 17:00:00

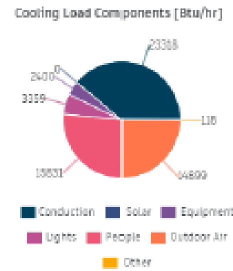
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F

Zone
DB: 74.9 F
HR: 0.0114 lb/lb
RH: 61.7 %

ENGINEERING CHECKS

Capacity per Floor Area:	54.73 Btu/hr-ft2
Floor Area per Capacity:	18.2729 ft2/kBtu-hr
Outdoor Air Percentage:	30.12 %
Airflow per Floor Area:	1.627112 ft3/min-ft2
Airflow per Capacity:	356.785386 ft3/min-ton
Number of People:	40.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,436	-	12,436	32.3
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	78	-	78	0.2
Below-grade Wall	-	-5,452	-	-5,452	-14.2
Partition	-	183	-	183	0.5
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-5,151	-	-5,151	-13.4
Other - Floor	-	0	-	0	0.0
Infiltration	8	-	10	18	0.0
Subtotal	**8**	**2,094**	**10**	**2,112**	**5.5**
Internal Gains					
People	7,000	831	8,000	15,831	41.1
Lights	3,359	0	-	3,359	8.7
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.2
Subtotal	**12,759**	**831**	**8,000**	**21,590**	**56.1**
Systems					
Zone Ventilation	6,550	-	8,349	14,899	38.7
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,550**	**0**	**8,349**	**14,899**	**38.7**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-118	-	-118	-0.3
Grand Total	**19,317**	**2,808**	**16,359**	**38,484**	**100.0**

Zone Load Summary | Zone 1 UPM | COOLING

CONDITIONS AT TIME OF PEAK

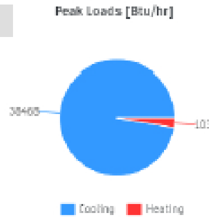
Time at Peak: 3/21 17:00:00

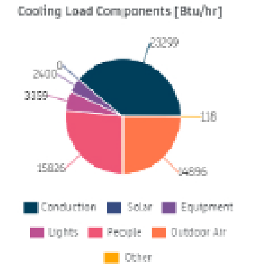
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F

Zone
DB: 74.9 F
HR: 0.0114 lb/lb
RH: 61.7 %

ENGINEERING CHECKS

Capacity per Floor Area: 54.70 Btu/hr-ft2
Floor Area per Capacity: 18.2804 ft2/kBtu-hr
Outdoor Air Percentage: 30.14 %
Airflow per Floor Area: 1.627112 ft3/min-ft2
Airflow per Capacity: 356.931280 ft3/min-ton
Number of People: 40.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,435	-	12,435	32.3
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	78	-	78	0.2
Below-grade Wall	-	-5,449	-	-5,449	-14.2
Partition	-	171	-	171	0.4
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-5,149	-	-5,149	-13.4
Other - Floor	-	0	-	0	0.0
Infiltration	8	-	10	18	0.0
Subtotal	**8**	**2,086**	**10**	**2,104**	**5.5**
Internal Gains					
People	7,000	826	8,000	15,826	41.1
Lights	3,359	0	-	3,359	8.7
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.2
Subtotal	**12,759**	**826**	**8,000**	**21,585**	**56.1**
Systems					
Zone Ventilation	6,549	-	8,347	14,896	38.7
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,549**	**0**	**8,347**	**14,896**	**38.7**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-118	-	-118	-0.3
Grand Total	**19,316**	**2,795**	**16,357**	**38,468**	**100.0**

Zone Load Summary

Zone Teachers Room | COOLING

CONDITIONS AT TIME OF PEAK

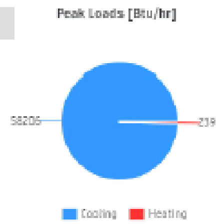
Time at Peak: 5/21 16:00:00

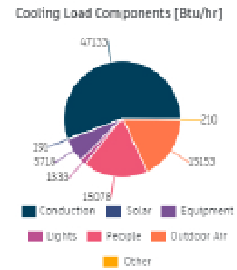
Outside
DB: 92.6 F
HR: 0.0196 lb/lb
WB: 80.3 F

Zone
DB: 74.9 F
HR: 0.0104 lb/lb
RH: 56.5 %

ENGINEERING CHECKS

Capacity per Floor Area: 28.51 Btu/hr-ft2
Floor Area per Capacity: 35.0735 ft2/kBtu-hr
Outdoor Air Percentage: 12.60 %
Airflow per Floor Area: 0.975637 ft3/min-ft2
Airflow per Capacity: 410.629094 ft3/min-ton
Number of People: 37.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	28,243	-	28,243	48.5
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	1,543	-	-	1,543	2.7
Glass - Solar	-	191	-	191	0.3
Door	-	471	-	471	0.8
Wall	-	1,755	-	1,755	3.0
Below-grade Wall	-	0	-	0	0.0
Partition	-	48	-	48	0.1
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	-10,239	-	-10,239	-17.6
Slab	-	-2,856	-	-2,856	-4.9
Other - Floor	-	0	-	0	0.0
Infiltration	612	-	1,366	1,978	3.4
Subtotal	**2,154**	**17,613**	**1,366**	**21,134**	**36.3**
Internal Gains					
People	6,475	1,203	7,400	15,078	25.9
Lights	1,333	0	-	1,333	2.3
Return Air - Lights	0	-	-	0	0.0
Equipment	5,718	0	0	5,718	9.8
Subtotal	**13,526**	**1,203**	**7,400**	**22,129**	**38.0**
Systems					
Zone Ventilation	4,687	-	10,466	15,153	26.0
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**4,687**	**0**	**10,466**	**15,153**	**26.0**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-210	-	-210	-0.4
Grand Total	**20,367**	**18,607**	**19,232**	**58,206**	**100.0**

Zone Load Summary | Zone 1 UTEM | COOLING

CONDITIONS AT TIME OF PEAK

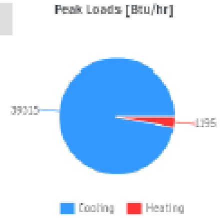
Time at Peak: 3/21 17:00:00

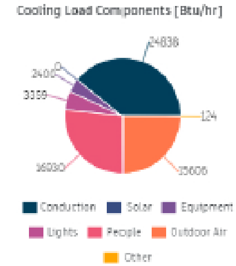
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F

Zone
DB: 74.9 F
HR: 0.0116 lb/lb
RH: 62.5 %

ENGINEERING CHECKS

Capacity per Floor Area: 55.91 Btu/hr-ft2
Floor Area per Capacity: 17.8866 ft2/kBtu-hr
Outdoor Air Percentage: 32.17 %
Airflow per Floor Area: 1.627112 ft3/min-ft2
Airflow per Capacity: 349.243087 ft3/min-ton
Number of People: 43.0



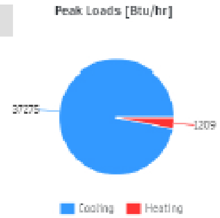


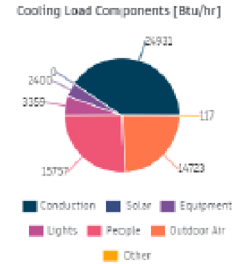
	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,747	-	12,747	32.4
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	106	-	106	0.3
Below-grade Wall	-	-7,140	-	-7,140	-18.2
Partition	-	113	-	113	0.3
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-4,707	-	-4,707	-12.0
Other - Floor	-	0	-	0	0.0
Infiltration	11	-	14	25	0.1
Subtotal	**11**	**1,119**	**14**	**1,144**	**2.9**
Internal Gains					
People	7,525	805	8,600	16,930	43.1
Lights	3,359	0	-	3,359	8.5
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.1
Subtotal	**13,284**	**805**	**8,600**	**22,689**	**57.7**
Systems					
Zone Ventilation	6,981	-	8,625	15,606	39.7
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,981**	**0**	**8,625**	**15,606**	**39.7**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-124	-	-124	-0.3
Grand Total	**20,276**	**1,799**	**17,239**	**39,315**	**100.0**

Zone Load Summary | Zone 3 UTM | COOLING

CONDITIONS AT TIME OF PEAK
Time at Peak: 3/21 17:00:00
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F
Zone
DB: 74.9 F
HR: 0.0115 lb/lb
RH: 62.3 %

ENGINEERING CHECKS	
Capacity per Floor Area:	53.01 Btu/hr-ft2
Floor Area per Capacity:	18.8652 ft2/kBtu-hr
Outdoor Air Percentage:	31.61 %
Airflow per Floor Area:	1.536717 ft3/min-ft2
Airflow per Capacity:	347.886945 ft3/min-ton
Number of People:	40.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,765	-	12,765	34.2
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	91	-	91	0.2
Below-grade Wall	-	-7,146	-	-7,146	-19.2
Partition	-	161	-	161	0.4
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-4,743	-	-4,743	-12.7
Other - Floor	-	0	-	0	0.0
Infiltration	11	-	14	25	0.1
Subtotal	**11**	**1,128**	**14**	**1,153**	**3.1**
Internal Gains					
People	7,000	757	8,000	15,757	42.3
Lights	3,359	0	-	3,359	9.0
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.4
Subtotal	**12,759**	**757**	**8,000**	**21,516**	**57.7**
Systems					
Zone Ventilation	6,549	-	8,174	14,723	39.5
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,549**	**0**	**8,174**	**14,723**	**39.5**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-117	-	-117	-0.3
Grand Total	**19,319**	**1,768**	**16,188**	**37,275**	**100.0**

