THE ENERGY ANALYSIS FOR NET ZERO ENERGY BUILDING USING HOURLY ANALYSIS PROGRAM: A CASE STUDY OF A RESIDENTIAL BUILDING IN BAGHDAD

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Prepared as
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Lara Raad JAWAD

ABSTRACT

M. Sc. Thesis

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This study investigates the impact of exterior paint and insulation layers on the thermal loads of a building in both summer and winter seasons. The heating and cooling load of a structure is the amount of thermal energy required to maintain a building's interior temperature during cold or hot weather. It is crucial in designing and sizing heating and cooling systems, as it determines the capacity and effectiveness of the heating and cooling equipment’s needed to maintain a suitable indoor climate. The heating load and cooling load changes with the changes of the outside temperature, and the insulation of the building's walls, windows, doors, and roof significantly affects the amount of energy required for heating and cooling. Larger structures typically have higher heating and cooling loads due to their larger surface area and volume. The building's layout, including the number and size of rooms, also impacts heat dispersion even effect on cooling and heating loads. The amount of heating and cooling required depends on the building's ventilation needs and air leaks or drafts. Solar radiation from windows can counteract the heating and cooling demand during the day, lowering the need for a heating system. Heat is produced inside the building by electronics, lighting, and appliances, and internal heat gain can either reduce or raise the heating and cooling load. The goal of efficient heating system design and operation is to precisely satisfy the heating and cooling load while avoiding equipment over- or under-sizing. The results show Insulation in light paint significantly reduces cooling load by half, with a cooling load of 3 KW in a living room increasing to 6.8 KW without insulation. This difference can be beneficial for improving cooling loads. Insulation also affects the cooling load in living room with dark paint decreasing to half from 7 KW to 3 kilowatts, this clears the insulation decreasing the cooling load to half whether the coating light or dark and same case for the heating load for example its decreasing for the living room from 3.3 KW insulated to 1.6 KW not insulated. While the effect of coating type on the cooling load and heating load depends basicly on the quantity of the coating area and numbers of the windows on the building for example cooling load is decreasing for the insulated dark coating for the(first floor master bed room 2) is 3.1 kilowatts to 3 KW for light coating as well as for the heating load the results clear its decreasing for example (first floor master bedroom 2) heating load for insulated dark coating 1.9 KW while 2KW for insulated light coating. The reason for the rooms which the heating load and cooling load is equal in the light and dark coting is the lack of area exposed to coating. The effect of the VRF system requires 5.94 KW of power in summer and 3.66 KW in winter to reach zero power state. Solar panels are needed twice as much for cooling and heating systems. During summer, energy extraction (total cooling load) is 17.6 KW while in winter, it reaches (total heating load) 10.5 KW. The HAP and Trace 700 programs were simulated and reprogrammed for light paint with insulation, resulting in an acceptable 5% difference. These resolvers presented a reliable and acceptable difference.

Key Words : Net zero energy building, effect of insulation and coating on thermal loads

Science Code : 91408

ÖZET

Yüksek Lisans Tezi

SAATLİK ANALİZ PROGRAMI KULLANILARAK NET SIFIR ENERJİLİ BİNA İÇİN ENERJİ ANALİZİ: BAĞDAT'TA BİR KONUT BİNASI ÖRNEK ÇALIŞMASI

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Bu çalışma, dış cephe boyasının ve yalıtım katmanlarının bir binanın hem yaz hem de kış mevsimlerindeki termal yükleri üzerindeki etkisini araştırıyor. Bir yapının ısıtma ve soğutma yükü, soğuk veya sıcak havada binanın iç sıcaklığını korumak için gereken termal enerji miktarıdır. Isıtma ve soğutma sistemlerinin tasarımında ve boyutlandırılmasında çok önemlidir, çünkü uygun bir iç iklim sağlamak için gereken ısıtma ve soğutma ekipmanlarının kapasitesini ve etkinliğini belirler. Isıtma yükü ve soğutma yükü dış sıcaklığın değişmesiyle birlikte değişir ve binanın duvarlarının, pencerelerinin, kapıların ve çatısının yalıtımı, ısıtma ve soğutma için gereken enerji miktarını önemli ölçüde etkiler. Daha büyük yapılar, daha büyük yüzey alanı ve hacimleri nedeniyle genellikle daha yüksek ısıtma ve soğutma yüklerine sahiptir. Binanın düzeni, oda sayısı ve büyüklüğü gibi faktörler de ısı dağılımını etkileyerek dolaylı olarak soğutma ve ısıtma yüklerine etki eder. Gerekli ısıtma ve soğutma miktarı, binanın havalandırma ihtiyaçlarına ve hava sızıntılarına veya cereyanlara bağlıdır. Pencerelerden gelen güneş radyasyonu, gündüz saatlerinde ısıtma ve soğutma talebini karşılayarak ısıtma sistemine olan ihtiyacı azaltabilir. Binanın içinde elektronik cihazlar, aydınlatma ve ev aletleri tarafından ısı üretilir ve içten gelen ısı kazancı, ısıtma ve soğutma yükünü ya azaltabilir ya da artırabilir. Verimli ısıtma sistemi tasarımı ve işletimimin amacı, ekipmanın aşırı boyutlandırılmasını veya yetersiz boyutlandırılmasını önleyerek ısıtma ve soğutma yükünü tam olarak karşılamaktır. Sonuçlar, açık renkli boyadaki yalıtımın soğutma yükünü önemli ölçüde yarı yarıya azalttığını, yalıtımsız bir oturma odasında 3 KW olan soğutma yükünün 6,8 KW'a çıktığını göstermektedir. Bu fark, soğutma yüklerini iyileştirmek için faydalı olabilir. Yalıtım ayrıca koyu boyalı oturma odasındaki soğutma yükünü de yarı yarıya 7 KW'dan 3 KW'a düşürür, bu da açık veya koyu renkli boyada yalıtımın soğutma yükünü yarı yarıya azalttığını ve ısıtma yükü için de aynı durumun geçerli olduğunu, örneğin oturma odası için yalıtımlı 3,3 KW'dan yalıtımsız 1,6 KW'a düştüğünü göstermektedir. Boya türünün soğutma ve ısıtma yükü üzerindeki etkisi temel olarak boya alanının miktarına ve binadaki pencere sayısına bağlıdır, örneğin yalıtımlı koyu renkli boya için (birinci kat ana yatak odası 2) soğutma yükü açık renkli boyaya göre 3,1 KW'tan 3 KW'a düşer, ısıtma yükü için de sonuçlar açıktır, örneğin (birinci kat ana yatak odası 2) yalıtımlı koyu renkli boya için ısıtma yükü 1,9 KW, yalıtımlı açık renkli boya için ise 2 KW'dir. Işık ve koyu renkli boyalı odalarda ısıtma ve soğutma yükünün eşit olmasının nedeni, boyaya maruz kalan alanın olmamasıdır. VRF sisteminin sıfır güç durumuna ulaşmak için yazın 5,94 KW, kışın ise 3,66 KW güç gerektirir. Güneş panelleri soğutma ve ısıtma sistemleri için iki kat daha fazla gereklidir. Yaz aylarında enerji çekimi (toplam soğutma yükü) 17,6 KW iken, kış aylarında (toplam ısıtma yükü) 10,5 KW'a ulaşır. HAP ve Trace 700 programları yalıtımlı açık renkli boya için simüle edildi ve yeniden programlandı, %5'lik kabul edilebilir bir farkla sonuçlandı. Bu çözümleyiciler güvenilir ve kabul edilebilir bir fark sunmuştur.

Anahtar Kelimeler : Net sıfır enerji binası, yalıtım ve kaplamanın termal yüklere etkisi

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SYMBOLS AND ABBREVIATIONS

SYMBOLS

A : Area
$Cltd$: cooling load temperature difference
Fsa : Lighting allowance factor (ballast + lamp)
Ful : Lighting use factor (ratio of wattage in use)
Fp : Heat loss coefficient of slab floor construction
N : Number of lights
q equipment : Heat transfer by equipment
q floor : Heat transfer by floor
q people : Heat transfer by people
q roof : Heat transfer by roof
q total : Total heat transfer load
q wall : Heat transfer by wall
q window : Heat transfer by window
$SHGF$: Solar heat gain factor
U : Material conductance value
V : Voltage
V_{mpp} : Voltage at the maximum power point (MPP) of a system or device.
V_{ref} : Reference voltage.
V_i : İnfiltration debit, (L/s)
W_{oa} : Outdoor specific humidity, (kg/kg)
W_r : Room specific humidity, (kg/kg)
W : Wattage
ΔV : Voltage difference.
φ_{error} : The error in a quantity φ.
φ_{in} : Measured value of φ.
φ_{ref} : Reference value for φ.

ΔT : Temperature difference between indoors and outdoors

ABBREVIATIONS

ASHRAE : American society of heating refrigerating and air conditioning engineers
BTU : British thermal unit
F.F : First floor
G.F : Ground floor
HAP : Hourly analysis program
HVAC : Heating, ventilation and air conditioning
IGBTs : Insulated gate bipolar transistors
LEED : Leadership in energy and environmental design
MPPT : Maximum power point tracking
NZEB : Net zero energy building
PLL : Phase-locked loop
PV panels : Photovoltaic panels
RH : Relative humidity
RSI : Repetitive strain injury
VRF : Variable refrigerant flow

PART 1

INTRODUCTION

1.1. BACKGROUND

A new great of 2,500 Mt CO_2 carbon dioxide was reached in 2021 by direct emissions from heating buildings, which now account for 80 % of all direct CO_2 emissions in the building industry [1]. Despite this increase, CO_2 emissions caused by the utilization of heating-related energy are just 1.5 percent greater than they were in 2010. There have been several parameters that have contributed to the modifications, including the implementation of more stringent building energy regulations, a shift away from boilers, which utilization fossil fuels that are the least effective, and greater availability of heating pumps and sustainable sources of heating in the stock [2].

Nevertheless, to satisfy the net-zero scenario milestones, the pace of quality enhancement will essential to be quickly accelerated [3], with the CO_2 intensity of heated homes in the scenario dropping by almost 10% per year to 2030, as opposed to 2 % each year between 2000 and 2021. The technology required to accomplish these decreases is now accessible, developed, and affordable in several markets [4].

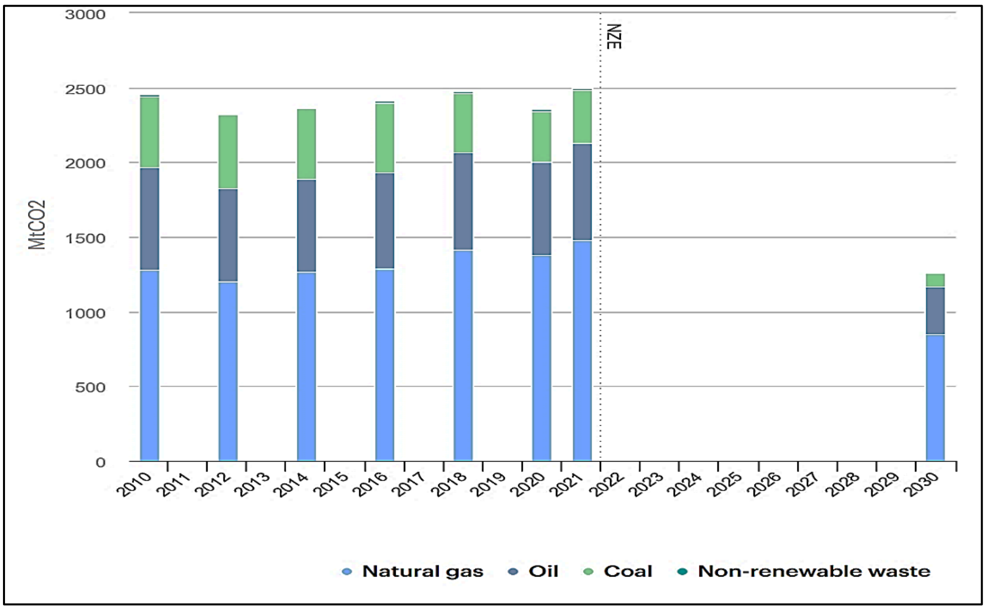


Figure 1.1. Net zero condition, heating-related CO_2 emissions from building structures by fuel between 2010 and 2020 [91].

1.2. HEATING AND COOLING SYSTEM BASICS

The heating lost via the outside of the property is replaced by a heating system [5]. The energy amount needed by the heating system to make up for the heating lost relies on four things: the location of the home (heating loss is more significant in colder areas), its size, its energy efficacy, and the heating system's efficacy [6]. Regarding the home's energy efficacy, increasing insulation, plugging air leaks, and fixing the heating distribution system (pipes or ducts) give fantastic chances to save money and energy [7,8].

1.2.1. Heating System Types

1.2.1.1. Furnace (Forced Air Distribution System)

Air is pumped via a network of ducts utilizing a furnace, often fueled by gas. By doing this, warm, conditioned air is dispersed throughout the house. Although furnaces may heating the air utilizing propane, electricity, or petroleum, natural gas is the preferred fuel for most American houses [9]. Because the air conditioner may utilize the forced air distribution network (duct work) throughout the summer, gas furnaces have become the most common heating system.[10].

1.2.1.2. Boiler (Radiator distribution system)

Another popular heating method is the boiler. To provide warmth, steam or hot water is usually sent via pipes [11]. While it makes it possible to utilize zonal cooling and heating, it also makes them more costly to build and maintain [12]. Since the heating is produced in a central location of the residence and then dispersed, boilers and furnaces are referred to as central heating systems [13].

1.2.1.3. Heating Pump

The house may be heated and cooled utilizing heating pumps. Instead of producing heating directly like a gas furnace, they transfer heating via electricity and refrigerant [14]. They are thus frequently far more effective than other kinds of heating systems. However, the system performs best in temperate settings with little cold conditions [15].

1.2.1.4. Hybrid Heating

Hybrid heating combines a gas furnace's power with a heating pump's energy efficacy. The heating pump would typically work to cool and heating the house. The furnace only turns on in very hot weather. Additionally, because users will not depend only on one system, it would lessen the load on both devices and consequently lower the need for replacement and repair. [16].

1.2.1.5. Ductless Mini-Splits

Mini-split units eliminate the requirement for several air ducts, enabling customers to set up distinct HVAC regions, all with its thermostat, which is especially useful in bigger houses and additions without ducting [17].

1.2.1.6. Radiant Heating

With radiant heating, heating is transmitted via specialized floor tubes utilizing hot water or electricity (and sometimes in the walls or ceiling). Oil, propane, gas, or electricity are all viable options for producing heat. The radiant heating distribution system may survive for a very long period; repairs could be costly when a problem occurs. The heating source system affects how long radiant heating lasts [18].

1.2.1.7. Baseboard Heaters

Baseboard heating is often utilized as an additional source of heating or as a source of heating in addition. Regarding baseboard heating, users have two options: electrical or hydronic. For further details about baseboard heaters, see the local HVAC contractor. [19].

1.2.1.8. Cooling System Basics

Cooling building systems are critical components of modern construction, designed to keep indoor environments comfortable in a variety of climatic situations. These systems are critical in maintaining occupant comfort and productivity by regulating temperature, humidity, and air quality within buildings. Understanding the fundamentals of building cooling systems is critical for effective and sustainable construction methods. To create pleasant, energy-efficient, and sustainable interior environments, architects, engineers, building managers, and everyone else involved in the construction and maintenance of buildings must understand the foundations of cooling building systems [20].

1.2.2. Cooling System Types

1.2.2.1. Air Conditioning Systems

Central air conditioning systems are most typically seen in larger buildings or households. To chill and dehumidify air, they use a central cooling unit, which is generally positioned outside the structure. The cooled air is then dispersed throughout the building via ducts. Split systems are made up of an interior unit (evaporator) and an outdoor unit (condenser). These systems are appropriate for single rooms or smaller locations, and they provide flexibility and convenience of installation. Variable refrigerant flow (VRF) systems enable precise control over cooling and heating in different zones of a building. They transport heat using a refrigerant, allowing for energy-efficient operation and personalized temperature control [21].

1.2.2.2. Chilled Water Systems

Chilled water systems employ chillers to generate cold water, which is then pumped through a network of pipes to cooling coils or air handling units (AHUs) within the structure. These systems are often found in large commercial and industrial buildings [22].

1.2.2.3. Evaporative Cooling Systems

Direct Evaporative Cooling: These systems cool air by using the natural process of water evaporation. Air is circulated through wet pads or surfaces, which cools the air as it evaporates. They save energy but function best in dry conditions. Two air streams are employed in this type, one to cool the entering air by indirect contact with water and the other to supply the cooled air to the space. In humid settings, this approach may be more successful [15].

1.2.2.4. Radiant Cooling Systems

Hydronic Radiant Cooling: Hydronic systems use water flowing through pipes in the floor, ceiling, or walls to cool building surfaces, which then radiate coolness throughout the room. They are well-known for their consistent comfort and energy efficiency [24].

1.2.2.5. Passive Cooling Systems

Natural ventilation relies on the circulation of outdoor air to cool interior rooms. It frequently utilizes carefully positioned windows, vents, and architectural design elements to promote ventilation. Night ventilation entails cooling a building during the colder evening hours and then sealing it during the day to keep the cooled air inside. It is especially beneficial in climates with large diurnal temperature fluctuations [25].

1.3. ZERO ENERGY BUILDING

A zero-energy building (ZEB) is any construction or structure with zero net energy utilization and zero carbon emissions calculated over time. Additionally, a ZEB is also regarded simply as a net-zero-energy building. Most ZEBs, also known as ZEBs, are entirely independent of the regional (electric) grid because ZEBs create their entire energy on-site and utilization far less energy than traditional buildings. ZEBs have developed in reaction to strict environmental regulations that were placed in position to address more serious environmental challenges, including population, ecology, contamination, natural resource conservation, and climate change [91].

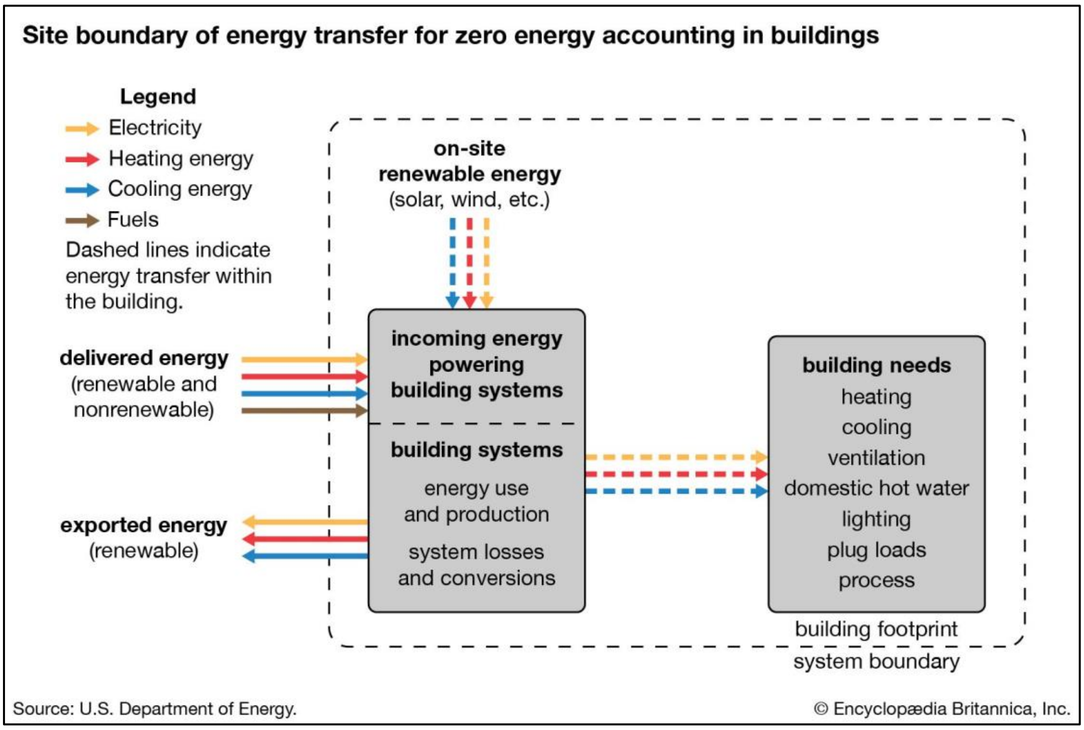


Figure 1.2. ZEB: Location border for transferring energy [91].

Net zero energy buildings (NZEBs) represent a paradigm shift in the construction industry, as they strive to achieve a delicate equilibrium between energy consumption and renewable energy production. At the core of NZEBs is an unwavering commitment to energy efficiency. These buildings are designed with a meticulous focus on reducing energy demand through advanced insulation, efficient lighting systems, and the incorporation of smart technologies that optimize energy usage. By minimizing energy needs, NZEBs set the stage for a more sustainable and resource-efficient built environment.

Central to the concept of net zero energy buildings is the integration of on-site renewable energy sources. Solar panels, wind turbines, and geothermal systems are commonly deployed to harness clean and renewable energy, ensuring that the building generates as much energy as it consumes over the course of a year. This shift towards decentralized energy production not only reduces reliance on traditional grid systems but also contributes to a more resilient and decentralized energy infrastructure. The visual presence of solar panels or wind turbines on NZEBs serves as a tangible reminder of the commitment to environmental stewardship and sustainable practices.
To further optimize energy use, net zero energy buildings employ sophisticated energy monitoring and management systems. These systems provide real-time data on energy consumption patterns, allowing occupants and building managers to make informed decisions about when and how energy is used. Additionally, NZEBs often incorporate energy storage solutions, such as advanced battery technologies, to store surplus energy generated during periods of peak renewable energy production. This stored energy can then be utilized during times of high demand or when renewable sources are less productive, ensuring a consistent and reliable energy supply.

The journey towards net zero energy is not just about technological advancements; it requires a holistic approach to building design and operation. Passive design strategies, such as optimal building orientation, natural ventilation, and strategic shading, are integral components of NZEBs. These strategies leverage the inherent properties of the building site and environment to minimize the need for active heating and cooling systems. Additionally, a focus on sustainable materials and landscaping further contributes to the overall environmental impact of NZEBs. As the demand for sustainable and energy-efficient structures grows, net zero energy buildings stand as beacons of innovation, demonstrating that it is indeed possible to create spaces that meet human needs while minimizing their ecological footprint.

A net zero energy building (NZEB) is a structure designed to produce as much energy as it consumes over the course of a year, achieving a balance between energy usage and renewable energy generation. The primary goal of NZEBs is to minimize environmental impact, enhance energy efficiency, and contribute to a more sustainable future. Several key features distinguish net zero energy buildings from conventional structures:

1. Energy Efficiency: NZEBs prioritize energy-efficient design and construction techniques to minimize energy consumption. This includes high levels of insulation, energy-efficient windows, advanced lighting systems, and smart building technologies to optimize energy use.
2. Renewable Energy Integration: To achieve net-zero status, NZEBs incorporate on-site renewable energy sources such as solar panels, wind turbines, or geothermal systems. These systems generate clean energy to offset the building's energy demand.
3. Energy Monitoring and Management: NZEBs utilize advanced energy monitoring and management systems to track energy consumption patterns. Real-time data helps occupants and building managers make informed decisions to further optimize energy use.
4. Passive Design Strategies: Passive design strategies, such as optimal building orientation, natural ventilation, and strategic shading, are employed to harness natural energy sources and reduce the need for active heating and cooling systems.
5. Energy Storage: NZEBs often incorporate energy storage systems, such as batteries, to store excess energy generated during periods of high renewable energy production. This stored energy can then be utilized during periods of high demand or low renewable energy availability.
6. Holistic Approach: Achieving net-zero energy requires a holistic approach that considers all aspects of building design, construction, and operation. This

includes attention to materials, landscaping, and lifestyle factors that impact energy use.

Net zero energy buildings play a crucial role in mitigating the environmental impact of the built environment and addressing climate change. They serve as examples of sustainable construction practices and contribute to the global transition toward a low-carbon and energy-efficient future.

Many people in developed countries (and other parts of the world) are forced to live in zero-energy constructions such as tunnels, tents, and huts, tents, and because they cannot afford better housing. These folks are forced to endure severe weather conditions and do not have electricity. The concept of "zero-energy buildings" in its present sense was the subject of discussion since the 1970s, once the oil shocks of that period and the ensuing fears about the repercussions of dependency on fossil fuels first arose. ZEB explanations can range from those that evaluate the net energy inputs to outputs to those that evaluate the financial energy bills utilization with the expenses connected with the tool utilized in the configuration for energy production PV (solar cells) and wind turbines, for example, with the advantages connected with attempting to export energy generated by the structure. ZEB descriptions can also evaluate the financial electricity bills utilization with the costs connected with the tool utilized in the configuration for power generation PV (solar cells) and wind turbines. Various opinions exist on the relative significance of energy generation and conservation in attaining a net energy balance. Several methods exist to evaluate the energy in a structure (for example, energy, cost, or carbon pollution) [91].

1.3.1. ZEB energy generation

So as to satisfy their requirements for electrical and either cooling or heating, ZEBs are required to generate their own energy on-site. So as to supply the buildings with heating and power, many forms of microgeneration technology, such as the following, might be utilized:

1. Solar [PV] and solar hot water).

2. Wind turbines.
3. Biomass (community heating and cooling) schemes, boilers, stoves, and heaters).
4. Sewage gas, biomass, natural gas other biogases may power combined power and heating (CHP) and micro-CHP systems.
5. Heating for the whole community (involving utilizing waste heating from large-scale power production).
6. The utilization of heating systems (air source [ASHP] and ground source [GSHP], and geothermal heating systems).
7. Water (small-scale hydropower).
8. Other (involving fuel cells utilizing hydrogen produced from any of the above renewable sources).

Numerous homebuilders have significant reservations about the viability of microgeneration and renewable energy sources to fulfill the power production needs necessary to manufacture ZEBs that are appropriate, functional, and affordable. Builders are concerned that owners and occupants of the building would not embrace the necessary new technology and could instead prefer to refit energy-intensive appliances and systems that could eventually undercut the zero-energy goals. There are also worries that if owners and occupants of a building do not appropriately maintain the new technology and systems, they may be jeopardizing their own health and safety.

1.3.2. Home Energy Rating System

The home energy rating system, often known as HERS, is a method that is primarily utilized in America to determine how energy efficient a home is. The HERS measure is a relative energy-utilization index that is utilized in the calculation of HERS ratings. The HERS Index covers a range from 0 to 150, with a magnitude of 150 indicating that a residence is very energy heavy in terms of the quantity of bought energy required. The "American Standard Structure" has a HERS Index of 100, corresponding to the energy it consumes. A HERS index of 0 signifies that the planned building will not utilize net bought energy ZEBs.

There are such programs in other nations. In Australia, this system is referred to as the nationwide house energy rating scheme, based on a ten-star rating. On the other hand, in the UK, the energy performance certificates (EPCs) were graded from A to G. In both countries, the ratings were based on the same ten-point scale. The house energy rating system (HERS) is a standardized method that may evaluate the energy efficacy of a home as well as the anticipated expenses of energy utilization. Standardized procedures carry out the assessment, which involves a comprehensive analysis of the home's energy consumption. This analysis is carried out by an assessor the state has approved, utilizing various nationally recognized methods and software applications. The rating may be utilized to measure the energy efficacy of a house in its existing state and predict the energy efficacy of a house that is currently constructed or renovated. The United States department of energy suggests a home energy rating assessment, and it will typically include the following information:

1. The house's overall rating is out of a possible 10.
2. Recommendations for energy improvements that are also cost-effective
3. Predictions of how long the adjustments are expected to be usable, how much money they will save annually, and how much money they will save overall.
4. The possible increased rating score that might be achieved after the implementation of the proposed improvements.
5. The anticipated and expected yearly energy expenses for the current residence, both before and after the alterations to the home.

Figure 1.3. An example of zero heating building [91].

1.3.3. Build Zero Energy

How we heating our houses becomes a significant concern as regional building regulations in Canada, and the United States are starting to investigate zero energy ready solutions to lower the total carbon footprint of residential buildings. Although, in theory, practically any draughty old house could have a pile of photovoltaic solar panels installed on its roof and be labeled "net zero," doing so would be prohibitively expensive and could hardly be known as environmentally friendly. As was noted earlier, one of the most critical aspects of building environmentally friendly homes in the future would be to minimize consumption right from the start via careful planning. When designing and modeling a house, one of the first things that should be considered is whether or not it should be a large or a smaller one, which is one of the several possible ways that the energy usage of a residence may be reduced throughout the modeling and design process, the next step is to concentrate on creating an effective envelope by constructing houses that are more insulated and airtight.

1.3.4. Better Insulated Homes Need Less Heating

The equivalent of purchasing clothes with holes in the pockets and saving individual money fall out is designing a house to comply with the essential energy performance of the building code. It is a real tragedy that most big developers continue to provide the market with subpar houses in an era of climate change, green home-building methods, and incentives to achieve zero energy homes. In other circumstances, the only economical alternative available for residents is to heat their homes with gas since these houses have poor insulation and a lot of air leakage.

Moreover, to go back to the initial argument, by performing those above, the cost of electric heating and cooling makes sense both now and as a far more reliable investment in the future. The system is shifting toward clean, renewable energy, even if some lawmakers are reluctant to acknowledge it. According to estimates from the US energy information administration (EIA), the power generated from renewable sources will increase to 22% in 2021 from 17% in 2019 and 20% in 2020. Therefore, as we continue to move towards more renewable energy, utilizing electricity for heating is the only sustainable alternative.

1.4. ENERGY ANALYSES

Building energy studies are crucial for determining efficiency, environmental impact, and cost-effectiveness. These evaluations assist architects, engineers, and building owners in making knowledgeable decisions concerning system design, operation, and maintenance.

Energy analysis of a building's cooling system, EER is a measure of the efficiency of a cooling system and is defined as the ratio of cooling output BTUs to electrical energy input (in watts). A higher EER suggests greater efficiency. EER, SEER measures the system's efficiency throughout a whole cooling season, taking into a count part load situation. It's a common metric for assessing the efficiency of air conditioning systems. This is the process of assessing a building's cooling load by taking into a count Elements such as outside temperature, insulation, solar heat gain, and internal heat generation. Oversizing is avoided by properly sizing the cooling system based on the cooling load calculations. Installation of energy meters and data loggers to monitor the energy consumption of cooling equipment and the entire system over time. This information aids in the identification of energy-saving opportunities and performance concerns. By altering motor speed based on load needs, variable speed drives (VSDs) in cooling equipment such as pumps and fans can optimize energy utilization. Advanced control systems, such as direct digital control (DDC), can enhance cooling system operation by altering set points and schedules based on occupancy and weather conditions. Waste heat from cooling processes can be captured and used for heating or other applications, improving total energy efficiency [26].

Energy analysis of a building's heating system the ratio of heating output to electrical or fuel energy input is a measure of heating system efficiency. Greater efficiency is indicated by higher COP values. Cooling load analysis, heating load analysis evaluates a building's heat loss depending on parameters such as exterior temperature, insulation, and ventilation. To reduce energy usage, heating equipment must be properly sized. Evaluate the cost and environmental impact of the heating energy source (e.g., natural gas, electricity, solar, geothermal). Consider renewable energy sources for more environmentally friendly heating solutions. Optimize heat distribution within the building by maintaining ducts, pipes, and insulation. Zoning and thermostat control can also assist in managing heating demands in various regions. Inspect and maintain boilers and furnaces on a regular basis to ensure they are working at peak efficiency. If necessary, consider upgrading to high-efficiency systems. Install programmable or smart thermostats to alter heating schedules depending on occupancy patterns, decreasing energy consumption during non-occupied hours. Implement heat recovery systems to capture waste heat from exhaust air or industrial operations for use in space heating, eliminating the requirement for extra energy input [27].

1.5. PROBLEM STATEMENT

In places with great heating demand, it is challenging to meet this need with renewable energy since solar electricity is scarce throughout the heating season, which indicates that a significant portion of the energy utilized for heating in heavily urbanized regions comes indirectly or directly from fossil fuels. Should the EU become less reliant on fossil fuels, some 2000 TWH of season energy storage would be required to satisfy its winter heating demand [20,21]. There is an obvious necessity for seasonal electricity storage, given that heating is primarily powered by electricity (for example, utilizing heating pumps). About 40 TWH of seasonal storage is needed in Germany alone [22]. The ZEBs require significant social infrastructure improvements, which the zero-heating building avoids, thereby solving significant problems [23].

In statistics regarding emissions, greenhouse gases from electricity and heating have often been combined. As a result, we could not determine the precise amount from heating alone. Furthermore, now for what we do know [24]. According to the Prairie climate centre [25], using fossil fuels to produce energy, such as heating and electricity, results in around 45 percent of emissions, much greater than transportation (28 percent). Approximately half of it comes from homes, businesses, schools, and other public and private structures. In figure 1.2, the other half is represented by the industry.

