ASSESSING THE ENERGY EFFICIENCY OF DIFFERENT CONSTRUCTION MATERIALS IN EDUCATION BUILDINGS: A CASE STUDY FROM ALBANIAN PRACTICE

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **“Assessing the Energy Efficiency of Different Construction Materials in Education Buildings: A Case Study from Albanian Practice”** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

ASSESSING THE ENERGY EFFICIENCY OF DIFFERENT CONSTRUCTION MATERIALS IN EDUCATION BUILDINGS: A CASE STUDY FROM ALBANIAN PRACTICE

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The escalating energy requirements in edifices, especially in academic establishments, emphasize the necessity for improved energy efficacy and sustainable energy mechanisms. The EnergyPlus simulation software and OpenStudio tools, in combination with SketchUp, are employed to conduct the assessment. The thesis endeavours to assess the energy efficiency of various building materials, namely Autoclaved Aerated Concrete, Brick, Insulated Concrete Forms, and Structural Insulated Panels, identifying the optimal configurations that are best suited to the prevailing climatic conditions of the city. This thesis employs a comparative approach to acknowledge the intrinsic diversity and multifaceted factors present in educational buildings. The analysis encompasses a range of factors, such as the orientation of the openings, thermal mass, and insulation layers. The study reveals that Structural Insulated Panels (SIPs) exhibit the highest energy efficiency among the four materials, with 11.8% less site energy and 9% less source energy than brick, which has the lowest efficiency.

Keywords: *Energy Efficiency, Building Materials, EnergyPlus Software, OpenStudio, Sketchup, Autoclaved Aerated Concrete, Brick, Insulated Concrete Forms, Structural Insulated Panels.*

ABSTRAKT

VLERËSIMI I EFIÇENCAVE ENERGJIKE TË MATERIALEVE TË NDRYSHME TË NDËRTIMIT NË NDËRTESA ARSIMORE: NJË RAST STUDIMOR NGA PRAKTIKA SHQIPTARE

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Udhëheqësi: Prof. Dr. Hüseyin Bilgin

Kërkesat e përshkallëzuara për energji në ndërtesa, veçanërisht në institucionet akademike, theksojnë domosdoshmërinë për rritjen e efikasitetit të energjisë dhe mekanizmave të qëndrueshëm të energjisë. Softueri i simulimit EnergyPlus dhe mjetet OpenStudio, në lidhje me SketchUp, janë përdorur për të kryer vlerësimin. Teza synon të vlerësojë efikasitetin energjetik të materialeve të ndryshme të ndërtimit, përkatësisht betonit të gazuar të autoklavuar, tullave, formave të betonit të izoluar dhe paneleve strukturorë të izoluar, duke identifikuar konfigurimet optimale që i përshtaten më së miri kushteve klimatike mbizotëruese të qytetit. Kjo tezë përdor një qasje krahasuese për të njohur diversitetin e brendshëm dhe faktorët e shumanshëm të pranishëm në ndërtesat arsimore. Analiza përfshin një sërë faktorësh, si orientimi i hapjeve, masa termike dhe shtresat izoluese. Studimi zbulon se panelet strukturore të izoluara (SIP) shfaqin efikasitetin më të lartë të energjisë midis katër materialeve, me 11.8% më pak energji në terren dhe 9% më pak energji burimore sesa tulla, e cila ka efikasitetin më të ulët.

Fjalët kyçe: *Efikasiteti Energjitik, Materialet Ndertimore, Softueri EnergyPlus, OpenStudio, SketchUp, Betoni AAC, Tullë, Forma të Izoluara me Beton.*

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The built environment has witnessed an increasing emphasis on sustainability and energy efficiency in recent times. The increased focus on energy efficiency can be attributed to a growing recognition of the environmental impact of energy consumption, the pressing need to reduce carbon emissions, and the potential economic advantages that may arise from enhanced energy efficiency. Educational facilities constitute a substantial fraction of the total energy usage in the construction industry.

The exact choice and implementation of appropriate building materials are crucial factors in determining the energy efficiency of a structure. The distinct thermal, mechanical, and environmental properties of diverse materials have an impact on the overall energy efficiency of a given structure. A thorough comprehension of the performance of these materials in varying climatic conditions and their influence on building energy performance (BEP) is crucial for making informed decisions during the design and construction phases.

The significance of energy efficiency and sustainability in the constructed environment is becoming more apparent on both local and international scales. Comprehending the potential impact of this research necessitates an understanding of the significance of this topic in the Balkans, Europe, and its worldwide applications. The Balkan region has experienced swift urbanization, resulting in an increasing need for novel and energy-efficient infrastructure, including educational establishments. The building industry in several Balkan nations has been typified by outdated construction materials and techniques, leading to elevated levels of energy consumption. The adoption of energy-efficient building materials and design strategies is crucial for reducing energy consumption, improving the overall quality of life, and supporting regional and global initiatives to address climate change.

This thesis aims to explore the energy efficiency of different building materials in the construction industry, focusing on an educational facility in Albania. The study will compare the energy consumption and carbon footprint of four types of building materials: brick, autoclaved aerated concrete (AAC), insulating concrete forms (ICFs), and structural insulated panels (SIPs). The comparison will cover the life cycle energy consumption, embodied energy, operational energy.

1.2 Organization on Thesis

The thesis is organized into five chapters as follows:

Chapter 1 provides an overview of the research topic, including the significance of energy efficiency in educational buildings, and the importance of different building materials. Chapter 2 examines the energy challenges faced by Albania with a particular focus in increasing energy consumption in educational structures. It delves into a detailed analysis of factors affecting energy consumption and gives a comprehensive understanding of various elements contributing to energy efficiency in educational institutions. In Chapter 3 a comparative analysis of bricks, AAC, ICFs, and SIPs focusing on their properties and performance in educational buildings is presented. This is followed by Chapter 4 which outlines the research methodology, including the selection of the educational building, data collection, and the use of EnergyPlus software for energy performance assessment. Chapter 5 presents the results of the energy performance assessment for each building material, followed by a comparative analysis using EnergyPlus software. The discussion highlights the advantages and disadvantages of each material in the context of educational buildings and energy efficiency. And finally, Chapter 6 summaries the key findings of the research and offers recommendations for architects, engineers regarding the selection of energy-efficient building materials in educational buildings.

CHAPTER 2

LITERATURE REVIEW

2.1 The Energy Problem in Albania

Albania faces distinctive energy challenges due to its rapidly growing population, urbanization, and economic progress. The above-mentioned factors have led to an increase in energy demand and consumption practices that are not sustainable, as reported by INSTAT in 2016 [5]. The construction sector, encompassing both residential and non-residential edifices, constitutes a significant proportion of the nation's overall energy usage.

According to a report by the Albanian Institute of Statistics (INSTAT) in 2016, there was a notable rise of 31% in energy consumption within the building sector from 2000 to 2010. The issue of expansion in question is attributed to various factors, such as outdated building design, inadequate insulation, and inefficient HVAC systems, as stated by the Ministry of Architecture and Energy in 2017. As per the 2016 report by INSTAT, the energy consumption in the building sector is majorly contributed by the residential sector, which constitutes approximately 70%. The non-residential structures, such as commercial and educational institutions, account for the remaining 30% of the overall energy consumption. The residential structures in Albania exhibit a higher energy consumption per square meter of floor space, as reported by the 2011 study conducted by the structures Performance Institute Europe [7]. The study reveals that the energy consumption per square meter of floor space in Albania is approximately 134 kWh/m^2, which is significantly higher than the European average of 104 kWh/m^2. Moreover, according to the data provided by INSTAT in 2016, electricity constitutes 68% of the overall energy consumption in the residential domain of Albania. According to the World Bank (2018), the nation's dependence on hydroelectric power renders it vulnerable to the impacts of climate change and poses challenges in terms of seasonal energy provision.

Albania has implemented various legislative measures to tackle its escalating energy-related issues. These measures include the adoption of the Law on Energy Performance of Buildings in 2016 and the execution of the National Energy Efficiency Action Plan for 2017-2020, as reported by the Ministry of Infrastructure and Energy in 2017. The objective of these initiatives is to advance the adoption of energy-efficient practices, establish benchmarks for energy performance that are at a minimum threshold, and encourage the utilization of sustainable energy sources within the realm of construction.

2.2 Energy Consumption in Educational Institutions' Buildings

Due to the increasing demand for sustainable practices and appropriate energy management in this sector, the issue of energy consumption in educational buildings has received substantial attention. Institutions of education, including schools, universities, and research facilities, are known to consume substantial quantities of energy to facilitate heating, cooling, lighting, and the operation of electronic equipment. Given the increasing apprehensions regarding climate change and the exhaustion of natural resources, it is imperative to scrutinize and enhance energy utilization in such edifices to attain sustainability objectives.

The energy consumption of educational buildings is subject to a range of factors, including but not limited to the size of the building, its age, the materials used in their construction, and the patterns of occupancy. According to Santamouris et al. (2017), empirical evidence suggests that the implementation of enhanced building design, adoption of energy-efficient technologies, and modification of behavioural patterns can result in noteworthy decreases in energy consumption. The implementation of energy management systems, utilization of natural lighting, and enhancement of insulation are potential measures that can lead to energy conservation, as suggested by Pérez-Lombard et al. (2008).