Zone Load Summary | Zone 3 UTEM | COOLING

CONDITIONS AT TIME OF PEAK

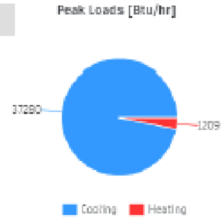
Time at Peak: 3/21 17:00:00

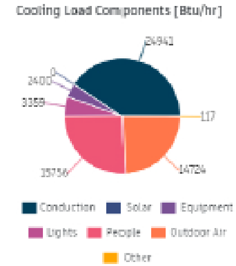
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F

Zone
DB: 74.9 F
HR: 0.0115 lb/lb
RH: 62.3 %

ENGINEERING CHECKS

Capacity per Floor Area: 53.01 Btu/hr-ft2
Floor Area per Capacity: 18.8627 ft2/kBtu-hr
Outdoor Air Percentage: 31.60 %
Airflow per Floor Area: 1.536717 ft3/min-ft2
Airflow per Capacity: 347.840775 ft3/min-ton
Number of People: 40.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,765	-	12,765	34.2
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	97	-	97	0.3
Below-grade Wall	-	-7,147	-	-7,147	-19.2
Partition	-	162	-	162	0.4
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-4,744	-	-4,744	-12.7
Other - Floor	-	0	-	0	0.0
Infiltration	11	-	14	25	0.1
Subtotal	**11**	**1,133**	**14**	**1,158**	**3.1**
Internal Gains					
People	7,000	756	8,000	15,756	42.3
Lights	3,359	0	-	3,359	9.0
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.4
Subtotal	**12,759**	**756**	**8,000**	**21,515**	**57.7**
Systems					
Zone Ventilation	6,549	-	8,175	14,724	39.5
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,549**	**0**	**8,175**	**14,724**	**39.5**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-117	-	-117	-0.3
Grand Total	**19,319**	**1,772**	**16,189**	**37,280**	**100.0**

Zone Load Summary

Zone 3 UPM | COOLING

CONDITIONS AT TIME OF PEAK

Time at Peak: 3/21 17:00:00

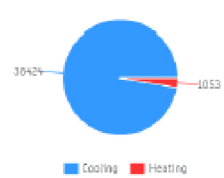
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F

Zone
DB: 74.9 F
HR: 0.0114 lb/lb
RH: 61.7 %

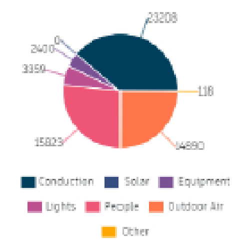
ENGINEERING CHECKS

Capacity per Floor Area: 54.64 Btu/hr-ft2
Floor Area per Capacity: 18.3014 ft2/kBtu-hr
Outdoor Air Percentage: 30.19 %
Airflow per Floor Area: 1.596980 ft3/min-ft2
Airflow per Capacity: 350.724000 ft3/min-ton
Number of People: 40.0

Peak Loads [Btu/hr]



Cooling Load Components [Btu/hr]



	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,489	-	12,489	32.5
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	51	-	51	0.1
Below-grade Wall	-	-5,437	-	-5,437	-14.1
Partition	-	81	-	81	0.2
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-5,133	-	-5,133	-13.4
Other - Floor	-	0	-	0	0.0
Infiltration	8	-	10	18	0.0
Subtotal	**8**	**2,051**	**10**	**2,069**	**5.4**
Internal Gains					
People	7,000	823	8,000	15,823	41.2
Lights	3,359	0	-	3,359	8.7
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.2
Subtotal	**12,759**	**823**	**8,000**	**21,582**	**56.2**
Systems					
Zone Ventilation	6,550	-	8,340	14,890	38.8
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,550**	**0**	**8,340**	**14,890**	**38.8**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-118	-	-118	-0.3
Grand Total	**19,316**	**2,757**	**16,351**	**38,424**	**100.0**

Zone Load Summary

Zone 1 UKM | COOLING

CONDITIONS AT TIME OF PEAK

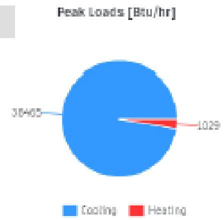
Time at Peak: 3/21 17:00:00

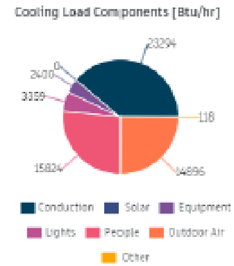
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F

Zone
DB: 74.9 F
HR: 0.0114 lb/lb
RH: 61.7 %

ENGINEERING CHECKS

Capacity per Floor Area: 54.70 Btu/hr-ft2
Floor Area per Capacity: 18.2815 ft2/kBtu-hr
Outdoor Air Percentage: 30.14 %
Airflow per Floor Area: 1.627112 ft3/min-ft2
Airflow per Capacity: 356.953444 ft3/min-ton
Number of People: 40.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,442	-	12,442	32.3
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	78	-	78	0.2
Below-grade Wall	-	-5,447	-	-5,447	-14.2
Partition	-	161	-	161	0.4
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-5,148	-	-5,148	-13.4
Other - Floor	-	0	-	0	0.0
Infiltration	8	-	10	18	0.0
Subtotal	**8**	**2,086**	**10**	**2,104**	**5.5**
Internal Gains					
People	7,000	824	8,000	15,824	41.1
Lights	3,359	0	-	3,359	8.7
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.2
Subtotal	**12,759**	**824**	**8,000**	**21,583**	**56.1**
Systems					
Zone Ventilation	6,550	-	8,346	14,896	38.7
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,550**	**0**	**8,346**	**14,896**	**38.7**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-118	-	-118	-0.3
Grand Total	**19,317**	**2,792**	**16,357**	**38,465**	**100.0**

Zone Load Summary

Zone 1 USM | COOLING

CONDITIONS AT TIME OF PEAK

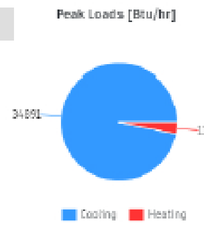
Time at Peak: 3/21 17:00:00

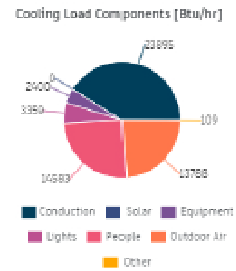
Outside
DB: 93.0 F
HR: 0.0168 lb/lb
WB: 77.4 F

Zone
DB: 74.9 F
HR: 0.0115 lb/lb
RH: 62.1 %

ENGINEERING CHECKS

Capacity per Floor Area: 49.62 Btu/hr-ft2
Floor Area per Capacity: 20.1546 ft2/kBtu-hr
Outdoor Air Percentage: 31.44 %
Airflow per Floor Area: 1.446322 ft3/min-ft2
Airflow per Capacity: 349.801512 ft3/min-ton
Number of People: 37.0





	Instant Sensible [Btu/hr]	Delayed Sensible [Btu/hr]	Latent [Btu/hr]	Total [Btu/hr]	Percent of Total [%]
Envelope					
Roof	-	12,099	-	12,099	34.7
Other - Roof	-	0	-	0	0.0
Ceiling	-	0	-	0	0.0
Glass - Conduction	0	-	-	0	0.0
Glass - Solar	-	0	-	0	0.0
Door	-	0	-	0	0.0
Wall	-	104	-	104	0.3
Below-grade Wall	-	-6,918	-	-6,918	-19.8
Partition	-	154	-	154	0.4
Other - Wall	-	0	-	0	0.0
Exterior Floor	-	0	-	0	0.0
Interior Floor	-	0	-	0	0.0
Slab	-	-4,595	-	-4,595	-13.2
Other - Floor	-	0	-	0	0.0
Infiltration	11	-	14	25	0.1
Subtotal	**11**	**845**	**14**	**870**	**2.5**
Internal Gains					
People	6,475	708	7,400	14,583	41.8
Lights	3,359	0	-	3,359	9.6
Return Air - Lights	0	-	-	0	0.0
Equipment	2,400	0	0	2,400	6.9
Subtotal	**12,234**	**708**	**7,400**	**20,342**	**58.3**
Systems					
Zone Ventilation	6,117	-	7,671	13,788	39.5
Transfer Air	0	-	0	0	0.0
DOAS Direct to Zone	0	-	0	0	0.0
Return Air - Other	0	-	-	0	0.0
Power Generation Equipment	0	0	-	0	0.0
Refrigeration	0	-	0	0	0.0
Water Use Equipment	0	-	0	0	0.0
HVAC Equipment Loss	0	0	-	0	0.0
Subtotal	**6,117**	**0**	**7,671**	**13,788**	**39.5**
Total					
Sizing Factor Adjustment	0	-	-	0	0.0
Time Delay Correction	-	-109	-	-109	-0.3
Grand Total	**18,363**	**1,443**	**15,085**	**34,891**	**100.0**

VRV X SERIES OUTDOOR UNIT LINE UP (Part 1)

Outdoor Unit Lineup

VRV X Series

The outdoor unit capacity is up to 60 HP (168 kW) in increments of 2 HP.