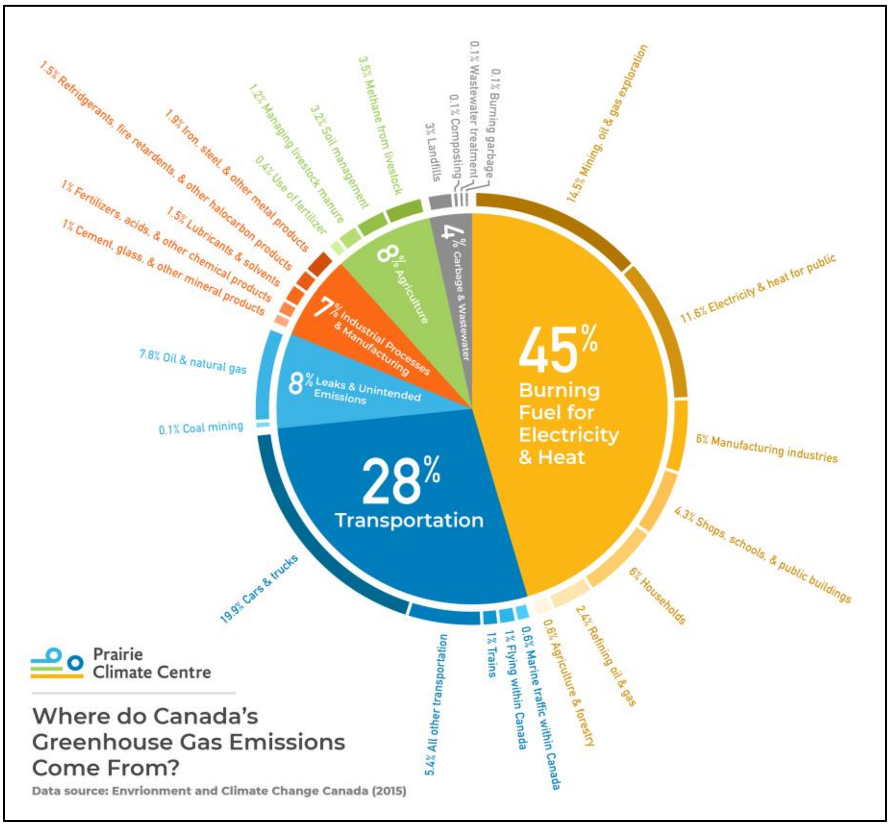


Figure 1.4. CO_2 production per sector [33].

According to 2014 research [26], the residential sector utilizations about 70% of its energy from fossil fuels. According to statistics, the bulk of central heating systems is forced steam boilers and hot water or air furnaces with radiators that typically utilization fossil fuels like natural gas [27].

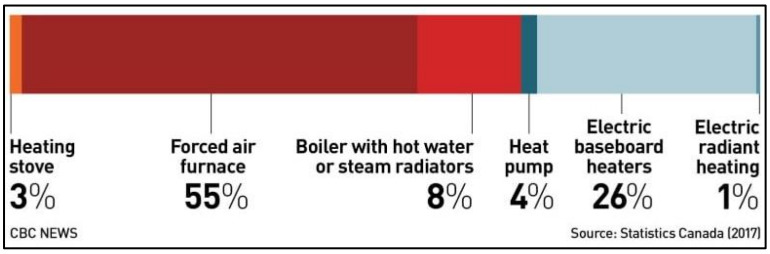


Figure 1.5. Primary heating system and energy type [35].

1.6. RESEARCH SCOPE

The current project aims to optimize the integration of two renewable energy sources (sun and ground) to decrease the heating and cooling energy bill to zero.

1. Choice building and study conditions in winter and summer.
2. Estimate the heating and cooling loads.
3. Evaluate the power consumption.
4. Design the zero energy for the building.

1.7. THESIS OUTLINE

The structure of the thesis was separated into five chapters.

Chapter 1. Contains basic information about energy and the problems related to heating and cooling, the zero-energy concept, the problem statement, aims, and objectives.

Chapter 2. Give a complete description of the zero-energy heating and cooling process and a relevant literature survey of the current work.

Chapter 3. Contains the simulation of zero energy heating and cooling process outcomes from the HAP software program and make simulation for the electric power needed by Simulink MATLAB software program.

Chapter 4. Making graphics to compare heating and cooling loads from where insulating and coating

Chapter 5. Conclusions and scope for future work have been stated finally.

PART 2

BASIC INFORMATION AND LITERATURE REVIEW

Recently, there was increasing interest in buildings that utilization zero net additional energy. Since the 1970s, net energy was already employed in various industries, ranging from fossil fuel and nuclear energy to sustainable power [28]. Comparing the quantity of energy provided to society by a technique to the total quantity of energy needed to manufacture it in a form that can be utilized compares these two quantities of energy utilizing a method known as net energy analysis. The term "net energy" is frequently employed in the construction industry. It refers to the equilibrium between the energy utilized inside a structure and the energy generated by the building's renewable energy systems. Various academics have come up with their definitions for "zero energy buildings" (also known as "ZEBs") and "net zero energy buildings" (also known as "NZEBs"). Marszal et al. [29] and Sartori et al. [30] have articles with definitions and descriptions that go into great detail. The term "net-zero energy buildings" (NZEBs) can describe any structures wired into the power grid. Throughout a certain quantity of time, often one year, there has been a balance achieved in NZEBs between the quantity of energy that is drawn from and added to the energy (mostly electricity) grid. The term "ZEBs" refers to a more generic category that might involve independent buildings. In this analysis, we refer to ZEBs as "zero-energy batteries." Several countries, including the United States department of energy's building technology program and the European union's directive on energy performance of buildings [31], have already established zero energy buildings (ZEBs) as their future building energy targets or are in the process of doing so. There were also several case studies conducted all around the globe that have shown the possibility of ZEBs to assist in mitigating the depletion of energy supplies and the degradation of the environment [32,33].

2.1. BUILDING ENVELOPES

So as to accommodate the local weather patterns that are most common in a given location, the design of the building envelope must take into acount a variety of environmental factors. So as to evaluate the thermal effectiveness of buildings envelopes, several indices and criteria were advanced. These include the OTTV (as a whole thermal transfer magnitude) for subtropical climates [34], the EETP (assessment on energy and thermal performance) for zones with hot summers and cold winters, the ETTV (envelope thermal transfer magnitude) for tropical regions.

Chua et al.[35] bioclimatic approach utilizes passive design approaches for various climate zones. The quantity of heating and cooling gained and loosing during the summer and winter via the building envelope be kept to a minimum if we are to achieve our goal of reducing the quantity of energy needed for cooling and heating the inside of the structure. The following is an expansion on some of the most important concerns with the following four energy-efficient building envelope measures:

Daouas et al. [36] insulation against the elements, among other things, should be emphasized. To begin, insulation generally is more effective (both in terms of cost and the benefits it provides to the environment) in heating-dominated buildings in colder regions. In warmer climes, it has a lower degree of effectiveness in cooling-dominated structures with significant interior heating loads. Second, according to the principle, increasing the insulation amount should reduce the heating gained or lost by conduction, resulting in improved energy efficacy. In actuality, this is not true 100 percent of the time. When the building envelope is over-insulated, the decrease in heating loss during the cooling mode (particularly in the middle of the season) tends to raise the cooling need, which might result in an overall rise in the quantity of energy utilized for space conditioning. It is referred to as the "point of thermal inflection", and it is the limit beyond which adding further insulation might be counterproductive. Thirdly, the best possible insulation thickness could be determined by conducting a simple economic cost analysis, a more complicated energy and carbon dioxide emission analysis, and an analysis of the cost-optimal levels of energy-efficacy minimum specifications for structures and building elements.

Aggerholm [37] all of these analyses can be done in conjunction with one another. People are becoming more concerned with the cost-effectiveness of energy-efficient measures and the environmental efficacy of these assessments. It is hoped that researchers and designers all around the globe will start utilizing life-cycle carbon dioxide emission analysis more frequently.

Giovani [38] many designers and researchers have utilized design strategies depending on thermal mass to reduce the temprature of the interior of the building during the daytime. In more recent times, the advantages of thermal mass have been methodically studied via sensitivity analysis. It is widely believed that nighttime ventilation, whether natural or mechanical, must be integrated with thermal mass to utilization the building's full potential for conserving energy.

Artmann et al. [39] design method prevents excessive summer heating and lowers the required cooling amount, which might assist in lessening climate change's influence on the built environment inside buildings.

Loutzenhiser et al. [40] windows and glazing (involving day lighting) the general strategy seems to be to lower the WWR (window-to-wall proportion) (for example, smaller window area) and then utilization double or multiple glazed windows systems that are low-emissivity glass and an inert gas-filled cavity to minimize the quantity of heating obtained or loss. Daylight- the general strategy would be to maximize the quantity of daylight that enters the building. Again, double or multiple glazing could not be particularly successful in cooling-dominated buildings in warmer regions with substantial interior heating loads since single reflective glass is often employed in these situations to restrict the solar heating absorption amount. Nevertheless, designs with less window space and more reflective glass do not lend themselves well to adequate daylight. As a result of the dual savings in power generation utilization, such as artificial light and air conditioners (less heating dissipation from lighting installations), daylight systems have been demonstrated to have an excellent energy-saving possibility, particularly in cooling-dominated buildings because both numerical and experimental works have indicated a great energy-saving potential of daylighting schemes.

Tian et al. [41] analyzing the possible combinations of daylight apertures (light transmittance WWR) and solar apertures (shading coefficient WWR) is the best way to achieve the optimal balance between the beneficial effects of daylight and the potentially harmful effects of excessive solar heat. Throughout the preliminary conception phase of windows and glazed system design, several design considerations relating to the thermal, acoustic, visual, and solar performances of the window and glazing system must be examined simultaneously. Various types of glazing, structures, and climates have all been accounted for in developing generalized energy rating systems. These grading systems are significant design tools that may help contribute to the creation of sustainable and environmentally friendly buildings development.

Akbari et al. [42] heating obtained via the roof of a low-rise building, especially a single-story structure, may contribute significantly to the overall cooling load of the building envelope and can be mitigated by utilizing reflective or green roofing materials. Roofs that are reflective or cool reflect most of the sun's heating and, as a result, minimize the quantity of heating gained by conduction. Reflective roofs result in significant energy savings. explored 11 prototypical buildings (for example, health care, school, store, office, and residential) in 11 United states metropolitan statistical areas. They predicted that if all roofs were changed to optimum reflectivity, the reduction in peak demand would be equivalent to avoiding the construction of more than 13 power plants with a capacity of 0.5 GW based on the assumption that all roofs would have the same level of reflectivity.

Boixo et al. [43] more subsequently, discovered that employing a method of a similar kind for residential structures in Andalusia, Spain, may save 295 MWH of power annually. Greening rooftops in humid, tropical, or subtropical climates have excellent temp performance because of increased latent heating dissipation. They can prevent the majority of solar heating from being performed in the building. Greening rooftops allows for greater water evaporation from the plant's leaves. In the context of ZEBs, these energy-saving methods may not be appropriate due to the restricted roof space available for installing sustainable power systems, including photovoltaic panels (PVs) and wind turbines. These two criteria directly oppose one another; thus, a middle ground must be found.

2.2. RENEWABLE ENERGY AND OTHER TECHNOLOGIES

Even after implementing all of the most cutting-edge strategies for reducing a building's energy consumption that is presently accessible, energy is still necessary to power the property's day-to-day operations, which is accomplished with zero-emission buildings (ZEBs) thru the utilization of sustainable power and other techniques (for a description of the technologies utilized in some recent case projects [44], as shown in table 2.1. The following seems to be a list of main techniques that are often utilized: (the first four are examples of on-site applications, whereas the fifth and final example is an off-site application)

2.2.1. Photovoltaic and Building-Integrated Photovoltaic

Photovoltaic (PV) is among the most promising techniques for attaining sustainable development in sustainable power. All of the ZEBs research papers presented in table (2.1) utilized PV technology in some capacity. Solar photovoltaic panels, also known as modules or arrays, are frequently installed on the roofs of residential and commercial structures in urban and suburban regions (for example, schools, hotels, and offices) [45]. Other aspects of the built environment are often exploited to maximize the number of photovoltaic modules placed and, as a result, the quantity of electrical power produced. This kind of system is referred to as building-integrated photovoltaic (BIPV). Because BIPV helps to enhance the quantity of power produced per unit floor space of the building, solar energy can become a more feasible alternative to the electrical grid and complement it.

Li et al. [46] nevertheless, this does tend to block the perspective, which may impact the natural sunshine penetration. Recent research utilizing semi-transparent Photovoltaic panels for the buildings envelope of office buildings in subtropical Hong Kong has also illustrated that the double function of allowing sunlight to access the indoor environment to facilitate natural lighting designs is reasonably possible. This research was done to illustrate that the double function of generating electricity and enabling sunlight to access the interior spaces is feasible.

Cheng et al. [47] hybrid photovoltaic thermal system is a more recent innovation developed to increase the energy efficacy of PV. Solar cells generally have an efficacy ranging between 9-18 percent when converting energy from the sun into electricity, which means that more than an 80 percent of the solar radiation absorbed is not transformed into electricity but reflected or lost as thermal energy. This results in a greater temp at which the solar panel was functioning, which in turn causes the efficacy of the converting to be reduced. A great-performance thermal electric (HPVT) system has utilized a thermoelectric cooling module to bring the temp of the solar cells down. It capitalizes on the hot water that is created by the creation of waste heat. Therefore, great-pressure variable temperature (HPVT) creates thermal and electrical energy.

Strzalka et al. [48] electricity produced is utilized to satisfy the electrical needs of the respective building. Any excess electricity will be feed directly into the electric grid utilizing a measurement and connection arrangement for photovoltaic and building integrated photovoltaic systems connected to the power grid. A photovoltaic (PV) system's output power and system efficacy fluctuate at various times of the day and throughout various seasons depending on the current local weather situations overall and the solar radiation amount accessible. This is because solar radiation levels differ throughout the day and the year. When designing and analyzing a PV system, architects and engineers would better understand the system's expected performance if they had access to data on seasonal and daily variations. On-line monitoring and measurements taken directly at the installation site of operational PV systems provide the means to ascertain this data. An important technique to improve the proportion of renewable energy inside the grid is to investigate the possibility of generating electricity on-site utilizing photovoltaic cells and adding any surplus power to the grid served by the neighborhood utility. Recent research that looked at the large-scale integration of PVs in cities determined that PV systems can achieve 35 percent of the demand for power , this relieves pressure on fossil fuels and reduces the carbon dioxide emission caused by their utilization.

On the other hand, widespread usage of photovoltaic energy might result in unstable electricity and strain the already inadequate quality of current power grid structures. There is a need for more study on "smart grids". In addition, zero-emission buildings must ideally be constructed to work in tandem with the regional power grid, thus that they do not place additional strain on the power infrastructure that is already in place.

2.2.2. Wind Turbines

Because wind is inherently unpredictable, traditional thermal power production cannot be directly compared to wind power generation. Reliable wind energy predicting the future plays a significant function in the planning and analysis of wind turbine systems. It is essential to address the difficulties of balancing the supplying and demand in any electricity network. Wind turbine systems have a significant function in the planning and assessment of wind turbine systems. Once solar accessibility is low, wind access is usually great.

Foley et al. [49] conversely, that also proposes that wind and solar energy could compensate for each other throughout various times of the year. Generally, wind and solar accessibility play similar properties (for example, once solar accessibility is low, wind accessibility tends to be great, and conversely). Because of this, the construction of hybrid PV-wind power generating systems at utility size and small automated systems has been made possible. It was also discovered that hybrid systems utilized to have a superior energy performance compared to either Photovoltaic or wind systems operating alone. The problem for ZEBs will be maintaining the grid's stability, regardless of whether or not they were implemented as single or hybrid systems.

Liu et al. [50] underlined the relevance of grid stability in integrating large-scale fluctuation sustainable power with the current electrical infrastructure. Although their focus was not specifically on the utilizations of ZEBs, their findings are relevant to ZEBs. Once again, further effort is needed in this particular domain.

2.2.3. Solar Water Heaters

Domestic hot water heating accounts for a significant quantity of a household's overall energy usage, making it one of the most energy-intensive activities in the residential sector. Recent research results that included a range of innovative water heaters, including solar water heaters (SWH), into a city-scale residential power end-utilization model for Osaka in Japan revealed significant potential for decreasing CO_2 emissions and energy consumption. Over the years, there has been fresh and inventive improvement in enhancing the total energy efficacy of SWHs. This development, which can conveniently be applied to ZEBs, was thus made possible by recent technological advancements. For example, a low-profile integrated collector space hot water system has been improved to solve the problem of traditional architecture.

Additionally, a solar water heater (SWH) has evolved utilizing a solar water pump. The pumping power is generated by the steam from a flat plate collector, and the total cost was significant compared to a traditional SWH. Other recent developments in SWHs involve a two-phrase thermo syphon SWH, with an ideal charge efficacy of 82%, which is greater than traditional SWHs; an SWH utilizing stationary V-trough collector, that has demonstrated remarkable findings in both the optical efficacy of the reflector and the total thermal effectiveness of the system; and a PV combi system that simultaneously satisfies domestic hot water and space heating specifications [51].

2.2.4. Heating Pumps

Heating pumps provide practical options for recovering heating from various energy source documents for various building utilizations. Recent developments in heating pump technology have focused on expanding utilization and application scope, improving cycle elements and working fluids, and developing more sophisticated cycle designs for heat- and work-actuated systems. Heating pumps typically have a performance coefficient (COP), also known as a measure of efficacy that falls somewhere between 3 and 5. The coefficient of performance (COP) of air-source heating pumps is typically close to the bottom of the range. ASHPs could be assimilated with the solar collector to enhance their energy performance, which allows energy to be supplied to the evaporator at a greater temprature than the ambient outdoor air, which increases capacity and a greater coefficient of performance (COP). The prevailing air temperature may limit the ability of an ASHP and cause it to operate at a lower efficacy level throughout times of peak cooling or heating demand.

In recent years, several studies have been conducted on developing ground-source heating pumps, also known as GSHPs, to cover peak loads without requiring supplementary plants. The benefits involve lower operating costs, greater reliability, longer unit life, energy conservation, and decreased carbon dioxide emission. In most cases, there is also no need for an outdoor unit. It is generally agreed upon that GSHPs can obtain better operating effectiveness in climates where the specifications for cooling and heating buildings are well-balanced throughout the year. Nevertheless, most buildings have unbalanced loads, with either cooling or heating specifications predominating; this is particularly true in relatively warm and colder climatic zones. A significant quantity of heating would be transferred to the ground thru borehole heating exchangers in buildings that rely primarily on cooling in regions with hotter areas. Throughout a predetermined time, heating would then accumulate, leading to an increase in the ground temp and consequently impacting operational efficacy, which could be resolved by utilizing hybrid systems with additional heating-rejecting units, including cooling towers, to eliminate the accumulated heating. In cooling-dominated buildings with similar hot water needs, hybrid ground-source heating pump systems with hot heating water could also be an attractive option (for example, showers and washing). GSHPs may also lead to thermal heating deprivation of the ground in houses in colder climate areas where heating is the primary function of the building. Because of this, the temp of the working fluid would gradually drop, resulting in a loss in the system's efficacy. A typical strategy is to utilize hybrid ground-source heating pumps (GSHPs) with solar collectors. These systems recharge the ground via boreholes, preventing the earth's heating from depleting. The most efficient setup is one in which solar energy is utilized to heating water for home utilization throughout the warmer months of the year while also being utilized to replenish groundwater supplies. The ideal size should be determined by striking a balance between the hot water needed during the summer and the amount needed during the winter [52,53].

2.2.5. District Heating and Cooling

DHC, or district cooling and heating, has the potential to have energy and community users benefits in terms of efficacy, the environment, and operation costs. DHC is helping to substitute less efficient tool in residential houses with a more efficient cooling and heating system for space cooling and heating via the installation of central cooling and heating systems. DHC can contribute positively to the fight against climate change and other energy-related environmental problems, including acid rain, ozone depletion, and air pollution [54].

Lund and Gebremedhin et al. [55,56]. due to the "amount impact" and the" operational grade," research conducted in Japan discovered that the energy efficacy of cooling in a DHC system seems much greater than that of single cooling systems, which was determined to be the case. Recent research on district heating in Norway and Denmark has shown that switching to district heating may result in a significant decrease in the quantity of fuel utilized, the quantity of Carbon dioxide emissions produced, and the quantity of money spent on operational costs.

2.3. INSULATION BUILDING

Thermal modernization in Poland is often seen as an economic benefit, but it also has significant environmental benefits. The study explores the economic and environmental benefits of thermal insulation for building walls. Insulation reduces thermal energy consumption, reducing CO_2 emissions. The cost of insulation is tied to the purchase, transportation, and installation, while profits are proportional to the reduction in energy consumption. The optimal insulating layer thickness is determined using a two-criteria optimization approach, considering energy sources, wall building materials, and insulating materials. The sustainable development paradigm is considered in the analysis [57].

Simona et al. [58] paper investigates the effectiveness of insulation on building energy efficiency in residential structures. It examines the movement of freezing point in exterior walls when additional insulation is applied to the outer surface of the wall, highlighting the importance of climate-friendly measures in enhancing energy efficiency.

Aditya et al. [59] study explores the use of thermal insulation in the home sector, focusing on its efficiency and environmental benefits. It aims to compile recent innovations in building thermal insulations and explore life-cycle analyses and potential emissions reductions by utilizing appropriate insulation materials.

Azkorra et al. [60] approach helps reduce energy consumption and improve thermal comfort. Greenery on buildings is gaining popularity for improving urban quality of life and noise attenuation. Green walls are promising architectural greenery systems, but there is limited research on their sound insulation capabilities. Two standardized laboratory tests found a 15 DB weighted sound reduction index and a 0.40 weighted sound absorption coefficient for modular-based green walls. While green walls have potential as sound insulation strategies, design improvements, such as improving the sealing of seams between modular sections, are needed. Malaysia's electricity usage has increased significantly in the last decade due to the growing number of air-conditioned buildings. A study aims to predict the long-term environmental impact of thermal insulation materials for Malaysian building external walls.

Shekarchian et al. [61] study found that 2.2 cm fiberglass-urethane insulation offers the greatest cost savings and is the most economically feasible insulation material, reducing annual CO_2 emissions by 16.4 kg/m^2. The study also forecasts future emission production fluctuations over the next 20 years, revealing that increasing renewable power plants and phasing out traditional thermal coal plants will significantly reduce CO_2 emissions.

Dombayci [62] Denizli, Turkey's third climatic area, requires heating for five months. Thermal insulation is crucial for energy efficiency and emissions reduction. A study explored the environmental impact of optimal insulation thickness in external walls using coal as fuel and expanded polystyrene as insulating material. Results showed that optimal insulation reduced energy usage by 46.6% and CO_2 and SO_2 emissions by 41.53%.

Bolattürk [63] study explores the optimal insulation thickness for Turkey's coldest cities, Erzurum, Kars, and Erzincan, based on a cost-benefit analysis of the life cycle. The optimal insulation thickness results in significant energy savings, with Erzurum potentially saving up to $12.113 \$/m^2 of wall area. Insulation is increasingly popular due to its environmental impact and high energy cost.

2.4. COOLING AND HEATING LOAD

This research presents a machine-learning technique for predicting residential building heating and cooling loads using a deep neural network (DNN). The DNN uses nonlinear information extraction in a hierarchical framework for learning and pattern recognition. The energy data set was divided into training and testing sets, and statistical performance metrics like variance accounted for (VAF) and relative average absolute error (RAAE) were used to evaluate the model's performance. The DNN and GPR models generated best-predicted VAFs of 99.76% and 99.84% for cooling and heating loads, respectively, demonstrating the importance of accurate models in building design [64].

Erdemir et al. [65] study explores the use of thermal energy storage to balance electricity production and demand by transferring cooling and heating loads to off-peak hours. In Canada, electricity is the primary energy source for cooling and heating, impacting peak electricity demand. The study found that thermal energy storage can transfer peak power load to off-peak periods, lowering peak loads by 25% and 45%, respectively. Additionally, thermal energy storage systems can reduce cooling and heating costs by 20% and 18% in Canadian homes.

Bagheri-Esfeh et al. [66] research aimed to minimize cooling and heating loads in a residential building using phase change material (PCM). Energy Plus numerical modeling, GMDH-type artificial neural network (ANN), and NSGA-II were used to achieve this goal. Design variables included melting temperature, PCM thickness, thermal resistance, internal gain, and infiltration rate. The aim was to minimize annual cooling and heating demands. The Energy Plus program computed objective functions and trained the neural network. Polynomials were created for goal functions, and Pareto optimum points were determined. The optimal PCM layer thickness and melting temperature were determined.

Ahmad et al. [67] research presents six data mining-based models for predicting future heating and cooling load demand of water source heat pumps. These models, including tree bagger, Gaussian process regression, multiple linear regression, bagged tree, boosted tree, and neural network, use readily available measurements of a limited number of variables relevant to water source heat pump operation in the building environment. Simulations were run from July 8th to August 7th, 2016, with performance indicators such as mean absolute error, coefficient of correlation, coefficient of variation, root mean square error, mean square error, and mean absolute percentage error. The models were found to be effective in predicting anomalous behavior and future cooling and heating load demand in the building environment.

G et al. [68] article explores the impact of various window glazing materials on heat gain in buildings. The study measured spectral data of various window panes in the sun spectrum range of 300-2500 nm and used MATLAB scripts to calculate solar optical parameters, solar heat gain coefficient, and heat transfer through the glazing material. Thermal analysis was performed in India using nine window panes in eight directions and three different meteorological conditions. Grey reflective glass was found to be the most energy-saving, saving the most money in net annual cooling and heating costs. In Jodhpur's south orientation, it reduced heating and cooling costs by $61.24 per year.

Zhao et al. [69] research presents a load forecasting method for office buildings using artificial intelligence and regression analysis. The method includes wavelet transform, support vector machines, and partial least squares regression. The approach is validated using an office building in Tianjin, China, and tested over various prediction horizons. The results show that the proposed method provides high-accuracy dynamic load forecasting over various time horizons, and the impact of weather forecast precision on the model is also examined.

Gunay et al. [70] study outlines a method for selecting an inverse black box model to accurately define building-level heating and cooling load patterns. It uses data from five office buildings, including temperature, sun irradiance, wind speed, and humidity. 18 models with variable inputs and parameters were developed for each building. The model with a one-layer artificial neural network, six inputs, and a one-hour input history was chosen. The study presents various use-cases for inverse black box models in operational decision-making.

Berger et al. [71] climate change is affecting office building performance, causing rising outdoor temperatures and CO_2 emissions. This study uses dynamic thermal simulation to estimate heating and cooling demands in Vienna, Austria. Results show that heating demands decrease marginally, while cooling demands increase dramatically. The study also reveals that unique constructions of buildings may lead to increased or stagnant energy demand under climate change conditions.

Daouas [72] The Tunisian environment requires heating and cooling for comfort. To address the growing energy consumption, external wall insulation has been implemented with thicknesses ranging from 4cm to 5cm. This analysis calculates insulation thickness, energy savings, and payback period for a typical wall structure based on cooling and heating loads. The study uses the Complex Finite Fourier Transform (CFFT) method to estimate annual transmission loads. The south orientation is the most cost-effective, with an optimum insulating thickness of 10.1cm, 71.33% energy savings, and a 3.29-year payback period. Wall orientation affects energy savings, reaching a maximum value of 23.78TND/m^2. Economic criteria like insulation cost, energy cost, inflation and discount rates, and building duration also impact optimal insulation and energy savings.

Qu et al. [73] Carnegie Mellon University conducted a study on a solar thermal cooling and heating system. The system, which includes 52 m^2 linear parabolic trough solar collectors, a 16-KW double effect water-lithium bromide absorption chiller, and a heat recovery heat exchanger, produces chilled and heated water for space cooling and warmth. This is the world's smallest high-temperature solar cooling system and has been operational for over a year. The performance of the system was evaluated using the transient system Simulation software (TRNSYS). The study found that a correctly sized storage tank and short, low diameter connecting pipes could deliver 39% of cooling and 20% of heating energy for a Pittsburgh, PA building space.

Synnefa et al. [74] cool roof coatings can significantly reduce cooling and heating loads, improve indoor thermal comfort, and reduce peak cooling demand in air-conditioned buildings. Increased solar reflectance can reduce cooling loads by 18-93% and peak cooling demand by 11-27%. Indoor thermal comfort can be enhanced by reducing discomfort hours by 9-100% and maximum temperatures by 1.2-3.3°C. The heating penalty is less significant than the cooling load reduction. Cool roof coatings are an efficient, low-cost, and simple technology.

2.5. ZERO HEATING BUILDING

Zero-heating buildings are constructed like passive homes, with the addition of ultra-low u-magnitude glass to take benefit of current advancements in the field. It has been demonstrated that the need for heating in buildings with window u-magnitudes that are closer to 0.3 W/(m^2K) causes a reduction in demand [75,76]. Because of this, the structure would not require a power reserve for the winter and would not require any seasonal energy storage. Structures constructed by the Passive-house standard may make provisions for eliminating the central heating tool while requiring a minor auxiliary heating supply in the ventilation system.

2.5.1. Zero-Heating Building Developments

Zero-heating buildings may be the foundation of a market-acceptable solution to the problem of carbon dioxide abatement, which would be accomplished by reducing the requirement for seasonal power storage. In addition to a decrease in the requirement for storing energy, there are also reductions in shading and a shortening of the heating arrangements. Abandoning modulated exterior blinds, which are now widespread, and moving to more expensive multiple glazed with built-in solar control glass may increase the required cooling. The cooling demand, Q'NC, of the zero-heating buildings must be kept at much less than 20 KWH(m2a) for offices building and much less than 15 KWH/(m^2a) for all other kinds of buildings when it is designed. After taking advantage of the benefits of nearly zero-heating buildings, one could further enhance such a structure by installing Photovoltaic to create something akin to a winter-positive energy building. This type of structure has the potential to expedite the resolution of societal energy problems by delivering additional power at the appropriate moment. Therefore, the residual need for ventilation and cooling may be advantageously coordinated with solar radiation, in which the greatest power generated by PV panels roughly corresponds with the max power required for cooling [77].

2.5.2. Construction Costs

The cost of quadruple glazing, the primary add-on component to the passive home, is equivalent to that of triple glazing plus one more intermediate glass pane and comes in at around 10 euros per square meter because quadruple units make it possible for the u-magnitude of glazed to be lower than 0.4 W/(m^2K). Externally modulated sunlight shading, and the significant expense that goes with it, maybe eliminated without causing any degradation in the building's ability to save energy [76]. The current pricing reality differs from what was expected. Because there is no long-term experience, design guideline, or established assessment standard, there is a tendency to charge quintuple-glazed windows units at a cost equal to the cost of a quadruple and a triple unit, which is done in preparation for the possibility that something will be turn out to be seriously flawed in the future, necessitating the substitute of building glazing.

2.6. FEATURES OF ZERO-HEATING BUILDINGS

2.6.1. Marketability Analysis

The primary reasons for the limited market penetration of energy-efficient buildings seem to be the inability of energy-efficient structures to compete in the marketplace and inefficiencies in integrated design approaches. As an alternative to simply focusing on the improvement of energy efficacy, one strategy that has been suggested as a method for reducing energy requirements in the construction industry seems to be to increase the number of energy-efficient buildings that have improved marketability as a result of enhancements made to their aesthetic features (product differentiation). The empirical evidence gathered up to this point demonstrates that improving aesthetic features and window design may be a supplementary method to overcoming current market barriers [78].

Haddock et al. [79] market barriers include a great initial cost, a low market magnitude, and an absence of financial demand for energy-efficient buildings. According to the study, the greater glazed area is the most important factor in desirable architectural product distinction. Unless features including certain tenant comfort, service reliability, and maintenance cost, some particular varying capabilities seem to be indoor clean air, ambient daylight allocation, and fresh air flow, are addressed in product marketing, the possibility of opting for green construction seems to be most likely to be greater.

2.6.2. Design Freedom

No size restriction is placed on glazed sections owing to energy needs since the glazing being utilized has extraordinarily low u-magnitudes. NZEB buildings can be constructed with entirely glazed walls [80]. Because of this, some of the limits placed on the structure's design by the two and three-pane windows are removed. Most importantly, a structure that requires no heating does not necessarily have to be constructed to function as a passive solar building.