2.3 Affecting Factors and Design Principles

The establishment of minimum energy performance standards for structural components that significantly impact the energy efficiency of a building envelope is deemed critical as per the European Directive 2010/31. Furthermore, the Directive places significant emphasis on the implementation of tactics that enhance the thermal efficiency of buildings, with a particular focus on the summer season.

Enhancing energy efficiency in educational structures, particularly in schools, is a crucial concern owing to its impact on indoor air quality and thermal comfort. A plethora of resources, such as literature, directives, and research, offer valuable perspectives on the determinants of energy usage and the crucial variables that require meticulous consideration in academic facilities. The Energy Smart Schools initiative, implemented by the U.S. Department of Energy, provides guidance to designers and engineers regarding energy efficiency and renewable energy considerations in educational institutions. The program delineates ten crucial design disciplines and objectives, encompassing site design, daylighting and windows, energy-efficient building shell, lighting and electrical systems, mechanical and ventilation systems, renewable energy systems, water conservation, recycling systems and waste management, transportation, and resource-efficient building products.

The Centre for Renewable Energy Sources and Saving (C.R.E.S) identifies various factors that impact energy consumption and comfort levels. These factors include inadequate insulation during winter due to improper orientation of spaces, excessive heat during warm periods, and suboptimal lighting conditions throughout the year. The C.R.E.S recommends aligning with energy efficiency strategies to address these issues. Insufficient design of apertures, illumination by natural light, and artificial lighting mechanisms may result in non-uniform dispersion of light within educational spaces. Excessive infiltration via window frames and uncontrolled ventilation can lead to substantial heat dissipation in the winter season, while suboptimal heating system design and upkeep can lead to subpar efficiency. Insufficient shading and ventilation systems, in conjunction with an absence of mechanical cooling system specifications, may result in overheating during periods of elevated temperatures. The proposed interventions centre around the building envelope and installations, with the objective of achieving uniform light distribution in classrooms, minimizing heat losses through the building envelope and uncontrolled ventilation, enhancing winter solar heat gains, mitigating solar heat gains during the cooling period, improving summer comfort conditions through ventilation, and optimizing heating and lighting systems to reduce energy consumption.

The study conducted by Hoes et al., (2009) aims to investigate the user's perception of energy efficiency in the design of school buildings. The research emphasizes the impact of user behaviour on the energy balance of a building. The research employed questionnaires as a means of assessing the students' perspectives on ventilation, design, noise, and awareness of energy efficiency.

2.3.1. Orientation of Buildings

The orientation of a building is a crucial element of its design that has a significant influence on its energy efficiency and overall comfort. Krarti (2018) posits that the orientation of a building with respect to the cardinal directions can have a substantial impact on its requirements for heating, cooling, and lighting. The solar radiation received by a building throughout the day and seasons, and consequently its energy consumption for space heating, cooling, and lighting, can be influenced by the building's orientation. An exemplar scenario involves a building oriented towards the south in the Northern Hemisphere, which can reap advantages from passive solar heating during the winter season (*Figure 1*). This is due to the sun's low position in the sky, which generates heating loads.

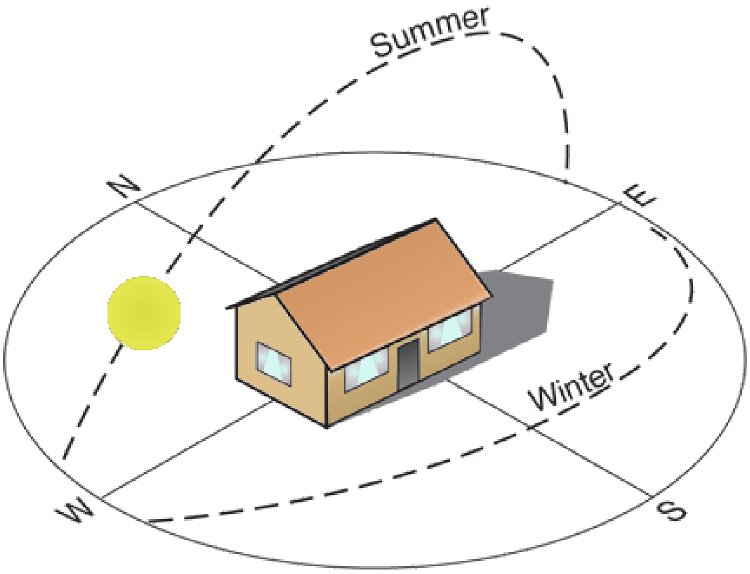


Figure 1. Building Orientation

2.3.2 Assessment of Sun Exposure

Assessing solar irradiance is a crucial aspect in comprehending the energy efficiency of a structure. According to Yezioro et al. (2008), the orientation of a building with respect to the sun can have a significant impact on the amount of heat and light that it receives. This, in turn, can have implications for the building's heating and cooling requirements. The utilization of sun exposure can be optimized to augment natural illumination and diminish the necessity for synthetic lighting, consequently resulting in energy conservation. Excessive exposure to sunlight can result in overheating, especially in the summer season, thereby augmenting the demand for cooling. Thus, it is crucial to achieve equilibrium between optimizing solar exposure for illumination purposes and reducing excessive heat gain.

2.3.3 Analysis of Shading

Krarti (2018) posits that the thermal performance of a building can be significantly influenced by its shading, which may originate from its internal structure, external devices, or surrounding elements. The implementation of efficient shading techniques can potentially mitigate the issue of excessive solar heat gain in the summer season, thereby reducing the reliance on air conditioning. The implementation of this measure has the potential to effectively regulate glare, thereby enhancing the visual comfort of individuals occupying space. Various shading techniques can be employed such as stationary or adaptable shading apparatus, tactically positioned foliage, or other structural or environmental elements. It is imperative to meticulously devise shading tactics that do not obstruct advantageous winter sunlight.

2.3.4 The Positioning and Dimensions of Windows

The utilization of windows allows for the incorporation of natural light, thereby diminishing the necessity for artificial illumination. Nonetheless, windows can also act as a conduit for thermal energy transfer, leading to either heat loss or gain, thereby influencing the heating and cooling requirements of the edifice. Hence, it is imperative to meticulously contemplate the placement and dimensions of windows to optimize the advantages of daylighting, while simultaneously minimizing undesirable heat loss or gain.

2.3.5 Local Conditions

The city of Tirana, where EPOKA University is situated, exhibits a Mediterranean climate characterized by warm and arid summers, as well as mild and rainy winters. The prevailing climatic conditions necessitate the implementation of techniques aimed at mitigating cooling demands during summer and regulating heating requirements throughout winter.

Optimizing the building orientation can effectively minimize exposure to the intense summer sun and simultaneously harness the lower-angled winter sun for passive heating purposes. According to research, the implementation of shading techniques can effectively reduce solar heat gain during the summer season. Additionally, the utilization of thermal mass has the potential to store and subsequently release heat, thereby regulating indoor temperatures.

Apart from the implementation of passive solar design, the utilization of natural ventilation techniques can prove to be efficacious in mitigating high temperatures during the summer season. It has been suggested that the utilization of the regional winds in Tirana could facilitate cross-ventilation, thereby diminishing the necessity for air conditioning.

The incorporation of passive design potential and local climate considerations are crucial factors in achieving optimal energy efficiency in buildings. When implemented within the framework of EPOKA University, these factors have the potential to facilitate energy conservation and enhance the quality of indoor environments, thereby bolstering the institution's sustainability objectives.

CHAPTER 3

COMPARATIVE ANALYSIS

3.1 Bricks

Bricks are small, cuboid units typically composed of baked or air-dried clay, which are employed in construction. Their high durability and longevity are commonly regarded as their traditional characteristics. In addition, these materials exhibit fire-resistant properties and provide commendable thermal and acoustic insulation. Bricks possess the ability to be manufactured in a diverse spectrum of hues, and they can be moulded or surfaced to augment the aesthetic appeal of a building, (*Figure 2*). They are frequently utilized in constructions such as walls and pavements. Additionally, bricks are widely recognized for their eco-friendliness. Commonly, they are fabricated using natural clay or repurposed substances and possess the potential to be repurposed again upon reaching the end of their lifespan.

Nevertheless, bricks possess considerable weight and might necessitate supplementary reinforcement in certain scenarios. In addition to being comparatively pricier than certain alternative construction materials, their installation necessitates a greater amount of manual effort.

Bricks are frequently employed as the primary load-bearing component, subsequently concealed with stucco, stone cladding, or alternative materials to enhance visual allure and augment resistance against atmospheric conditions. Bricks are available in diverse forms, with the two most prevalent types being clay and concrete.

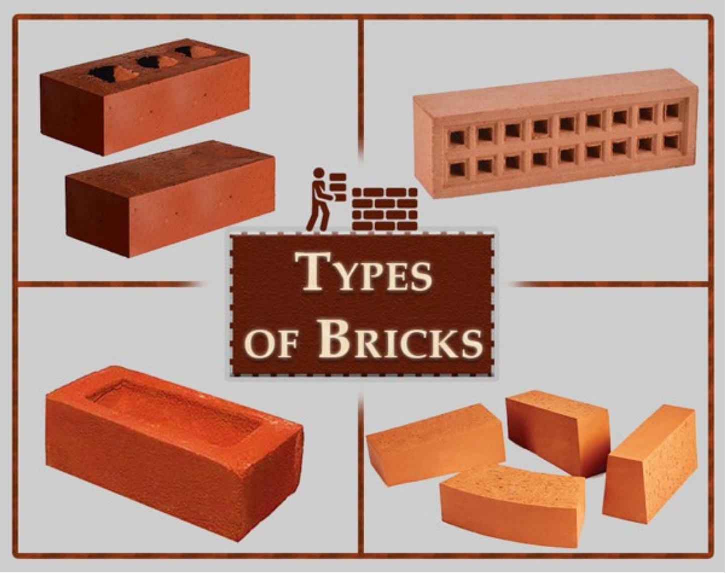


Figure 2. Types of Bricks

3.2 Autoclaved Aerated Concrete (AAC)

Autoclaved Aerated Concrete (AAC) is a type of lightweight concrete that is produced by mixing cement, lime, water, and a small amount of aluminium powder. The mixture is then poured into meld and allowed to cure. Once cured, the blocks are cut into the desired size and shape and then placed in an autoclave, where they are subjected to high pressure and steam. This process causes the aluminium powder to react with the other ingredients, resulting in the formation of numerous small air pockets throughout the material. The resulting product is a lightweight, strong, and durable building material that is commonly used in construction, (*Figure 3*).