Lineup

	HP	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
VRV X SERIES	Single outdoor units	●	●	●	●	●	●	●	●																				
	Double outdoor units				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●										
	Triple outdoor units							●	●											●	●	●	●	●	●	●	●	●	●

Outdoor unit combinations

HP	kW	Capacity index	Model name	Combination	Outdoor unit multi connection piping kit*1	Total capacity index of connectable indoor units*2	Maximum number of connectable indoor units*2
6	16.0	150	RXUQ6A	RXUQ6A	–	75 to 195 (300)	9 (15)
8	22.4	200	RXUQ8A	RXUQ8A	–	100 to 260 (400)	13 (20)
10	28.0	250	RXUQ10A	RXUQ10A	–	125 to 325 (500)	16 (25)
12	33.5	300	RXUQ12A	RXUQ12A	–	150 to 390 (600)	19 (30)
14	40.0	350	RXUQ14A	RXUQ14A	–	175 to 455 (700)	22 (35)
16	45.0	400	RXUQ16A	RXUQ16A	–	200 to 520 (800)	26 (40)
18	50.0	450	RXUQ18A	RXUQ18A	–	225 to 585 (900)	29 (45)
20	56.0	500	RXUQ20A	RXUQ20A	–	250 to 650 (1,000)	32 (50)
12	32.0	300	RXUQ12AM	RXUQ6A + RXUQ6A	BHFP22P100	150 to 390 (480)	19 (24)
14	38.4	350	RXUQ14AM	RXUQ6A + RXUQ8A		175 to 455 (560)	22 (28)
16	44.8	400	RXUQ16AM	RXUQ8A + RXUQ8A		200 to 520 (640)	26 (32)
18	50.4	450	RXUQ18AM	RXUQ8A + RXUQ10A		225 to 585 (720)	29 (36)
20	55.9	500	RXUQ20AM	RXUQ8A + RXUQ12A		250 to 650 (800)	32 (40)
18	48.0	450	RXUQ18AM1	RXUQ6A x 3	BHFP22P151	225 to 585 (585)	29 (29)
20	54.4	500	RXUQ20AM1	RXUQ6A x 2 + RXUQ8A		250 to 650 (650)	32 (32)
22	61.5	550	RXUQ22AM	RXUQ10A + RXUQ12A	BHFP22P100	275 to 715 (880)	35 (44)
24	67.0	600	RXUQ24AM	RXUQ12A x 2		300 to 780 (960)	39 (48)
26	73.5	650	RXUQ26AM	RXUQ12A + RXUQ14A		325 to 845 (1,040)	42 (52)
28	78.5	700	RXUQ28AM	RXUQ12A + RXUQ16A		350 to 910 (1,120)	45 (56)
30	83.5	750	RXUQ30AM	RXUQ12A + RXUQ18A		375 to 975 (1,200)	48 (60)
32	89.5	800	RXUQ32AM	RXUQ12A + RXUQ20A		400 to 1,040 (1,280)	52 (64)
34	96.0	850	RXUQ34AM	RXUQ14A + RXUQ20A		425 to 1,105 (1,360)	55 (64)
36	101	900	RXUQ36AM	RXUQ16A + RXUQ20A		450 to 1,170 (1,440)	58 (64)
38	106	950	RXUQ38AM	RXUQ18A + RXUQ20A		475 to 1,235 (1,520)	61 (64)
40	112	1,000	RXUQ40AM	RXUQ20A x 2		500 to 1,300 (1,600)	64 (64)
42	117	1,050	RXUQ42AM	RXUQ12A x 2 + RXUQ18A	BHFP22P151	525 to 1,365 (1,365)	64 (64)
44	123	1,100	RXUQ44AM	RXUQ12A x 2 + RXUQ20A		550 to 1,430 (1,430)	
46	130	1,150	RXUQ46AM	RXUQ12A + RXUQ14A + RXUQ20A		575 to 1,495 (1,495)	
48	135	1,200	RXUQ48AM	RXUQ12A + RXUQ16A+ RXUQ20A		600 to 1,560 (1,560)	
50	140	1,250	RXUQ50AM	RXUQ12A + RXUQ18A + RXUQ20A		625 to 1,625 (1,625)	
52	146	1,300	RXUQ52AM	RXUQ12A + RXUQ20A x 2		650 to 1,690 (1,690)	
54	152	1,350	RXUQ54AM	RXUQ14A + RXUQ20A x 2		675 to 1,755 (1,755)	
56	157	1,400	RXUQ56AM	RXUQ16A + RXUQ20A x 2		700 to 1,820 (1,820)	
58	162	1,450	RXUQ58AM	RXUQ18A + RXUQ20A x 2		725 to 1,885 (1,885)	
60	168	1,500	RXUQ60AM	RXUQ20A x 3		750 to 1,950 (1,950)	

Notes: *1. For multiple connection, the outdoor unit multi connection piping kit (separately sold) is required.
*2. Values inside brackets are based on connection of indoor units rated at maximum capacity, 200% for single outdoor units, 160% for double outdoor units, and 130% for triple outdoor units. Refer to page 24 for notes on connection capacity of indoor units.

VRV X SERIES INDOOR UNIT LINEUP (Part 2)

Outdoor Units

VRV X Series

Specifications

MODEL			RXUQ6AYM(W)	RXUQ8AYM(W)	RXUQ10AYM(W)	RXUQ12AYM(W)	RXUQ14AYM(W)	RXUQ16AYM(W)	RXUQ18AYM(W)	RXUQ20AYM(W)
Combination units			—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—
Power supply			3-phase 4-wire system, 380-415 V/380 V, 50/60 Hz							
Cooling capacity		Btu/h	54,600	76,400	95,500	114,000	136,000	154,000	171,000	191,000
		kW	16.0	22.4	28.0	33.5	40.0	45.0	50.0	56.0
Power consumption		kW	3.23	4.82	6.29	7.81	9.46	11.4	12.8	14.8
Capacity control		%	23-100	19-100	13-100	12-100	11-100	9-100		7-100
Casing colour			Ivory white (5Y7.5/1) (Metallic brown *)							
Compressor	Type		Hermetically sealed scroll type							
	Motor output	kW	2.4×1	3.4×1	4.2×1	5.2×1	(3.4×1)+(2.9×1)	(3.4×1)+(3.9×1)	(3.7×1)+(4.3×1)	(4.9×1)+(4.2×1)
Airflow rate		m³/min	119	178		191	218		268	297
Dimensions (H×W×D)		mm	1,657×930×765		1,657×1,240×765					
Machine weight		kg	185 (195 *)		215 (235 *)		275 (295 *)		291 (316 *)	
Sound level		dB(A)	54	56		58	59		62	65
Operation range		°CDB	10 to 49							
Refrigerant	Type		R-410A							
	Charge	kg	6.4	6.6	8.3	8.5	9.7	9.8	11.7	
Piping connections	Liquid	mm	ϕ 9.5 (Brazing)			ϕ 12.7 (Brazing)			ϕ 15.9 (Brazing)	
	Gas	mm	ϕ 19.1 (Brazing)		ϕ 22.2 (Brazing)	ϕ 28.6 (Brazing)				

MODEL			RXUQ28AMYM(W)	RXUQ30AMYM(W)	RXUQ32AMYM(W)	RXUQ34AMYM(W)	RXUQ36AMYM(W)	RXUQ38AMYM(W)	RXUQ40AMYM(W)
Combination units			RXUQ12AYM(W)	RXUQ12AYM(W)	RXUQ12AYM(W)	RXUQ14AYM(W)	RXUQ16AYM(W)	RXUQ18AYM(W)	RXUQ20AYM(W)
			RXUQ16AYM(W)	RXUQ18AYM(W)	RXUQ20AYM(W)	RXUQ20AYM(W)	RXUQ20AYM(W)	RXUQ20AYM(W)	RXUQ20AYM(W)
			—	—	—	—	—	—	—
Power supply			3-phase 4-wire system, 380-415 V/380 V, 50/60 Hz						
Cooling capacity		Btu/h	268,000	285,000	305,000	328,000	345,000	362,000	382,000
		kW	78.5	83.5	89.5	96.0	101	106	112
Power consumption		kW	19.2	20.6	22.6	24.3	26.2	27.6	29.6
Capacity control		%	5-100			4-100			
Casing colour			Ivory white (5Y7.5/1) (Metallic brown *)						
Compressor	Type		Hermetically sealed scroll type						
	Motor output	kW	(5.2x1)+(3.4x1)+(3.9x1)	(5.2x1)+(3.7x1)+(4.3x1)	(5.2x1)+(4.9x1)+(4.2x1)	(3.4x1)+(2.9x1)+(4.9x1)+(4.2x1)	(3.4x1)+(3.9x1)+(4.9x1)+(4.2x1)	(3.7x1)+(4.3x1)+(4.9x1)+(4.2x1)	(4.9x1)+(4.2x1)+(4.9x1)+(4.2x1)
Airflow rate		m³/min	191+218	191+268	191+297	218+297		268+297	297+297
Dimensions (H×W×D)		mm	(1,657×1,240×765)+(1,657×1,240×765)						
Machine weight		kg	215+275 (235+295 *)	215+291 (235+316 *)		275+291 (295+316 *)		291+291 (316+316 *)	
Sound level		dB(A)	62	63	66			67	68
Operation range		°CDB	10 to 49						
Refrigerant	Type		R-410A						
	Charge	kg	8.5+9.8	8.5+11.7		9.7+11.7	9.8+11.7	11.7+11.7	
Piping connections	Liquid	mm	ϕ 19.1 (Brazing)						
	Gas	mm	ϕ 34.9 (Brazing)				ϕ 41.3 (Brazing)		