2.6.3. Comfort

The environmental quality of the interior of a building is an essential characteristic that plays a role in determining the well-being of the residents of the building. The utilization of dynamic solar shading frequently results in the inhabitants' and workers' having restricted or no interaction with the surrounding environment and a diminished quantity of daylight. On the other hand, glazing with several panes allows for continuous interaction with the surrounding environment. A low seasonal selected solar gain [81], which gives comfort in the summer, and a system u-magnitude of around 0.3 W/(m^{2}K), which delivers practically negligible heating demand in the winter even in Scandinavia, are both characteristics that offer summer comfort. The temperature s on the interior of the glass are kept at a constant level throughout the year utilizing a system with a low u-magnitude. In addition, an unmatched draught-free zone has been established around the panoramic window.

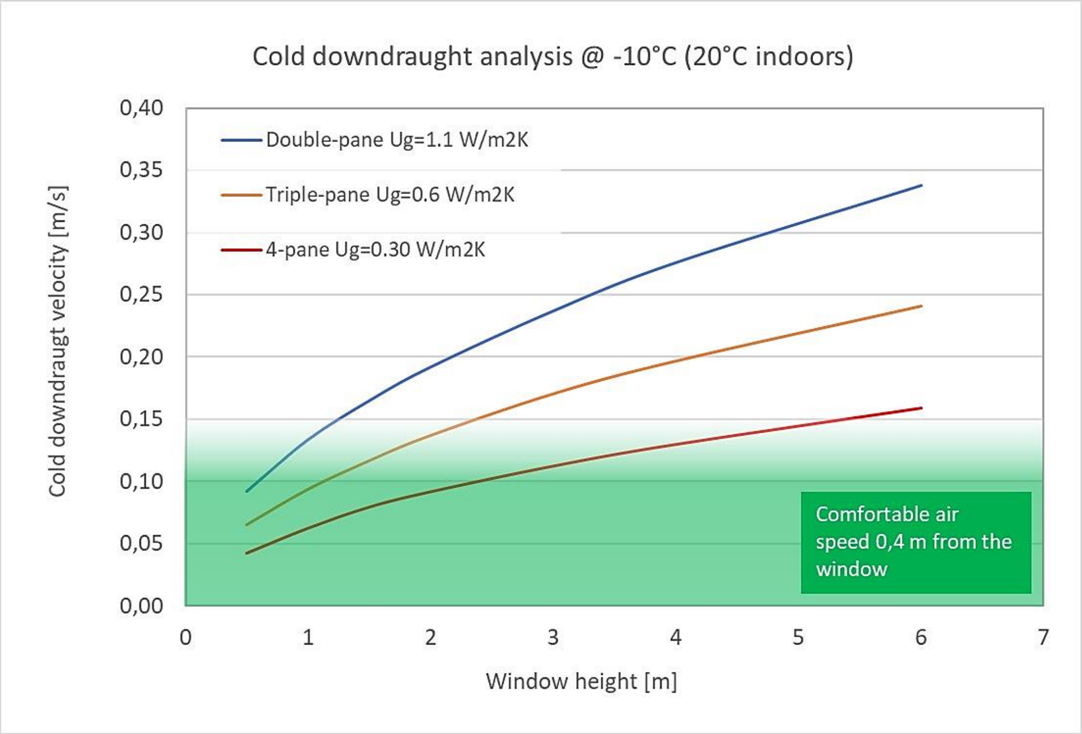


Figure 2.1. Cold downdraft 0.4 m from the window estimated for double-pane, triple-pane, and krypton-filled quadruple-pane glazing at given glazing heights [81].

2.7. CASE STUDY

Table (2.1) provides an overview of some recent research that has been conducted. In general, zero-energy buildings involve two different design strategies: (i) reducing the need for building energy consumption (particularly for cooling and heating) by implementing more energy-efficient indicators, and (ii) adopting sustainable power and other techniques to satisfy the limited energy requirements. Both of these design approaches aim to minimize the quantity of energy that is utilized in buildings. This study presents an overview of the ZEBs' previous research, and consequences for sustainable growth are discussed. Research that is not specifically relevant to ZEBs but is directly related to the two design methods and favorable to the growth of ZEBs will also be considered to provide a complete picture and a better grasp of the underlying challenges and key aspects. Instead of a full study of each specific technology or system, the purpose of this presentation was to provide an overview. The strategy consisted of providing a concise description/discussion of the most important concerns and prominent aspects linked to particular systems/techniques and quoting the appropriate references. This allowed readers to turn to the material mentioned for more in-depth information and analysis. It is hoped that scholars in the energy field, as well as those responsible for formulating policy, find this review interesting.

Table 2.1. Brief of ZEBs recent research.

Study area	**Sources**	**Buildings**	**Energy-efficient measures**	**Zero energy techniques**
Cincinnati	[32]	Factory, FC	LEED EB Platinum Certified construction [82].	GSHP, biomass stoves, wind turbines, solar thermal, and PV.
Denmark	[83]	RS	low energy glazing and thermal insulation.	Three alternatives energy supplements: (i) PV with DH grid, (ii) PV with GSHP, and (iii) PV and air/solar HP with solar thermal.
Hong Kong	[33]	RS	Without measurements for particular energy-efficient.	Wind turbines, solar hot water, BIPV, and PV.
Las Vegas	[84]	RS	Water-cooling air conditioner, great thermal mass walls, great performance windows, great R-magnitude attic, insulated slab.	Solar heater water and PV tiles.
Madrid and Shanghai	[85]	RS	Evaporative cooling, sun shading, thermal mass.	Solar thermal hybrids HP and reversible HP supplied by Photovoltaic
Serbia	[86]	RS	Thermal insulation.	GSHP, Photovoltaic with water/water HP,

Table 2.2. Brief of ZEBs recent research on energy-efficacy processes applied to buildings.

Study area	Sources	Buildings	Building energy consequences and energy-efficient techniques
Australia, eight climates' areas	[87]	RS	Technologies such as dual-glazed and low-emissivity glass, thermal insulation, and great-efficacy home appliances (particularly for cool-dominated climates).
	[88]	FC	Insulation against the heating (less effective in areas that favor cool), a lower window/wall proportion (WWR), reflective glass, and a lower light/shadow proportion (LLD) (lighting load density, most effective in cool-dominated climate).
China, five main architectural climates areas	[89–91]	FC	Reduced WWR, increased summer SST (setting point temp), decreased LLD, improved chiller COP (performance coefficient), dual and three glass, thermal insulation (useful in very cold and frigid areas).
Hong Kong SAR	[92,93]		Residential Thermal mass, reflecting window coatings, decreased WWR, solar shading, a 9–19 percent decrease in cooling load, and an 11–29 percent decrease in peak cooling demand.
United Arab Emirates	[94]	RS	Thermal mass, dual glazed, reduced WWR, day lighting, and a 28 percent decrease.
America, eight climates' areas	[95]	Non-RS (school, hotel, FC, etc.)	Day lighting, solar shading, low-emissivity windows, and thermal insulation reduce carbon dioxide emissions.
UK	[96]	RS	Dual glazed, cavity wall, thermal insulation (optimum choice due to greatest saving in heating energy demand and lowest induced increase in cooling load).
	[97,98]	FC	LED lighting, triple glazing, low-emissivity glass, thermal insulation, thermal mass with great ventilation, and solar shading aid decrease summer overheating.
Berlin (cold), Barcelona (temperate),	[99]	General, no exact buildings kind	Conventional air-cavity wall, ventilated wall, plus-insulated wall (air-cavity with extra cork covering), environmental

Palermo (warm)			saving, and good energy in extreme weather situations in Palermo and Berlin.
Switzerland	[100]	FC	To prevent summer overheating and lower the demand for cooling energy usage, utilize unique design techniques, night ventilation, and solar shading.
Burkina Faso (sub-Saharan Africa)	[101]	FC	Solar shading may reduce cooling demand by as much as forty percent.

Office=FC, residential= RS

2.8. LITERATURE REVIEW

All new buildings in Europe must have an energy usage that is "almost zero" by the year 2020 [102] as part of the European Union's energy strategy and policy for decreasing the utilization of fossil fuels. Because of this, there is a significant need for research into cost-effective technologies and solutions to satisfy these aggressive energy decrement goals without sacrificing daylight conditions or interior temperature. It is common knowledge that windows significantly impact the energy utilized and the atmosphere within a building. Large windows, for instance, may let in more natural light into a room. However, they can also cause visual discomfort and extreme heating losses or gains that can impact the energy required for cooling or heating the space and the thermal condition within the room. Suppose we want to obtain the goal of "nearly zero" energy usage and the goal of buildings with a comfortable and healthy indoor environment. In that case, it is essential to detect a balance between the quantity of daylight available, the level of thermal comfort, and the quantity of energy consumed. Much research has been done on the design of windows in office buildings about the energy utilized for heating, cooling, and lighting.

Ghisi et al. [103] and Suvorova et al. [104] focused on the impact that orientation, window size, and room geometry have on the quantity of energy that is consumed for lighting, cooling, and heating in offices located in a variety of temperature zones.

Suvorova et al. [104] assessed the impact of geometrical parameters on a commercial office building's energy efficacy, including window orientation, window/wall ratio, and room width/depth ratio. Six climatic areas—area 2 hot (Boston, TX), area 3 warm (los Angeles, CA), area 4 mixed (Seattle, WA), area 5 cool (Chicago, IL), area 6 cold (Minneapolis, MN), and area 7 extremely cold—were each subjected to a series of energy simulations (Duluth, MN). Utilizing a model of a room in a typical office building made in design builder, an energy analysis program, we evaluated total annual energy consumption in the United States (area 1 very hot was excluded from the estimations since it represents a very small portion of the US territory such as with southern Florida and the Hawaiian Islands). The simulation findings are obtained to determine possible energy savings for office buildings in different temp areas and the combination of factors giving the lowest energy usage. According to the research, geometrical considerations have a substantial impact on energy usage in cold regions (Areas 6 and 7) and hot regions (Areas 2 and 3) but very little in moderate areas (Areas 4 and 5). In warmer climates (Areas 2 and 3), energy savings have been on a mean between 3 and 6 percent, with a max between 10 and 14, and 1 percent in moderate and cold climates (Areas 4–7).

Ghisi et al. [103] propose a technique for estimating the potential for energy savings on lighting when there is efficient daylight integration with the artificial lighting system utilizing the Ideal Window Area concept. The approach created five distinct room proportions and ten different room dimensions. The visual doe application was utilized to do the energy analysis work for the climates of Leeds, UK, and Florianopolis, Brazil. Then, utilizing an approach based on daylight Parameters, the potential for lighting energy savings was evaluated for each room. For an exterior illumination of 5000 lux, it was found that the potential energy savings for lighting in Leeds varied from 10.8 to 44.0 percent for all room sizes and room proportions. In contrast, in Florianopolis, the potential ranged between 20.6 and 86.2 percent for an external illumination of 10000 lux. Anywhere in the globe may utilize the technique that has been described.

Lee et al. [105] investigated the impact of window/wall proportions, orientation, u-magnitude, g-magnitude, and optical transmittance on the search for the best window designs for offices in five of Asia's most common climate regions.

Motuziene et al.[106] studied the impact of window/wall proportions, window orientation, and glazed window kinds on the total power usage for an office building in the cool climatic regions of Lithuania. Meanwhile.

Ko [107] identified many examples of optimization access to daylight and energy savings by applying regression analysis to determine the most efficient combination of window area and glazed windows characteristics for offices in 6 various climates in the United States to determine the ideal combination In residential buildings, the connection between energy usage, thermal climate, and natural lighting becomes less clear than in commercial structures because residential building utilization and occupancy are less expected than commercial building utilization and occupancy. In addition, although the majority of energy in offices is utilized for air conditioning and lighting, the primary emphasis of energy conservation efforts in residential buildings has traditionally been on lowering the energy required for heating. The integrated assessment of window design and its combination influence on heating, cooling, and lighting needs to be addressed in residential structures, which could be some of the reasons why.

Several studies on lighting in residential buildings have investigated the availability of natural light and the possibility of cost reductions in artificial lighting by experimenting with different window shapes and dimensions [108,109]. Investigations that looked at ways to reduce the need for cooling and heating in residential buildings recognized the impact of the size, orientation, and kind of glazing utilized in windows. The outcomes of this research proposed that the size of south-facing windows was essential to decrease the need for heating [110–113].

Person et al. [114] conducted on the effectiveness of passive homes in Sweden revealed that the size of the windows is no longer as significant as it once was for the decrease in the quantity of energy required for heating the home. Reducing the danger of overheating must be the primary concern in residential structures with good insulation.

Person et al. [114] experimented so as to determine how the reduction in the size of the windows facing south and the increase in the size of the windows facing north in these low-energy residences might well affect the quantity of energy consumed and the maximum quantity of power required to maintain an indoor temp between 23 and 26 degrees celsius. Various window types and orientations, as well as their respective effects, have been examined. The dynamic building modeling program DEROB-LTH was utilized, and the results of the simulations reveal that the dwellings have an exceptionally modest need for energy. According to the findings, the size of the energy-efficient windows will not significantly impact the heating requirements during the winter. However, it does impact the requirement for cooling during the summer, which suggests that as an alternative to the conventional method of constructing passive homes, it is conceivable to increase the quantity of window space facing north and achieve improved lighting conditions. A window facing south is best for reducing the danger of great temp s or the quantity of energy required for cooling, and this window size is less than the original size of the buildings analyzed.

Andersen et al. [115] as part of a larger movement toward environmentally friendly buildings that emphasize the health and happiness of their occupants.

Mardaljevic et al. [116] has recently become a resurgence in focus placed on the indoor thermoelectric environment and the possibility of nonvisual impacts of natural daylight in residential buildings.

Paridari et al. [117] "Active houses" must be designed, for instance, to enable optimum solution lighting systems and attractive viewpoints to the outside while also helping to ensure an excellent indoor temprature and low energy usage without having a negative effect on the environment, which can be accomplished without needing a negative effect on the environment.

Alliance et al. [118] part of the model home 2020 project that aims to create weather patterns structures with a greater extent of livability a home known as "Home for life" has been constructed and designed in Denmark.

Panagiotidou et al. [119] design of this house followed the Active house requirements. and it was named after the project's name. So as to meet the requirements for a mean daylight parameter of 5 percent, the window/floor proportion in the home is 40 percent, which is almost twice as much window space as is typically utilized in single-family home.

Foldbjerg et al. [120] despite this, the total thermal atmosphere of the indoor space is favorable thanks to the careful attention paid to solar control thru the utilization of dynamic passive solar and ventilation cooling thru the utilization of natural cross ventilation thru the utilization of roof windows.

Steen Larsen et al. [121] one such illustration of this may be seen in the planning of a passive home in Denmark, where the glazed area was chosen to ensure that there would be a sunlight variable of 2 percent to the rear of the principal rooms.

Brunsgaard et al.[122] on the other hand, there have been problems with the temperature reaching dangerous levels since no sun control is offered.

The main originality of this study is obtaining zero energy by studying an office, calculating the cooling and heating loads in the summer and winter seasons, inserting a VRF system into it, and knowing the amount of electrical energy needed to feed the system by PV panels and getting heating and cooling load relative to (insulation, coating) in four cases and comparing to get the perfect case.

PART 3

METHODOLOGY

3.1. HOURLY THERMAL LOAD ANALYSIS AND TRANSFER FUNCTION

The purpose of calculating load is determine peak heating and cooling loads which used to size and select equipment and these calculations dependent on:

- Room conditions
- Occupancy
- Building construction
- Location

Factors Effecting Human Comfort

- Temperature
- Humidity
- Air speed

General Practice Comfort Limits

- Air temperature maintained between 68˚F–80˚F (20˚C–26˚C)
- Summer: 74˚F – 80˚F (23˚C–26˚C) 50% RH Max 60% RH
- Winter: 68˚F –75˚F (20˚C–23˚C) Min 35% RH
- 5.4˚F (3˚C) maximum head-to-foot temperature gradient
- Air Speed in occupied zone: 50 fpm (0.254 m/s) cooling, 30 fpm (0.15 m/s) heating

Heating LOAD– Heat Loss

Envelope Heat Loss

1. Walls
2. Floor
3. Windows
4. Roof

Heating LOAD Equation

$$q_{\text{wall}} = q_{\text{window}} = q_{\text{roof}} = Area \text{ x } U \text{ x } \Delta T \tag{3.1}$$

$$q_{\text{floor}} = Perimeter \text{ x } F \text{ x } \Delta T \tag{3.2}$$

$$q_{\text{total}} = q_{\text{wal l}} + q_{\text{window}} + q_{\text{roof}} + q_{\text{floor}} \tag{3.3}$$

$q = Load$
Unit : BTU /h (Watts)
$U = U$-value as calculated based on material properties
Unit: BTU/(h· ft^2·°F) {W/(m^2·°C)}
Fp = Heat loss coefficient of slab floor construction
Unit: BTU/(h·ft^2·°F) {W/(m^2·°C)}
ΔT = Temperature difference between indoors and outdoors

Determined using ASHRAE published weather tables [129].

Cooling Heat Gain

Internal Heat Gain

1. People
2. Equipment

3. Lights

Envlope heat Gain

Conductive

1. Walls
2. Floor
3. Windows
4. Roof

Solar

1. Windows

Cooling Load Equations

$$q_{\text{wall}} = U \text{ x } A \text{ x } CLTD_{\text{wall}} \quad (3.4)$$

$CLTD_{\text{wall}}$ depends on: construction (mass), orientation, latitude, time, Δt

$$q_{\text{roof}} = U \text{ x } A \text{ x } CLTD_{\text{roof}} \quad (3.5)$$

$CLTD_{\text{roof}}$ depends on: construction (mass), time, Δt

$$q_{\text{window \_cond}} = U \text{ x } A \text{ x } CLTD_{\text{window}} \quad (3.6)$$

$CLTD_{\text{window \_ cond}}$ depends on: construction, time, Δt

$$q_{\text{window \_ solar}} = U \text{ x } SC \text{ x } SHGF \quad (3.7)$$

$SHGF$: Solar heat gain factor

$SHGF$ depends on: orientation, time

$$q_{\text{light}} = 3.412\, W\, F_{\text{ul}}\, F_{\text{sa}}\, N \tag{3.8}$$

W = wattage

F_{ul} = lighting use factor (ratio of wattage in use)

F_{sa} = lighting allowance factor (ballast + lamp)

N = number of light

$$q_{\text{total}} = q_{\text{envlope}} + q_{\text{people}} + q_{\text{equipment}} + q_{\text{light}} \tag{3.9}$$

(q people, q equipment) depends on number of people and equipment [129].

3.2. THE HOURLY ANALYSIS PROGRAM (HAP)

The "Iraqi refrigeration blog" is an informative and valuable online platform that caters to professionals, enthusiasts, and stakeholders within the field of refrigeration, cooling, and HVAC (heating, ventilation, and air conditioning) systems in Iraq. This blog serves as a dynamic hub of knowledge, insights, and discussions centered on various aspects of refrigeration technology, energy efficiency, sustainability, regulations, and best practices specifically tailored to the Iraqi context. The Iraqi refrigeration blog offers a diverse range of articles, guides, case studies, and resources that address the unique challenges and opportunities faced by the refrigeration industry in Iraq. It aims to foster a deeper understanding of the intricacies involved in designing, installing, operating, and maintaining refrigeration and cooling systems across different sectors, such as residential, commercial, industrial, and healthcare. The Iraqi refrigeration blog plays a vital role in bridging the gap between theory and practice in the field of refrigeration within Iraq. It facilitates continuous learning, professional development, and the exchange of ideas among individuals involved in the refrigeration and cooling industry. By offering reliable, up-to-date, and context-specific information, the blog contributes to improved system design, enhanced energy efficiency, and the overall advancement of the refrigeration sector in Iraq. In essence, the Iraqi refrigeration blog serves as an indispensable resource, empowering professionals to navigate the complexities of refrigeration technology, promote sustainable practices, and drive innovation in line with the unique requirements and opportunities presented by the Iraqi landscape.

Carrier’s hourly analysis Program (HAP**)** is a computer tool which assists engineers in designing HVAC systems for commercial buildings. HAP is two tools in one. First it is a tool for estimating loads and designing systems. Second, it is a tool for simulating energy use and calculating energy costs. In this capacity it is useful for leed, schematic design and detailed design energy cost evaluations. HAP uses the ASHRAE-endorsed transfer function method for load calculations and detailed 8,760 hour-by-hour energy simulation techniques for the energy analysis. This program is released as two similar, but separate products. The "HAP system design load" program provides the system design and load estimating features. The full "HAP" program provides the same system design capabilities plus energy analysis features. This quick reference guide deals with both programs. HAP system design features. HAP estimates design cooling and heating loads for commercial buildings in order to determine required sizes for HVAC system components. Ultimately, the program provides information needed for selecting and specifying equipment. Specifically, the program performs the following tasks:

1. Calculates design cooling and heating loads for spaces, zones, and coils in the HVAC system.
2. Determines required airflow rates for spaces, zones and the system.
3. Sizes cooling and heating coils.
4. Sizes air circulation fans.
5. Sizes chillers and boilers.

HAP Energy Analysis Features.

HAP estimates annual energy use and energy costs for HVAC and non-HVAC energy consuming systems in a building by simulating building operation for each of the 8,760 hours in a year. Results of the energy analysis are used to compare the energy use and energy costs of alternate HVAC system designs so the best design can be chosen. Specifically, HAP performs the following tasks during an energy analysis.

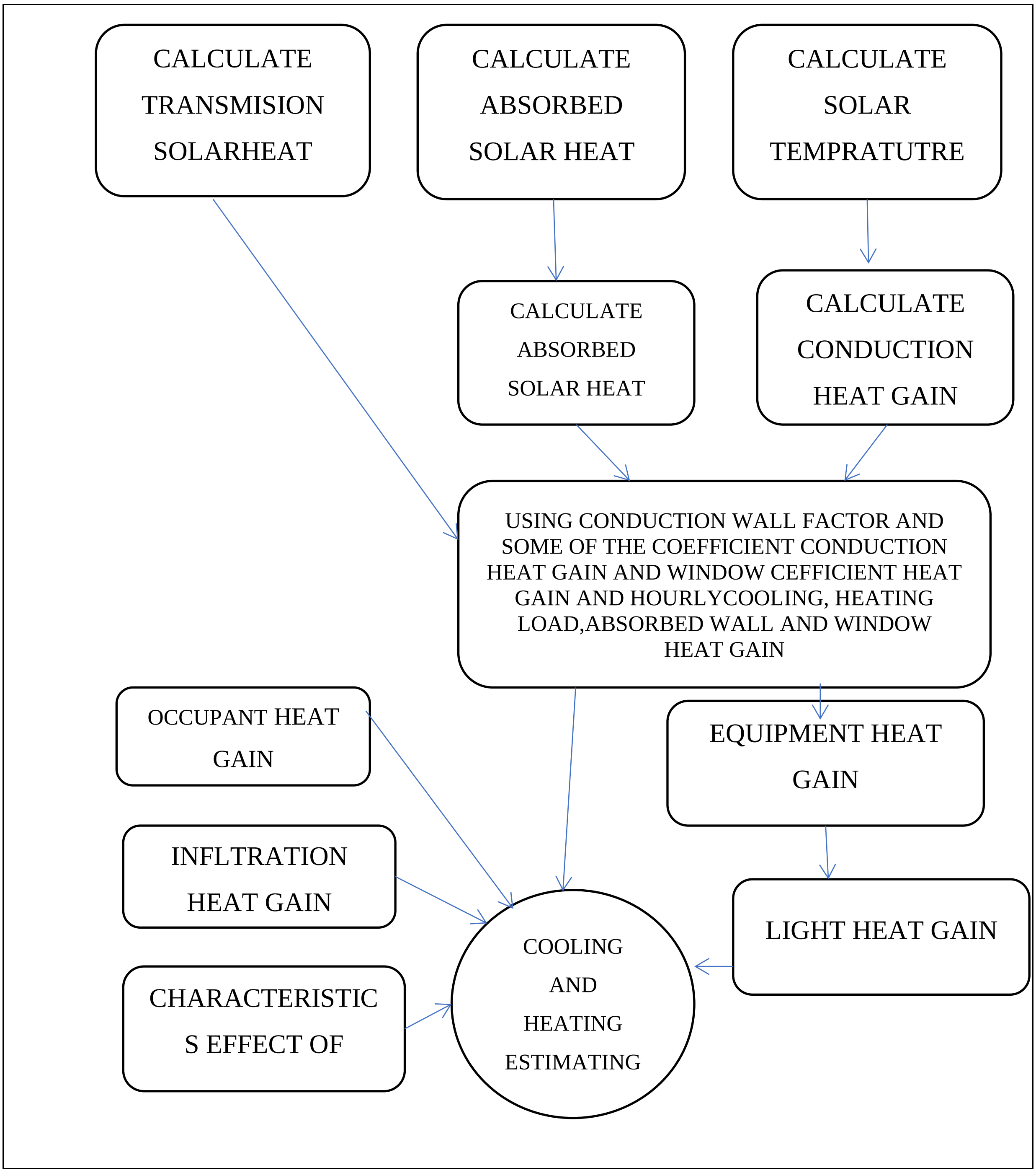
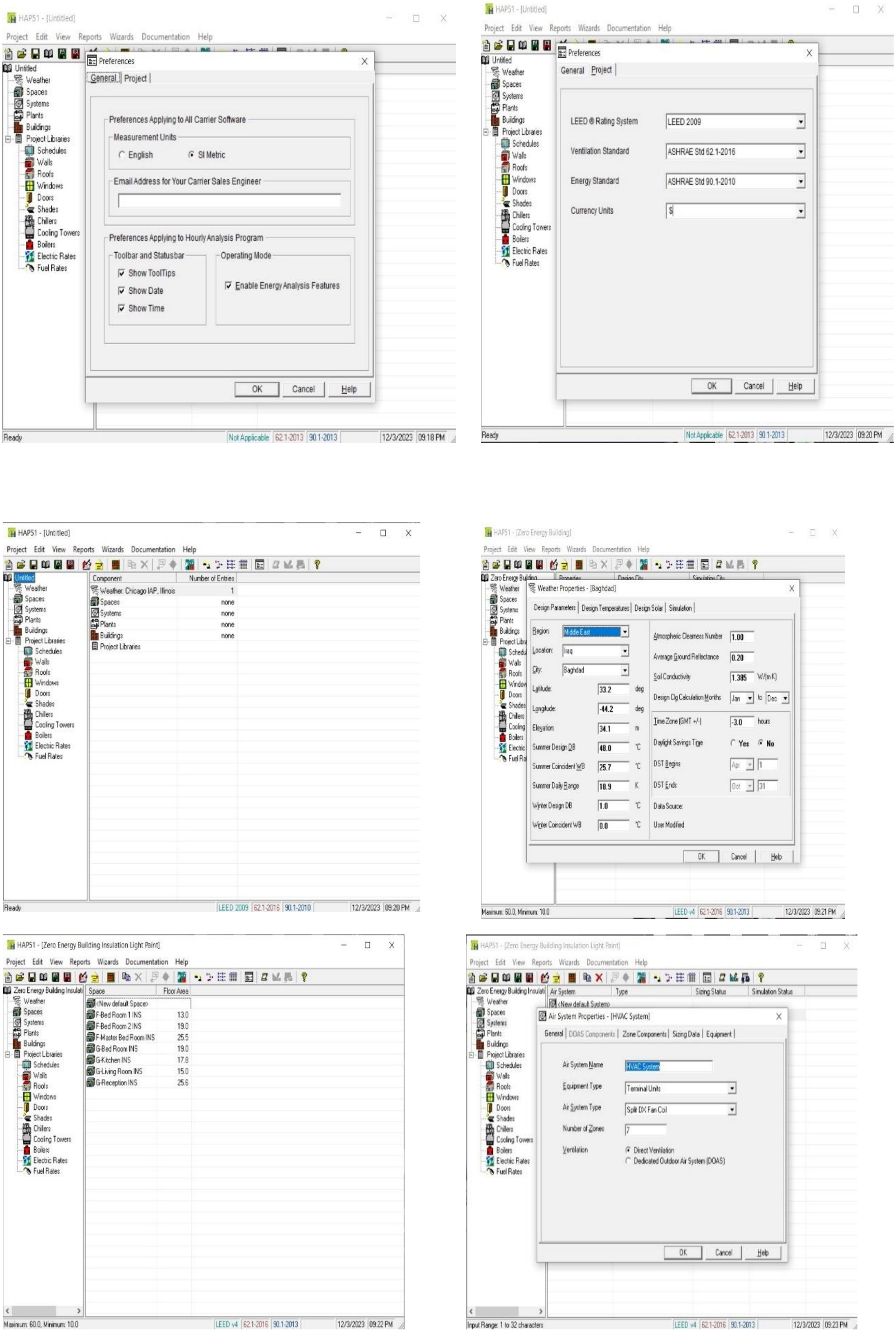


Figure 3.1. Flow chart HAP software.



Preferences Applying to All Carrier Software
Measurement Units: ○ English ● SI Metric
Email Address for Your Carrier Sales Engineer:
Preferences Applying to Hourly Analysis Program
Toolbar and Statusbar: ☑ Show ToolTips ☑ Show Date ☑ Show Time
Operating Mode: ☑ Enable Energy Analysis Features
Not Applicable | 62.1-2013 | 90.1-2013 | 12/3/2023 | 09:18 PM

LEED ® Rating System: LEED 2009
Ventilation Standard: ASHRAE Std 62.1-2016
Energy Standard: ASHRAE Std 90.1-2010
Currency Units: $
Not Applicable | 62.1-2013 | 90.1-2013 | 12/3/2023 | 09:20 PM

Component	Number of Entries
Weather: Chicago IAP, Illinois	1
Spaces	none
Systems	none
Plants	none
Buildings	none
Project Libraries	

LEED 2009 | 62.1-2016 | 90.1-2010 | 12/3/2023 | 09:20 PM

HAP51 - [Zero Energy Building]
Weather Properties - [Baghdad]
Design Parameters | Design Temperatures | Design Solar | Simulation
Region: Middle East
Location: Iraq
City: Baghdad
Latitude: 33.2 deg
Longitude: -44.2 deg
Elevation: 34.1 m
Summer Design DB: 48.0 °C
Summer Coincident WB: 25.7 °C
Summer Daily Range: 18.9 K
Winter Design DB: 1.0 °C
Winter Coincident WB: 0.0 °C
Atmospheric Clearness Number: 1.00
Average Ground Reflectance: 0.20
Soil Conductivity: 1.385 W/(m K)
Design Clg Calculation Months: Jan to Dec
Time Zone (GMT +/-): -3.0 hours
Daylight Savings Time: ○ Yes ● No
DST Begins: Apr 1
DST Ends: Oct 31
Data Source: User Modified
Maximum: 60.0, Minimum: 10.0 | LEED v4 | 62.1-2016 | 90.1-2013 | 12/3/2023 | 09:21 PM

HAP51 - [Zero Energy Building Insulation Light Paint]

Space	Floor Area
<New default Space>	
F-Bed Room 1 INS	13.0
F-Bed Room 2 INS	19.0
F-Master Bed Room INS	25.5
G-Bed Room INS	19.0
G-Kitchen INS	17.8
G-Living Room INS	15.0
G-Reception INS	25.6

Maximum: 60.0, Minimum: 10.0 | LEED v4 | 62.1-2016 | 90.1-2013 | 12/3/2023 | 09:22 PM

Air System Properties - [HVAC System]
General | DOAS Components | Zone Components | Sizing Data | Equipment
Air System Name: HVAC System
Equipment Type: Terminal Units
Air System Type: Split DX Fan Coil
Number of Zones: 7
Ventilation: ● Direct Ventilation ○ Dedicated Outdoor Air System (DOAS)
Input Range: 1 to 32 characters | LEED v4 | 62.1-2016 | 90.1-2013 | 12/3/2023 | 09:23 PM

Figure 3.2. Interface of HAP software.

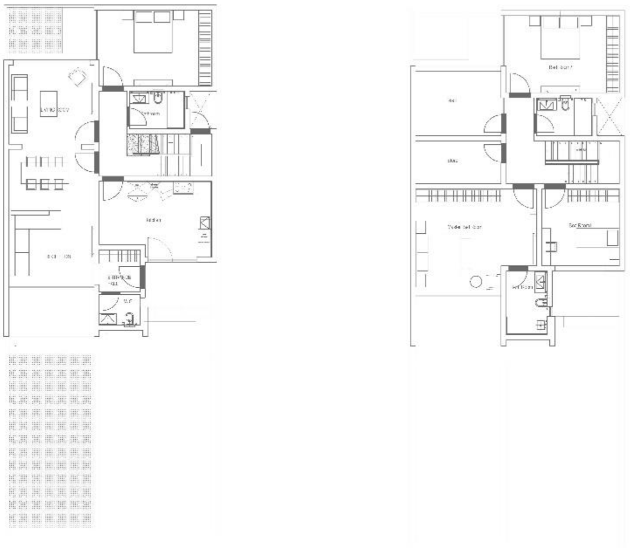
To know the change in the cooling and heating loads values of buildings. Multiple cases of the same building were studied in terms of insulation and gating where two-floor building was taken (design house) as in Table 3.1 and HAP program applied on this building for cases: -

1. Light coating with insulation
2. Dark coating with insulation.
3. Light coating without insulation.
4. Dark coating without insulation.