The amalgamation is introduced into casts and subsequently solidified within an autoclave, a pressurized vessel that employs steam. The material obtained exhibits a cellular architecture that confers remarkable thermal insulation characteristics and endows it with resistance to fire, pests, and meld. Autoclaved Aerated Concrete has emerged as a viable and environmentally conscious construction material, which has garnered significant attention in contemporary times owing to its multifarious advantages.

AAC provides a significant benefit in the construction sector owing to its efficient and convenient installation process, in addition to its insulating properties. The attribute is ascribed to the material's capacity to undergo routing, sanding, and on-site sizing through the utilization of conventional power tools made of carbon steel.

The weight of Autoclaved Aerated Concrete blocks is roughly 20% of the weight of conventional concrete blocks. Moreover, they are produced in a variety of sizes and levels of robustness. The lightweight characteristic and the ease of cutting of the material possess the potential to significantly reduce the construction time. Autoclaved Aerated Concrete blocks possess significant potential for application in the construction of high-rise buildings due to their considerable dimensions and relatively lower weight as compared to traditional concrete materials.

AAC displays remarkable properties with regards to thermal insulation and sound absorption. AAC presents enhanced durability against fire and pests, alongside providing economic and environmental benefits in comparison to traditional structural construction materials such as concrete, wood, brick, and stone. However, the strength of Autoclaved Aerated Concrete may not be equivalent to that of traditional concrete, which limits its potential application in certain construction situations.

Figure 3. Autoclaved Aerated Concrete (AAC)

3.3 Insulated Concrete Forms (ICFs)

Insulated concrete forms (ICFs) are a building material commonly employed for wall construction. The production procedure of said entities entails the insertion of an insulating layer, commonly made of concrete, between two foam layers. The procedure described above yields a robust and long-lasting barrier that demonstrates exceptional energy efficiency, soundproofing capabilities, and resistance to pests, fires, and extreme weather conditions, (*Figure 4*).

A range of exterior cladding options, such as brick, stucco, and siding, can be employed, while traditional interior finishes are appropriate for the inside. The durability and robustness of ICFs are widely acknowledged. The utilization of ICFs in the construction industry demonstrates exceptional durability against natural disasters due to their sturdiness and ability to endure significant impact forces. This pertains to the capacity to endure seismic events, tropical cyclones, and tornadoes. In addition, structures constructed with Insulated Concrete Forms often demonstrate exceptional

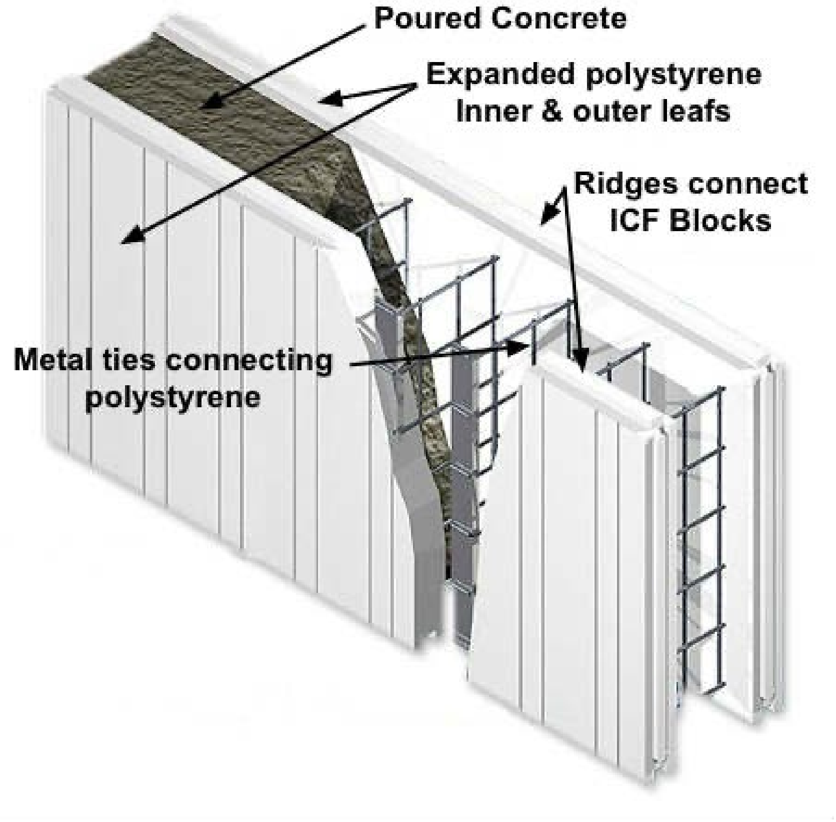


Figure 4. Insulated concrete forms (ICFs)

fire retardancy. Despite the benefits they offer, the utilization of ICFs may result in increased expenses in contrast to other construction techniques, and mandates specific training for builders to guarantee accurate installation. This has the potential to increase both the costs and timeline of the construction process.

3.4 Structural Insulated Panels (SIPs)

Structural Insulated Panels (SIPs) are a construction material comprising of two panels, usually made of oriented strand board (OSB) or plywood, with a foam core in between, (*Figure 5)*. Further, the panels are manufactured in a controlled factory environment and can be customized to meet the unique needs of individual homes.

These panels are being utilized in the construction industry for several purposes including the fabrication of walls, roofs, and floors. Thus, it can be said that SIPs have become increasingly prevalent in contemporary times owing to their straightforward installation process, resilience, and capacity to curtail energy expenditures.

Structural Insulated Panels (SIPs) offer several benefits, including improved thermal resistance, durability, exceptional structural integrity, and expedited construction. It is worth mentioning that Structural Insulated Panels are acknowledged for their exceptional energy efficiency. Buildings constructed using SIPs often demonstrate significantly lower heating and cooling costs compared to structures built using traditional methods. This can be especially critical in areas that are distinguished by significant variations in temperature. Also, these types of panels have shown exceptional performance in the development of residential and light commercial buildings. Another benefit of SIPs is the form of reduced costs due to the diminished duration of construction and the minimization of on-site wastes. Thus, it can be said that the costs related to SIPs construction are generally commensurate with those of wood frame construction.

Despite these advantages, it is important to note that Structural Insulated Panels may be vulnerable to damage caused by water and moisture if proper protection measures are not in place. Achieving an airtight seal during installation is crucial to ensure optimal insulation performance of the components. Thus, it is crucial to ensure meticulous installation to ensure impermeability of the system.

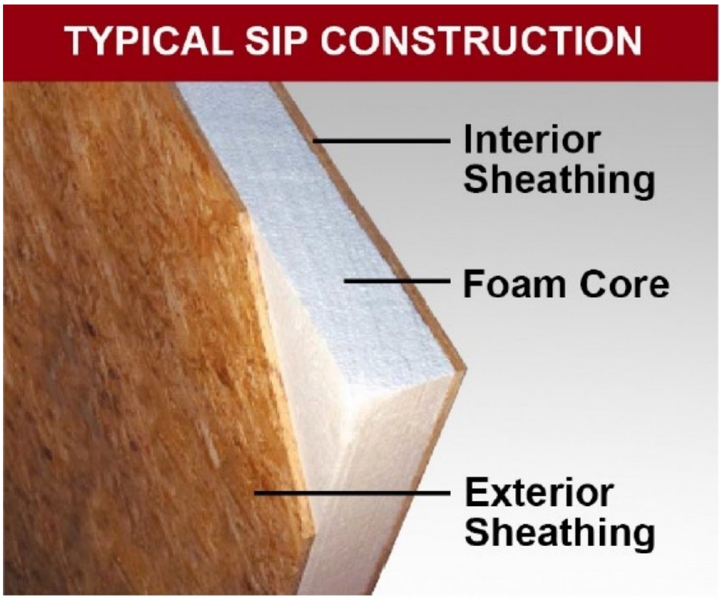


Figure 5. Structural Insulated Panels (SIPs)

3.5 A Comparative Analysis of Materials Utilized for Energy Conservation

To make a comparative analysis, (*Table 1)* provides a summary of factors that affect different construction materials, such as bricks, AAC, ICfs and SIPs. On the other hand, on the (*Table 2*) gives a summary of the pros and cons of each material.