Notes: Specifications are based on the following conditions;
- Cooling: Indoor temp.: 27°CDB, 19°CWB, Outdoor temp.: 35°CDB, Equivalent piping length: 7.5 m, Height difference: 0 m.
- Sound level: Anechoic chamber conversion value, measured at a point 1 m in front of the unit at a height of 1.5 m.
  During actual operation, these values are normally somewhat higher as a result of ambient conditions and oil recovery mode.
  When there is concern for noise to the surrounding area such as residences, we recommend investigating the installation location and taking soundproofing measures.

29

VRV X SERIES OUTDOOR UNIT SPECIFICATION (Part 3)

Indoor Unit Lineup

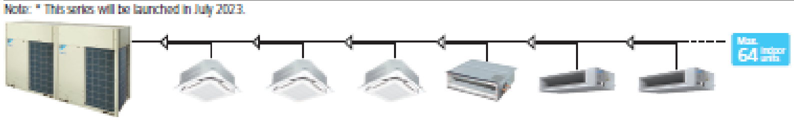
VRV X Series

Enhanced range of choices

● New lineup | VRT smart: Indoor units subject to VRT smart control | VRT: Indoor units subject to VRT control

Category	Type	Model Name	Control		20	25	32	40	50	63	71	80	100	125	140	200	250	400	500
				Capacity Range	0.8 HP	1 HP	1.25 HP	1.6 HP	2 HP	2.5 HP	3 HP	3.2 HP	4 HP	5 HP	6 HP	8 HP	10 HP	16 HP	20 HP
				Capacity Index	20	25	31.25	40	50	62.5	71	80	100	125	140	200	250	400	500
Ceiling Mounted Cassette	Round Flow Cassette with Sensing and Streamer	New **FXFTQ-AVM**	VRT smart			●	●	●	●	●		●	●	●	●				
	Round Flow Cassette with Streamer	New **FXFRQ-AVM**	VRT smart			●	●	●	●	●		●	●	●	●				
	Round Flow Cassette with Sensing	FXFSQ-AVM	VRT smart			●	●	●	●	●		●	●	●	●				
	Round Flow Cassette	FXFQ-AVM	VRT smart			●	●	●	●	●		●	●	●	●				
	Compact Multi Flow Cassette	New **FXZQ-BVM**	VRT smart		●	●	●	●	●										
	Double Flow Cassette	New **FXCQ-BVM**	VRT smart		●	●	●	●	●	●		●		●					
	Single Flow Cassette	FXKQ-MAVE	VRT			●	●	●		●									
Ceiling Concealed Duct	3D Airflow Duct with Sensing	FXDSQ-AVM	VRT		●	●	●	●	●	●									
	Bedroom Duct	FXDBQ-AVM	VRT smart					●	●	●		●							
	Slim Duct (Standard)	FXDQ-PDVE (with drain pump)	VRT smart	(700 mm width type)	●	●	●												
		FXDQ-PDVET (without drain pump)	VRT smart		●	●	●												
		FXDQ-NDVE (with drain pump)	VRT smart	(900/1,100 mm width type)				●	●	●									
		FXDQ-NDVET (without drain pump)	VRT smart					●	●	●									
	Slim Duct (Compact)	FXDQ-SPV1	VRT		●	●	●	●	●	●									
	Middle Static Pressure Duct	FXSQ-PAVE	VRT smart		●	●	●	●	●	●		●	●	●	●				
	Middle-High Static Pressure Duct	FXMQ-PAVE	VRT smart		●	●	●	●	●	●		●	●	●	●				
	High Static Pressure Duct	FXMQ-PVM	VRT smart													●	●		
	Outdoor-Air Processing Unit	FXMQ-MFV1												●		●	●		
		New **FXMQ-BFVM**	VRT									●			●	●	●		
Ceiling Suspended	4-Way Flow Ceiling Suspended	FXUQ-AVEB	VRT								●		●						
	Ceiling Suspended	FXHQ-MAVE	VRT				●			●			●						
		New **FXHQ-BVM**	VRT											●	●				
Wall Mounted		FXAQ-AVM	VRT smart		●	●	●	●	●	●									
Floor Standing	Floor Standing	FXLQ-MAVE	VRT		●	●	●	●	●	●									
	Concealed Floor Standing	FXNQ-MAVE	VRT		●	●	●	●	●	●									
	Floor Standing Duct	FXVQ-NY1	VRT											●		●	●	●	●
		FXVQ-NY16 (high static pressure type)	VRT																●
Clean Room Air Conditioner		FXBQ-PVE	VRT					●	●	●									
		FXBPQ-PVE	VRT							●									
Heat Reclaim Ventilator with DX-Coil		VKM-GCVE			Airflow rate 500-950 m³/h														
Heat Reclaim Ventilator		VAM-HVE			Airflow rate 150-2000 m³/h														
Air Handling Unit		AHUR														6–120 HP			

Note: * This series will be launched in July 2023.



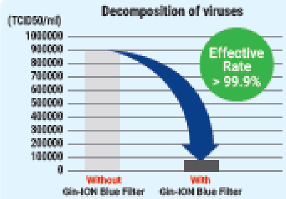
* If a system has indoor units subject to both vrt smart and vrt control, the system is operated under vrt control.
* If a system has both outdoor-air processing air conditioners [illegible] and outdoor-air processing type indoor units, vrt smart control and vrt control are disabled.

28

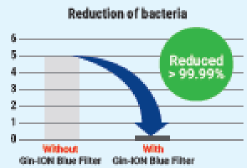
VRV X Series

Gin-ION Blue Filter Test Result

The Gin-ION Blue Filter has been tested and confirmed to decompose viruses, bacteria, and inhibit fungal growth on the filter surface.



Test Measuring Method: Textiles -Determination of antiviral activity of textile products (ISO 18184-2014)
Testing Organization : GuangDong Detection Center of Microbiology
Test Number : 2020FM24347R01, 2020FM26047R01
Test Result : The effectiveness rate of virus decomposition is increased by more to 99.9% in 2 hours.



Test Measuring Method: Test for antimicrobial activity of plastic (JIS Z 2801 : 2010)
Testing Organization : GuangDong Detection Center of Microbiology
Test Number : 2021FM05003R01E
Test Result : The effectiveness rate of bacterial reduction is more than 99.99% in 24 hours.

	Tested Specimen	Test Result	Test Organisation	Test Report
Virus	Influenza H1N1	99.94% in 2 hours	Guangdong detection center of microbiology	No.2020FM24347R01
	"Chicken Coronavirus Infectious bronchitis Virus"	99.94% in 2 hours	Guangdong detection center of microbiology	No.2020FM26047R01
Bacteria	Escherichia Coli	> 5.9 (99.99987%)	Guangdong detection center of microbiology	No.2021FM05003R01E
	Staphylococcus aureus	> 4.7 (99.99749%)		
Fungus	"Aspergillus niger, Penicillium pinophilum, Trichoderma viride, Chaetomium globosum, Poecilomyces variotii"	"Grade 0 (no fungus visible under microscope)"	Guangdong detection center of microbiology	No.2021FM05004R01E