Table 3.1. External design conditions for Iraqi cities [122].

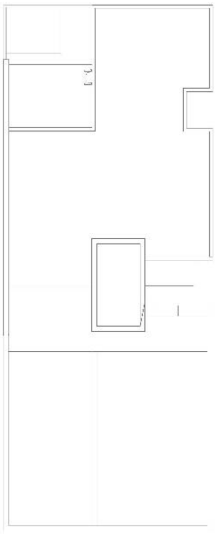
N	**City**	**Design dry bulb temperature**		**Design dry bulb temperature**		**Daily range (summer)**	**Level**	**Latitude**	**Longitude**
		summer	**winter**	**summer**	**winter**				
1	Baghdad	18	1	25.7	0	18.7	34.1	33.23	4.23
2	Basra	50	0.5	35	3.7	15	2.4	30.57	47.78
3	Mosul	46	0.5	25.2	0	18.5	223	36.32	43.15
4	Sulaymaniyah	42	0.5	17	0	15	853	35.55	45.45
5	Kirkuk	46	2	25.5	1	6	331	35.47	44.40
6	Najaf	48	4	24.8	2.8	17	50	32.0	44.32
7	Samawah	47	4.5	24	3.5	13.5	6	31.30	45.25
8	Sinjar	42	1.5	22.5	0.2	12.5	538	36.32	41.83
9	Modern	46	1	25.5	0.5	15	108	34.07	42.37
10	Salahaddin	40	1	24.5	0	16	1088	36.6	44.2
11	Khanaqin	48	5	26.5	3.2	17	202	34.3	45.4
12	Nazareth	50	3	27.5	0	15	3	31.1	46.2

This table clear the external condition for Baghdad city which is the input condition for HAP program.



Ground

First



Roof

Figure 3.3. House design.

The cooling load calculations were made according to the pick-up load. In the summer season, the pick-up was in July, and in the winter season every January, hap program has been applied on the planning Figure 3.1 and according to the following cases:

1. Light coating without insulation
    - Winter heating
    - Summer cooling
2. Dark coating without insulation
    - Winter heating

   - Summer cooling
3. Light coating with insulation
   - Winter heating
   - Summer cooling
4. Dark coating with insulation
   - Winter heating
   - Summer cooling

Table 3.2. Design parameters.

City Name	Baghdad	
Location	Iraq	
Latitude	33.2	Deg.
Longitude	-44.2	Deg.
Elevation	34.1	m
Summer design dry-bulb	48.0	°C
Summer coincident wet-bulb	25.7	°C
Summer daily range	18.7	°C
Winter design dry-bulb	1.0	°C
Winter design wet-bulb	0.0	°C
Atmospheric clearness number	1.00	
Average ground reflectance	0.20	
Soil conductivity	1.385	W/(m °C)
Local time zone (GMT +/- N hours)	-3.0	hours
Consider daylight savings time	No	
Simulation weather data	N/A	
Current data is	User modified	
Design cooling months	January to December	
These conditions clear the parameters for Baghdad city which is the input condition for hap program		

Tables for walls, ceilings, floors, windows and partition walls have been taken according to each case in terms of insulation and coating, and they will be. Explained in detail in each case. Through these tables, the cooling and heating loads were calculated for each case and according to the hap program. To reach the best thermal load (cooling and heating) for the best case (insulation and coating) for summer and winter as Figure 3.2, 3.3.

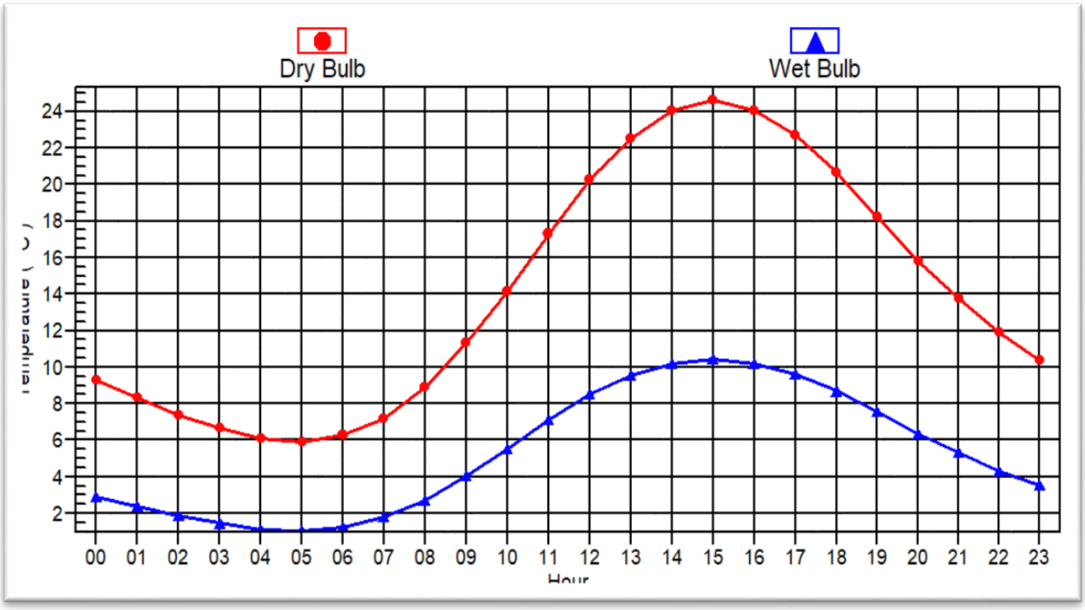


Figure 3.4. Design temperature profiles for January.

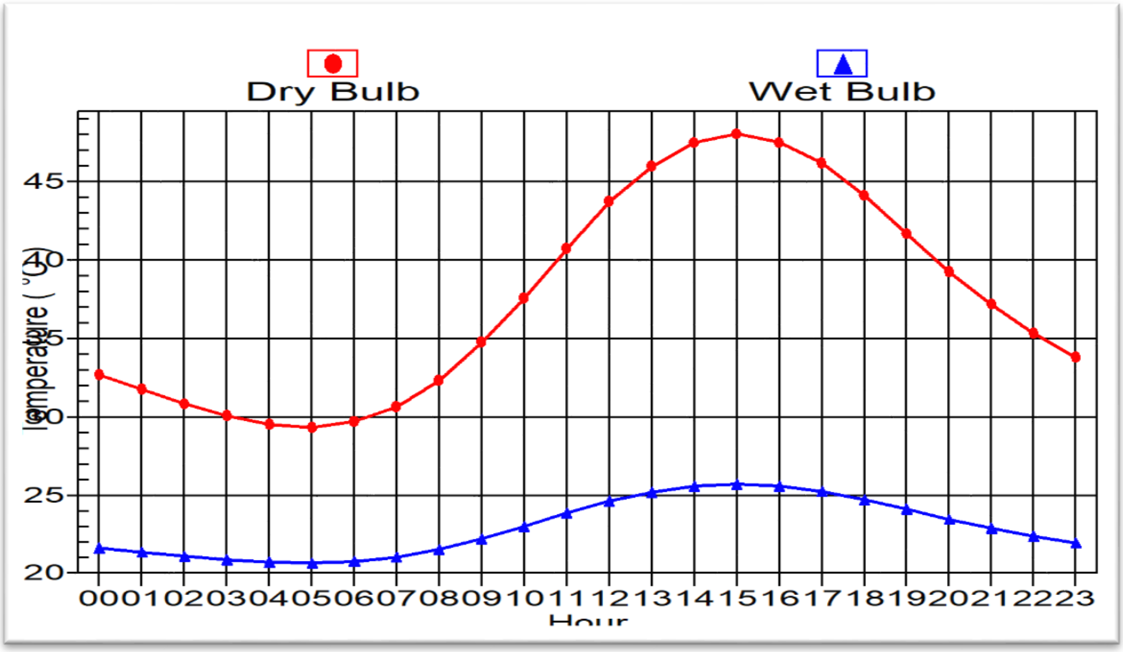


Figure 3.5. Design temperature profiles for July.

3.2.1. Light Coating with Insulation

Light coatings reflect a significant portion of solar radiation, reducing heat absorption by building exterior surfaces. This results in less heat gain within the building, as brightly colored buildings have lower surface temperatures and less cooling demand.

Darker coatings absorb more solar radiation, increasing heat absorption by exterior surfaces. This can lead to higher heat gain within the building, as dark coating absorbs more heat, causing higher interior temperatures. Structures with dark coating may have a higher cooling burden compared to light-coating buildings without insulation, as they absorb more heat, requiring more cooling to maintain a comfortable temperature. Light coating tends to absorb less heat than dark coating and may have a slightly lower cooling load. However, dark coating absorbs more heat when there is no insulation, resulting in a slightly increased cooling load. Effective insulation outweighs the impact of coating color on cooling load, as it creates a thermal barrier that prevents heat from passing through the building envelope. Increasing insulation is a more efficient way to improve a building's thermal performance and reduce the need for cooling.

Exposure wall with insulation where the outside Surface Color is Light, the Absorptivity is 0.450 and the overall u-value is 0.518 W/ ($m^2 \cdot K$).

In this case the thermal load (cooling and heating) was calculated for the building, and consider this building is insulate and light coated . Table 3.3 clear the extra insulation layer and this layer is (gypsum plaster, gum. brick, RSI -2-3 batt insulation, air space, (ceramic). Table 3 clear partition walls detail and the insulation layers for it. Table 3.5 clear floor layers. Table 3.6 clear partition walls for first floor. Table 3.7 clear ceiling layers. From this tables cooling load was calculated for the building in case of (insulation and light coating) by HAP program and this cooling load as in Table 3.9, As well as heating load clear in Table 3.10

Table 3.3. Exposure wall layers details (inside to outside) for light coating with insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
RSI-2.3 batt insulation	50	8.0	0.84	1.11113	0.4
Air space	50	0.0	0.00	0.16026	0.0
Ceramic	8	336.4	0.80	0.14978	2.7
Totals	320.5	-		1.93115	396.5

Partition wall with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall -value is 1.768W/ (m²·K).

Table 3.4. Partition wall layers details (inside to outside) for light coating with insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum Plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Totals	225	-		0.56554	402.5

Floor with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 0.519 W/ (m²·K).

Table 3.5. Floor layers details (inside to outside) for light coating with insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Concrete slab	350	2242.6	0.84	0.20223	784.9
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Tile	10	336.4	0.80	0.18723	3.4
Totals	440	-		1.92824	878.0

Partition floor with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 0.527W/ (m²·K).

Table 3.6. Partition floor layers details (inside to outside) for light coating with insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05	9.0
Concrete slab	200.0	2242.6	0.84	0.11	448.5
Asphalt roll	80.0	1121.3	1.51	1.35	89.7
Acoustical tile	10.0	336.4	0.80	0.18	3.4
Totals	302.5	-		1.89	550.6

Roof with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 0.250 W/ (m²·K).

Table 3.7. Roof layers details (inside to outside) for light coating with insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum board	12.5	800.9	1.09	0.07766	10.0
Concrete slab	200	2242.6	0.84	0.11556	448.5
RSI-2.5 board insulation	50	32.0	0.92	2.40746	1.6
Asphalt roll	50	1121.3	1.51	0.84969	56.1
Acoustical tile	20	336.4	0.80	0.37446	6.7
Totals	332.5	-		4.00410	522.9

High performance glass has height 1.00 m, width 1.00 m, overall U-value 1.300 W/(m²·K), and overall, shade coefficient 0.220.

Table 3.8. Air system information for light coating with insulation.

Air system information	
Air system name	HVAC system
Equipment class	Term
Air system type	VRF
Number of zones	7
Floor area	134.9 m²
Location	Baghdad, Iraq
Calculation months	Jan to Dec
Sizing Data	Calculated
Zone l/s sizing	Sum of space airflow rates
Space l/s sizing	Individual peak space loads

Table 3.9. Terminal unit sizing data - cooling for light coating with insulation.

	Total	**Sensible**	**Coil**	**Coil**	**Water**	**Time**	
	coil	coil	entering	leaving	flow	of	
	load	Load	DB / WB	DB / WB	@ 5.6 K	peak coil	Zone
Zone name	(KW)	(KW)	(°C)	(°C)	(L/s)	load	L/(s·m²)
G-F reception	3.1	2.8	27.5 / 19.0	15.0 / 14.2	-	Jul 1600	7.34
G-F living room	3.0	2.8	26.8 / 18.9	15.5 / 14.8	-	Aug 1500	13.85
G-F kitchen	2.6	2.4	26.5 / 18.6	15.1 / 14.3	-	Jul 1500	9.87
G-F bed room	2.1	2.0	26.4 / 18.6	14.9 / 14.1	-	Jul 1500	7.51
F-F bed room 1	1.6	1.5	25.9 / 18.4	15.0 / 14.2	-	Jul 1600	8.64
F-F bed room 2	2.2	2.0	26.3 / 18.6	15.0 / 14.3	-	Jul 1500	7.95
F-F master bed room	3.0	2.8	26.0 / 18.4	15.0 / 14.3	-	Jul 1500	8.31

Table 3.10. Terminal unit sizing data - heating, fan, and ventilation for light coating with insulation.

		Heating coil					
	Heating	Coil	Water	Fan			OA vent
	coil	ent/lvg	flow	design	Fan	Fan	Design
	load	DB	@11.1 K	airflow	motor	motor	airflow
Zone Name	(KW)	(°C)	(L/s)	(L/s)	(BHP)	(KW)	(L/s)
G-F reception	1.9	18.4 / 26.5	**-**	188	0.000	0.000	23
G-F living room	1.6	18.9 / 25.2	**-**	208	0.000	0.000	20
G-F kitchen	1.5	19.0 / 25.7	**-**	176	0.000	0.000	14
G-F bed room	1.3	19.3 / 26.9	**-**	143	0.000	0.000	11
F-F bed room 1	1.1	19.5 / 27.5	**-**	112	0.000	0.000	6
F-F bed room 2	1.3	19.3 / 26.5	**-**	151	0.000	0.000	11
F-F master bed room	2	19.5 / 27.3	**-**	212	0.000	0.000	13

3.2.2. Dark Coating with Insulation

Darker coating colors have a lower sun reflection than white or light colors, maximizing heat absorption. This results in reduced surface temperatures and a lower cooling load. Light-colored exteriors use less cooling power, reducing cooling costs and promoting energy efficiency. Light coating reduces cooling loads, resulting in more stable and comfortable indoor temperatures for occupant health. Darker coating absorbs more solar radiation, raising the surface temperature. This leads to higher surface temperatures and increased cooling load, resulting in higher cooling costs and potentially lower energy efficiency. Darkly coating buildings may experience less consistent indoor temperatures and greater temperature changes, leading to discomfort for residents. Light coating often performs better with insulating reducing cooling load, and improving energy efficiency. More solar heat is reflected by light coating, reducing heat absorption, requiring less cooling energy consumption, and enhancing indoor comfort. On the other hand, dark coating has a tendency of absorb more heat, leading to higher cooling loads, higher energy consumption, and potential occupant discomfort. Light-colored coating may be a wise choice in hot or sunny areas due to lower cooling load and increased energy efficiency.

Exposure wall with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 0.518 W/ ($m^2 \cdot K$).

In this case the thermal load (cooling and heating) was calculated for the building and consider this building is insulated and dark coated. Table 3.11 clear the extra insulation layers and this layer is (gypsum plaster common brick, RS E-2-3 batt insulation). Air space, ceramic. Table 3.12 clear partition walls detail and the insulation. Layers for it. Table 3.1, clear floor layers. Table 3.14 clear partition walls for the first floor. Table 3.15 clear ceiling layers. From this tables cooling load was calculated for the building in case of (insulation and dark coating) by HAP program and this cooling load as in the Table 3.17 as well as heating load as in Table 3.18

Table 3.11. Exposure wall layers details (inside to outside) for dark coating with insulation.

	Thickness	Density	Specific heat	R-value	Weight
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
RSI-2.3 batt insulation	50	8.0	0.84	1.11113	0.4
Air space	50	0.0	0.00	0.16026	0.0
Ceramic	8	336.4	0.80	0.14978	2.7
Totals	320.5	-		1.93115	396.5

Partition wall with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 1.768W/ (m²·K).

Table 3.12. Partition wall layers details (inside to outside) for dark coating with insulation.

	Thickness	Density	Specific heat	R-value	Weight
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Totals	225	-		0.56554	402.5

Floor with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 0.519 W/ (m²·K).

Table 3.13. Floor layers details (inside to outside) for dark coating with insulation.

	Thickness	Density	Specific heat	R-value	Weight
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Concrete slab	350	2242.6	0.84	0.20223	784.9
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Tile	10	336.4	0.80	0.18723	3.4
Totals	440	-		1.92824	878.0

Partition floor with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 0.527W/ (m²·K).

Table 3.14. Partition floor layers details (inside to outside) for dark coating with insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12	720.8	1.34	0.05556	9.0
Concrete slab	200	2242.6	0.84	0.11556	448.5
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Acoustical tile	10	336.4	0.80	0.18723	3.4
Totals	302.5	-		1.89713	550.6

Roof with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 0.250 W/ (m²·K).

Table 3.15. Roof layers details (inside to outside) for dark coating with insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum board	12.5	800.9	1.09	0.07766	10.0
Concrete slab	200	2242.6	0.84	0.11556	448.5
RSI-2.5 board insulation	50	32.0	0.92	2.40746	1.6
Asphalt roll	50	1121.3	1.51	0.84969	56.1
Acoustical tile	20	336.4	0.80	0.37446	6.7
Totals	332.5	-		4.00410	522.9

High performance glass has height 1.00 m, width 1.00 m, overall U-value 1.300 W/(m²·K), and overall, shade coefficient 0.220.

Table 3.16. Air system information for dark coating with insulation.

Air system information	
Air system name	HVAC system
Equipment class	Term
Air system type	VRF
Number of zones	7
Floor area	134.9 m²
Location	Baghdad, Iraq
Calculation months	Jan to Dec
Sizing data	Calculated
Zone l/s sizing	Sum of space airflow rates
Space l/s sizing	Individual peak space loads

Table 3.17: Terminal unit sizing data - cooling for dark coating with insulation.

Zone name	**Total** coil load (KW)	**Sensible** coil load (KW)	**Coil** entering DB / WB (°C)	**Coil** leaving DB / WB (°C)	**Water** flow @ 5.6 K (L/s)	**Time** of peak coil Load	Zone L/(s·m²)
G-F reception	3.1	2.9	27.3 / 18.9	14.9 / 14.1	-	Jul 1600	7.56
G-F living room	3.0	2.8	26.8 / 18.9	15.6 / 14.8	-	Aug 1500	14.03
G-F kitchen	2.6	2.5	26.7 / 18.8	15.2 / 14.5	-	Jul 1500	10.02
G-F bed room	2.2	2.0	26.3 / 18.5	14.9 / 14.2	-	Jul 1500	7.75
F-F bed room 1	1.6	1.5	25.9 / 18.4	15.0 / 14.3	-	Jul 1600	9.02
F-F bed room 2	2.3	2.2	26.2 / 18.5	14.9 / 14.2	-	Jul 1500	8.38
F-F master bed room	3.1	2.9	26.0 / 18.5	15.1 / 14.4	-	Jul 1500	8.61

Table 3.18. Terminal unit sizing data - heating, fan, and ventilation for dark coating with insulation.

	Heating	**Coil**					
Zone name	Heating coil Load (KW)	Coil ent/lvg DB (°C)	Water flow @11.1 K (L/s)	Fan design airflow (L/s)	Fan motor (BHP)	Fan motor (KW)	OA vent design airflow (L/s)
G-F reception	1.8	18.5 / 26.4	-	194	0.000	0.000	23
G-F living room	1.6	18.8 / 25.0	-	210	0.000	0.000	20
G-F kitchen	1.4	19.2 / 26.1	-	178	0.000	0.000	14
G-F bed room	1.3	19.4 / 26.9	-	147	0.000	0.000	11
F-F bed room 1	1.1	19.6 / 27.1	-	117	0.000	0.000	6
F-F bed room 2	1.3	19.2 / 26.0	-	159	0.000	0.000	11
F-F master bed room	1.9	19.4 / 26.7	-	220	0.000	0.000	13

3.2.3. Light Coating Without Insulation

Insulation is essential for a building's thermal performance and energy efficiency when comparing its cooling load with and without insulation. Proper insulation reduces heat transfer through floors, roofs, and walls, acting as a thermal barrier in hot weather. This decreases the cooling load, allowing for more stable indoor temperatures and reducing the need for frequent adjustments. Insulation also lowers the amount of heat that must be removed by the cooling system, improving energy efficiency. Insulation also lessens the impact of temperature changes outside, enhancing comfort inside and reducing the likelihood of passengers feeling uneasy. without insulated buildings allow more heat to escape through floors, walls, and roofs, increasing the cooling load. This increases the amount of heat gained from outside sources, making it difficult to maintain comfort without increasing cooling efforts. Without insulated buildings often result in higher cooling energy consumption and associated costs, as more energy is needed to keep indoor temperatures comfortable. Insulated buildings have decreased cooling loads, resulting in lower energy consumption, lower costs, and greater indoor comfort. Insulation is crucial for maximizing a building's comfort and energy efficiency, especially in places with significant temperature variations.

In this case the thermal load (cooling and. heating) was calculated for the building. And consider this building is (not insulated and light coated) . Table 3.19 clear the wall layers (gypsum plaster, common brick, stuck), and in this table, we notice the different between the insulated wall and this wall. Table 3.20 clear the partition walls. Table 3.21 clear the floor layers. Table 3.22 clear the portion walls for first floor. Table 3.23 clear the roof layers. From this tables cooling load was calculated for the building in case of (light coating without insulation) by HAP program and cooling load as in Table 3.25 as well as heating load as in Table 3.26

Exposure wall with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 1.896 W/ (m²·K).

Table 3.19. Exposure wall layers details (inside to outside) for light coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
Stucco	12.5	1858.1	0.84	0.01732	23.2
Totals	225	-		0.52730	416.7

Partition wall with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 1.768W/ (m²·K).

Table 3.20. Partition wall layers details (inside to outside) for light coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Totals	225	-		0.56554	402.5

Floor with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 0.519 W/ (m²·K).

Table 3.21. Floor layers details (inside to outside) for light coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Concrete slab	350	2242.6	0.84	0.20223	784.9
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Tile	10	336.4	0.80	0.18723	3.4
Totals	440	-		1.92824	878.0

Partition floor with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 0.527W/ (m²·K).

Table 3.22. Partition floor layers details (inside to outside) for light coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Concrete slab	200	2242.6	0.84	0.11556	448.5
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Acoustical tile	10	336.4	0.80	0.18723	3.4
Totals	302.5	-		1.89713	550.6

Roof with insulation where the outside surface color is light, the absorptivity is 0.450 and the overall U-value is 0.480 W/ (m²·K).

Table 3.23. Roof layers details (inside to outside) for light coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Concrete slab	200	2242.6	0.84	0.11556	448.5
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Acoustical tile	20	336.4	0.80	0.37446	6.7
Totals	312.5	-		2.08436	554.0

High performance glass has height 1.00 m, width 1.00 m, overall U-value 5.700 W/(m²·K), and overall, shade coefficient 0.850.

Table 3.24. Air system information for light coating without insulation.

Air system information	
Air system name	HVAC system
Equipment class	Term
Air system type	VRF
Number of zones	7
Floor area	134.9 m²
Location	Baghdad, Iraq
Calculation months	Jan to Dec
Sizing data	Calculated
Zone l/s Sizing	Sum of space airflow rates
Space l/s Sizing	Individual peak space loads

Table 3.25. Terminal unit sizing data - cooling for light coating without insulation.

Zone name	Total coil load (KW)	Sensible coil load (KW)	Coil entering DB / WB (°C)	Coil leaving DB / WB (°C)	Water flow @ 5.6 K (L/s)	Time of Peak Coil load	Zone L/(s·m²)
G-F reception	4.6	4.3	26.4 / 18.7	15.4 / 14.6	-	Jul 1600	12.75
G-F living Room	6.8	6.7	25.1 / 17.7	14.7 / 14.0	-	Aug 1500	36.03
G-F kitchen	3.7	3.5	26.0 / 18.5	15.3 / 14.6	-	Jul 1500	15.39
G-F bed room	4.0	3.8	25.7 / 18.4	15.3 / 14.6	-	Jul 1500	16.14
F-F bed room 1	2.9	2.7	25.5 / 18.4	15.3 / 14.7	-	Jul 1600	17.36
F-F bed room 2	4.2	4.0	25.6 / 18.4	15.2 / 14.5	-	Jul 1500	16.91
F-F master bed room	5.1	4.9	25.6 / 18.4	15.4 / 14.7	-	Jul 1500	15.61

Table 3.26. Terminal unit sizing data - heating, fan, and ventilation for light coating without insulation.

Zone Name	Heating coil load (KW)	Heating Coil ent/lvg DB (°C)	Coil Water Flow @11.1 K (L/s)	Fan design airflow (L/s)	Fan motor (BHP)	Fan motor (KW)	OA vent Design airflow (L/s)
G-F Reception	3.2	19.3 / 27.2	-	326	0.000	0.000	23
G-F Living Room	3.4	20.1 / 25.1	-	540	0.000	0.000	20
G-F Kitchen	2.5	19.8 / 27.3	-	274	0.000	0.000	14
G-F Bed Room	2.7	20.0 / 27.3	-	307	0.000	0.000	11
F-F Bed Room 1	2.2	20.0 / 27.8	-	226	0.000	0.000	6
F-F Bed Room 2	2.8	20.0 / 27.3	-	321	0.000	0.000	11
F-Fmaster bed Room	3.6	19.9 / 27.3	-	398	0.000	0.000	13

3.2.4. Dark Coating Without Insulation

Dark-coated structures absorb more solar heat, making them more susceptible to heat absorption. Insulation helps reduce heat absorption by creating a thermal barrier, reducing cooling requirements and improving energy performance. This results in lower energy consumption and cost savings. Insulated structures often have lower cooling costs than without insulated ones. Insulation also improves indoor conditions by lowering temperature differences, which is crucial for dark-coated structures. Without insulation, buildings absorb more solar heat, increasing the temperature inside and this increases the cooling load, causing more energy consumption and higher cooling costs. Without insulation, dark-coated structures are more susceptible to temperature swings, which can cause discomfort and require regular cooling system adjustments. In contrast, without insulation, dark-coated structures are more susceptible to excessive heat gain, increasing cooling load, energy consumption, and discomfort. Insulation is essential for dealing with dark-coated structures, particularly in regions with warm or hot climates.

Exposure wall with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 1.896 W/ (m²·K).

In this case the thermal load (cooing. and heating) was calculated for the building and consider this building is (not insulated and dark coated). Table 3.27 clear the wall layers (gypsum plaster, common brick, stuck), and in this table we notice the difference between the insulated walls. Table 3.28 clear the partition walls. Table 3.29 clear the floor layers. Table 3.30 clear the portion walls. For the first floor, Table 3.31 clear the roof layers. From this tables cooling load was calculated for the building in case of dark coating without insulation by HAP program and the cooling load as in Table 3.33 as well as heating load in Table 3.34

Table 3.27. Exposure wall layers details (inside to outside) for dark coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
Stucco	12.5	1858.1	0.84	0.01732	23.2
Totals	225	-		0.52730	416.7

Partition wall with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 1.768W/ (m²·K).

Table 3.28. Partition wall layers details (inside to outside) for dark coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Common brick	200	1922.2	0.84	0.27514	384.4
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Totals	225	-		0.56554	402.5

Floor with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 0.519 W/ (m²·K).

Table 3.29. Floor layers details (inside to outside) for dark coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Concrete slab	350	2242.6	0.84	0.20223	784.9
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Tile	10	336.4	0.80	0.18723	3.4
Totals	440	-		1.92824	878.0

Partition floor with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 0.527W/ (m²·K).

Table 3.30. Partition floor layers details (inside to outside) for dark coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Concrete slab	200	2242.6	0.84	0.11556	448.5
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Acoustical tile	10	336.4	0.80	0.18723	3.4
Totals	302.5	-		1.89713	550.6

Roof with insulation where the outside surface color is dark, the absorptivity is 0.9 and the overall U-value is 0.480 W/ (m²·K).

Table 3.31. Roof layers details (inside to outside) for dark coating without insulation.

	Thickness	**Density**	**Specific heat**	**R-value**	**Weight**
Layers	mm	kg/m³	kJ / (kg K)	(m²·K)/W	kg/m²
Gypsum plaster	12.5	720.8	1.34	0.05556	9.0
Concrete slab	200	2242.6	0.84	0.11556	448.5
Asphalt roll	80	1121.3	1.51	1.35950	89.7
Acoustical tile	20	336.4	0.80	0.37446	6.7
Totals	312.5	-		2.08436	554.0

High performance glass has height 1.00 m, width 1.00 m, overall U-value 5.700 W/(m²·K), and overall, shade coefficient 0.850.

Table 3.32. Air system information for dark coating without insulation.

Air system information	
Air system name	HVAC system
Equipment class	Term
Air system type	VRF
Number of zones	7
Floor area	134.9 m²
Location	Baghdad, Iraq
Calculation months	Jan to Dec
Sizing data	Calculated
Zone l/s sizing	Sum of space airflow rates
Space l/s sizing	Individual peak space loads

Table 3.33. Terminal unit sizing data - cooling for dark coating without insulation.

Zone name	**Total** coil load (KW)	**Sensible** coil load (KW)	**Coil** entering DB / WB (°C)	**Coil** leaving DB / WB (°C)	**Water** flow @ 5.6 K (L/s)	**Time** of peak coil Load	Zone L/(s·m²)
G-F reception	4.9	4.7	26.4 / 18.7	15.4 / 14.6	-	Jul 1600	13.74
G-F living room	7.0	6.9	25.5 / 18.1	15.1 / 14.4	-	Aug 1500	36.78
G-F kitchen	3.8	3.7	25.9 / 18.5	15.2 / 14.5	-	Jul 1500	16.03
G-F bed room	4.2	4.1	25.7 / 18.4	15.3 / 14.6	-	Jul 1500	17.29
F-F bed room 1	3.1	3.0	25.3 / 18.1	15.0 / 14.3	-	Jul 1600	18.55
F-F bed room 2	4.5	4.4	25.3 / 18.1	14.9 / 14.2	-	Jul 1500	18.37
F-F master bed room	5.4	5.2	25.6 / 18.4	15.4 / 14.7	-	Jul 1500	16.59

Table 3.34. Terminal unit sizing data - heating, fan, and ventilation for dark coating without insulation.

Zone name	**Heating coil load (KW)**	**Heating coil Ent/lvg DB (°C)**	**coil water flow @11.1 K (L/s)**	**Fan design airflow (L/s)**	**Fan motor (BHP)**	**Fan motor (KW)**	**OA vent design airflow (L/s)**
G-F reception	3.1	19.5 / 26.9	-	352	0.000	0.000	23
G-F living room	3.3	20.2 / 25.3	-	552	0.000	0.000	20
G-F kitchen	2.4	19.7 / 26.7	-	285	0.000	0.000	14
G-F bed room	2.7	20.0 / 26.8	-	329	0.000	0.000	11
F-F bed room 1	2.1	20.2 / 27.7	-	241	0.000	0.000	6
F-F bed room 2	2.8	20.0 / 26.7	-	349	0.000	0.000	11
F-F master bed room	3.5	20.1 / 27.2	-	423	0.000	0.000	13

3.3. MATLAB SIMULINK SOFTWARE AND PV PANELS

Simulink is a powerful tool for modeling and simulating dynamic systems, including photovoltaic (PV) panels. Modeling photovoltaic panels in Simulink involves creating a representation of the electrical behavior of the panels based on their physical characteristics and the principles of photovoltaic conversion. Designing a net zero energy building (NZEB) with photovoltaic (PV) panels in MATLAB Simulink involves a systematic approach to model and analyze the performance of the PV system, the steps for Simulink MATLAB is:

1. Define Building Energy Requirements: begin by understanding the energy requirements of the building you're modeling. Consider factors such as lighting, HVAC systems, appliances, and other electrical loads. This information will help you determine the size of the PV system needed.
2. Select a PV Model: choose an appropriate PV model in Simulink that represents the characteristics of the PV panels you plan to use. Simulink offers various PV models, including equivalent circuit models and detailed semiconductor models. Select a model that closely matches the specifications of your PV panels.
3. Configure Simulation Parameters: set up simulation parameters in Simulink to match the conditions under which the PV system will operate. This includes specifying the time of day, location (latitude and longitude), and weather conditions. Simulink allows you to simulate the performance of the PV system under different scenarios.
4. Integrate PV System with Building model: integrate the PV system model with the building energy model in Simulink. Connect the PV system to the electrical loads of the building and ensure proper synchronization between the building's energy consumption and the energy generated by the PV panels.
5. Implement Maximum Power Point Tracking (MPPT): if your PV system includes MPPT controllers, implement them in Simulink. MPPT controllers optimize the operation of the PV panels by adjusting the operating point to maximize power output under varying environmental conditions
6. Simulate and Analyses: run simulations in Simulink to analyze the performance of the integrated PV and building system. Evaluate how well the PV system meets the building's energy demands and contributes to achieving net zero energy.