Table 1. Comparative Analysis of the Factors that Affect Building Materials

Factors	**Bricks**	**Autoclaved Aerated Concrete (AAC)**	**Insulated Concrete Forms (ICFs)**	**Structural Insulated Panels (SIPs)**

Durability	High (especially when maintained properly)	Moderate to high (lower load-bearing capacity than regular concrete)	High (especially for disaster resistance)	Moderate to high (dependent on proper installation and maintenance)
Insulation	Moderate (usually require additional insulation for thermal efficiency)	High (Excellent thermal and acoustic insulation properties)	High (foam insulation provides excellent thermal resistance)	High (Insulation foam core offers high thermal resistance)
Cost	Moderate to high (depending on the quality and labour cost)	Moderate (lower installation and transportation costs, but moisture protection can add to the cost)	High (due to need for specialized labour and the premium initial cost)	High (due to specialized labour and material costs)
Installation	Labor-intensive (time-consuming and requires skilled masons)	Easier (lightweight nature allows for easier handling and installation)	Moderate to difficult (Requires specialized labour)	Moderate to difficult (Requires specialized labour and careful handling to prevent damage)

Maintenance	Low to moderate (low maintenance, but regular inspection is necessary to check for and repair cracks or damage)	Moderate (Requires effective moisture protection measures)	Moderate (Structural integrity checks are needed periodically, especially in regions prone to natural disasters)	Moderate to high (SIPs must be protected from moisture and checked periodically for damage or infestation)
Design Flexibility	High (can be shaped and coloured as required)	Moderate (Some limitations due to block sizes)	Moderate (Primarily rectangular shapes)	Moderate (Limited by panel sizes and need for additional structural support for large openings)
Environmental Impact	Moderate to High (Production process is energy-intensive and releases CO_2, but bricks can last for many years)	Moderate (AAC production is less energy-intensive than traditional concrete, but the process still produces CO_2)	Moderate to High (ICFs consist of non-biodegradable materials, but their energy efficiency reduces CO_2 emissions during building use)	Moderate (SIPs are energy-efficient, but their production involves the use of petrochemicals, and they are not readily recyclable)

The conservation of energy is a crucial factor to be considered during the construction of educational facilities. The incorporation of sustainable features in a building not only has an impact on the building's sustainability, but also influences the operational expenses incurred over the building's entire life cycle. Although bricks are known for their durability and sound-insulating properties, they offer relatively lower levels of thermal insulation. The statement suggests that there may be a requirement for supplementary insulation to enhance the energy efficiency of the edifice, thereby resulting in escalated expenses associated with construction (Ferraro, Zhang, & Ma, 2012).

In contrast, Autoclaved Aerated Concrete possesses remarkable thermal insulation characteristics that can contribute to the reduction of the building's energy consumption. Van Damme (2010) has pointed out that the load-bearing capacity of AAC is comparatively lower than that of conventional concrete. This factor may impose certain limitations on the use of AAC in larger educational structures. The exceptional thermal insulation properties of ICFs present a promising opportunity for achieving energy efficiency. According to Kosny, Asiz, and Desjarlais (2011), the foam insulation present in ICFs offers remarkable thermal resistance, thereby minimizing the requirement for supplementary insulation and thereby promoting energy efficiency.

Finally, Structural Insulated Panels (SIPs) possess exceptional thermal insulation characteristics, which can make a substantial contribution towards reducing energy consumption. According to Ferraro, Zhang, and Ma (2012), the utilization of insulation foam core in SIPs results in elevated thermal resistance, leading to a decrease in the amount of energy needed for regulating the temperature of the building.

According to the findings presented in (*Table 1)*, AAC exhibits the lowest thermal conductivity, while ICFs and bricks follow suit, AAC is the most effective insulator compared to the other two materials, while bricks are the least effective. ICFs exhibit the highest thermal resistance, suggesting their superior capacity to resist heat flow when compared to bricks and AAC. ICFs possess a higher heat capacity compared to bricks and AAC. The energy efficiency of educational buildings is highest with ICFs, followed by AAC and bricks.

Table 2. Pros and Cons of Bricks, AAC and ICFs

Material	Pros	Cons
Bricks	1. Durable and low maintenance	1. Moderate thermal performance compared to AAC and ICFs
	2. Aesthetic appeal	2. Can be susceptible to moisture issues
	3. Excellent sound insulation	3. Heavier compared to AAC, leading to higher transportation and handling costs
	4. Compatible with various passive design strategies	
Autoclaved Aerated Concrete (AAC)	1. Lightweight, reducing transportation and handling costs	1. Long-term thermal performance needs further investigation
	2. Good thermal insulation properties	2. Lower compressive strength compared to bricks and ICFs
	3. Fire-resistant and pest-resistant	3. Can be susceptible to moisture issues
	4. Easy to cut, shape, and install	4. Limited availability in some regions
Insulated Concrete Forms (ICFs)	1. Excellent thermal performance and energy efficiency	1. Higher initial construction costs compared to bricks and AAC
	2. High structural strength	2. More complex construction process

	3. Improved indoor air quality and reduced noise transmission	3. Limited design flexibility compared to bricks and AAC
	4. Faster construction time	4. Requires specialized labour for installation

CHAPTER 4

MODELING AND ANALYSIS

4.1 Building Description

EPOKA University, situated in Tirana, Albania, is a renowned academic establishment recognized for its contemporary and adequately furnished premises. The primary academic edifice provides cutting-edge classrooms and lecture halls, whereas specialized amenities comprise of research laboratories and computer labs. The institution places emphasis on the welfare of its students by offering a wide range of amenities, including a well-stocked library and a sports centre that encompasses both indoor and outdoor facilities. EPOKA University priorities sustainability in its construction practices by utilizing premium materials and implementing energy-efficient systems in its buildings. In general, EPOKA University provides a dynamic and favourable atmosphere that fosters both scholarly achievement and individual development.

4.2 EnergyPlus Overview

The simulation tool EnergyPlus, which was created by the U.S. Department of Energy (USDOE) [34], is frequently employed by engineers and architects for diverse objectives. The software primarily serves as a tool for thermal load and energy analysis, facilitating the assessment of building performance, retrofitting inquiries, HVAC system choice, and energy efficiency optimization.

EnergyPlus utilizes the input data provided by the user regarding the building's characteristics and operational attributes to perform calculations that ascertain the heating and cooling loads required to sustain the desired temperature set points throughout the year.

The software exhibits a noteworthy characteristic in its capacity to establish a concurrent linkage between the building's reaction and the thermal system. User-defined thermal steps can provide an accurate depiction of the interface between a building's interior spaces and the external environment. Moreover, text-formatted weather files are accessible and utilized for various geographical locations.

It operates as a simulation engine and does not possess a specialized user interface. However, it depends on supplementary programs to augment its usability. While it is possible for users to import input files in text format, Google Sketch-up and integrated Open Studio provide a graphical user interface (GUI) that facilitates a more intuitive and streamlined input definition process. The tools offered by Google Sketch-up are commonly employed for the purpose of generating architectural drawings and specifying the components of the building envelope, such as windows, doors, and shading features [32].

The Open Studio interface enables users to specify all relevant parameters for the program, and analysis is performed according to schedules and time intervals that are defined by the user. The following analytical sections demonstrate the designated parameters aimed at facilitating the attainment of a thorough Whole Building Analysis [33].

4.3 Analysis Steps

The process of analysis requires the development of a model using Open Studio, wherein the user initiates the specification of their individual requirements. The model encompasses various aspects of the building, such as architectural envelope details, materials inventory, load definitions, schedules, HVAC systems, and other relevant components.

The primary building parameters, including the geographical coordinates (latitude and longitude) and orientation, are inputted at the inception. The geometric form of a building is constructed by drafting the architectural envelope details, such as walls, roofs, floors, and fenestrations, using Google Sketch-up. From a thermal standpoint, a solitary stratum interface linking indoor and outdoor areas, or indoor spaces, is sufficient. The subsequent phases entail the establishment of material layers for every component of the building enclosure.

The establishment of spatial relationships holds significant importance in the definition of boundary conditions. As an illustration, a spatial constituent could be subjected to external atmospheric circumstances, such as solar radiation and air currents, or to terrestrial surfaces. On the contrary, it is possible for an internal space to be contiguous with another internal space, thereby rendering it susceptible to indoor environmental factors.

The software allows for manual specification of material properties. Accurate knowledge of the thermal characteristics and thickness of materials is imperative for the development of a multi-layered envelope component. The simulation of a building's behaviour over a desired time span requires the definition of loads and schedules. The program computes solar loads and conduction loads based on location, orientation, time of day, and outdoor weather conditions, while the user is required to input internal loads, such as occupancy, lighting, equipment, and other relevant factors that are specific to the building.

- Step 1:

The procedure begins with the creation of a Sketchup layout (*Figure 6)*, which is then broken into smaller regions. At this step, the floor height and number of floors are determined. A window is then added to the model, its precise placement established by a measuring instrument.