Specification

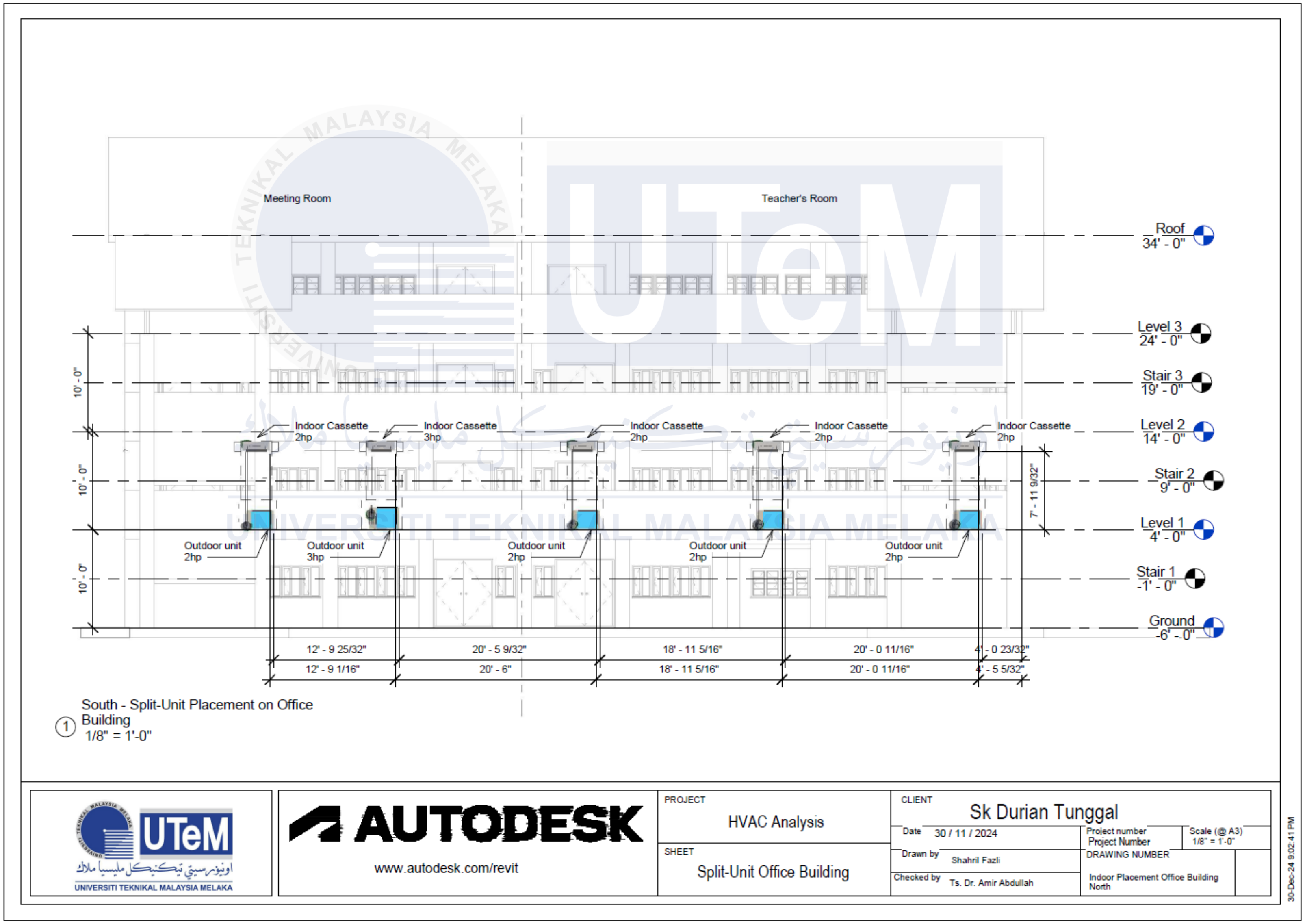
FTV-P Series **R32**

Model name								
Indoor unit	Wireless			FTV28PBV1MF9	FTV35PBV1MF9	FTV50PBV1MF	FTV60PBV1MF	FTV85PBV1MF
Indoor unit	Wired			FTV28PBV1MW9	FTV35PBV1MW9	FTV50PBV1MW	FTV60PBV1MW	FTV85PBV1MW
Outdoor unit				RV28PBV1M9	RV35PBV1M9	RV50PBV1M	RV60PBV1M	RC85BV1M
Rated Cooling Capacity			Btu/h	9,500	12,000	18,000	22,500	30,000
			kW	2.78	3.52	5.28	6.59	8.79
Power Consumption			W	865	1,040	1,660	2,130	2,900
Nominal Running Current			A	3.86	4.61	7.38	9.52	13.10
CSPF			Wh/Wh	3.42	3.59	3.37	3.28	3.22
Indoor	Air Flow Rate		cfm	342	355	531	614	931
	Sound Pressure Level (H//M/L/Q)		dBA	37 / 33 / 27 / 25	39 / 35 / 29 / 28	42 / 39 / 36 / 35	46 / 43 / 39 / 37	51 / 46 / 42 / 39
	Dimension (H x W x D)		mm	288 x 800 x 212		310 x 1,065 x 228		310 x 1,289 x 240
	Unit Weight		kg	9.0		14.0		16.0
Outdoor	Sound Pressure Level		dBA	46	48	52	52	54
	Dimension (H x W x D)		mm	550 x 658 x 273		615 x 845 x 300		695 x 930 x 350
	Unit Weight		kg	28	28	40	46	53
	Piping Connection Size	Liquid	mm	ø6.35				ø9.52
		Gas	mm	ø9.52		ø12.70		ø15.88
	Maximum Pipe Length		m	25		30		50
	Maximum Pipe Elevation		m	15		15		30
	Coil Type			Hydrophillic Blue Fin				
Power Supply				220-240 V/1ph/50Hz (Power to Indoor)				
Heat Insulation				Both Liquid and Gas Piping				
Energy Rating				3 Star				-

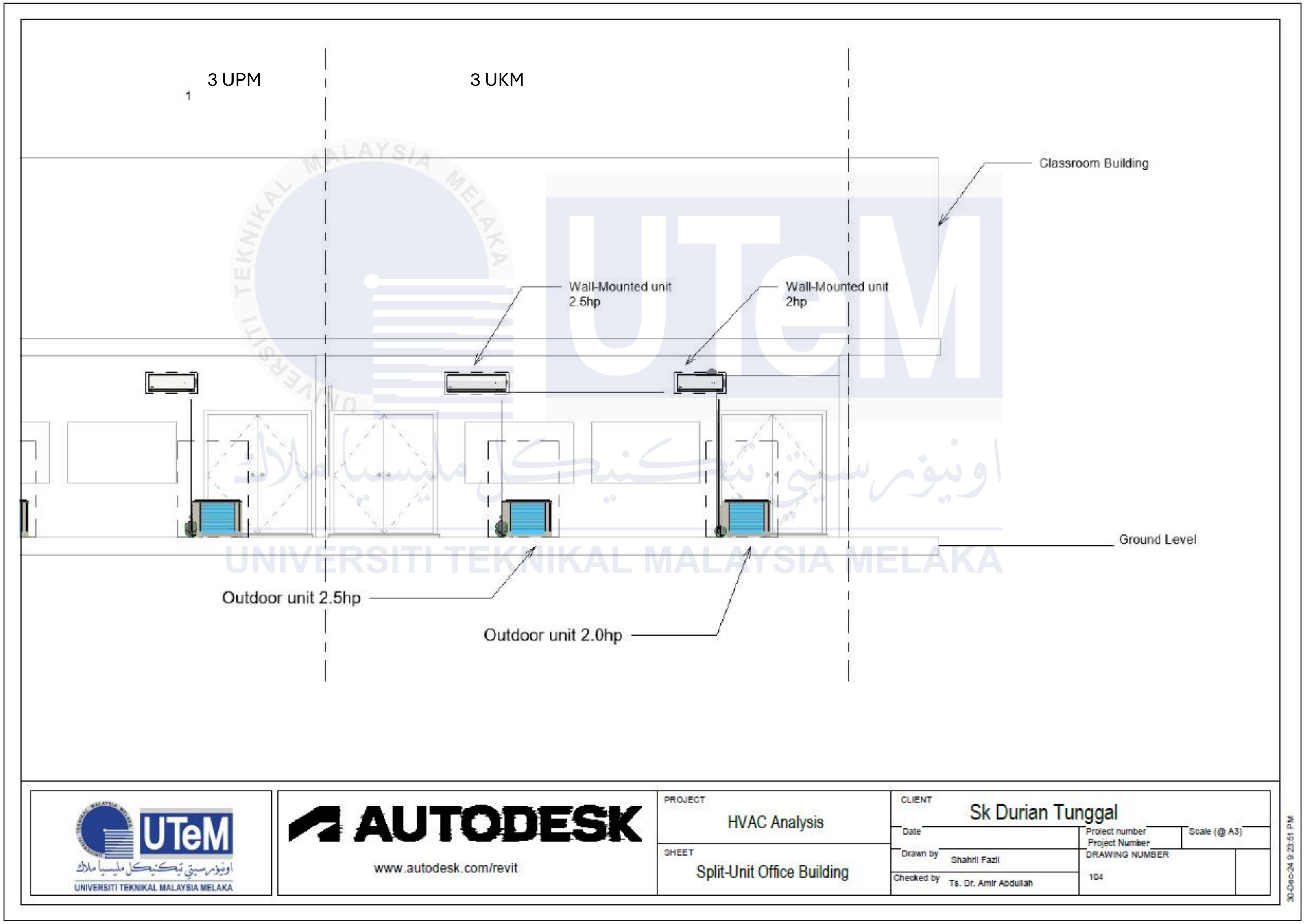
Remarks:
1. Due to product innovation, all specifications are subjected to change by the manufacturer without prior notice.
2. All units are being tested and comply to ISO5151.
3. Nominal cooling capacity are based on the conditions: 27°C DB / 19°C WB indoor and 35°C DB outdoor.
4. Sound pressure levels are measured in anechoic chamber according to JIS C 9612 standard. During actual operation, sound pressure level will be higher as a result of room specification condition.
5. The Gin-ION Blue Filter is not a medical device. Benefits shown are only effective for substances which are directly attached on the filter surface.
6. Wireless model will be supplemented with a Wireless Remote Controller and a built-in network adaptor (AWM61A01).
7. Wired model will come with only a Wired Remote Controller (DSLM8). To enable the Smart Control function, optional NS Splitter (R50044157819) is required.