7. Optimization and Sensitivity Analysis:: Conduct optimization studies and sensitivity analyses to explore the impact of changing parameters such as PV panel orientation, the angle, and system size. Use Simulink tools to iteratively refine the PV system design for optimal performance.
8. Evaluate Storage Options (Optional): if your NZEB design includes energy storage (batteries), integrate storage components into the Simulink model. Evaluate the effectiveness of energy storage in enhancing the building's ability to achieve net zero energy status
9. Documentation and Reporting: document the Simulink model, including the specifications of the PV system, simulation parameters, and key results. Generate reports summarizing the performance and effectiveness of the PV system in contributing to the NZEB goals.
10. Validation and Verification: validate the Simulink model against real-world data or benchmarks to ensure its accuracy and reliability. Verify that the simulated PV system aligns with expected outcomes and is capable of meeting the building's energy needs.

These action steps provide a comprehensive framework for using MATLAB Simulink to model and analyze the integration of PV panels into a net zero energy building. Adjustments and refinements can be made based on simulation results and real-world considerations to achieve an optimized and sustainable NZEB design.

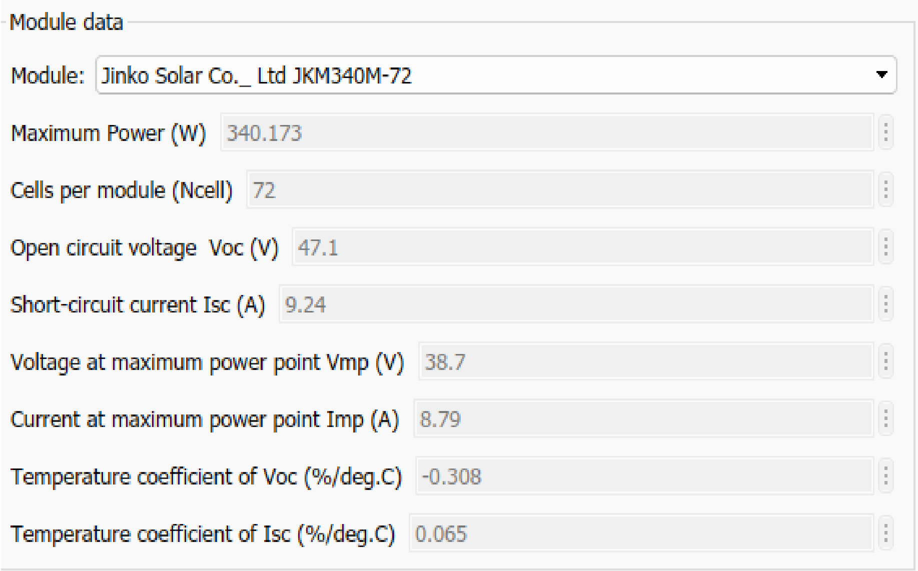
Photovoltaic (PV) panels, also referred to as solar panels, are specifically engineered to transform sunlight into electrical energy. They consist of multiple solar cells, predominantly composed of silicon. These cells function through the photovoltaic effect, in which light energy dislodges electrons from atoms within the cell, creating an electric current. PV panels are renowned for their sustainability due to their ability to generate renewable energy and their minimal foot print in comparison to conventional electricity sources. The efficacy of photovoltaic panels is a pivotal aspect of their performance. Solar panel efficiency is the measure of the percentage of sunlight that can be converted into usable electricity. Conventional solar panels generally exhibit an efficiency range of 15% to 20%. However, advancements in technologies and materials are continuously expanding these limits. Variables such as the inclination of the panels, the occurrence of shade, and the geographic position can also greatly impact their efficiency. Both residential and commercial users must prioritize the installation and upkeep of PV panels. Installation entails placing the panels in a location that receives the most sunlight, typically on rooftops or in expansive solar farms. The maintenance is relatively minimal, typically involving routine cleaning and periodic inspections for any signs of damage. Solar panels are renowned for their exceptional longevity, typically accompanied by warranties spanning 20-25 years, Photovoltaic panels are crucial in the worldwide transition towards renewable energy. They play a crucial role in decreasing carbon emissions and addressing climate change. In addition, progress in photovoltaic (PV) technology, such as the creation of pliable and see-through solar cells, is broadening the range of possible uses for solar energy. Due to declining costs and increasing efficiency, photovoltaic (PV) panels are becoming more widely available and widely chosen for energy generation globally [46].

The increasing popularity of PV panels also brings attention to their significant environmental impact. Solar panels, in contrast to fossil fuels, do not release detrimental pollutants or greenhouse gases while in use, rendering them an environmentally friendly energy source. This significantly contributes to the reduction of the carbon footprint associated with energy generation. Furthermore, the manufacturing processes and recycling methods for solar panels are continuously improving, making their production more sustainable, although not completely free from environmental consequences. These enhancements are essential for minimizing the overall environmental impact of solar panels in comparison to traditional energy sources. From an economic standpoint, photovoltaic (PV) panels provide advantages in both the short-term and the long-term. At first, the installation of solar panels may require a substantial financial commitment, but in the long run, they offer considerable cost savings on electricity expenses. Various governments in numerous regions provide incentives such as tax credits, rebates, and feed-in tariffs to promote the adoption of solar energy, thereby enhancing its financial feasibility for households and businesses. Moreover, with the increasing prevalence of the technology, the price of solar panels continues to decline, thereby augmenting their economic attractiveness. The ability of PV panels to scale is a distinct advantage. They have a wide range of applications, ranging from small-scale systems for individual homes to large solar farms that provide power to entire communities. The ability of solar energy to scale up or down makes it a flexible and adaptable solution for various energy requirements. Solar panels provide a dependable and autonomous energy source in areas that are distant or rural and may not have access to the power grid. In addition, advancements in solar technology are driving the progress of integrated photovoltaic systems, which involve the integration of solar cells into various building materials, vehicles, and even wearable technology. Anticipating the future, photovoltaic panels are projected to assume a progressively pivotal position in the worldwide energy composition. With the aim of achieving their climate objectives and shifting towards sustainable energy sources, countries are expected to experience a substantial growth in solar power. This expansion is not solely confined to power generation; ongoing research is being conducted to explore the utilization of solar energy in areas such as desalination, heating, and even transportation. The ongoing advancements in photovoltaic (PV) panel technology, coupled with increasing environmental consciousness and governmental backing, are paving the way for a future powered by solar energy. This offers a long-lasting and environmentally friendly solution for future generations [47].

Table 3.35. Specifications of PV panels [123].

Type of PV panel	Power	Price per watt in dollar
Lianfa Jinko	340 W	0.29

Where the specifications were taken through a complete program programmed inside the Simulink laboratory, dealing with the existing international companies.



Module data

Module: Jinko Solar Co._ Ltd JKM340M-72

Maximum Power (W) 340.173

Cells per module (Ncell) 72

Open circuit voltage Voc (V) 47.1

Short-circuit current Isc (A) 9.24

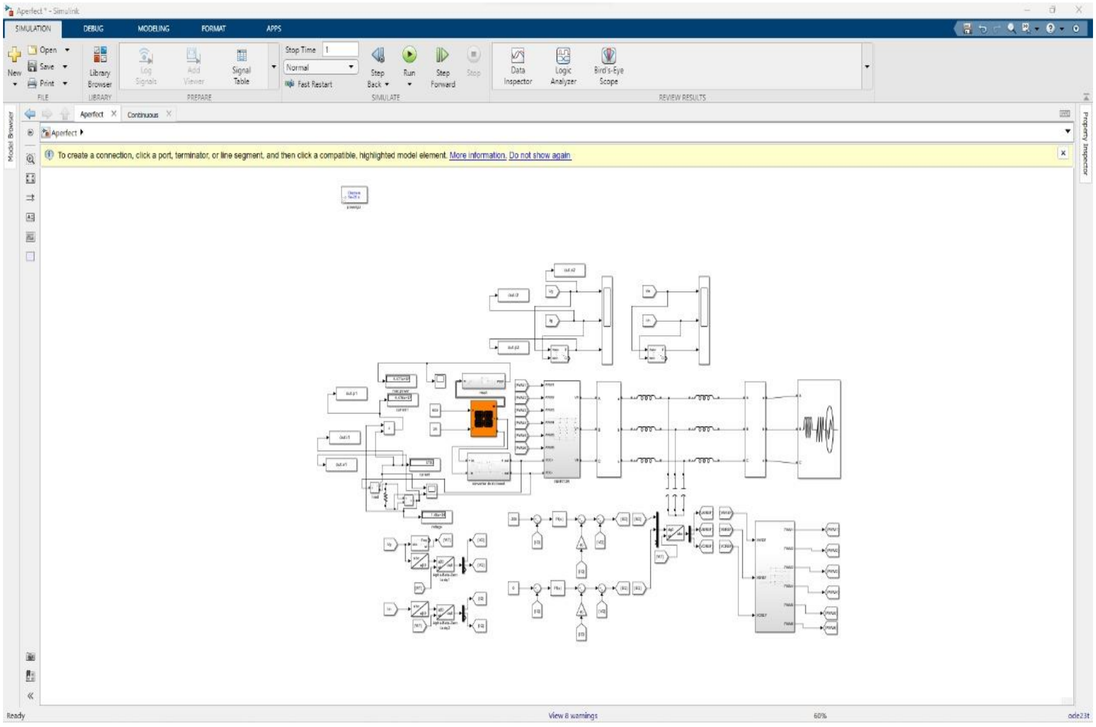
Voltage at maximum power point Vmp (V) 38.7

Current at maximum power point Imp (A) 8.79

Temperature coefficient of Voc (%/deg.C) -0.308

Temperature coefficient of Isc (%/deg.C) 0.065

Figure 3.4. Performance of PV panels.



To create a connection, click a port, terminator, or line segment, and then click a compatible, highlighted model element. More information. Do not show again

Figure 3.5. MATLAB Simulink software.

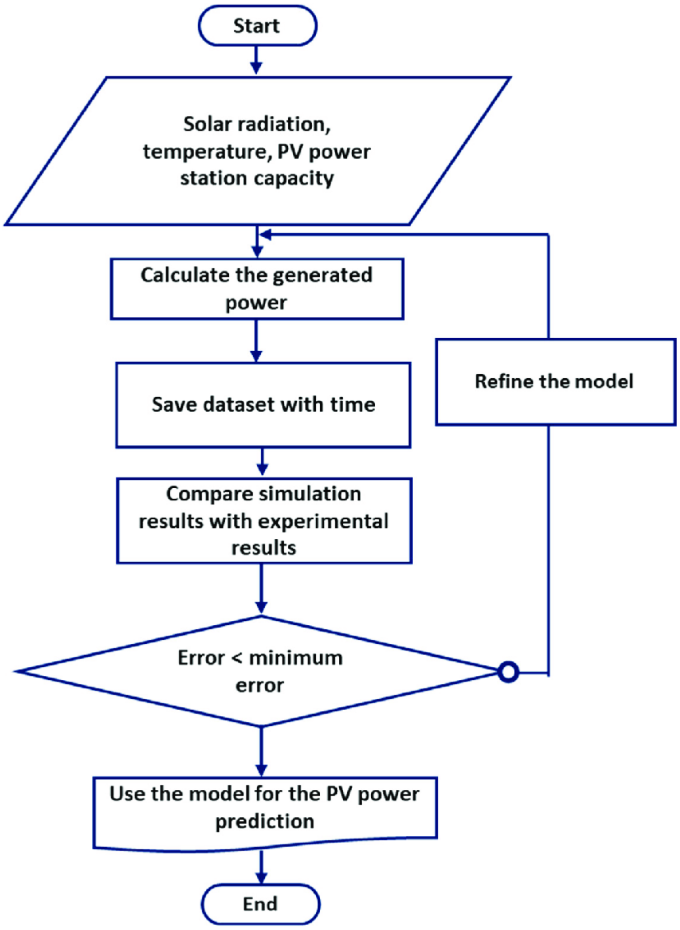


Figure 3.6. Flow chart for choosing PV panels

3.3.1. DC-DC Boost Converter

A DC-DC boost converter is a power electronic circuit that steps up a DC voltage to a higher level. It is widely used in various applications, including renewable energy systems, electric vehicles, and portable electronic devices. Simulink, a simulation and modeling environment provided by MATLAB, offers a powerful tool to design and analyze DC-DC boost converters.

The basic operation of a boost converter involves the periodic switching of a transistor or a MOSFET to control the energy flow. When the switch is closed, energy is stored in an inductor, and when the switch is open, the energy is transferred to the output through a diode. This periodic switching action enables voltage boosting.

Equation for DC-DC Boost Converter:

Input-output relationship:

$$V_{out} = D^{*} V_{in} /(1 - \mathrm{D}) \tag{3.10}$$

Where: V_{out} is the output voltage V_in is the input voltage D is the duty cycle, which represents the ratio of the switch on-time to the switching period Inductor current equation:

$$V_{in} * (1 - \mathrm{D}) = \mathrm{L} * \mathrm{diL}/\mathrm{dt} \tag{3.11}$$

Where: L is the inductance of the boost converter di_L/dt is the rate of change of inductor current

Switching node equation:

$$V_{in} = V_{L} + V_{out} \tag{3.12}$$

Where: V_L is the voltage across the inductor

These equations govern the operation and behavior of the boost converter, including its steady-state and transient characteristics.[124]

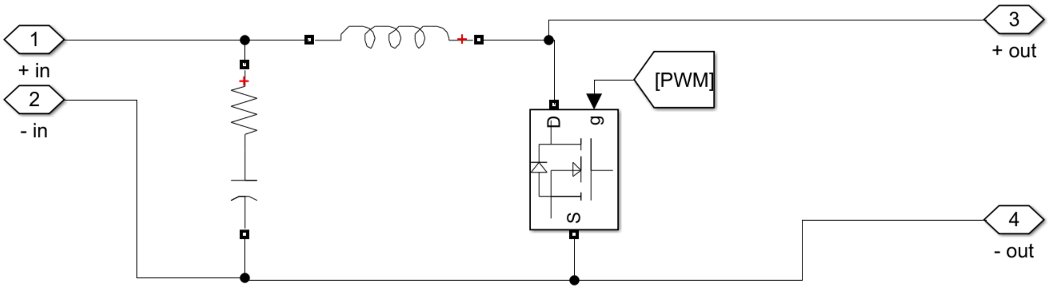


Figure 3.7. DC-DC boost converter in Simulink.

3.3.2. MPPT

Maximum power point tracking (MPPT) is a technique used in photovoltaic (PV) systems to optimize the power output from solar panels by continuously tracking the point on the voltage-current (V-I) characteristic curve where the maximum power is obtained. Simulink, a simulation and modeling environment provided by MATLAB, offers a powerful tool to design and simulate MPPT algorithms for PV systems. MPPT algorithms adjust the operating point of the PV system to maximize the power output, taking into a count factors such as solar irradiance, temperature, and the characteristics of the PV panel. Simulink provides a flexible platform to model and evaluate different MPPT techniques and their performance under varying operating conditions.

Equation for MPPT:

The most commonly used MPPT algorithm is the perturb and observe (P&O) method. It adjusts the duty cycle of a DC-DC converter to track the maximum power point (MPP). The P&O algorithm can be described by the following equation:

$$V\_{ref} = V\_{mpp} + \Delta V \tag{3.13}$$

Where: V_{ref} is the reference voltage used to adjust the duty cycle of the converter V_{mpp} is the voltage at the maximum power point ΔV is a small perturbation added to V_{mpp}.

The P&O algorithm periodically perturbs the reference voltage and observes the power output. If the power increases, the perturbation is continued in the same direction. If the power decreases, the perturbation is reversed. By continuously adjusting the reference voltage, the algorithm converges to the MPPT [125].

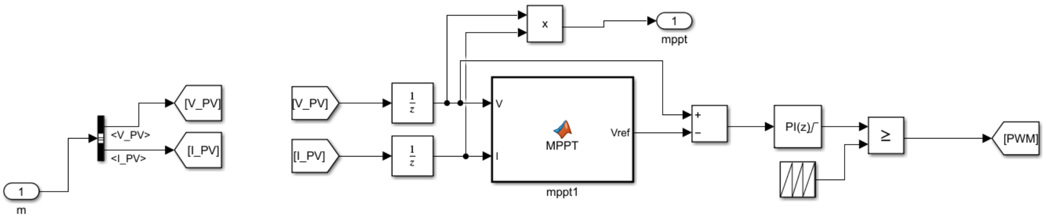


Figure 3.8. MPPT in Simulink.

3.3.3. Invertor

A three-phase inverter is a power electronic device used to convert DC power into AC power with three-phase output voltages. It is commonly employed in various applications, including motor drives, renewable energy systems, and grid-connected power converters. simulink, a simulation and modeling environment provided by MATLAB, offers a powerful tool to design and analyze three-phase inverters using insulated gate bipolar transistors (IGBTs).

IGBTs are widely used as the switching devices in three-phase inverters due to their high voltage and current handling capabilities. Simulink provides a versatile platform to model and simulate the operation of three-phase inverters using IGBTs, allowing for detailed analysis of the inverter's performance, including voltage and current waveforms, efficiency, and harmonic content [4].

The operation of a three-phase inverter can be described by the following equations:

Output Voltage: $V_{\_out} = \sqrt{2} * V\_dc * (m * \sin(\omega t) * s\_a + m * \sin(\omega t - 2\pi/3) * s\_b + m * \sin(\omega t + 2\pi/3) * s\_c)$ (3.14)

Where: V_out is the output voltage of the inverter V_dc is the DC link voltage m is the modulation index (determines the amplitude of the output voltage) ω is the angular frequency of the AC output voltage s_a, s_b, and s_c are the switching signals for the three IGBTs. Modulation index: The modulation index (m) is defined as the ratio of the peak amplitude of the fundamental component of the output voltage to the peak amplitude of the carrier waveform [124].

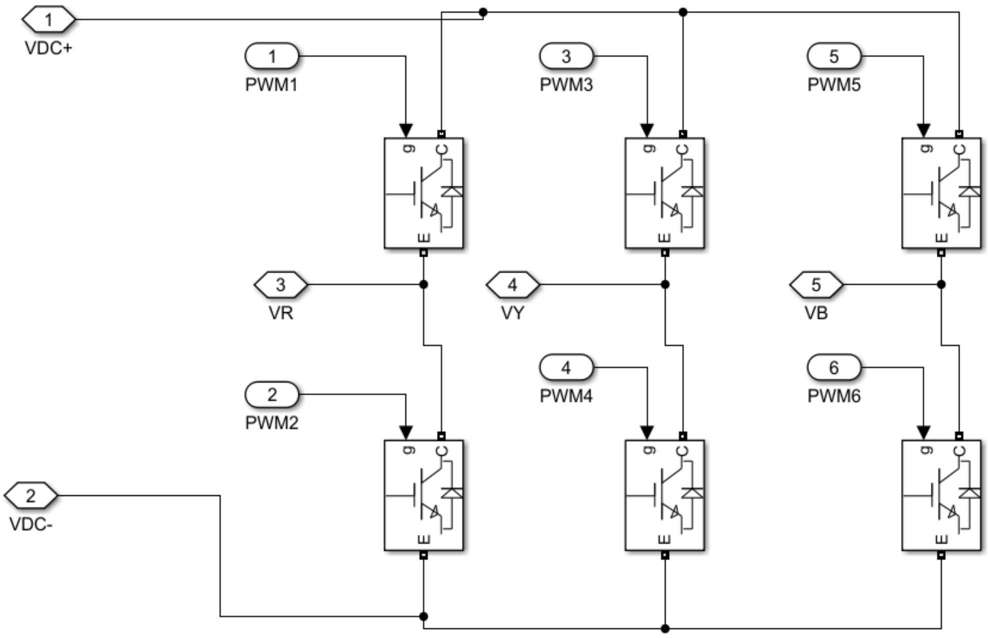


Figure 3.9. Invertor in simulink.

3.3.4. LCL Filter

A three-phase LCL filter is a common choice for mitigating harmonics and reducing the ripple in the output voltage of a three-phase inverter. It consists of inductors, capacitors, and resistors arranged in an LCL configuration. Simulink, a simulation and modeling environment provided by MATLAB, offers a powerful tool to design and analyze three-phase LCL filters, allowing for the evaluation of their filtering characteristics and performance.

The LCL filter is designed to provide a low-impedance path to the high-frequency harmonics generated by the switching operation of the inverter, while allowing the fundamental frequency component to pass through with minimal distortion. Simulink enables the modeling and simulation of the LCL filter's behavior, including its impedance characteristics, resonance frequencies, and overall filtering performance.
The behavior of a three-phase LCL filter can be described by the following equations:

Inductor current equations: $di\_L_1/dt = (V\_{}_{L1} - V\_{}_{out}) / L_1$ $di\_L_2/dt = (V\_{}_{L2} - V\_{}_{out}) / L_2$
$di\_L_3/d_t = (V\_L_3 - V\_{}_{out}) / L_3$ (3.15)

Where: di_L_1/dt, di_L_2/dt, and di_L_3/dt are the rates of change of the inductor currents V_L_1, V_L_2, and V_L_3 are the voltages across the inductors V_out is the output voltage of the LCL filter

Capacitor current equations: $i\_C_1 = C_1 * dV\_C_1/dt$ $i\_C_2 = C_2 * dV\_C_2/dt$ $i\_C_3 = C_3 * dV\_C_3/dt$ (3.16)

Where: i_C_1, i_C_2, and i_C_3 are the currents flowing through the capacitors C_1, C_2, and C_3 are the capacitance values of the capacitors dV_C_1/dt, dV_C_2/dt, and dV_C_3/dt are the rates of change of the capacitor voltages [124].

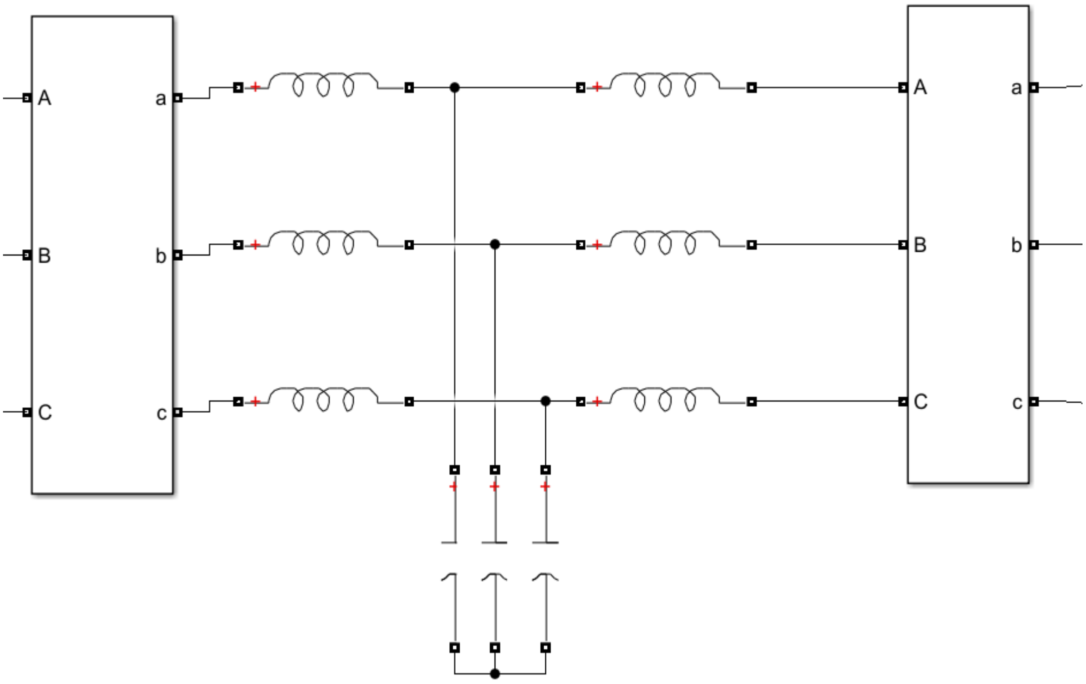


Figure 3.10. LCL filter in Simulink.

3.3.5. Grid

A three-phase grid refers to the utility power grid that supplies electrical energy to consumers in a three-phase AC format. Simulink, a simulation and modeling environment provided by MATLAB, offers a powerful tool to model and analyze three-phase grids, allowing for the study of grid-connected power systems, power flow analysis, and grid integration of renewable energy sources.

Simulink provides various blocks and libraries that enable the modeling of three-phase grid systems, including generators, transformers, transmission lines, loads, and control systems. These components can be interconnected to represent a realistic three-phase grid scenario, allowing for the examination of power flow, voltage regulation, and fault analysis.

The behavior of a three-phase grid can be described by the following equations:

Power Flow Equations:

$$P = \sqrt{3} * V * I * \cos(\theta) \; Q = \surd 3 * V * I * \sin(\theta) \tag{3.17}$$

Where: P is the real power transmitted by the grid Q is the reactive power transmitted by the grid V is the line-to-line voltage of the grid I is the line current flowing through the grid θ is the phase angle difference between the voltage and current

Synchronous Generator Equations:

$$V = E + j_{X\_d} * I \; P = V * I * \cos(\delta - \theta) \; Q = V * I * \sin(\delta - \theta) \tag{3.18}$$

Where: V is the terminal voltage of the generator E is the internal generated voltage of the generator X_d is the synchronous reactance of the generator I is the current flowing through the generator δ is the rotor angle of the generator θ is the voltage angle difference between the generator and the grid [126].

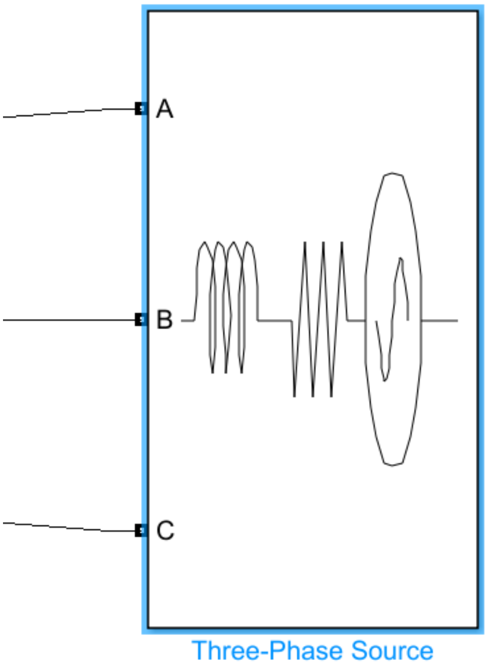


Figure 3.11. Grid in Simulink.

3.3.6. Phase-Locked Loop

A Phase-locked loop (PLL) is a control system commonly used in communication and signal processing applications to synchronize the phase and frequency of an input signal with a reference signal. Simulink, a simulation and modeling environment provided by MATLAB, offers a powerful tool to design and analyze PLL systems, allowing for the study of frequency and phase synchronization, tracking performance, and noise suppression.

In a PLL, the input signal is compared with a reference signal, and the control loop adjusts the output signal to minimize the phase and frequency differences between the two signals. Simulink provides various blocks and functions to model PLL components, such as phase detectors, loop filters, voltage-controlled oscillators (VCOs), and frequency dividers. These blocks can be interconnected to represent a complete PLL system, enabling the examination of its dynamic behavior and performance.

Equations for PLL:

$\varphi\_{error} = \varphi\_{ref} - \varphi\_{in}$ (3.19)

Where: φ_{error} is the phase error between the reference signal (φ_{ref}) and the input signal (φ_{in})

Loop Filter: $V\_{out} = K_p * \varphi\_{erro}r + K_i * \int \varphi\_{error}\, dt$ (3.20)

Where: V_{out} is the output voltage of the loop filter K_p is the proportional gain of the loop filter Ki is the integral gain of the loop filter

Voltage-Controlled Oscillator (VCO): $f\_{out} = f\_{ref} + K\_{vco} * V\_{out}$ (3.21)

Where: f_{out} is the output frequency of the VCO f_ref is the reference frequency K_{vco} is the VCO gain [127].

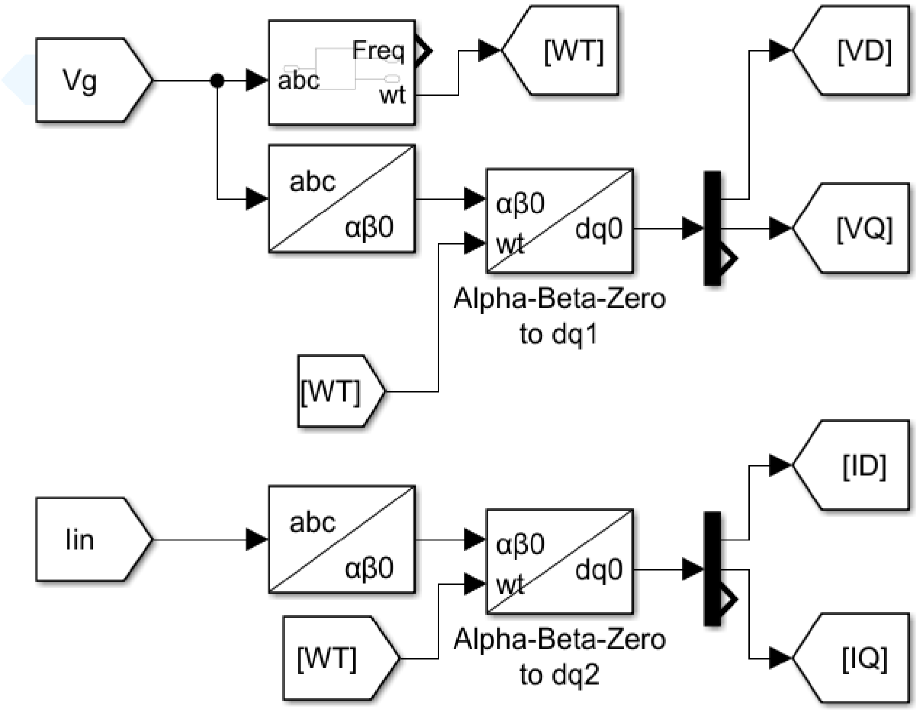


Figure 3.12. Phase-locked loop in Simulink.

3.3.7. P&O Algorithm

The Perturb and Observe (P&O) algorithm is a widely used maximum power point tracking (MPPT) technique in photovoltaic (PV) systems. It is employed to extract the maximum available power from a solar panel by adjusting the operating point of the PV system based on the power output variations. Simulink, a simulation and modeling environment provided by MATLAB, offers a powerful tool to design and simulate the P&O algorithm for MPPT applications.

The P&O algorithm operates by perturbing the operating point of the PV system, typically the voltage or duty cycle, and observing the resulting power change. Based on the observed power change, the algorithm determines the direction of perturbation to converge towards the maximum power point (MPP). Simulink provides a range of blocks and functions that enable the implementation and simulation of the P&O algorithm.

Equation for P&O algorithm:

$$V\_{ref} = V\_{mpp} + \Delta V \tag{3.22}$$

Where: V ref is the reference voltage or duty cycle used to adjust the PV system's operating point V mpp is the voltage or operating point at the maximum power point (MPP) ΔV is a small perturbation added to V_mpp

The P&O algorithm periodically perturbs the operating point and monitors the resulting power change. If the power increases, the perturbation is continued in the same direction. If the power decreases, the perturbation is reversed. This iterative process helps the algorithm converge to the MPP of the solar panel [128].

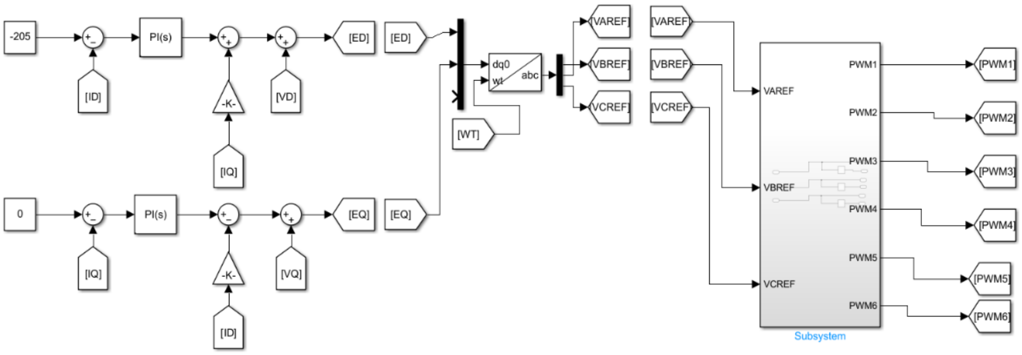


Figure 3.13. P&O Algorithm in Simulink.