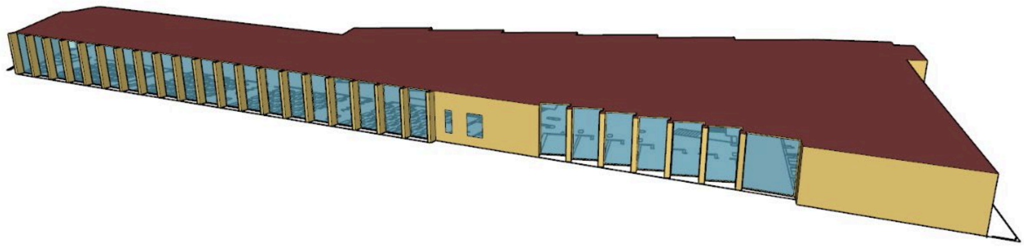
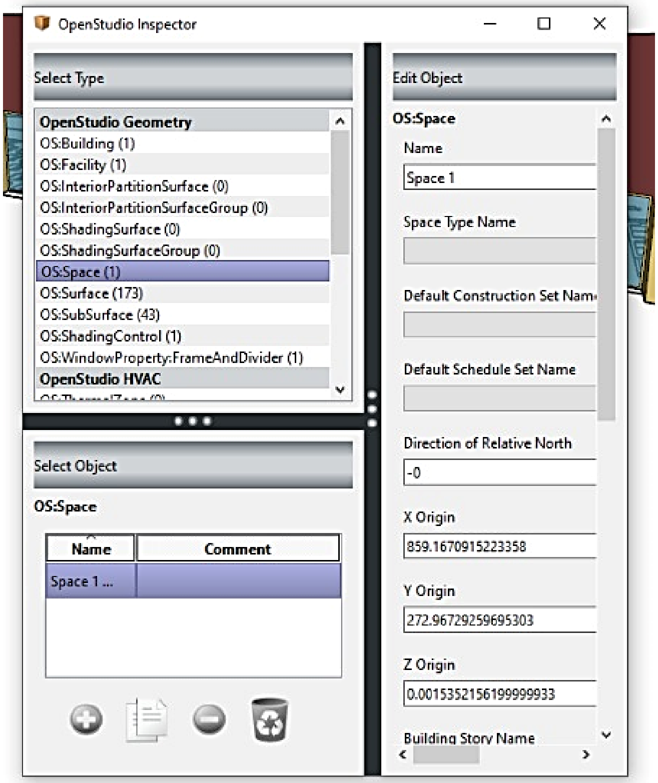


Figure 6. *General View of Analysis's Building*

- Step 2:

The model is divided into independent rooms or sections, each with its own window. An examination of the model reveals the existence of these regions. However, the initial model does not assign heat zones to these spaces. To address this, the Open Studio users' script is used to introduce model parts and allocate heat zones (*Figure 7)*.



OS:Space

Name	Comment
Space 1 ...	

OS:Space

Name: Space 1

Space Type Name:

Default Construction Set Nam

Default Schedule Set Name:

Direction of Relative North: -0

X Origin: 859.1670915223358

Y Origin: 272.96729259695303

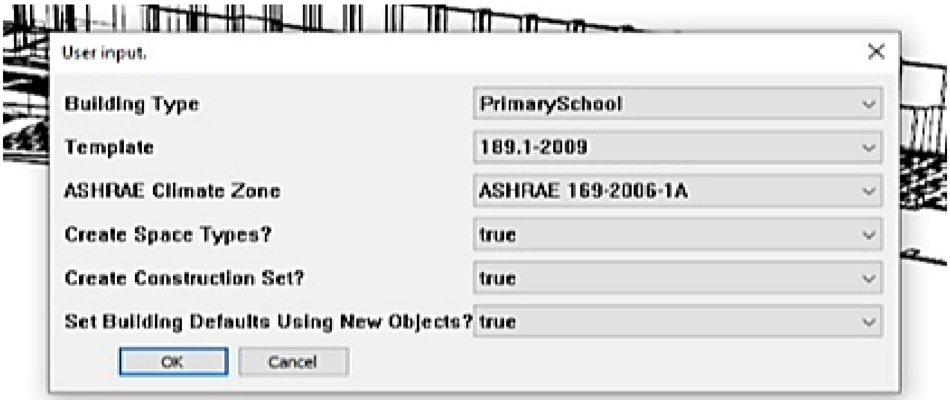
Z Origin: 0.0015352156199999933

Building Story Name

Figure 6. *Dividing the Building into sections.*

- Step 3:

Following that, the building is classified as a school and a corresponding template is assigned (*Figure 8)*. This template includes internal gains, structures, and time codes. This assignment streamlines subsequent steps because these items do not need to be added individually later in EnergyPlus. The limits of all surfaces in the building are then examined. A wall that shares a border condition with another wall is discovered. The surface matching feature is used to determine the suitable boundary condition for this.



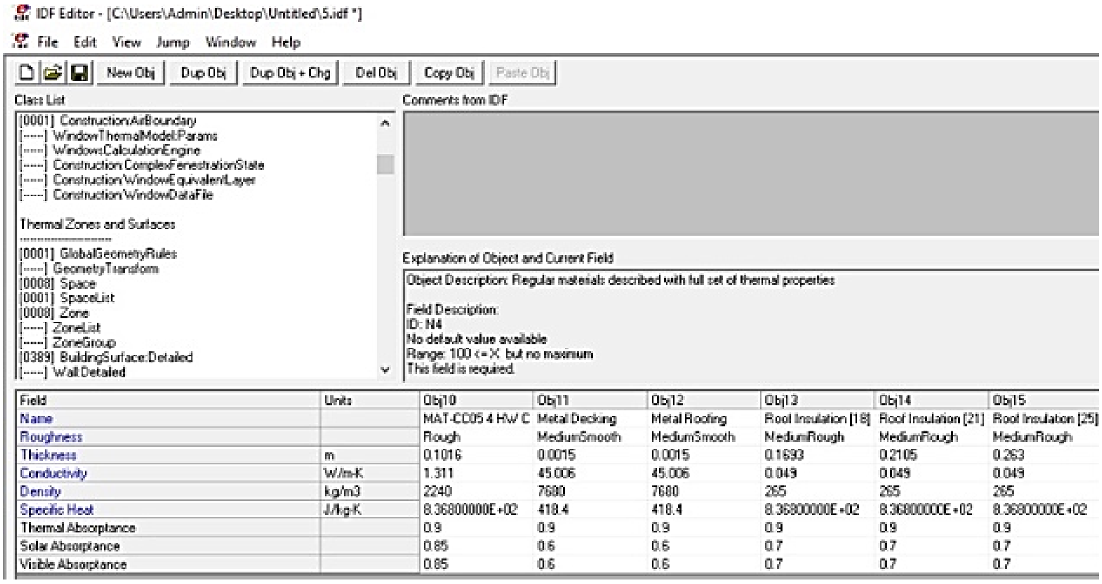
Building Type: PrimarySchool
Template: 189.1-2009
ASHRAE Climate Zone: ASHRAE 169-2006-1A
Create Space Types?: true
Create Construction Set?: true
Set Building Defaults Using New Objects?: true

Figure 7. *Classifying the Building*

- Step 4:

The method of changing material parameters in Energy Plus, a building energy simulation software, is explained. The significance of these qualities is highlighted since they have a substantial impact on the cooling load demand within a space.

An investigation of the material properties in an existing model is carried out. These attributes are essential to the model's building inputs. For example, the wall's construction is made up of membranes and wall insulation. Roughness, thickness, conductivity, density, and specific heat are all material qualities of these components (*Figure 9*).



[0001] Construction:AirBoundary
[-----] WindowThermalModel:Params
[-----] WindowsCalculationEngine
[-----] Construction:ComplexFenestrationState
[-----] Construction:WindowEquivalentLayer
[-----] Construction:WindowDataFile

Thermal Zones and Surfaces

[0001] GlobalGeometryRules
[-----] GeometryTransform
[0008] Space
[0001] SpaceList
[0008] Zone
[-----] ZoneList
[-----] ZoneGroup
[0389] BuildingSurface:Detailed
[-----] Wall:Detailed

Object Description: Regular materials described with full set of thermal properties

Field Description:
ID: N4
No default value available
Range: 100 <= X but no maximum
This field is required.

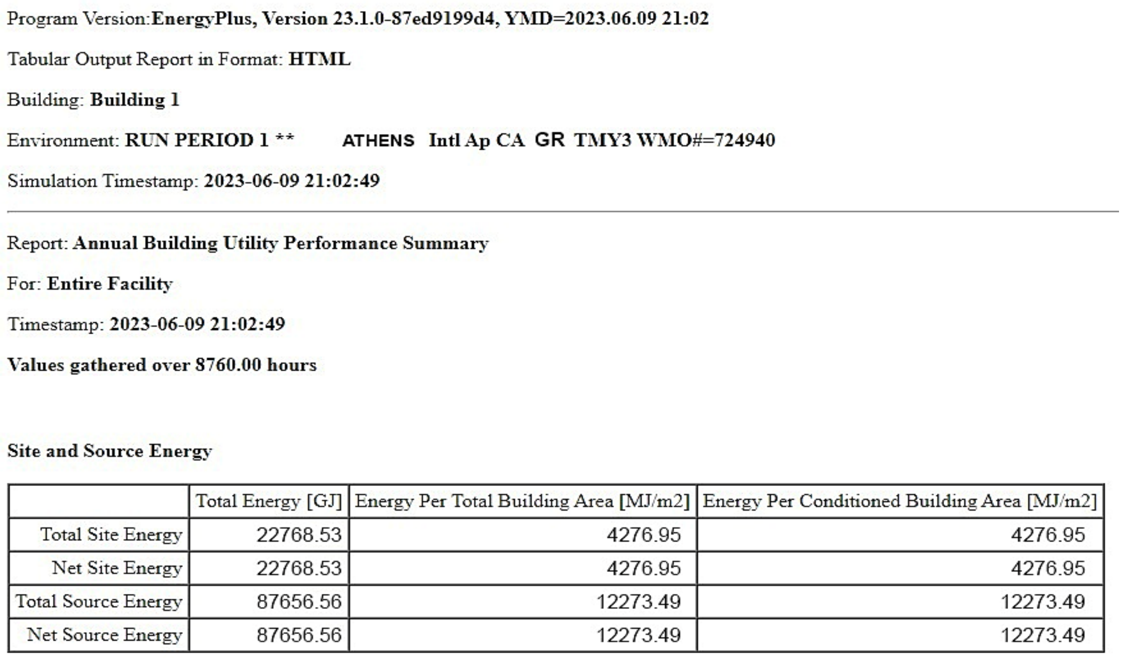
Field	Units	Obj10	Obj11	Obj12	Obj13	Obj14	Obj15
Name		MAT-CC05 4 HW C	Metal Decking	Metal Roofing	Roof Insulation [18]	Roof Insulation [21]	Roof Insulation [25]
Roughness		Rough	MediumSmooth	MediumSmooth	MediumRough	MediumRough	MediumRough
Thickness	m	0.1016	0.0015	0.0015	0.1693	0.2105	0.263
Conductivity	W/m-K	1.311	45.006	45.006	0.049	0.049	0.049
Density	kg/m3	2240	7680	7680	265	265	265
Specific Heat	J/kg-K	8.36800000E+02	418.4	418.4	8.36800000E+02	8.36800000E+02	8.36800000E+02
Thermal Absorptance		0.9	0.9	0.9	0.9	0.9	0.9
Solar Absorptance		0.85	0.6	0.6	0.7	0.7	0.7
Visible Absorptance		0.85	0.6	0.6	0.7	0.7	0.7