APPENDIX E

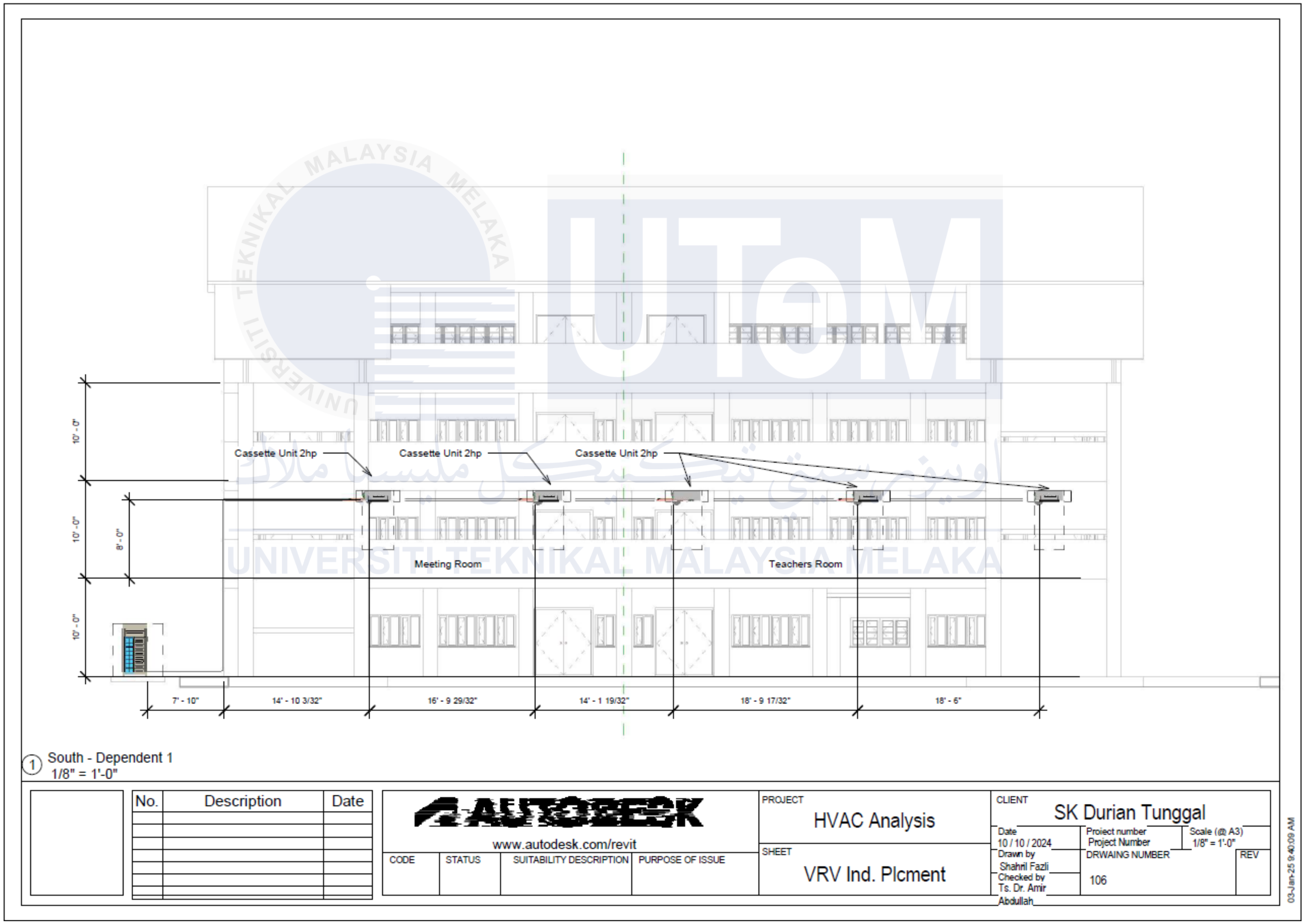
SPLIT-UNIT PLACEMENT OFFICE BUILDING (Part 1)



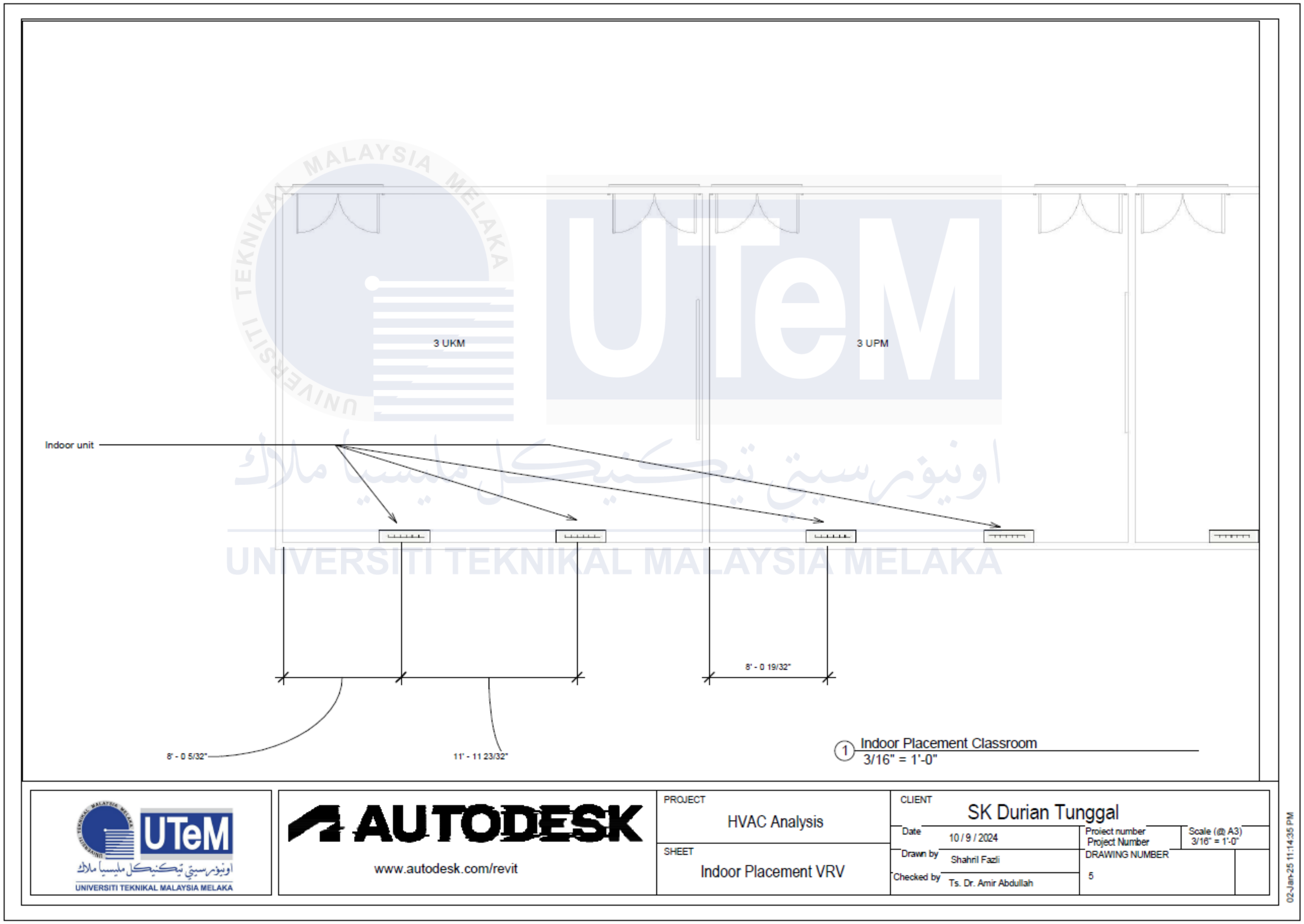
SPLIT-UNIT PLACEMENT CLASSROOM BUILDING (Part 2)