PART 4

RESULTS AND DISSECTION

4.1. VALIDATION WITH TRANE TRACES 700 SOFTWARE

Both the HAP (hourly analysis program) and TRACE 700 software programs are frequently used in the building energy analysis and HVAC (heating, ventilation, and air Conditioning) engineering fields. For doing thorough energy analyses and load calculations for buildings, HAP and TRACE 700 were both developed. They aid engineers and designers in evaluating the energy efficiency of HVAC systems and how they affect the amount of energy used by buildings. Both tools enable the simulation and examination of HVAC systems on an hourly basis. Understanding how a system functions over time, taking into a count changes in weather and occupancy, requires this degree of information. To satisfy the heating and cooling load requirements of a facility, HAP and TRACE 700 both help in sizing HVAC equipment, such as chillers, boilers, air handling units, and pumps. This guarantees that the systems are sized adequately for comfort and efficiency. Both applications are capable of doing load calculations to ascertain the heating and cooling loads for the building. The system's capacity requirements are calculated using variables such as the environment, building orientation, insulation, and occupancy. HAP and TRACE 700 can be used to determine whether a building meets with local building rules, ASHRAE Standard 90.1, LEED (L leadership in energy and environmental design), and other energy codes and standards. Engineers can use both software tools to create energy models of buildings, which they can then use to compare different design options and energy-saving strategies. Engineers may simply enter building data, system parameters, and design specifications using the user-friendly graphical interfaces offered by both HAP and TRACE 700. Both software applications produce reports, charts, and graphs that allow users to see the outcomes of their simulations. This facilitates the analysis and communication of the results to clients and stakeholders. HAP and TRACE 700 frequently offer customization options that let users specify particular HVAC system configurations and operational schedules that are suited to the needs of the project. Using both software programs, it is possible to determine how energy-saving solutions, such as variable-speed drives, high-efficiency machinery, and control methods, will affect a building's energy usage and operating expenses. While HAP and TRACE 700 have many things in common, they also could have particular qualities and skills that set them apart. The decision between the two software packages frequently comes down to considerations like user preference, project needs, and software familiarity within an engineering organization. Engineers and designers can choose the tool that best suits their individual requirements and project goals.

Where it was taken into a count all the parameters used and the joins that were simulated with the HAP program and then reprogrammed with the Trace 700 program. The case of light paint with insulation was taken in the presence of the resolver, and the results showed that the difference between the two programs does not exceed 5%, which is an acceptable difference that can be relied upon, as in Tables 4.1 and 4..2 .The loads extracted from the trace 700 program were compared to the results in Tables 3.9, 3.10 in the third chapter coaling load and heating load.

Table 4.1. Terminal unit sizing data – cooling.

Zone name	**Cooling coil load (KW) (HAP)**	**Cooling coil load (KW) (Trace 700)**	**Sensible coil load (KW) (HAP)**	**Sensible coil load (KW) (Trace 700)**	**Zone (L/(s.m^2)) (HAP)**	**Zone (L/(s.m^2)) (Trace 700)**
Reception	3.1	3.0	2.8	2.7	7.3	7.0
Living room	3.0	2.9	2.8	2.7	13.9	13.3
Kitchen	2.6	2.5	2.4	2.3	9.9	9.5
Bed room	2.1	2.0	2.0	1.9	7.5	7.2
Bed room 1	1.6	1.5	1.5	1.4	8.6	8.3
Bed room 2	2.2	2.1	2.0	1.9	8.0	7.6
Master bed room	3.0	2.9	2.8	2.7	8.3	8.0

Table 4.2. Terminal unit sizing data - heating, fan, ventilation.

Zone Name	Heating coil load (KW) (HAP)	Heating coil load (KW) (Trace 700)	Fan design airflow (L/s) (HAP)	Fan design airflow (L/s) (Trace 700)	OA vent design air flow (L/s) (HAP)	OA vent design air flow (L/s) (Trace 700)
Reception	1.9	1.8	188.0	180.5	23.0	22.1
Living room	1.6	1.5	208.0	199.7	20.0	19.2
Kitchen	1.5	1.4	176.0	169.0	14.0	13.4
Bed room	1.3	1.2	143.0	137.3	11.0	10.6
Bed room 1	1.1	1.1	112.0	107.5	6.0	5.8
Bed room 2	1.3	1.2	151.0	145.0	11.0	10.6
Master bed room	2.0	1.9	212.0	203.5	13.0	12.5

4.2. COOLING LOAD

An essential part of designing an HVAC (heating, ventilation, and air conditioning) system is determining the cooling load for a building to maintain comfortable, energy-efficient, and congenial interior environments for people. The program HAP (heating, ventilation, and air conditioning analysis program) is essential to this procedure since it gives engineers and designers in-depth knowledge of a building's cooling needs. The quantity of heat energy that must be efficiently removed from a building's interior environment to maintain a desired and comfortable temperature during the warmest anticipated exterior circumstances is known as the cooling load and is estimated through the HAP program. This crucial computation is the outcome of a detailed analysis that takes into a count a variety of elements, such as the design, orientation, insulation, occupancy patterns, and historical weather information for the structure. Proper selection and sizing of HVAC equipment, including air conditioners, chillers, cooling coils, and fans, depend on accurate cooling load calculations. The HVAC system runs at its most effective level when given accurate data from HAP, which lowers energy usage and related expenses. Keeping the interior of the building at a suitable temperature is important for the residents' health as well as their productivity and level of satisfaction. The HVAC system can supply the necessary cooling capacity to achieve and maintain pleasant circumstances thanks to the cooling load results from the HAP program. Building energy use significantly increases greenhouse gas emissions. HAP aids in the design of HVAC systems that are environmentally responsible, lowering the building's carbon footprint, by precisely calculating and limiting the cooling load. Engineers and designers select the proper cooling equipment with the use of HAP-generated cooling load data, which also helps them choose the right system type, capacity, and energy sources. Energy efficiency compliance with building codes and standards is a key factor in construction and remodeling projects. The building will comply with or surpass these regulatory criteria thanks to the cooling load study carried out by HAP. Accurate cooling load calculations aid in the prediction of the long-term maintenance and operational expenses related to the HVAC system. This data helps with budgeting and guarantees that the system will remain affordable over the course of its life. In conclusion, the HAP program's cooling load calculation is an essential stage in the design of an HVAC system. It enables architects and engineers to build spaces that are not only thermally cozy but also environmentally friendly and sustainable. These estimates serve as the basis for making well-informed judgments on HVAC equipment, system design, and operational tactics, resulting in structures that provide the maximum level of comfort and have the lowest possible environmental effect.

4.2.1. Cooling Load Comparison with and without Insulation Using Light Coating

The thermal performance and energy efficiency of a building should be taken into a count when comparing cooling load with insulation to cooling load without insulation. Structures with adequate insulation have less heat transfer through their floors, roofs, and walls. In hot weather, insulation serves as a thermal barrier to keep heat from the outside from entering the interior. Consequently, the cooling load is reduced. Insulation aids in preserving more constant indoor temperatures. It lessens temperature swings brought on by changes in the outside temperature, which eliminates the need for repeated cooling adjustments. Insulated buildings often use less energy for cooling and pay less for it. The insulation reduces the quantity of heat that the cooling system must remove, increasing its energy efficiency. By lessening the effects of temperature fluctuations outside, insulation helps to improve indoor comfort. It is less likely that inside temperatures may make occupants uncomfortable. Without insulation, buildings allow for more heat to pass through the floors, walls, and roofs. As a result, there is an increase in the heat gain from external sources, which raises the cooling load. Insulated structures are more vulnerable to temperature changes. Based on ambient conditions, indoor temperatures might change greatly, making it more difficult to maintain comfort without stepping up cooling efforts. Buildings lacking insulation typically have higher cooling energy consumption and higher associated expenses because of the increased cooling load. To maintain pleasant indoor temperatures, more energy is required. During severe weather, occupants of buildings without insulation could feel uncomfortable. Overheating indoor areas can create an unfavorable and unproductive environment. The amount of insulation a building has a big impact on how much it needs to cool. Lower cooling loads in insulated buildings translate into lower energy use, cheaper prices, and enhanced indoor comfort. Lack of insulation increases cooling loads since more heat is transferred, which can result in higher energy costs and inconsistent indoor temperatures. Insulation is therefore essential for maximizing a building's comfort and energy efficiency, especially in areas with wide temperature changes.

Figure 4.1 shows the comparison between the insulation states or not in the light paint. Where it is noted that the value of the cooling load is reduced to half in the case of insulation, and this indicates its usefulness in using it to reduce the cooling load. In the living room, the value of the cooling load when isolated was 3KW, but with the absence of the insulation, it rises to 6.8 KW, and this difference is vast and can be benefited It is to improve cooling loads.

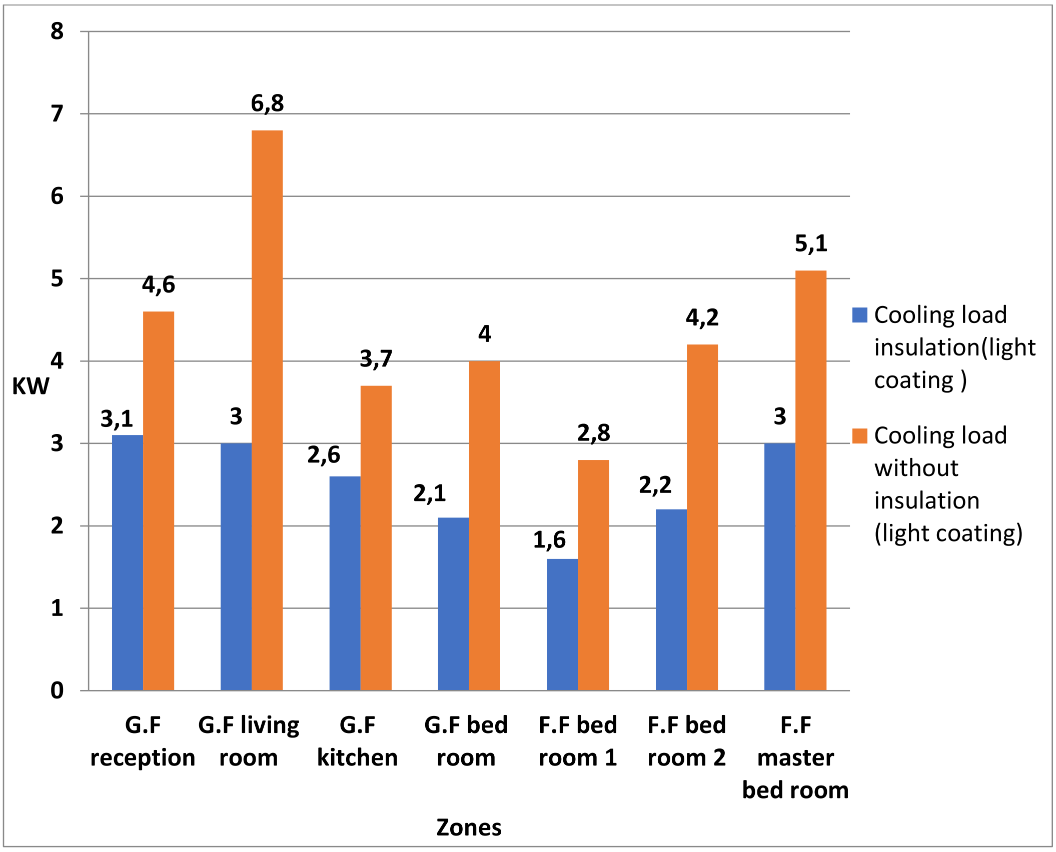


Figure 4.1. Cooling load insulation vs. cooling load without insulation (light coating).

4.2.2. Cooling Load Comparison with and Without Insulation Using Light Coating

Dark-coated structures tend to absorb more solar heat. By forming a thermal barrier, insulation added to these buildings can assist reduce some of the heat absorption. When compared to an insulated, dark-coated building, this can increase the overall cooling demand. By keeping heat from entering the inside, insulation helps maintain a constant indoor temperature. Insulation becomes especially important in dark-coated structures since they can absorb a lot of heat. It increases energy efficiency and decreases the need for intensive cooling. Lower energy use and cost savings result from reduced cooling loads brought on by insulation. In comparison to their insulated equivalents, insulated dark-coated buildings often have cheaper cooling costs. By reducing temperature variations, insulation makes indoor environments more comfortable. This is crucial for dark-coated structures since they can get uncomfortably hot without insulation and cause pain for residents. Without insulation, darkly painted structures can absorb a large quantity of solar heat, raising indoor temperatures. As a result, more heat must be evacuated to keep the environment comfortable, increasing the cooling load. Dark-coated buildings without insulation have a higher cooling load, which increases energy use and, ultimately, cooling expenses. Dark-coated structures without insulation are more vulnerable to temperature changes, particularly on sunny days. As a result, the inside environment may become uncomfortable, necessitating frequent cooling system changes. In dark-coated structures without insulation, inhabitants may feel uncomfortable as a result of the high temperatures inside. The pain may have an impact on both health and productivity. In conclusion, adding insulation to dark-coated buildings can significantly improve energy efficiency and the decrease of cooling load. Because insulation reduces the heat-absorbing qualities of dark surfaces, less cooling energy is needed, which saves money and improves indoor comfort. Dark-coated structures are vulnerable to excessive heat gain in the absence of insulation, which raises the cooling load, requires more energy, and raises the risk of discomfort. Therefore, when dealing with dark-coated structures, insulation is an important factor, especially in areas with warm or hot climates.

Figure 4.2 shows the effect of the presence of insulation with no insulation on the cooling load using dark paint. The results prove once again the effectiveness of using insulators in reducing the cooling load. In the same living room, the value of the cooling load in the case of insulation was 3 KW, but with the absence of the cooling load, it rises to 7 KW, which is a big difference.

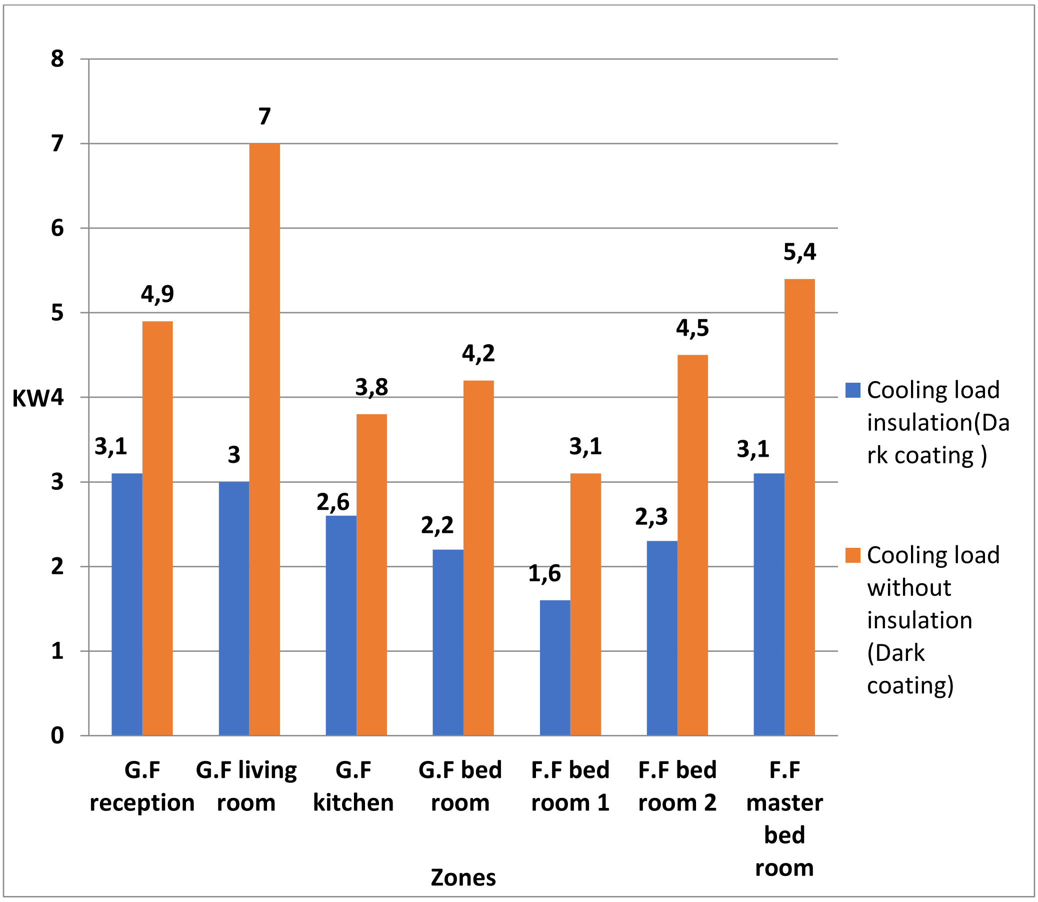


Figure 4.2. Cooling load insulation vs. cooling load without insulation (dark coating).

4.2.3. Cooling Load Insulation Comparison Between Light and Dark Coating

White or light colors of coating often have a higher solar reflection than darker hues. This reduces heat absorption by reflecting more solar radiation away from the building's surface. The exterior of the building absorbs less heat since light paint reflects a large amount of solar energy. Lower surface temperatures are the outcome, which lowers the requirement for cooling and the overall cooling load. Light-colored exteriors of buildings often require less cooling energy because light paint reduces heat absorption. This lowers the cost of cooling and encourages energy efficiency. Lower cooling loads brought on by light paint result in more stable and comfortable indoor temperatures, which are better for the inhabitants' health. Darker paint has a lower albedo and tends to absorb more solar energy, which causes the exterior of the building to gain more heat. Because dark paint absorbs and holds onto more heat, surface temperatures are higher. As a result, the cooling load rises since more heat must be removed to keep the interior comfortable. Buildings painted in dark colors often need more cooling energy because they absorb more heat. This result in increased cooling expenses and perhaps decreased energy efficiency. Due to the higher cooling load, dark-painted buildings may experience less stable indoor temperatures with greater temperature variations. Residents may feel uncomfortable as a result. Light paint is typically more efficient than dark paint at insulating the cooling load, lowering the cooling load, and increasing energy efficiency. Light exterior colors reflect more solar heat, which leads to less heat absorption, less cooling energy use, and improved indoor comfort. Dark paint, on the other hand has a tendency to absorb more heat, resulting in higher cooling loads, increased energy usage, and a risk for occupant discomfort. As a result, choosing light-colored paint in hot or sunny locations might be a smart move to reduce cooling load and increase energy efficiency.

The presence of windows and windows during the used building was many, and therefore the coating areas are few in Figure 3.1, as the difference between the light and dark coatings decreases, and this is what is noticeable in Figure 4.3, which shows the difference between the cooling load in the presence of light and dark coatings with an insulating coating, as the difference is non-existent in the living room and its value 3 KW for each floor. The difference increases in the master bedroom, so the value of the cooling load reached 3.1 KW during the dark coating and 3 KW in the light coating.

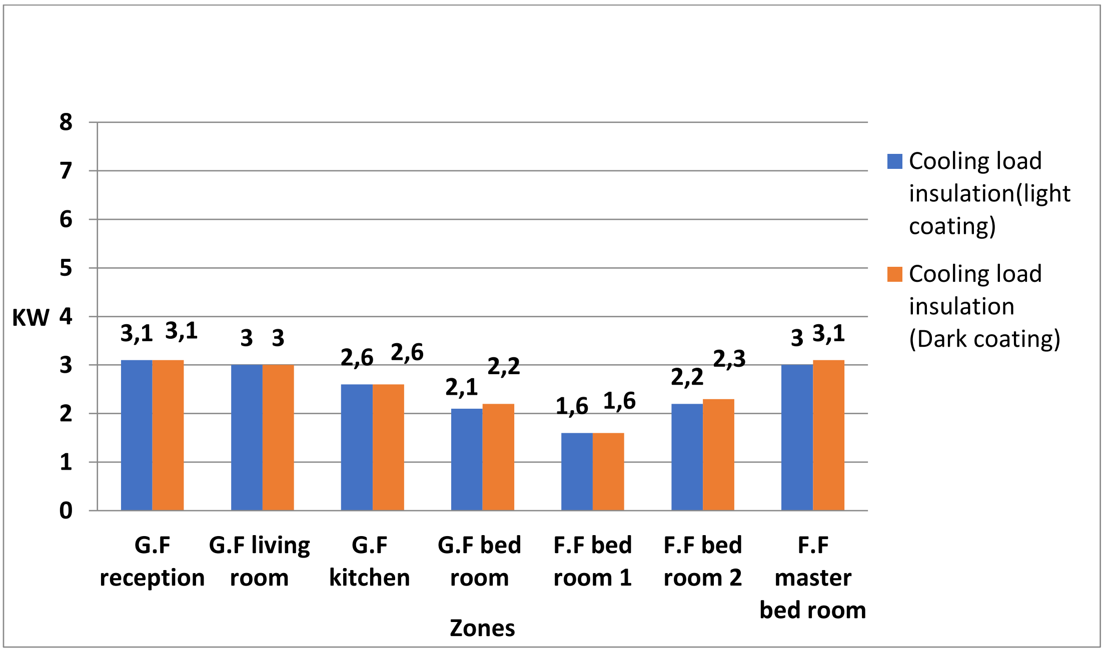


Figure 4.3. Cooling load insulation (light coating vs. dark coating).

4.2.4. Cooling Load without Insulation Comparison Between Light and Dark Paint

Light-colored paints reflect a sizable part of solar radiation, which causes the outside surfaces of the building to absorb less heat. Reduced heat gain inside the building may result from this. Surfaces that have been painted in light colors typically have lower surface temperatures, especially when they are exposed to direct sunshine. This implies that the building's outer materials absorb less heat, which may result in a more comfortable interior. In the absence of insulation, buildings painted in bright colors could have a little lower cooling load than those painted in dark colors. In order to ensure indoor comfort, less heat must be extracted from them because they absorb less heat. Darker paints, on the other hand, absorb more solar radiation, which causes the outer surfaces of the building to absorb more heat. Higher heat gain inside the building may result from this. Surface temperatures on dark-painted surfaces are typically greater, especially under direct sunshine. This implies that the building's outer materials are retaining more heat, which could result in hotter interior temperatures. Compared to light-painted buildings without insulation, structures with dark paint may have a slightly higher cooling burden. This is due to the fact that they absorb more heat, requiring more cooling to maintain a comfortable indoor climate. Compared to dark paint, light paint has a tendency to absorb less heat and may have a slightly reduced cooling load. When there is no insulation, dark paint absorbs more heat and may result in a somewhat higher cooling load. It's crucial to remember that effective insulation offers far more advantages than the effects of paint color on cooling load. By forming a thermal barrier that stops heat transmission through the building envelope, insulation contributes significantly more to improving energy efficiency and lowering the cooling load. Therefore, improving insulation is a more effective strategy to increase a building's thermal performance and decrease the need for cooling, even though paint color can have a little impact.

Figure 4.4 shows the same concept with regard to the effect of the paint, but in this case, with the absence of an insulator, the effect of changing the paint increased. The difference between the two types of paint in the cooling load reached the largest value in the master bedroom, as it was 5.4 KW in the dark paint and 5.1 KW in the light paint.

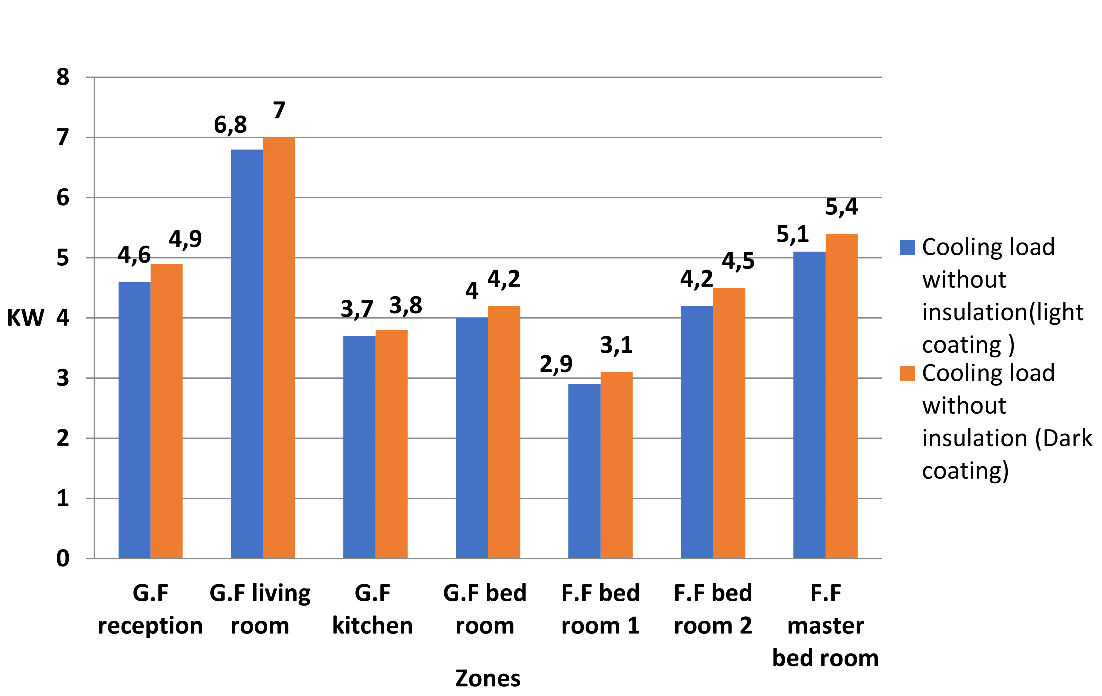


Figure 4.4. Cooling load without insulation (light coating vs. dark coating).

4.3. HEATING LOAD

The quantity of thermal energy needed to keep a building's interior temperature at a desired level during cold or winter weather is referred to as the heating load of the structure. It is a key factor in the design and sizing of heating systems because it establishes the capacity and effectiveness of the heating equipment required to maintain a suitable indoor climate. The heating demand increases with the outside low temperature. As the temperature differential between the ideal indoor temperature and the outside temperature widens, the heating load rises. The insulation of the building's walls, windows, doors, and roof significantly affects the amount of energy required for heating. Buildings with good insulation require less heating because less heat is lost through the building envelope. Due to their larger surface area and volume, larger structures typically have higher heating loads. The building's layout, including the number and size of rooms, has an impact on heat dispersion and, in turn, the heating load. The quantity of residents and the activities they engage in inside the structure cause heat to be produced. The heating load may increase with higher passenger density and heat-generating activities like cooking and equipment use. The amount of heating required depends on the building's ventilation needs and whether there are air leaks or drafts. The load can be increased by introducing cold outdoor air from ventilation, which is necessary for good interior air quality. During the day, solar radiation from windows can counteract the heating demand. Passive solar heating may be facilitated through south-facing windows, lowering the need for a heating system. Heat is produced inside the building by electronics, lighting, and appliances. Depending on the insulation and ventilation of the building, this internal heat gain may help to reduce the heating demand or raise it. The heating load is influenced by the desired indoor temperature set by occupants. Greater heating energy is needed at higher set points. The goal of efficient heating system design and operation is to precisely satisfy the heating load while avoiding equipment over- or under sizing. Undersized systems may struggle to maintain comfort in extremely cold conditions, while oversized systems may operate inefficiently and waste energy.

4.3.1. Heating Load Comparison with and without Insulation Using Light Coating

Insulation helps to keep indoor temperatures steady and comfortable. Insulation that is installed properly helps a building's inhabitants, heating systems, and appliances retain heat within the structure longer, requiring fewer adjustments to the heating system. Because buildings with insulation lose less heat to the outside, they often need less heating energy. As a result, heating expenses are reduced, and energy efficiency is raised. By minimizing temperature swings and cold patches, insulation contributes to a more comfortable indoor climate. This is especially helpful in the winter, when tenant comfort depends on maintaining steady warmth. A building loses heat more quickly through its outer surfaces in the lack of insulation. As a result, there is a higher heating load since more energy is needed to make up for the heat that is lost and keep the inside at a reasonable temperature. Insulated structures are more vulnerable to temperature changes. In response to cold spells outside, the temperature inside may drop quickly, necessitating regular use of the heating system to keep everyone comfortable. Heating systems must operate longer and harder without insulation to make up for heat loss. As a result, there is an increase in heating energy use and expenses. Buildings without insulation run the risk of having frigid interior regions close to exterior walls, windows, and doors. Residents there might not feel as comfortable. insulation greatly lowers a building's heating load regardless of the outside coating's color (such as paint). During the colder months, proper insulation helps to maintain heat, reduce heat loss, and provide a more energy-efficient and cozy indoor environment. While the external coating's color may have a little impact on solar heat gain, insulation's advantages outweigh its effects on heating load. As a result, adding insulation to a building will enhance its thermal efficiency and lower its heating needs.

Figure 4.5 shows a comparison between cases of insulation or not in light coatings. Where it is noted that the value of the heating load decreases to half in the case of insulation, and this indicates the benefit of using it in reducing the heating load. In the living room, the value of the heating load when isolated was 1.6 KW, but with the absence of the insulation it rises to 3.4 KW, and this difference is vast and can be used to improve heating loads.

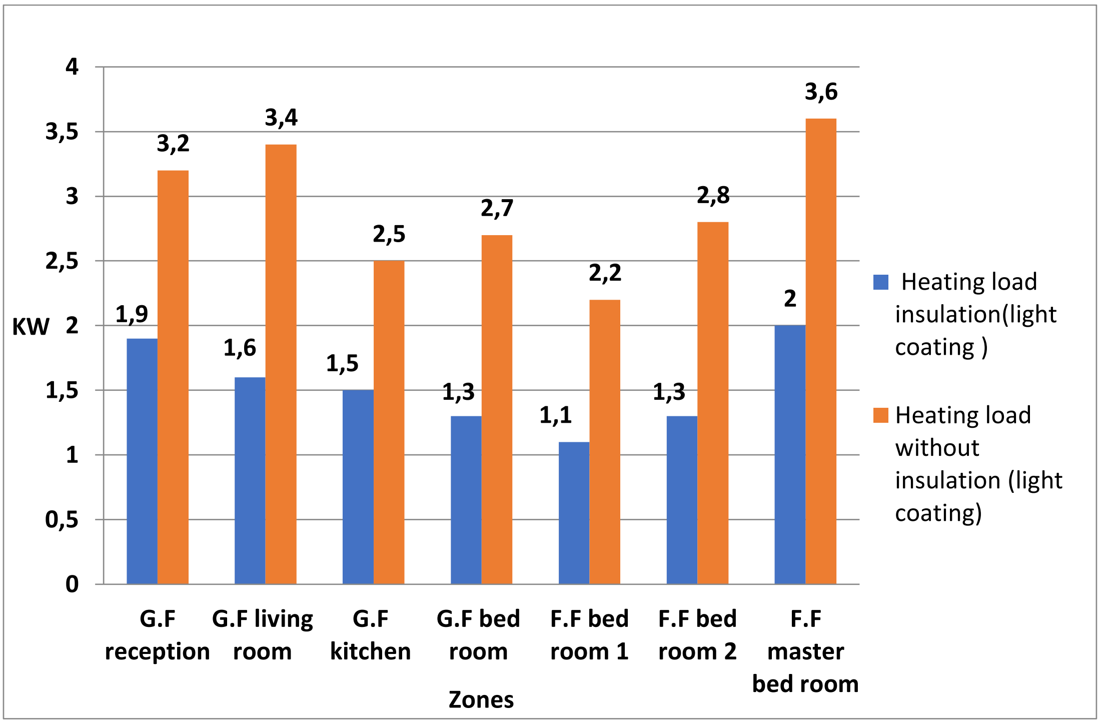


Figure 4.5. Heating load insulation vs. heating load without insulation (light coating).