Figure 8. *Materials Properties*

- Step 5:

The final step in Sketchup is to export the IDF file. This file is then imported into Energy Plus, ensuring that the Energy Plus version matches the IDF file version. The data contains simulation control and other features. The building materials, structures, and surface details are all validated. Internal gains for each zone are also confirmed, with each zone aggregated into one and only one internal gain listed.

The simulation is then started in Energy Plus by pressing the simulate button. Energy Plus analyses the energy of the building and displays the total energy and total building area (*Figure 10*).



Program Version:**EnergyPlus, Version 23.1.0-87ed9199d4, YMD=2023.06.09 21:02**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

Environment: **RUN PERIOD 1 ** ATHENS Intl Ap CA GR TMY3 WMO#=724940**

Simulation Timestamp: **2023-06-09 21:02:49**

Report: **Annual Building Utility Performance Summary**

For: **Entire Facility**

Timestamp: **2023-06-09 21:02:49**

Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	22768.53	4276.95	4276.95
Net Site Energy	22768.53	4276.95	4276.95
Total Source Energy	87656.56	12273.49	12273.49
Net Source Energy	87656.56	12273.49	12273.49

Figure 9. *IDF file version*

4.3.1 Analysis of the Existing Building

In accordance with the specifications of the software, it was necessary to manually redefine each thermal zone, a process that entailed redrawing the geometry of said thermal zone. The process of manually redrawing, in conjunction with the utilization of OpenStudio, resulted in the development of a building blueprint that could be seamlessly integrated into the EnergyPlus software. The structure chosen for simulation is the educational building, which is depicted as a three-story building in the accompanying illustration. The institution's net total building area measures 2,978.52 square meters per floor.

The lowermost level of the establishment encompasses a variety of amenities, such as lecture halls, administrative workspaces, a coffee shop, and restrooms that are tailored to cater to diverse gender identities and physical capabilities. The second level of the building replicates the layout of the first level and comprises various facilities such as classrooms, computer labs, a study area, an administrative office, and a conference hall. The academic institution provides computer labs on the second floors, which are furnished with a variety of monitors designated for student utilization, excluding CPUs and peripherals. The cafeteria is located on the first level near the kitchen. The educational edifice fulfils diverse overarching objectives, such as delivering lectures, conducting training sessions, and facilitating studio classes.

The comprehensive energy usage of the school is attributed to its varied assortment of electrical apparatus, which encompasses computers, monitors, projectors, lighting fixtures, electrical outlets, kitchen appliances, and exhaust fans that facilitate ventilation in areas without air conditioning, such as shower rooms and the gym showers located on the ground floor. The scheduling of equipment operation is based on the academic timetable, which varies between weekdays and holidays.

The heating, ventilation, and air conditioning (HVAC) system constitutes the primary source of energy consumption in the building. The default recommended systems were utilized in the conducted analyses. As per the ASHRAE Specifications of 2010, the HVAC apparatus for a "Secondary School" in Open Studio conforms to the norms for air conditioning equipment in benchmark structures.

The first step in the thermal modelling process for any energy simulation software is to identify the thermal zones of the building. The precise delineation of thermal zones not only improves the dependability of outcomes but also reduces the computational resources needed.

The weather data utilized by EnergyPlus is sourced from its exclusive database file. For the present study, the data was obtained from the Athens, Greece weather station report.

The present investigation involved the development of a school building model utilizing four distinct building materials by their properties such as roughness, thickness, conductivity etc., for the purpose of evaluating energy consumption, (*Table 3*). In the planning phase of the school analysis, it was assumed that the building would serve as a study centre and host summer school activities during the summer season. Consequently, the analysis was approached from a year-round standpoint. A distinctive work schedule was devised for the educational institution, with consideration given to the weekends and public holidays of the specified year.

Table 3. Building's Materials Properties for External Walls [4]

Material name	Roughness	Thickness (m)	Conductivity (W/m K)	Density (kg/m3)	Specific heat (J/kg K)
Brick	Rough	0.3	0.9	1800	800
Autoclaved Aerated Concrete	Smooth	0.3	0.15	600	1000
Insulating Concrete Foams	Smooth	0.5	0.1	450	1000
Structural Insulating Panels	Smooth	0.2	0.07	200	900

The custom monthly average ground temperatures were computed utilizing the basement utility program of EnergyPlus, based on the climatic data of Tirana, as presented in (*Table 4*). It should be noted that the temperatures were the sole factors taken into consideration, aside from the external air temperatures.

Table 4. Tirana's Average Temperature (°C) [5]

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AVERAGE MAX TEMP (°C)	12	12	15	18	23	28	31	31	27	23	17	14
AVERAGE TEMP (°C)	7	8	11	14	18	22	25	25	22	17	13	9
AVERAGE MIN TEMP (°C)	2	2	5	8	12	16	17	17	14	10	8	5

Table 5 presents the selected special days and holidays during which Albanian schools remain closed, in addition to weekends throughout the academic year. These days are taken into consideration in the school's operating schedule.

Table 5. Holidays in Albania During Semesters [35]

Holiday	**Date**	**Duration**
New Year's Holidays	January 1-January 8	8 days
Semester Break	March 6 - March 18	13 days
Summer Day	March 14	1 day
Nevruz Day	March 22	1 day
Catholic Easter	April 9 - April 10	2 days
Orthodox Easter	April 16-April 17	2 days
Eid al-Fitr	April 21- April 24	4 days
International Labor Day	May 1	1 day
Kurban Bajrami	June 29	1 day
Summer Break	July 8 - 31 October	116 days
Canonization of Saint Tereza	September 5	1 day
Flag and Independence Day	November 28	1 day
Liberation Day	November 29	1 day
Christmas Day	December 25	1 day
Second Day of Christmas	December 26	1 day
New Year's Holidays	December 27- December 31	5 days
TOTAL		**159 days**

4.4 Building Envelope and Constructions

The building comprises a configuration that comprises half a dozen offices, a corridor, a dozen classrooms, and a library. As a result of this arrangement, it is anticipated that every area within the building will possess similar attributes and demonstrate uniform thermal conditions (*Table 6*). Hence, it is justifiable and beneficial to classify these areas in a manner that is consistent with both analytical and engineering viewpoints.

Through the establishment of homogenous building spaces according to the architectural drawing, a methodical and concentrated strategy towards thermal analysis and engineering can be implemented. This facilitates enhanced comprehension, optimization of design, and effective management of the thermal performance of the building (*Figure 6*).

Table 6. Building's Area

	Area [m^2]
Total Building Area	2978.52
Net Conditioned Building Area	2978.52
Unconditioned Building Area	0.00

4.5 Simulation Tools

The accurate representation of the thermal behaviour of inner walls in EnergyPlus requires a detailed specification of material characteristics and construction attributes. The thermal performance of inner walls is a crucial factor in building energy analysis as they are responsible for facilitating heat transfer between different zones or spaces within the building (*Figure 7*).