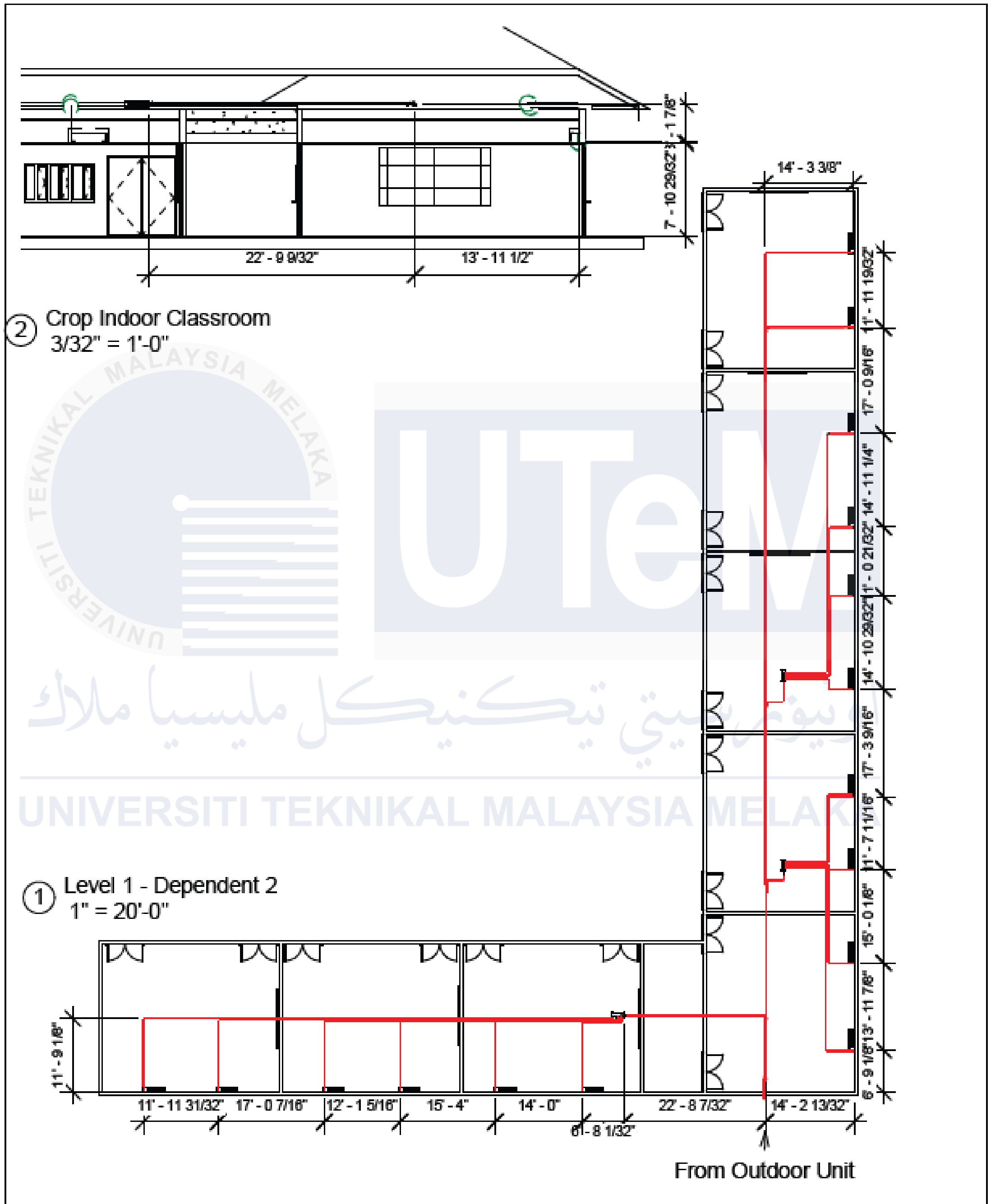
VRV SYSTEM PLACEMENT OFFICE BUILDING (Part 3)



VRV UNIT PLACEMENT CLASSROOM BUILDING (Part 4)



VRV SYSTEM PIPING STRUCTURE (Part 5)



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UTeM

PROJECT	HVAC Analysis
SHEET	VRV Piping Strct
CLIENT	Shahril Fazli
Date	10 / 10 / 2024
Project Number	Project Number
Scale (@ A4)	As indicated
REV	
Drawn by	Shahril Fazli
Checked by	Ts. Dr. Amir Abdullah

03-Jan-25 12:43:00 AM

APPENDIX F
ENERGY ANALYSIS SPLIT-UNIT CLASSROOM (Part 1)

Annual Energy and Emissions Summary

Project: untitled
Prepared by: Studio Analisis HVAC - FTKM

12/31/2024
1:55 PM

Table 2. Annual Energy Consumption

Component	Split-unit Classroom
HVAC Components	
Electric (kWh)	57,597
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	23,858
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Totals	
Electric (kWh)	81,454
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0

Table 3. Annual Emissions

Component	Split-unit Classroom
CO2 Equivalent (kg)	0

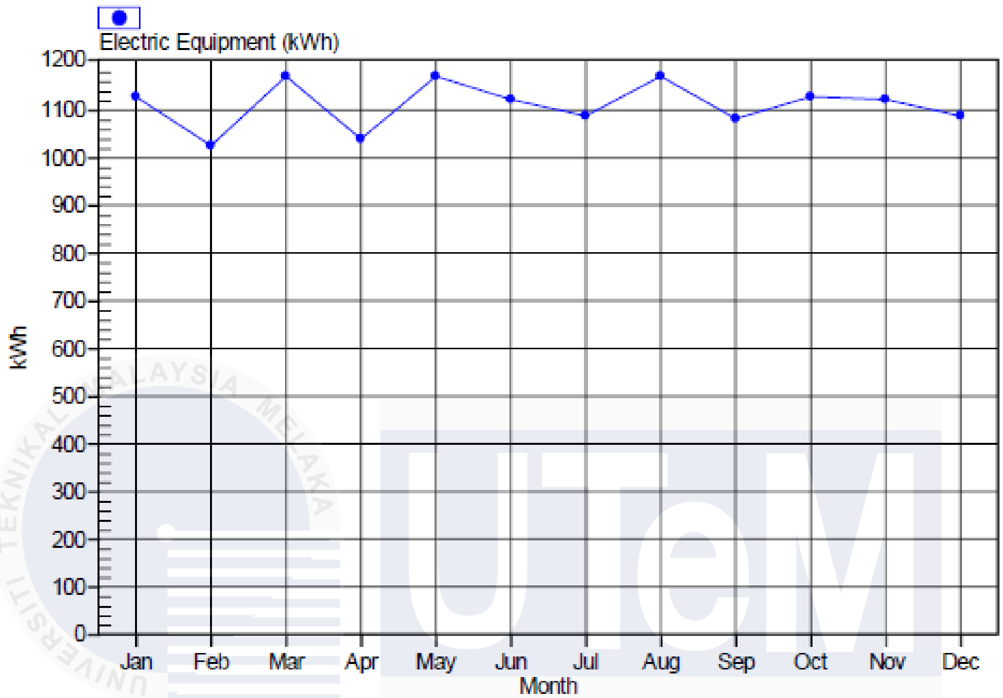
Monthly Simulation Results for Classroom Split-Unit

(In Alternative: Split-unit Classroom)

Project: untitled | 12/31/2024
Prepared by: Studio Analisis HVAC - FTKM | 1:55 PM

Air System Simulation Results (Table 1) :

Month	Terminal Cooling Coil Load (kWh)	Terminal Unit Clg Input (kWh)	Terminal Heating Coil Load (kWh)	Terminal Heating Coil Input (kWh)	Terminal Fan (kWh)	Lighting (kWh)	Electric Equipment (kWh)
January	14667	3768	0	0	105	890	1128
February	15246	4033	0	0	97	809	1025
March	19210	4976	0	0	112	924	1171
April	18485	4746	0	0	99	820	1040
May	21477	5473	0	0	113	924	1171
June	19294	4969	0	0	108	885	1122
July	18245	4638	0	0	103	858	1088
August	19880	5071	0	0	112	924	1171
September	17585	4517	0	0	103	854	1082
October	19476	4949	0	0	108	890	1128
November	19632	4918	0	0	107	885	1122
December	16835	4270	0	0	103	858	1088
Total	**220032**	**56328**	**0**	**0**	**1269**	**10521**	**13337**



Electric Equipment (kWh)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
kWh
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

ENERGY ANALYSIS SPLIT-UNIT OFFICE BUILDING (Part 2)

Annual Energy and Emissions Summary

Project: untitled 12/31/2024
Prepared by: Studio Analisis HVAC - FTKM 2:03 PM

Table 1. Annual Costs

Component	Split-unit Office ($)
HVAC Components	
Electric	0
Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Remote CW	0
HVAC Sub-Total	**0**
Non-HVAC Components	
Electric	0
Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Non-HVAC Sub-Total	**0**
Grand Total	**0**

Table 2. Annual Energy Consumption

Component	Split-unit Office
HVAC Components	
Electric (kWh)	17,396
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	10,006
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Totals	
Electric (kWh)	27,403
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0

Monthly Simulation Results for Office Split-Unit

(In Alternative: Split-unit Office)

Project: untitled 12/31/2024

Prepared by: Studio Analisis HVAC - FTKM 2:03 PM

Air System Simulation Results (Table 1) :