4.3.2. Heating Load Comparison with and without Insulation Using Dark Coating

When used on a building, insulation aids in reducing heat loss via the floors, roof, and walls. When maintaining or increasing the internal temperature during colder weather, this is very crucial. Insulation serves as a thermal barrier to keep heat inside and out. Insulation helps to keep indoor temperatures steady and comfortable. Insulation that is installed properly helps a building's inhabitants, heating systems, and appliances retain heat within the structure longer, requiring fewer adjustments to the heating system. Because buildings with insulation lose less heat to the outside, they often need less heating energy. As a result, heating expenses are reduced, and energy efficiency is raised. By minimizing temperature swings and cold patches, insulation contributes to a more comfortable indoor climate. This is especially helpful in the winter, when tenant comfort depends on maintaining steady warmth. A building loses heat more quickly through its outer surfaces in the lack of insulation. As a result, there is a higher heating load since more energy is needed to make up for the heat that is lost and keep the inside at a reasonable temperature. Without insulated structures are more vulnerable to temperature changes. In response to cold spells outside, the temperature inside may drop quickly, necessitating regular use of the heating system to keep everyone comfortable. Heating systems must operate longer and harder without insulation to make up for heat loss. As a result, there is an increase in heating energy use and expenses. Buildings without insulation run the risk of having frigid interior regions close to exterior walls, windows, and doors. Residents there might not feel as comfortable. Daytime solar heat absorption may be increased by dark-colored coatings like paint, which could reduce the need for heating. When compared to the effect of insulation, this effect is typically far less significant. In conclusion, insulation is crucial in lowering a building's heating load regardless of the outside coating's color (such as paint). During the colder months, proper insulation helps maintain heat, reduce heat loss, and provide a more energy-efficient and cozy indoor environment. While dark coatings may have some effect on solar heat gain, insulation's advantages outweigh its benefits in terms of heating load. Therefore, a building's thermal performance can be improved and its need for heating can be decreased by investing in insulation, especially in colder locations.

Figure 4.6 shows the effect of the presence of insulation with no insulation on the heating load using dark paint. The results prove once again the effectiveness of using insulators in reducing the Heating load. In the same living room, the value of the heating load in the case of insulation was 1.6 KW, but with the absence of the Heating load, it rises to 3.3 KW, which is a big difference.

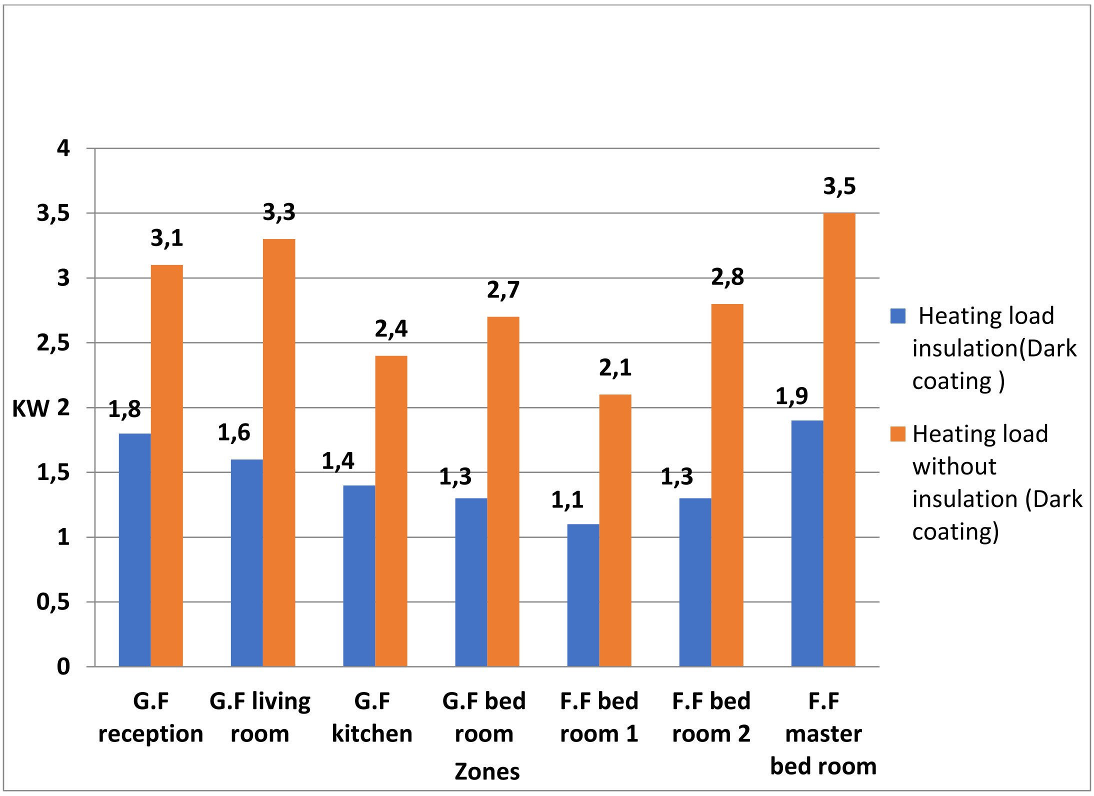


Figure 4.6. Heating load insulation vs. heating load without insulation (dark coating).

4.3.3. Heating Load Insulation Comparison Between Light and Dark Coating

Paint that is light in color, such white or light hues, tends to reflect a large amount of solar energy. As a result, the exterior surfaces of the structure absorb less heat when exposed to sunlight. When exposed to sunshine, light-painted surfaces often have lower surface temperatures. As a result, the building's outer materials retain less heat, perhaps resulting in cooler interior temperatures. dark paint can help reduce the heating load when combined with sufficient insulation. Light paint reflects solar heat while black paint absorb solar heat. when a building's outside surfaces are exposed to sunlight, dark-colored paint absorbs a greater share of solar radiation. When exposed to sunshine, dark-painted surfaces typically have hotter surface temperatures. This implies that the building's outer materials are retaining more heat, which could result in hotter interior temperatures. Compared to light paint, dark paint may result in a slightly higher heating load when combined with proper insulation. In order to maintain indoor comfort, the increased heat absorption helps to reduce the heating load. It's significant to note that insulation plays a larger influence in reducing the heating load than paint color does. Regardless of the paint color, insulation has a bigger impact on lowering heat loss from the building's envelope. The thermal barrier created by insulating materials like fiberglass, foam board, or cellulose reduces heat transfer through walls, roofs, and floors, which has a more significant impact on reducing the heating load. In conclusion, while the color of the outer coating (paint) can affect heat absorption, the advantages of insulation outweigh its influence on heating load. The key to lowering a building's heating load, increasing energy efficiency, and preserving indoor comfort throughout the winter months continues to be proper insulation. In order to maximize heating efficacy, insulation investment is therefore essential, especially in areas with cold climates.

Figure 4.7 shows an improvement in reducing the heating load for rooms painted with dark insulated paint compared to rooms painted with light insulated paint, due to the presence of more areas painted with dark paint than windows. Where an improvement is noticed in reducing the heating load in relation to the master bedroom 2, where the heating load in the insulated dark coating is 1.9 KW, while the heating load in the light coating is 2 KW.

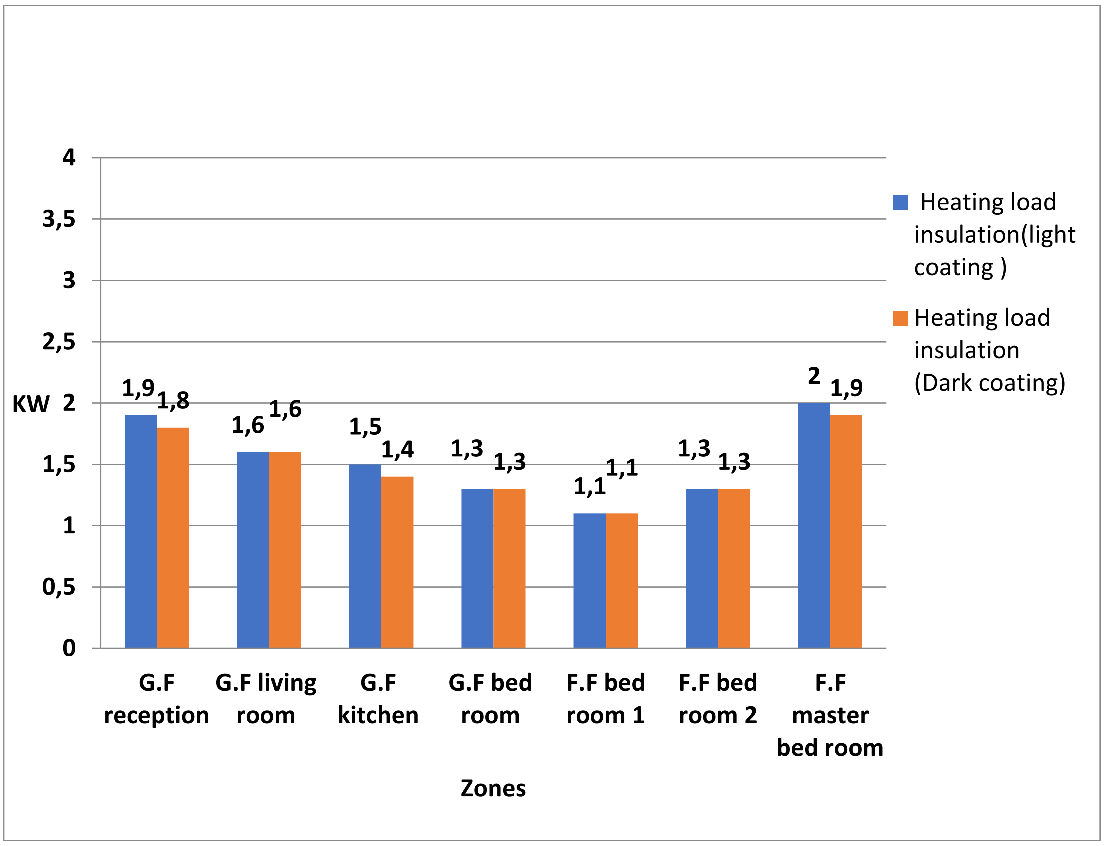


Figure 4.7. Heating load with insulation (light coating vs. dark coating).

4.3.4. Heating Load without Insulation Comparison Between Light and Dark Coating

Paint that is light in color, such white or light hues, tends to reflect a large amount of solar energy. As a result, light paint may help reduce heat absorption by the building's outside surfaces during the daytime hours when there is no insulation to stop heat loss. When exposed to sunshine, light-painted surfaces typically experience lower outside temperatures than dark-painted surfaces. This implies that the building's façade might not get as warm as it would with dark paint. Without insulation, the color of the paint only has a very small impact on the heating load. Without insulation, the building's heat loss through its walls, roof, and windows is the main determinant of heating load. Dark-colored paint absorbs more solar radiation, which causes the buildings outside surfaces to absorb more heat during the day. When exposed to sunlight, dark-painted surfaces typically experience warmer outside temperatures than light-painted surfaces. Dark paint could make the buildings outside warmer, according to this. Without insulation, the color of the paint only has a very small impact on the heating load.

Without insulation, the building's heat loss through its walls, roof, and windows is the main determinant of heating load. the outside paint color has only a small influence on heating load when taken into acount without insulation. The installation of adequate insulation, which helps retain heat and reduce heat loss through the building envelope, should be the main focus for reducing heating load and enhancing energy efficiency, regardless of the paint color.

Figure 4.8 shows the same concept with regard to the effect of the paint, but in this case, with the absence of an insulator, the effect of changing the paint increased. The difference between the two types of paint in the heating load reached the largest value in the master bedroom, as it was 3.5 KW in the dark paint and 3.6 KW in the dark paint. light paint.

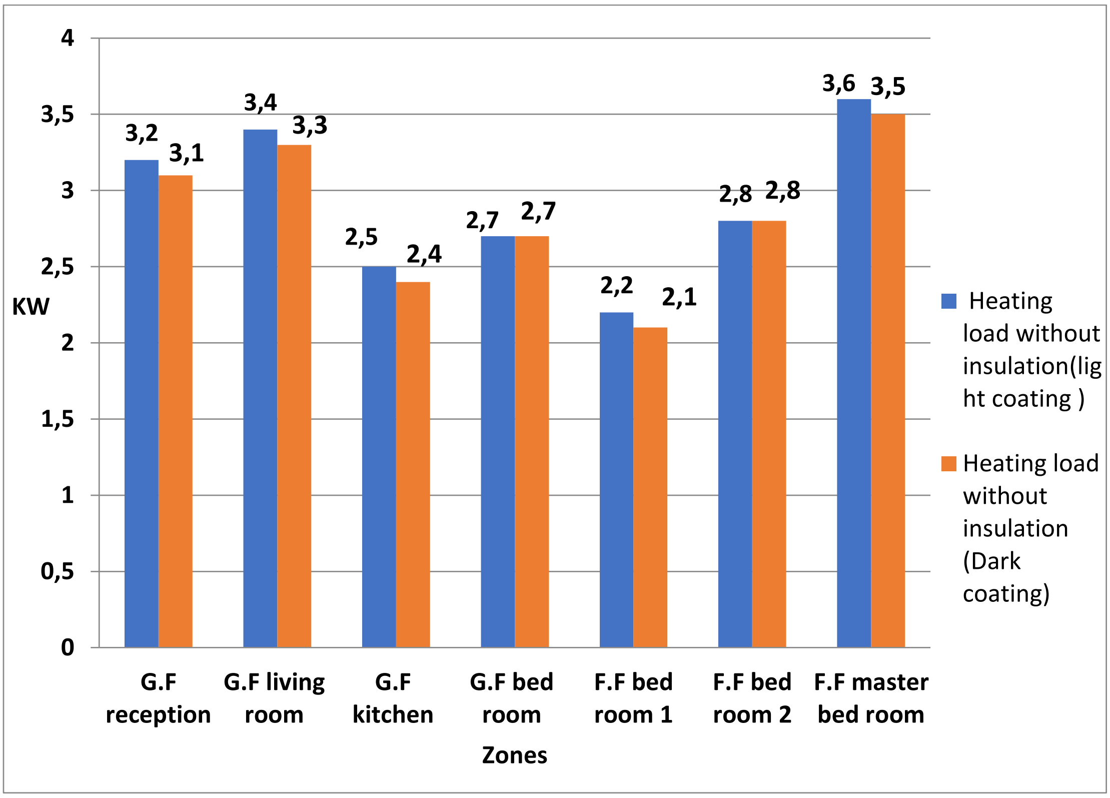


Figure 4.8. Heating load without insulation (light coating vs. dark coating).

4.4. TOTAL HEATING AND COOLING LOADS FOR EACH CASE

After the process of studying thermal loads during different seasons and knowing the amount of energy required to obtain an integrated system that achieves zero energy, work has been done on a solar panel system that feeds three phases capable of operating cooling and heating systems 24 hours a day. Where the electrical model was designed by the Simulink program, the solar panel system was simulated and the voltage was obtained to feed the systems used as in Figure 4.9.

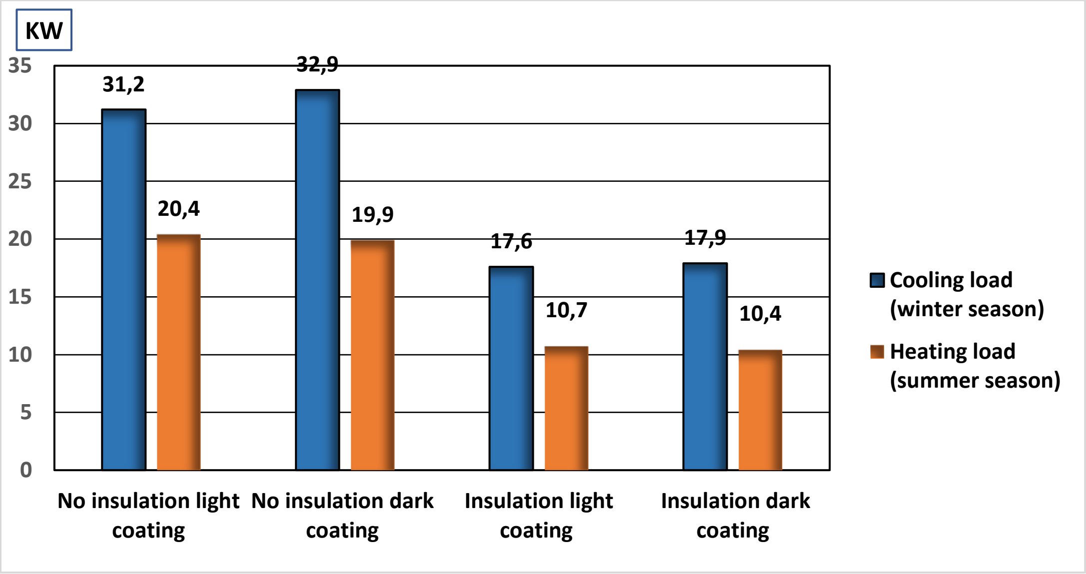


Figure 4.9. Total heating and cooling load (light coating vs. dark coating).

4.5. ZERO ENERGY CALCULATION

The size and efficiency of the Variable Refrigerant Flow (VRF) system, the insulation level of the building, and the type of exterior coating (light or dark) all affect how much electrical energy is needed to heat or cool a building. The effectiveness of the VRF system is an important consideration. Less electrical energy is needed by more efficient systems to produce the same amount of heating or cooling. The great efficiency of VRF systems is well known, especially when compared to conventional HVAC systems. Insulation significantly lowers the amount of electricity needed for heating and cooling. The strain on the VRF system is decreased by properly insulated structures that reduce heat transmission via the walls, roof, and floors. Less electrical energy is required to maintain indoor comfort in a building with good insulation. The exterior coating can affect how much solar heat a structure absorbs. Light-colored coatings have atendency to reflect more solar heat, which is useful in hotter areas since it lowers the cooling burden. This may lead to slightly increased heating needs in colder climes. More solar heat is absorbed by dark coatings, which can be advantageous in colder climates but may result in higher cooling needs. The heating and cooling load is significantly impacted by the local climate. Extremely hot or cold regions will need more energy to keep interior comfort levels high. The amount of humidity has an impact on how much energy is needed to cool. The heating and cooling load is also influenced by the building's size and design, which includes elements like window size and orientation. Internal heat gain is influenced by the amount of people and their activities inside the structure. Heat-generating activities and more people may raise cooling load while lowering heating load. The tenants' chosen indoor temperature has an impact on how much energy is used for heating or cooling. Energy consumption will increase with higher set points for cooling and lower set points for heating. To keep the VRF system running as efficiently as possible, proper maintenance is required, including cleaning the filters and coils. VRF systems with the proper controls and design can also save energy. In conclusion, a VRF system's heating and cooling energy requirements for insulation and light coating will vary based on a number of variables. By lowering the heating and cooling load, insulation and the selection of a light coating can improve energy efficiency. However, other elements, like climate and building design, also play a significant impact. It is advised to do energy modeling or speak with a qualified HVAC engineer who can perform load calculations for your particular structure and location in order to assess energy requirements accurately.

The electrical load was calculated in the case of insulation with light paint, since this case is the optimal case among the cases with which it was compared and achieved better results than the rest of the cases. In addition, Iraq is hot in the summer for a much longer period than in the winter, so the importance of cooling loads is more than heating loads.

the amount of electrical power needed for the VRF system in cases of:

The amount of electric power needed for the case of (light coating with insulation) for cooling and heating load.

Table 4.2. The amount of electrical energy calculated for the devices in the case of light coating with insulation for cooling load (summer season).

Summer							
Room name	Room load (KW)	Cooling capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	1.6	1.6	5940	380~415V/ 400V	3Ph	50Hz/ 60Hz	30
FF bed room 2	2.2	2.2					
FF master bed room	3.0	3.6					
GF bed room	2.1	2.2					
GF kitchen	2.6	2.8					
GF living room	3.0	3.6					
GF reception	3.1	3.6					

Table 4.3. The amount of electrical energy calculated for the devices in the case of light coating with insulation for heating load (winter season).

Winter							
Tag	Room load	Heating capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	1.1	1.8	3660	380~415V/400V	3Ph	50Hz/60Hz	20
FF bed room 2	1.3	1.8					
FF master bed room	2	2.5					
GF bed room	1.3	1.8					
GF kitchen	1.5	1.8					
GF living room	1.6	1.8					
GF reception	1.9	2.5					

The amount of electric power needed for the case (dark coating with insulation) for cooling and heating load.

Table 4.4. The amount of electrical energy calculated for the devices in the case of dark coating with insulation for cooling load (summer season).

Summer							
Room name	Room load (KW)	Cooling capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	1.6	1.6	5940	380~415V/400V	3Ph	50Hz/60Hz	30
FF bed room 2	2.3	2.2					
FF master bed room	3.0	3.6					
GF bed room	2.2	2.2					
GF kitchen	2.6	2.8					
GF living room	3.0	3.6					
GF reception	3.1	3.6					

Table 4.5. The amount of electrical energy calculated for the devices in the case of dark coating with insulation for heating load (winter season).

Winter							
Tag	Room load	Heating capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	1.1	1.8	3660	380~415V/400V	3Ph	50Hz/60Hz	20
FF bed room 2	1.3	1.8					
FF master bed room	1.9	2.5					
GF bed room	1.3	1.8					
GF kitchen	1.4	1.8					
GF living room	1.6	1.8					
GF reception	1.8	2.5					

The amount of electric power needed for the case of (light coating without insulation) for cooling and heating load.

Table 4.6. The amount of electrical energy calculated for the devices in the case of light coating without insulation cooling load (summer season).

Summer							
Room name	Room load (KW)	Cooling capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	2.9	3.6	9300	380~415V/400V	3Ph	50Hz/60Hz	32
FF bed room 2	4.2	4.5					
FF master bed room	5.1	5.6					
GF bed room	4	4.5					
GF kitchen	3.7	4.5					
GF living room	6.8	7.1					
GF reception	4.60	5.6					

Table 4.7. The amount of electrical energy calculated for the devices in the case of no insulation and light coating for heating load (winter season).

Winter							
Room name	Room load (KW)	Heating capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	2.2	2.5	5900	380~415V/ 400V	3Ph	50Hz/60Hz	30
FF bed room 2	2.80	3.2					
FF master bed room	3.6	4					
GF bed room	2.70	3.2					
GF kitchen	2.5	2.5					
GF living room	3.4	4					
GF reception	3.2	3.2					

The amount of electric power needed for the case of (dark coating without insulation) for cooling and heating load.

Table 4.8. The amount of electrical energy calculated for the devices in the case of dark coating without insulation for cooling load (summer season).

Summer							
Room name	Room load (KW)	Cooling capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	3.10	3.6	9300	380~415V/400V	3Ph	50Hz/60Hz	32
FF bed room 2	4.50	4.5					
FF master bed Room	5.40	5.6					
GF bed room	4.20	4.5					
GF kitchen	3.80	4.5					
GF living room	7	7.1					
GF reception	4.90	5.6					

Table 4.9. The amount of electrical energy calculated for the devices in the case of no insulation and dark coating for heating load (winter season).

Winter							
Room name	Room load (KW)	Heating capacity (KW)	Power input (W)	Power supply			
				Volts	Phase	Hz	FLA (A)
FF bed room 1	2.10	2.5	5900	380~415V/400V	3Ph	50Hz/60Hz	30
FF bed room 2	2.80	3.2					
FF master bed room	3.50	4					
GF bed room	2.70	3.2					
GF kitchen	2.40	2.5					
GF living room	3.30	4					
GF reception	3.10	3.2					

Figure 4.10 clear the actual need for electrical capacity for (cooling and heating load) in summer and winter seasons for each case, The figure shows that the electrical power required for the insulated cases is much less than the no insulated cases, while the electrical power for the light and dark coating for the two cases(insulating and no insulating)is equal due to the close cooling and heating capacities for the light and dark

coating cases therefore the selection of VRF system be similar for light and dark coating for two cases insulating and no insulating.

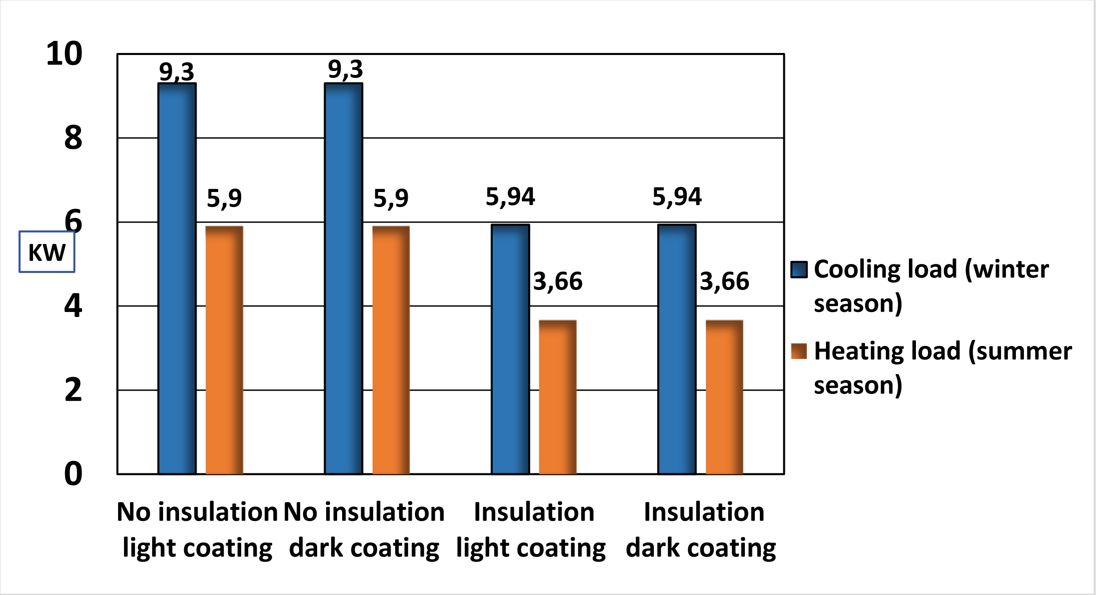


Figure 4.10. Electrical capacity for (cooling and heating load) in summer and winter seasons.

4.6. SUPPLYING COOLING AND HEATING SYSTEMS BY SOLAR PANELS

After the process of studying thermal loads during different seasons and knowing the amount of energy required to obtain an integrated system that achieves zero energy, work has been done on a solar panel system that feeds three phases capable of operating cooling and heating systems 24 hours a day. Where the electrical model was designed by the Simulink program, the solar panel system was simulated and the voltage was obtained to feed the systems used as in Figure 4.10.

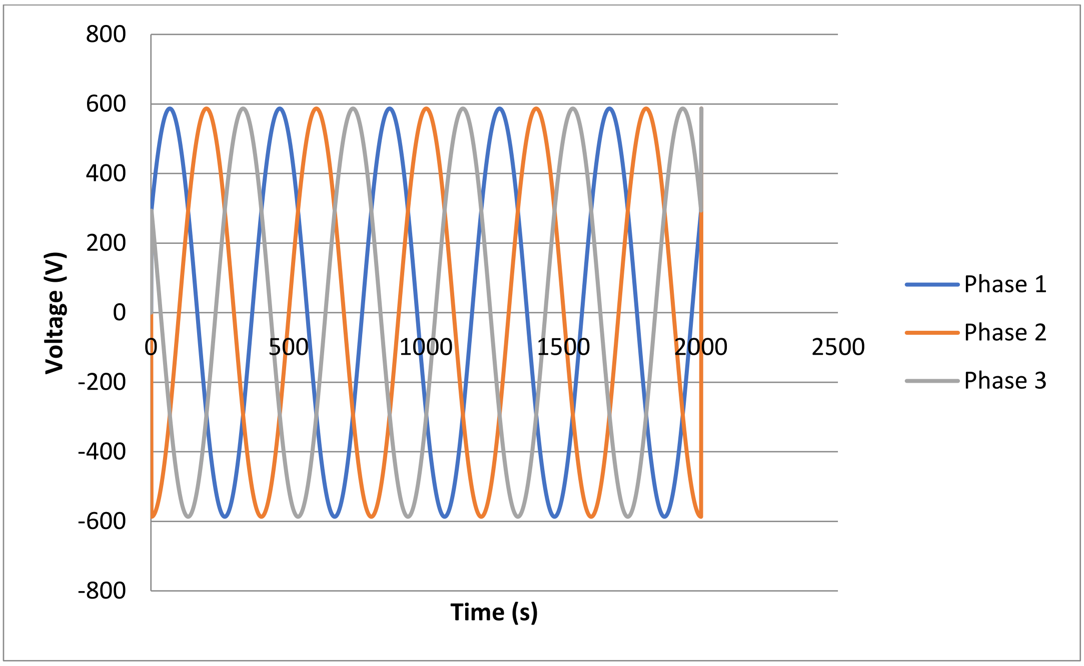


Figure 4.11. The output voltage of solar panel system.

In order to obtain an amount of capacity that can be used for processing and storing in batteries, it is necessary to use twice the solar panels for the energy required for the purpose of supplying cooling and heating systems over a 24-hour period. The values of the energy extracted from the solar panels during the summer were approximately 12 KW, but in the winter, they reached 8.3 KW as in Figure 4.11.

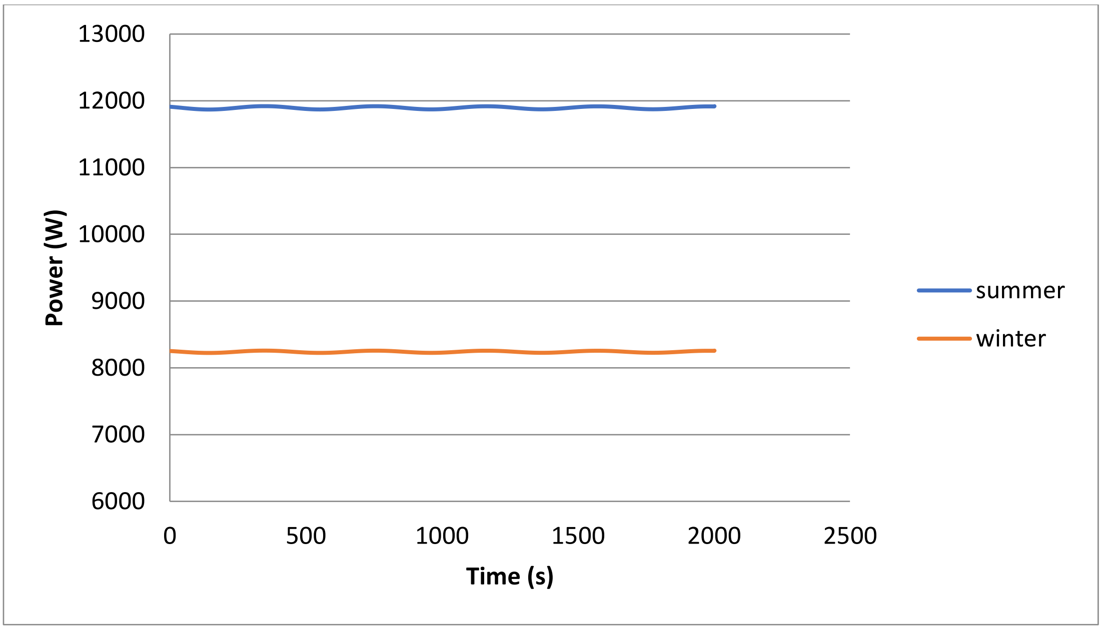


Figure 4.12. The output power of solar panel system.

PART 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

1. The results show that half in the case of insulation versus reduced the cooling load non-insulated for both light and dark paints. The cooling load in the light insulated paint for the living room was 3 KW, while the cooling load for the light, without insulated coating for the same room was 6.8 KW. as well as the cooling load in the dark insulated paint for the living room was 3 KW, while the cooling load in the dark, without insulated coating for the same room is 7 KW. In addition, from here it is clear that half in the case of insulation versus reduces the cooling load without insulated, regardless of the leaching of the paint. whether light or dark, these results clear in both types whether coating light or dark the cooling load reduced to half insulated than without insulated.
2. The results show that half in the case of insulation versus reduced the heating load non-insulated for both light and dark paints. The heating load in the light insulated paint of the living room was 1.6 KW, while the heating load in the light, non-insulated paint of the same room was 3.4 KW, as well as the heating load in the dark insulated paint of the living room was 1.6 KW, while the heating load in the dark non-insulated paint for the same room is 3.3 KW, and from here it is clear that half in the case of insulation reduce the heating load compared to without insulated, regardless of the leaching of the paint, whether light or dark, these results clear in both types whether coating light or dark the heating load reduced to half insulated than non-insulated
3. The effect of the type of coating on the cooling load is considered simple relative to the effect of insulation. The results showed a decrease in the cooling load for rooms that contain light coating compared to rooms that contain dark coating and according to the number of painted areas, for example the first floor (master

bed room 2) . Figure 4.3 the cooling load for the insulation case with light coating was 3 KW, while the cooling load for the insulation case was the dark paint is 3.1 KW. While the rooms in which the cooling loads are equal for the two types of light and dark paint, and the reason for this is the lack of areas exposed to paint and the presence of large windows. and the same effect applies to the case of the without insulated.