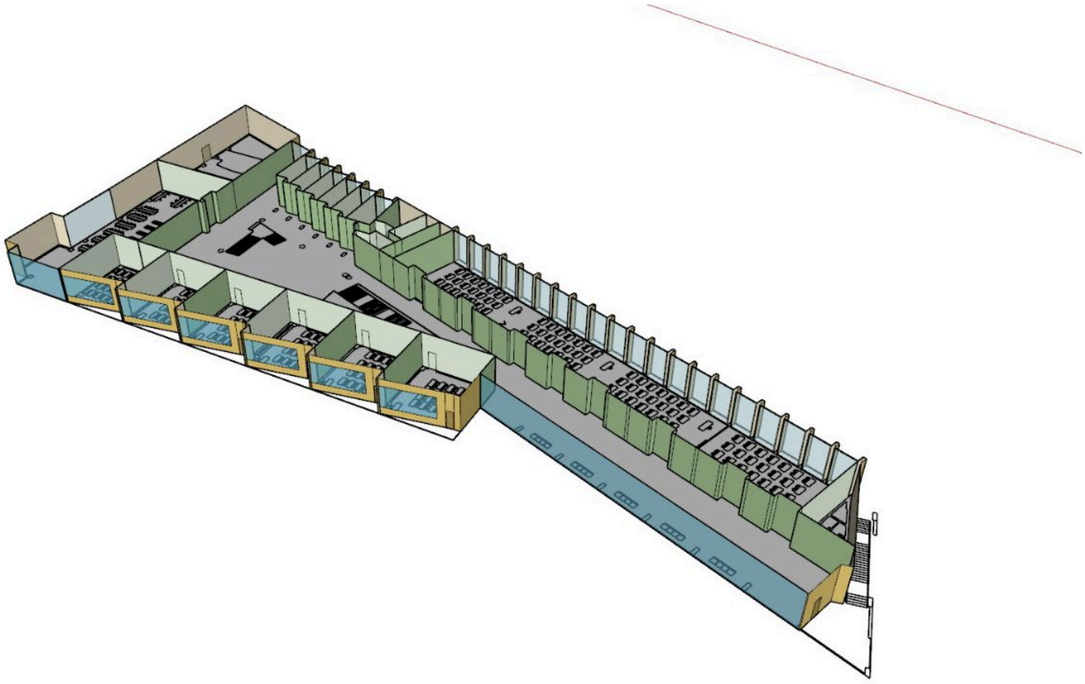


Figure 10. Representation of the Inner Walls and Outer Walls

4.5.1 Thermal Zones

EnergyPlus utilizes the concept of a thermal zone to denote a discrete and interconnected area within a building that exhibits comparable thermal properties. The term "building envelope" refers to a coherent assemblage of architectural components, including walls, floors, ceilings, windows, and HVAC systems, that are analysed for thermal and energy simulation objectives.

The process of defining a thermal zone in EnergyPlus typically involves a series of steps. Initially, the delineation of the zone is accomplished through the allocation of a distinctive appellation or symbol that precisely characterizes the area under consideration for simulation. Subsequently, the geometric demarcations of the region, encompassing the floor area, height, and configuration, are delineated to ensure precise computation of thermal dynamics and heat transmission within the said region.

The thermal zone is assigned with internal loads and occupancy schedules. This encompasses various variables, such as illumination, apparatus, individuals, and their respective timetables and thermal characteristics. The inputs facilitate the modelling of internal heat sources and occupant-related impacts on the thermal conditions within the given zone.

Moreover, the HVAC system that caters to the thermal zone has been specified. The process entails the identification of the system type, its capacity, controls, set points, and operating schedules. The HVAC system exerts a noteworthy influence on the thermal comfort and energy usage within a given area.

CHAPTER 5

RESULTS AND DISCUSSION

The present chapter examines the energy efficiency of four distinct building materials, namely, which were utilized in the construction of a prototype building situated in Tirana. The quantification of energy performance was conducted through the utilization of three primary parameters, namely total energy consumption, energy consumption per total building area, and energy consumption per conditioned building area (*Table 7).*

Table 7. Electricity Energy Consumption

Climatic zone (City)	Building Material		Total Energy (GJ)	Energy per Total Building Area (MJ/m^2)	Energy per Conditioned Building Area (MJ/m^2)
Tirana	BRICK	Total Site Energy	22,768.53	4,276.95	4,276.95
		Total Source Energy	87,656.56	12,273.49	12,273.49
	AAC	Total Site Energy	20,624.91	3,858.27	3,858.27
		Total Source Energy	79,459.16	11,743.72	11,743.72
	ICF	Total Site Energy	21,817.28	3,978.42	3,978.42
		Total Source Energy	80,752.33	12,484.56	12,484.56
	SIP	Total Site Energy	19,699.73	3,772.63	3,772.63
		Total Source Energy	78,922.51	11,172.11	11,172.11

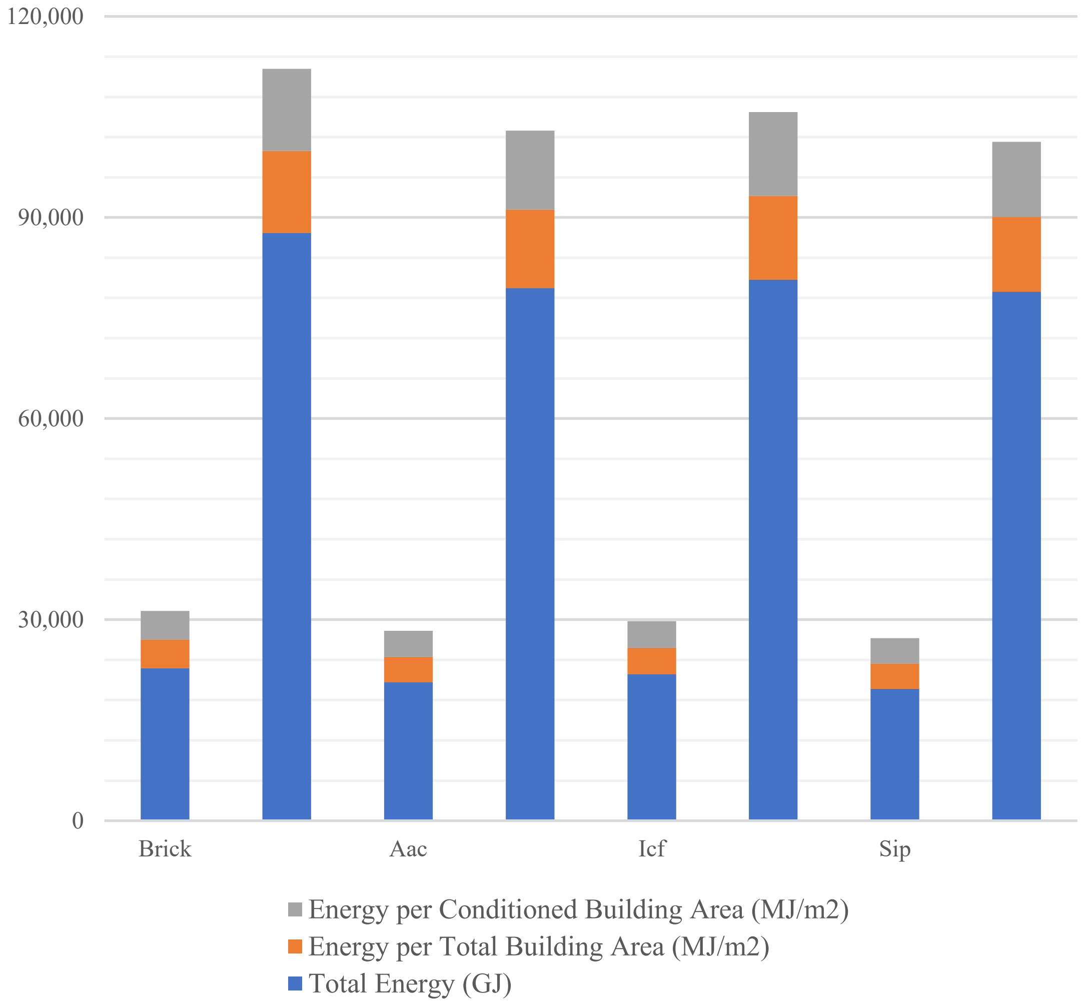


Figure 11. Energy Consumption

The analysis of the four materials being evaluated revealed that brick exhibited the greatest aggregate energy consumption (Figure 8), amounting to 22,768.53 GJ of site energy and 87,656.56 GJ of source energy. The AAC material exhibited reduced overall energy usage in contrast to brick, as evidenced by its 9.4% less site energy and 9.4% less source energy. Despite having a higher energy consumption of 4.2% more site energy and 2.1% less energy source compared to AAC, ICFs were found to be less energy-intensive than brick, with 4.2% less site energy and 7.9% less source energy. Among the various materials studied, Structural Insulated Panels (SIPs) demonstrated the least amount of total energy consumption, with a recorded value of 13.5% less for site energy and 9.9% less for source energy.

Upon analysis of the energy consumption per total building area, it was observed that brick exhibited the greatest energy intensity, registering at 4,276.95 MJ/m^2 for site energy and 12,273.49 MJ/m^2 for source energy. The utilization of AAC resulted in a site energy of 9.8% less and a source energy of 4.3% less than brick. Insulating Concrete Forms (ICFs) exhibited a marginally greater energy intensity in comparison to Autoclaved Aerated Concrete (AAC), albeit lower than that of brick, with respective values of 7% less for site energy and 6.4% less for source energy than brick. The study revealed that Structural Insulated Panels (SIPs) exhibited the least energy intensity, with a recorded value of 11.8% less for site energy and 9% less for source energy than brick.

The energy consumption per conditioned building area exhibited a similar pattern to that of the energy consumption per total building area. The results of the analysis indicate that brick exhibited the greatest energy intensity, followed by ICFs, AAC, and lastly SIPs, which demonstrated the lowest energy intensity.

As expected, there is an increase in the demand for heating during the winter season, while the need for cooling rises during the summer months. The uniformity of interior illumination is maintained across both materials, with a noticeable augmentation during the winter season owing to the decrease in daylight duration.

According to the analysis of energy demand patterns, it has been observed that the months of December and February exhibit the highest peak in energy demand for heating purposes. In these time intervals, there is a greater energy requirement for brick walls in comparison to walls made of Autoclaved Aerated Concrete (AAC). In contrast, the month of July exhibits the minimum cooling system requirement for brick, Structural Insulated Panels (SIPs), and Insulated Concrete Forms (ICF), whereas for AAC, the month of August demonstrates the lowest demand.