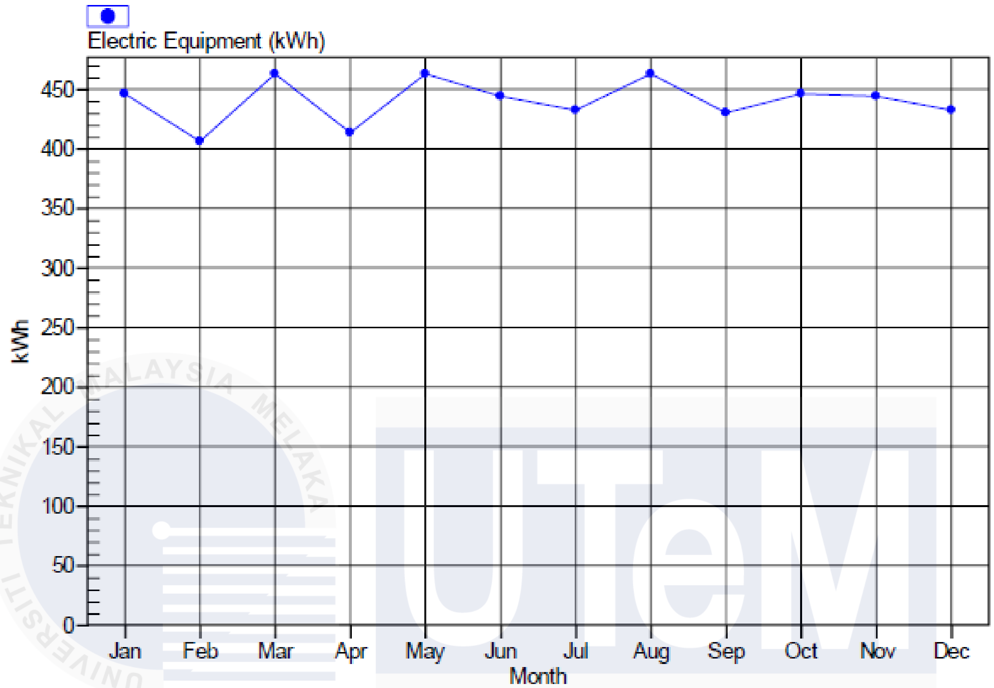
Month	Terminal Cooling Coil Load (kWh)	Terminal Unit Clg Input (kWh)	Terminal Heating Coil Load (kWh)	Terminal Heating Coil Input (kWh)	Terminal Fan (kWh)	Lighting (kWh)	Electric Equipment (kWh)
January	4330	1153	0	0	41	399	446
February	4486	1229	0	0	38	363	406
March	5459	1478	0	0	43	414	463
April	5185	1403	0	0	39	370	413
May	5995	1613	0	0	44	414	463
June	5508	1489	0	0	42	397	444
July	5261	1402	0	0	40	387	432
August	5665	1514	0	0	44	414	463
September	5078	1361	0	0	40	385	430
October	5545	1477	0	0	42	399	446
November	5568	1466	0	0	42	397	444
December	4994	1318	0	0	40	387	432
Total	**63073**	**16903**	**0**	**0**	**494**	**4724**	**5283**

Monthly Simulation Results for Office Split-Unit

(In Alternative: Split-unit Office)

Project: untitled 12/31/2024

Prepared by: Studio Analisis HVAC - FTKM 2:03 PM



ENERGY ANALYSIS VRV SYSTEM CLASSROOM (Part 3)

Annual Energy and Emissions Summary

Project: untitled | 12/31/2024
Prepared by: Studio Analisis HVAC - FTKM | 2:00 PM

Table 2. Annual Energy Consumption

Component	VRV System Classroom
HVAC Components	
Electric (kWh)	44,444
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	23,858
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Totals	
Electric (kWh)	68,302
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0

Table 3. Annual Emissions

Component	VRV System Classroom
CO2 Equivalent (kg)	0

Monthly Simulation Results for Classroom VRV System

(In Alternative: VRV System Classroom)

Project: untitled 12/31/2024

Prepared by: Studio Analisis HVAC - FTKM 2:00 PM

Air System Simulation Results (Table 1) :

Month	Terminal Cooling Coil Load (kWh)	Terminal Unit Clg Input (kWh)	Terminal Heating Coil Load (kWh)	Terminal Unit Htg Input (kWh)	Terminal Unit Aux. Htg. Load (kWh)	Terminal Unit Aux. Htg. Input (kWh)	Terminal Fan (kWh)
January	13049	2344	0	0	0	0	109
February	13866	2738	0	0	0	0	105
March	18150	3695	0	0	0	0	122
April	18136	3979	0	0	0	0	115
May	21104	4623	0	0	0	0	128
June	18489	3882	0	0	0	0	120
July	17515	3609	0	0	0	0	117
August	19000	3907	0	0	0	0	124
September	16563	3338	0	0	0	0	114
October	18806	3939	0	0	0	0	122
November	19042	3942	0	0	0	0	119
December	15747	3040	0	0	0	0	114
Total	**209468**	**43036**	**0**	**0**	**0**	**0**	**1408**

Air System Simulation Results (Table 2) :

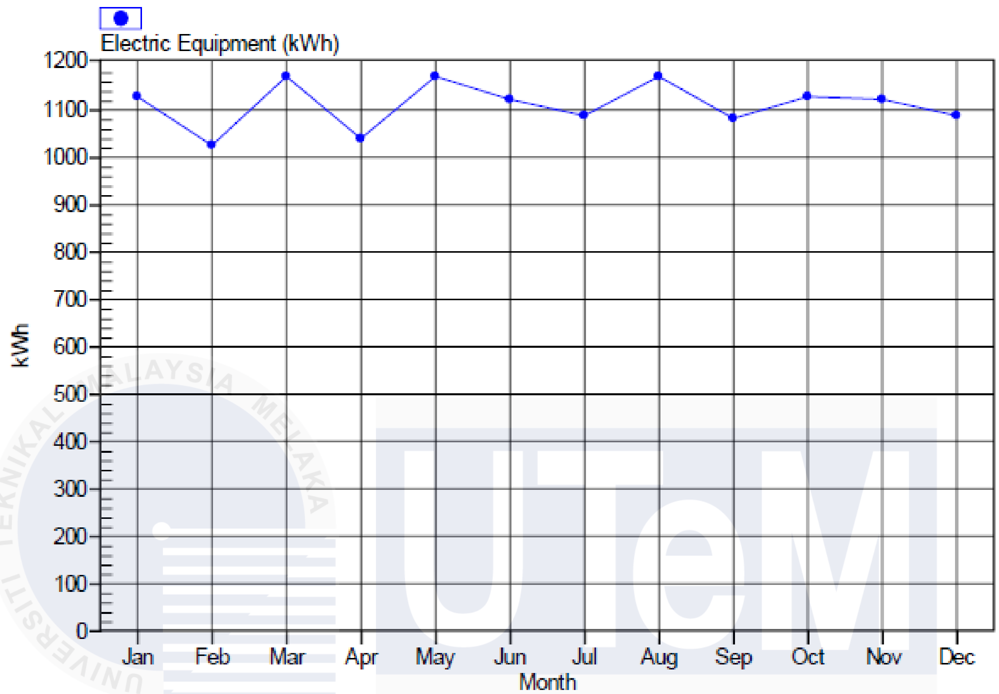
Month	Lighting (kWh)	Electric Equipment (kWh)
January	890	1128
February	809	1025
March	924	1171
April	820	1040
May	924	1171
June	885	1122
July	858	1088
August	924	1171
September	854	1082
October	890	1128
November	885	1122
December	858	1088
Total	**10521**	**13337**

Monthly Simulation Results for Classroom VRV System

(In Alternative: VRV System Classroom)

Project: untitled 12/31/2024

Prepared by: Studio Analisis HVAC - FTKM 2:00 PM



ENERGY ANALYSIS VRV SYSTEM OFFICE BUILDING (Part 4)

Annual Energy and Emissions Summary

Project: untitled 12/31/2024
Prepared by: Studio Analisis HVAC - FTKM 2:04 PM

Table 2. Annual Energy Consumption

Component	VRV System Office
HVAC Components	
Electric (kWh)	13,959
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	10,006
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Totals	
Electric (kWh)	23,966
Natural Gas (na)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0

Table 3. Annual Emissions

Component	VRV System Office
CO_2 Equivalent (kg)	0

Monthly Simulation Results for Office VRV System

(In Alternative: VRV System Office)

Project: untitled 12/31/2024

Prepared by: Studio Analisis HVAC - FTKM 2:04 PM

Air System Simulation Results (Table 1) :

Month	Terminal Cooling Coil Load (kWh)	Terminal Unit Clg Input (kWh)	Terminal Heating Coil Load (kWh)	Terminal Unit Htg Input (kWh)	Terminal Unit Aux. Htg. Load (kWh)	Terminal Unit Aux. Htg. Input (kWh)	Terminal Fan (kWh)
January	4106	778	0	0	0	0	43
February	4355	911	0	0	0	0	41
March	5377	1146	0	0	0	0	48
April	5226	1176	0	0	0	0	45
May	6038	1361	0	0	0	0	50
June	5488	1207	0	0	0	0	47
July	5254	1134	0	0	0	0	47
August	5627	1209	0	0	0	0	49
September	5015	1066	0	0	0	0	45
October	5544	1205	0	0	0	0	48
November	5563	1195	0	0	0	0	47
December	4927	1015	0	0	0	0	46
Total	**62522**	**13404**	**0**	**0**	**0**	**0**	**555**

Air System Simulation Results (Table 2) :

Month	Lighting (kWh)	Electric Equipment (kWh)
January	399	446
February	363	406
March	414	463
April	370	413
May	414	463
June	397	444
July	387	432
August	414	463
September	385	430
October	399	446
November	397	444
December	387	432
Total	**4724**	**5283**