4. The effect of the type of paint on the heating load is considered simple compared to the effect of insulation. The results showed a decrease in the heating load for rooms that contain dark paint compared to rooms that contain light paint, according to the amount of painted areas. For example, for the first floor (master bed room 2), the heating load for the case of insulation with dark paint was 1.9 KW while the heating load for the case of insulation with light paint was 2 KW Figure 4.7, the rooms in which the heating loads are equal for the two types of light and dark paint the reason for this is the lack of areas exposed to paint and the presence of large windows, and the same effect applies to the case of the non-insulated.
5. Light-colored coatings have atendency to reflect more solar heat, which is useful in hotter areas since it lowers the cooling burden. This may lead to slightly increased heating needs in colder climes, while more solar heat is absorbed by dark coatings, which can be advantageous in colder climates but may result in higher cooling needs. The heating and cooling load is significantly impacted by the local climate. Extremely hot or cold regions,
6. The VRF system requires 5.94 KW of electric power during the summer and 3.66 KW in the winter to reach zero power state. To process and store energy for cooling and heating systems, twice as many solar panels are needed. During summer, the energy extracted from solar panels was approximately 12 KW, while in winter, it reached 8.3 KW.
7. The HAP program and Trace 700 programs were simulated and reprogrammed for insulated and light coating, resulting in an acceptable difference of 5% between the two programs. The resolver was present, ensuring a reliable and acceptable difference.

5.2. RECOMMENDATIONS

1. Focus the Significance of Insulation in Enhancing Energy Efficiency: The significance of insulation in zero-energy buildings cannot be emphasized enough. Insulation plays a vital role in reducing heat transfer and maintaining a stable indoor environment, which is essential in both hot and cold climates. The presence of stability is crucial for minimizing the dependence on heating and cooling systems, resulting in a substantial reduction in energy consumption. In the realm of zero-energy buildings, where the goal is to generate as much energy as they consume, the effective performance of insulation is absolutely essential.
2. Light-colored coatings exhibit a propensity to reflect a greater amount of solar heat, thereby reducing the cooling load, making them advantageous in hotter regions. In colder climates, there may be a slight increase in heating requirements due to the absorption of more solar heat by dark coatings. This can be beneficial in colder climates, but it may also lead to higher cooling demands. The local climate has a substantial effect on the heating and cooling load. Regions characterized by extreme temperatures
3. Decreased Energy Expenditure: Insulation reduces energy costs by enhancing the thermal efficiency of a building. Ensuring a balance between energy consumption and on-site energy generation is particularly crucial in net-zero buildings. Efficient insulation alleviates the strain on renewable energy systems, such as solar panels, thereby enhancing the feasibility of attaining a net-zero energy equilibrium.
4. Insulation enhances indoor air quality and comfort. It decreases the probability of issues like drafts, hot spots, and cold spots, and aids in regulating humidity levels. This not only enhances the comfort of the indoor environment but also promotes better health by preventing the growth of mold and other moisture-related problems.
5. Environmental Impact: Net-zero buildings are specifically engineered to minimize their environmental footprint. Insulation mitigates the demand for energy obtained from fossil fuels, thereby reducing greenhouse gas emissions.

Insulation aids in reducing a building's impact on climate change by promoting energy efficiency.

6. Insulation contributes to the long-term sustainability of a building. By minimizing the reliance on external energy sources, it guarantees long-term energy efficiency of the building. This is especially crucial given the current trend of escalating energy expenses and the growing demand for sustainable lifestyle practices.
7. Regulatory Compliance and Market Value: Numerous areas are currently implementing more stringent building regulations that prioritize energy efficiency, and insulation plays a crucial role in achieving these criteria. Buildings that achieve net-zero energy consumption and incorporate superior insulation not only meet regulatory requirements but also possess a greater market worth as a result of their sustainable attributes.

Insulation is an essential component in the design and construction of net-zero buildings. It plays a direct role in conserving energy, lowering operational expenses, enhancing indoor comfort, promoting environmental sustainability, and ensuring compliance with energy efficiency regulations. These factors are crucial for the success and effectiveness of net-zero building initiatives.

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APPENDIX A.

SYSTEM

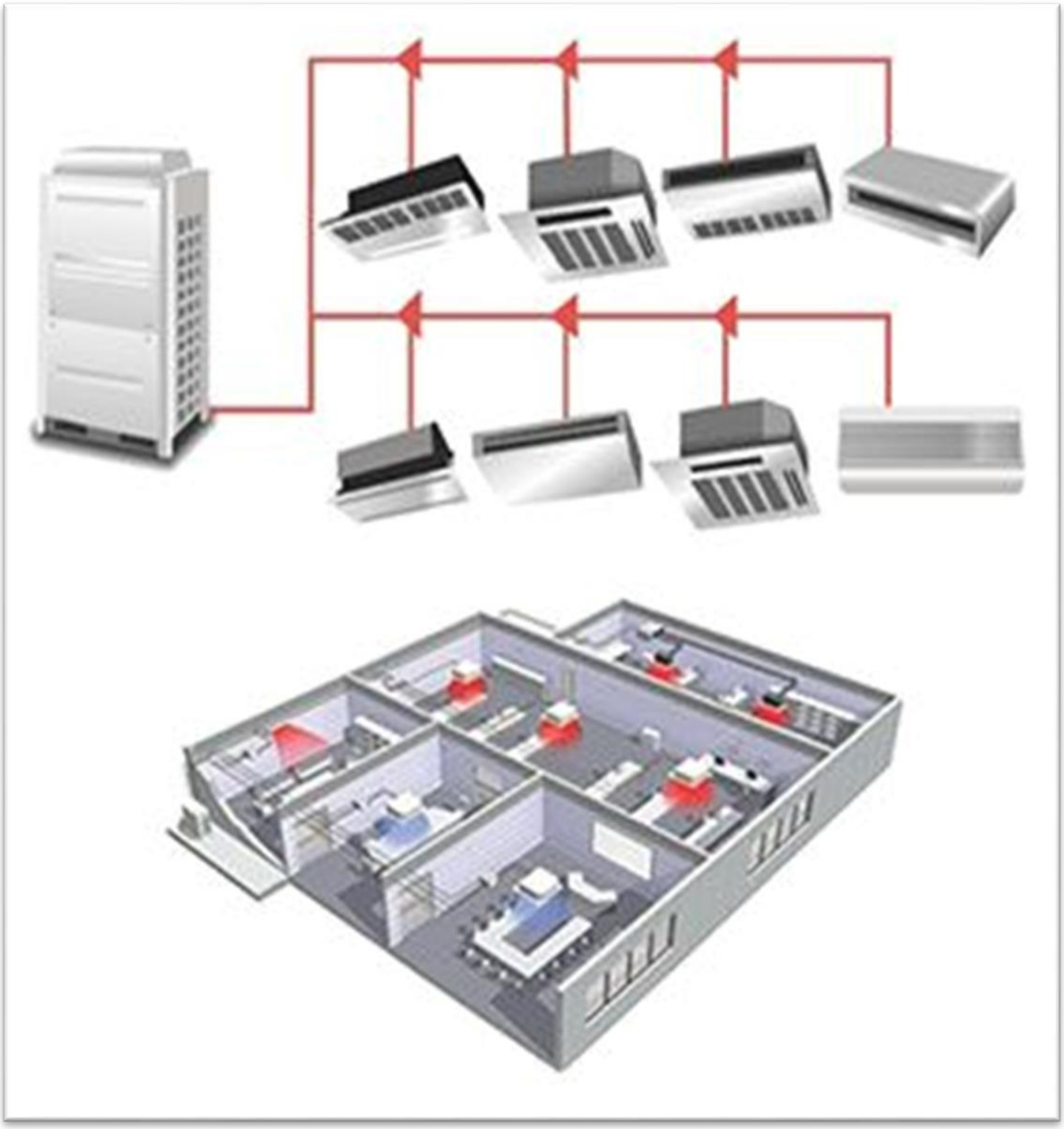
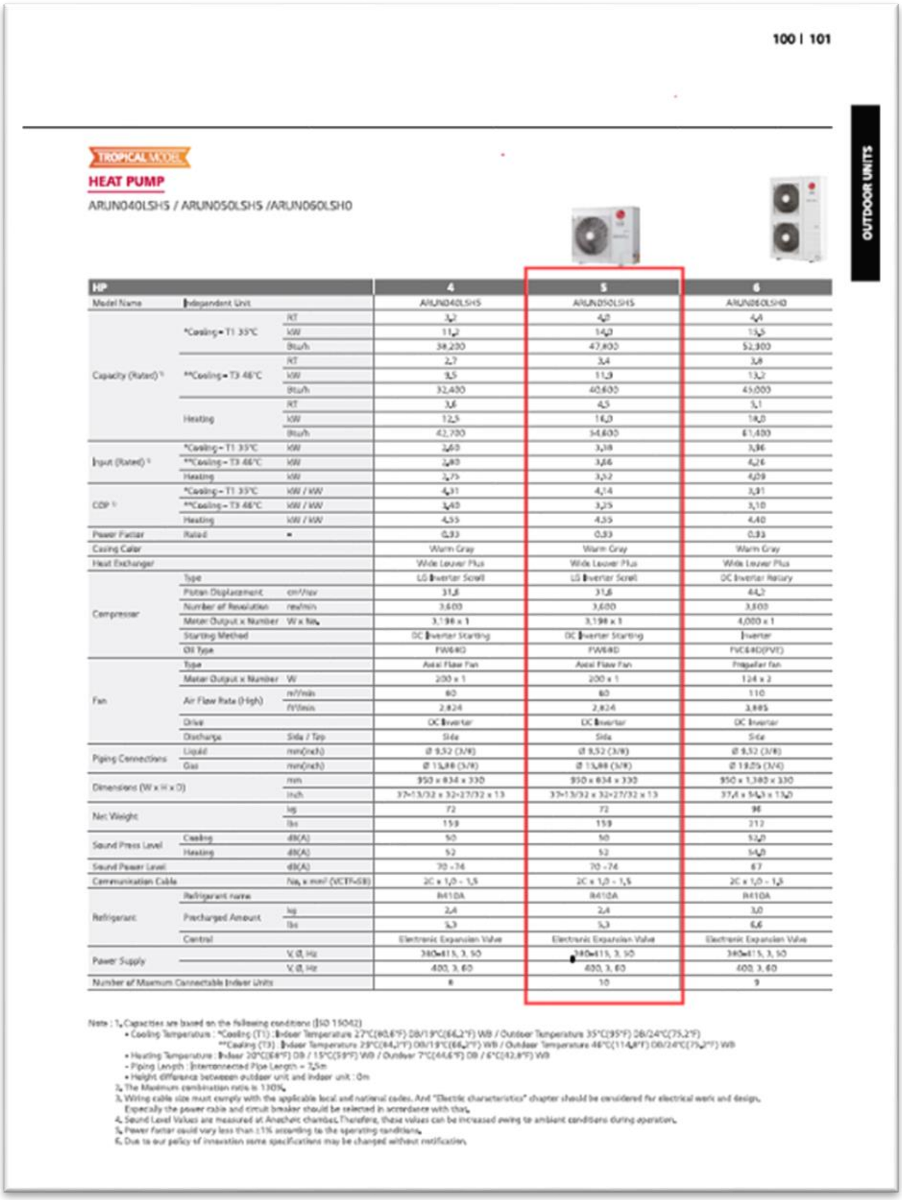


Figure Appendix A.1. VRF system.



100 | 101

OUTDOOR UNITS

TROPICAL MODEL

HEAT PUMP

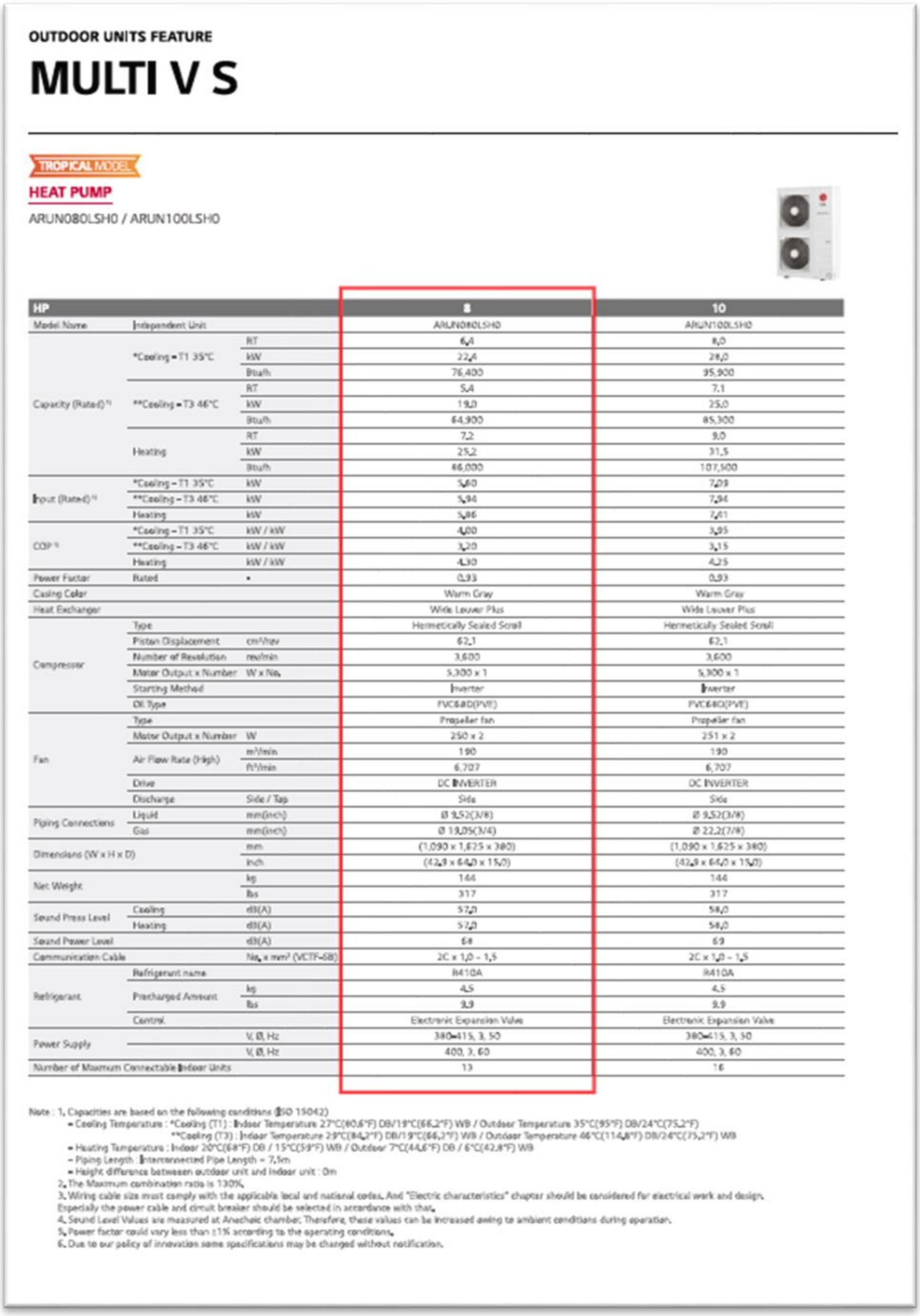
ARUN040LSHS / ARUN050LSHS /ARUN060LSH0

HP			4	5	6
Model Name	Independent Unit		ARUN040LSHS	ARUN050LSHS	ARUN060LSH0
Capacity (Rated) 1)	*Cooling - T1 35°C	RT	3,2	4,0	4,4
		kW	11,2	14,0	15,5
		Btu/h	38,200	47,800	52,900
	**Cooling - T3 46°C	RT	2,7	3,4	3,8
		kW	9,5	11,9	13,2
		Btu/h	32,400	40,600	45,000
	Heating	RT	3,6	4,5	5,1
		kW	12,5	16,0	18,0
		Btu/h	42,700	54,600	61,400
Input (Rated) 1)	*Cooling - T1 35°C	kW	2,60	3,38	3,96
	**Cooling - T3 46°C	kW	2,80	3,66	4,26
	Heating	kW	2,75	3,52	4,09
COP 1)	*Cooling - T1 35°C	kW / kW	4,31	4,14	3,91
	**Cooling - T3 46°C	kW / kW	3,40	3,25	3,10
	Heating	kW / kW	4,55	4,55	4,40
Power Factor	Rated	-	0,93	0,93	0,93
Casing Color			Warm Gray	Warm Gray	Warm Gray
Heat Exchanger			Wide Louver Plus	Wide Louver Plus	Wide Louver Plus
Compressor	Type		LG Inverter Scroll	LG Inverter Scroll	DC Inverter Rotary
	Piston Displacement	cm³/rev	31,6	31,6	44,2
	Number of Revolution	rev/min	3,600	3,600	3,800
	Motor Output x Number	W x No.	3,198 x 1	3,198 x 1	4,000 x 1
	Starting Method		DC Inverter Starting	DC Inverter Starting	Inverter
	Oil Type		FW68D	FW68D	FVC68D(PVE)
Fan	Type		Axial Flow Fan	Axial Flow Fan	Propeller fan
	Motor Output x Number	W	200 x 1	200 x 1	124 x 2
	Air Flow Rate (High)	m³/min	80	80	110
		ft³/min	2,824	2,824	3,885
	Drive		DC Inverter	DC Inverter	DC Inverter
	Discharge	Side / Top	Side	Side	Side
Piping Connections	Liquid	mm(inch)	Ø 9,52 (3/8)	Ø 9,52 (3/8)	Ø 9,52 (3/8)
	Gas	mm(inch)	Ø 15,88 (5/8)	Ø 15,88 (5/8)	Ø 19,05 (3/4)
Dimensions (W x H x D)		mm	950 x 834 x 330	950 x 834 x 330	950 x 1,380 x 330
		inch	37-13/32 x 32-27/32 x 13	37-13/32 x 32-27/32 x 13	37,4 x 54,3 x 13,0
Net Weight		kg	72	72	96
		lbs	159	159	212
Sound Press Level	Cooling	dB(A)	50	50	52,0
	Heating	dB(A)	52	52	54,0
Sound Power Level		dB(A)	70 - 74	70 - 74	67
Communication Cable		No. x mm² (VCTF-SB)	2C x 1,0 - 1,5	2C x 1,0 - 1,5	2C x 1,0 - 1,5
Refrigerant	Refrigerant name		R410A	R410A	R410A
	Precharged Amount	kg	2,4	2,4	3,0
		lbs	5,3	5,3	6,6
	Control		Electronic Expansion Valve	Electronic Expansion Valve	Electronic Expansion Valve
Power Supply		V, Ø, Hz	380~415, 3, 50	380~415, 3, 50	380~415, 3, 50
		V, Ø, Hz	400, 3, 60	400, 3, 60	400, 3, 60
Number of Maximum Connectable Indoor Units			8	10	9

Note : 1. Capacities are based on the following conditions (ISO 15042)
- Cooling Temperature : *Cooling (T1) : Indoor Temperature 27°C(80,6°F) DB/19°C(66,2°F) WB / Outdoor Temperature 35°C(95°F) DB/24°C(75,2°F)
  **Cooling (T3) : Indoor Temperature 29°C(84,2°F) DB/19°C(66,2°F) WB / Outdoor Temperature 46°C(114,8°F) DB/24°C(75,2°F) WB
- Heating Temperature : Indoor 20°C(68°F) DB / 15°C(59°F) WB / Outdoor 7°C(44,6°F) DB / 6°C(42,8°F) WB
- Piping Length : Interconnected Pipe Length = 7,5m
- Height difference between outdoor unit and indoor unit : 0m

2. The Maximum combination ratio is 130%.
3. Wiring cable size must comply with the applicable local and national codes. And "Electric characteristics" chapter should be considered for electrical work and design. Especially the power cable and circuit breaker should be selected in accordance with that.
4. Sound Level Values are measured at Anechoic chamber. Therefore, these values can be increased owing to ambient conditions during operation.
5. Power factor could vary less than ±1% according to the operating conditions.
6. Due to our policy of innovation some specifications may be changed without notification.

Figure Appendix A.2. LG catalogue (VRF system).



OUTDOOR UNITS FEATURE

MULTI V S

TROPICAL MODEL

HEAT PUMP

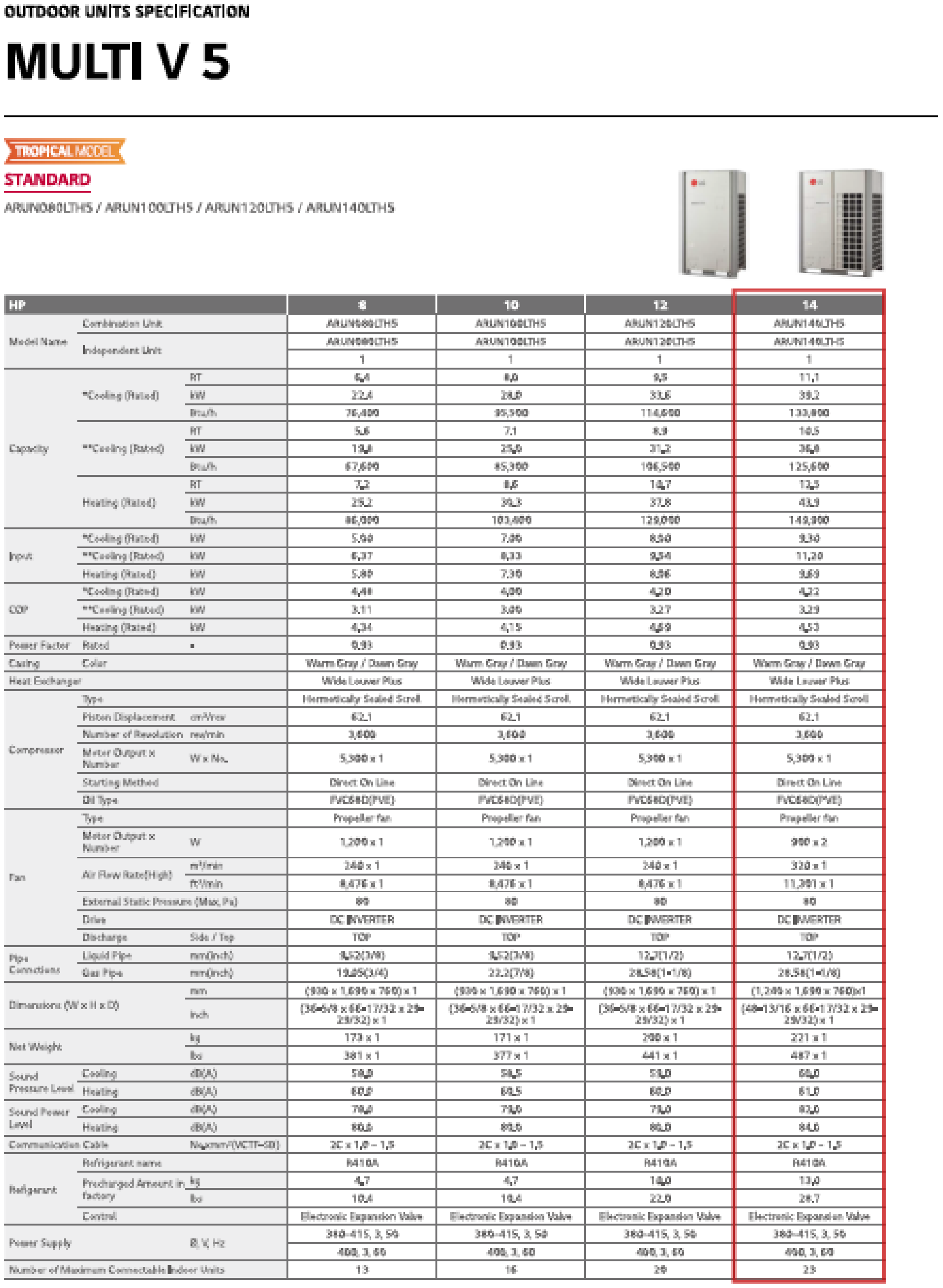
ARUN080LSH0 / ARUN100LSH0

HP			8	10
Model Name	Independent Unit		ARUN080LSH0	ARUN100LSH0
Capacity (Rated) [1]	*Cooling – T1 35°C	RT	6,4	8,0
		kW	22,4	28,0
		Btu/h	76,400	95,900
	**Cooling – T3 46°C	RT	5,4	7.1
		kW	19,0	25,0
		Btu/h	64,900	85,300
	Heating	RT	7,2	9,0
		kW	25,2	31,5
		Btu/h	86,000	107,500
Input (Rated) [1]	*Cooling – T1 35°C	kW	5,60	7,09
	**Cooling – T3 46°C	kW	5,94	7,94
	Heating	kW	5,86	7,41
COP [1]	*Cooling – T1 35°C	kW / kW	4,00	3,95
	**Cooling – T3 46°C	kW / kW	3,20	3,15
	Heating	kW / kW	4,30	4,25
Power Factor	Rated	•	0,93	0,93
Casing Color			Warm Gray	Warm Gray
Heat Exchanger			Wide Louver Plus	Wide Louver Plus
Compressor	Type		Hermetically Sealed Scroll	Hermetically Sealed Scroll
	Piston Displacement	cm³/rev	62,1	62,1
	Number of Revolution	rev/min	3,600	3,600
	Motor Output x Number	W x No.	5,300 x 1	5,300 x 1
	Starting Method		Inverter	Inverter
	Oil Type		FVC68D(PVE)	FVC68D(PVE)
Fan	Type		Propeller fan	Propeller fan
	Motor Output x Number	W	250 x 2	251 x 2
	Air Flow Rate (High)	m³/min	190	190
		ft³/min	6,707	6,707
	Drive		DC INVERTER	DC INVERTER
	Discharge	Side / Top	Side	Side
Piping Connections	Liquid	mm(inch)	Ø 9,52(3/8)	Ø 9,52(3/8)
	Gas	mm(inch)	Ø 19,05(3/4)	Ø 22,2(7/8)
Dimensions (W x H x D)		mm	(1,090 x 1,625 x 380)	(1,090 x 1,625 x 380)
		inch	(42,9 x 64,0 x 15,0)	(42,9 x 64,0 x 15,0)
Net Weight		kg	144	144
		lbs	317	317
Sound Press Level	Cooling	dB(A)	57,0	58,0
	Heating	dB(A)	57,0	58,0
Sound Power Level		dB(A)	68	69
Communication Cable		No. x mm² (VCTF-SB)	2C x 1,0 – 1,5	2C x 1,0 – 1,5
Refrigerant	Refrigerant name		R410A	R410A
	Precharged Amount	kg	4,5	4,5
		lbs	9,9	9,9
	Control		Electronic Expansion Valve	Electronic Expansion Valve
Power Supply		V, Ø, Hz	380~415, 3, 50	380~415, 3, 50
		V, Ø, Hz	400, 3, 60	400, 3, 60
Number of Maximum Connectable Indoor Units			13	16

Note : 1. Capacities are based on the following conditions (ISO 15042)
- Cooling Temperature : *Cooling (T1) : Indoor Temperature 27°C(80,6°F) DB/19°C(66,2°F) WB / Outdoor Temperature 35°C(95°F) DB/24°C(75,2°F)
  **Cooling (T3) : Indoor Temperature 29°C(84,2°F) DB/19°C(66,2°F) WB / Outdoor Temperature 46°C(114,8°F) DB/24°C(75,2°F) WB
- Heating Temperature : Indoor 20°C(68°F) DB / 15°C(59°F) WB / Outdoor 7°C(44,6°F) DB / 6°C(42,8°F) WB
- Piping Length : Interconnected Pipe Length = 7,5m
- Height difference between outdoor unit and indoor unit : 0m

2. The Maximum combination ratio is 130%.
3. Wiring cable size must comply with the applicable local and national codes. And "Electric characteristics" chapter should be considered for electrical work and design. Especially the power cable and circuit breaker should be selected in accordance with that.
4. Sound Level Values are measured at Anechoic chamber. Therefore, these values can be increased owing to ambient conditions during operation.
5. Power factor could vary less than ±1% according to the operating conditions.
6. Due to our policy of innovation some specifications may be changed without notification.

Figure Appendix A.3. Catalouge (VRF system).



OUTDOOR UNITS SPECIFICATION

MULTI V 5

TROPICAL MODEL

STANDARD

ARUN080LTH5 / ARUN100LTH5 / ARUN120LTH5 / ARUN140LTH5

HP			8	10	12	14
Model Name	Combination Unit		ARUN080LTH5	ARUN100LTH5	ARUN120LTH5	ARUN140LTH5
	Independent Unit		ARUN080LTH5	ARUN100LTH5	ARUN120LTH5	ARUN140LTH5
			1	1	1	1
Capacity	*Cooling (Rated)	RT	6.4	8.0	9.5	11.1
		kW	22.4	28.0	33.6	39.2
		Btu/h	76,400	95,500	114,600	133,800
	**Cooling (Rated)	RT	5.6	7.1	8.9	10.5
		kW	19.8	25.0	31.2	36.8
		Btu/h	67,600	85,300	106,500	125,600
	Heating (Rated)	RT	7.2	8.6	10.7	12.5
		kW	25.2	30.3	37.8	43.9
		Btu/h	86,000	103,400	129,000	149,800
Input	*Cooling (Rated)	kW	5.00	7.00	8.00	9.30
	**Cooling (Rated)	kW	6.37	8.33	9.54	11.20
	Heating (Rated)	kW	5.80	7.30	8.06	9.69
COP	*Cooling (Rated)	kW	4.48	4.00	4.20	4.22
	**Cooling (Rated)	kW	3.11	3.00	3.27	3.29
	Heating (Rated)	kW	4.34	4.15	4.69	4.53
Power Factor	Rated	-	0.93	0.93	0.93	0.93
Casing	Color		Warm Gray / Dawn Gray	Warm Gray / Dawn Gray	Warm Gray / Dawn Gray	Warm Gray / Dawn Gray
Heat Exchanger			Wide Louver Plus	Wide Louver Plus	Wide Louver Plus	Wide Louver Plus
Compressor	Type		Hermetically Sealed Scroll	Hermetically Sealed Scroll	Hermetically Sealed Scroll	Hermetically Sealed Scroll
	Piston Displacement	cm³/rev	62.1	62.1	62.1	62.1
	Number of Revolution	rev/min	3,600	3,600	3,600	3,600
	Motor Output x Number	W x No.	5,300 x 1	5,300 x 1	5,300 x 1	5,300 x 1
	Starting Method		Direct On Line	Direct On Line	Direct On Line	Direct On Line
	Oil Type		FVC68D(PVE)	FVC68D(PVE)	FVC68D(PVE)	FVC68D(PVE)
Fan	Type		Propeller fan	Propeller fan	Propeller fan	Propeller fan
	Motor Output x Number	W	1,200 x 1	1,200 x 1	1,200 x 1	900 x 2
	Air Flow Rate(High)	m³/min	240 x 1	240 x 1	240 x 1	320 x 1
		ft³/min	8,476 x 1	8,476 x 1	8,476 x 1	11,301 x 1
	External Static Pressure (Max, Pa)		80	80	80	80
	Drive		DC INVERTER	DC INVERTER	DC INVERTER	DC INVERTER
	Discharge	Side / Top	TOP	TOP	TOP	TOP
Pipe Connections	Liquid Pipe	mm(inch)	9.52(3/8)	9.52(3/8)	12.7(1/2)	12.7(1/2)
	Gas Pipe	mm(inch)	19.05(3/4)	22.2(7/8)	28.58(1-1/8)	28.58(1-1/8)
Dimensions (W x H x D)		mm	(930 x 1,690 x 760) x 1	(930 x 1,690 x 760) x 1	(930 x 1,690 x 760) x 1	(1,240 x 1,690 x 760)x1
		inch	(36-5/8 x 66-17/32 x 29-29/32) x 1	(36-5/8 x 66-17/32 x 29-29/32) x 1	(36-5/8 x 66-17/32 x 29-29/32) x 1	(48-13/16 x 66-17/32 x 29-29/32) x 1
Net Weight		kg	173 x 1	171 x 1	200 x 1	221 x 1
		lbs	381 x 1	377 x 1	441 x 1	487 x 1
Sound Pressure Level	Cooling	dB(A)	58.0	58.5	59.0	60.0
	Heating	dB(A)	60.0	60.5	60.0	61.0
Sound Power Level	Cooling	dB(A)	78.0	79.0	79.0	82.0
	Heating	dB(A)	80.0	80.0	80.0	84.0
Communication Cable		No. x mm²(VCTF-SB)	2C x 1.0 - 1.5	2C x 1.0 - 1.5	2C x 1.0 - 1.5	2C x 1.0 - 1.5
Refrigerant	Refrigerant name		R410A	R410A	R410A	R410A
	Precharged Amount in factory	kg	4.7	4.7	10.0	13.0
		lbs	10.4	10.4	22.0	28.7
	Control		Electronic Expansion Valve	Electronic Expansion Valve	Electronic Expansion Valve	Electronic Expansion Valve
Power Supply		Ø, V, Hz	380-415, 3, 50	380-415, 3, 50	380-415, 3, 50	380-415, 3, 50
			400, 3, 60	400, 3, 60	400, 3, 60	400, 3, 60
Number of Maximum Connectable Indoor Units			13	16	20	23

Figure Appendix A.4. Catalouge (VRF system).

RESUME

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