An observation of significance pertains to the conservation of energy across all materials during the months of July and August. The decrease in energy usage can be ascribed to the academic schedule of the institution. During the summer season, the university experiences a period of recess, leading to a notable decrease in the number of individuals occupying its premises. As a result, the employment of cooling systems is reduced, resulting in decreased energy consumption.

CHAPTER 6

CONCLUSIONS

This thesis provides significant insights into the energy efficiency implications of utilizing different building materials, namely Brick, Autoclaved Aerated Concrete (AAC), Insulated Concrete Forms (ICF), and Structural Insulated Panels (SIP), in the architectural design of an educational institution. The research conducted is meticulous and employs EPOKA University as a case study.

The EnergyPlus software was utilized to conduct simulations, facilitating a comprehensive comparison of these materials based on significant energy parameters such as total energy consumption, energy consumption per unit of total building area, and energy consumption per unit of conditioned building area. The findings of this research emphasize the crucial significance of the selection process of construction materials in determining the energy consumption of an educational facility.

In terms of overall energy consumption, it was observed that the brick material demonstrated the greatest energy demands, while the Structural Insulated Panels were found to be the least energy intensive. The trend endured when examining energy consumption per unit area, in both the context of overall building area and conditioned building area.

The tabular displays offered a concise and lucid graphical synopsis of the comparative energy efficiency of the different materials. The tables underscore the cruciality of making informed decisions regarding material selection in the context of building construction, as this can exert a substantial influence on the energy consumption and overall ecological sustainability of the building.

The study's findings suggest that Structural Insulated Panels exhibit superior energy efficiency compared to the other materials examined. This advantage translates into significant benefits in terms of reduced energy consumption, thereby implying the potential for cost savings. The conclusion highlights the capacity of Structural Insulated Panels (SIPs) to augment the energy sustainability of educational establishments and analogous architectural edifices. However, it is imperative to consider additional factors such as the financial expenses, longevity, and ecological effects throughout the lifespan of these substances to guarantee a holistic strategy towards eco-friendly architectural planning.

6.1 Recommendations for future research

In continuing the analysis from this master’s thesis, "Assessing the Energy Efficiency of Different Construction Materials in Education Buildings: A Case Study from Albanian Practice," future research should prioritize energy efficiency. The study could be expanded to incorporate additional locally accessible or new energy-efficient materials. Long-term energy consumption simulations using EnergyPlus and Open Studio could be performed to acquire a better understanding, investigating the energy performance of these materials under various weather and seasonal situations. It would also be beneficial to investigate how diverse architectural designs affect the energy efficiency of various materials. Along with energy efficiency, future work might include a more comprehensive sustainability assessment, considering variables such as economic impacts, lifecycle assessment, and end-of-life material handling. Finally, disseminating the research's ideas and findings to a wider audience can help promote the use of energy-efficient materials and designs in the building industry in Albania and abroad.

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APPENDIX

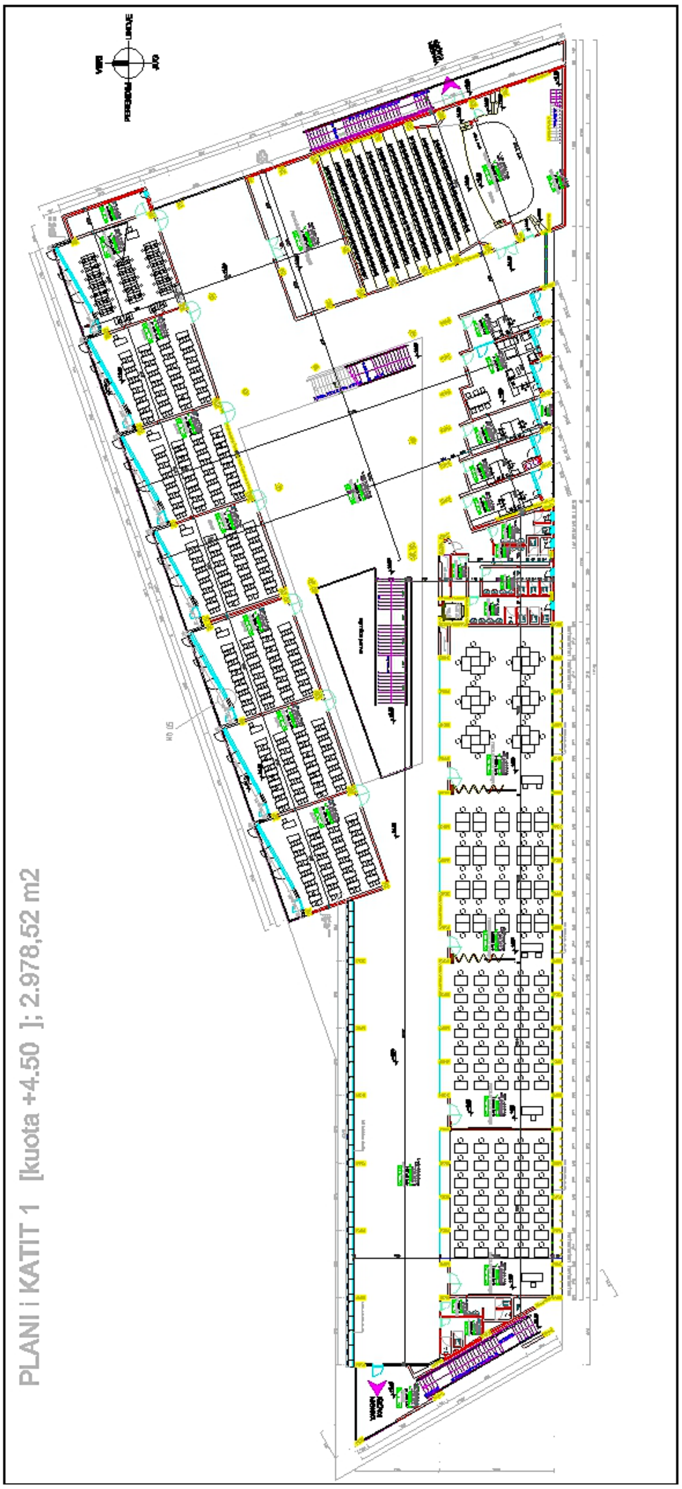
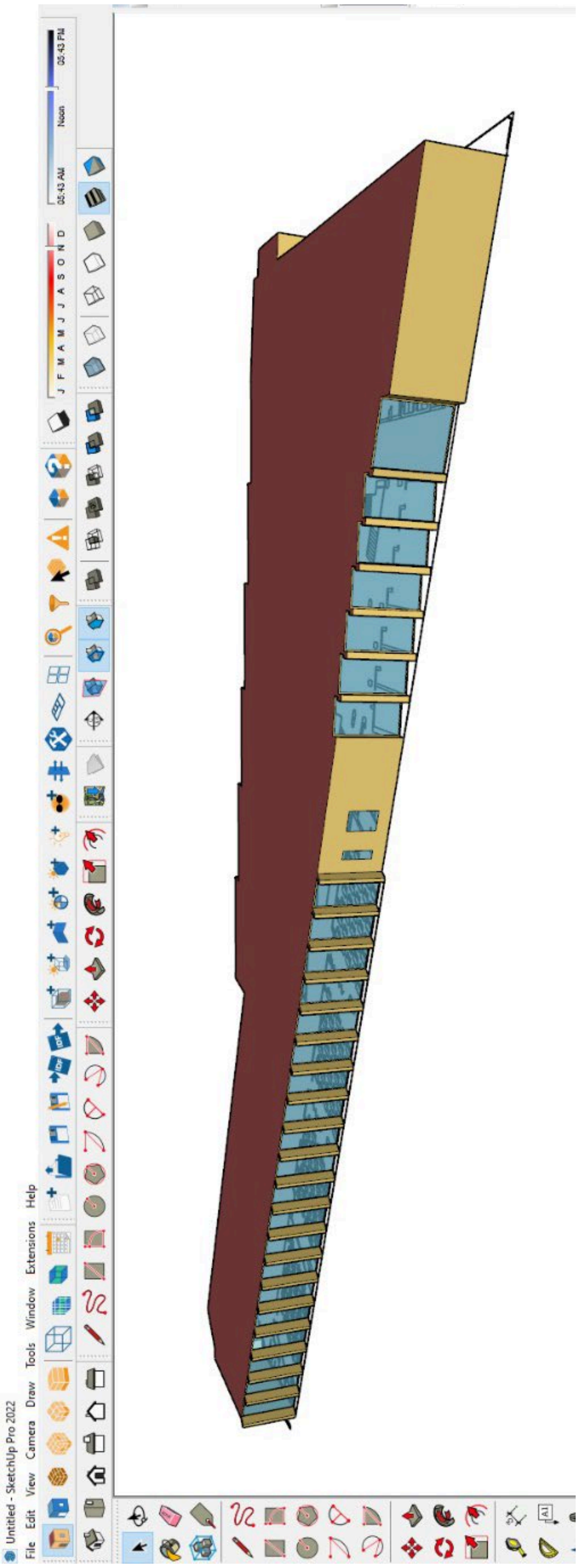


Figure 12. First floor plan for E-Building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File Edit View Camera Draw Tools Window Extensions Help
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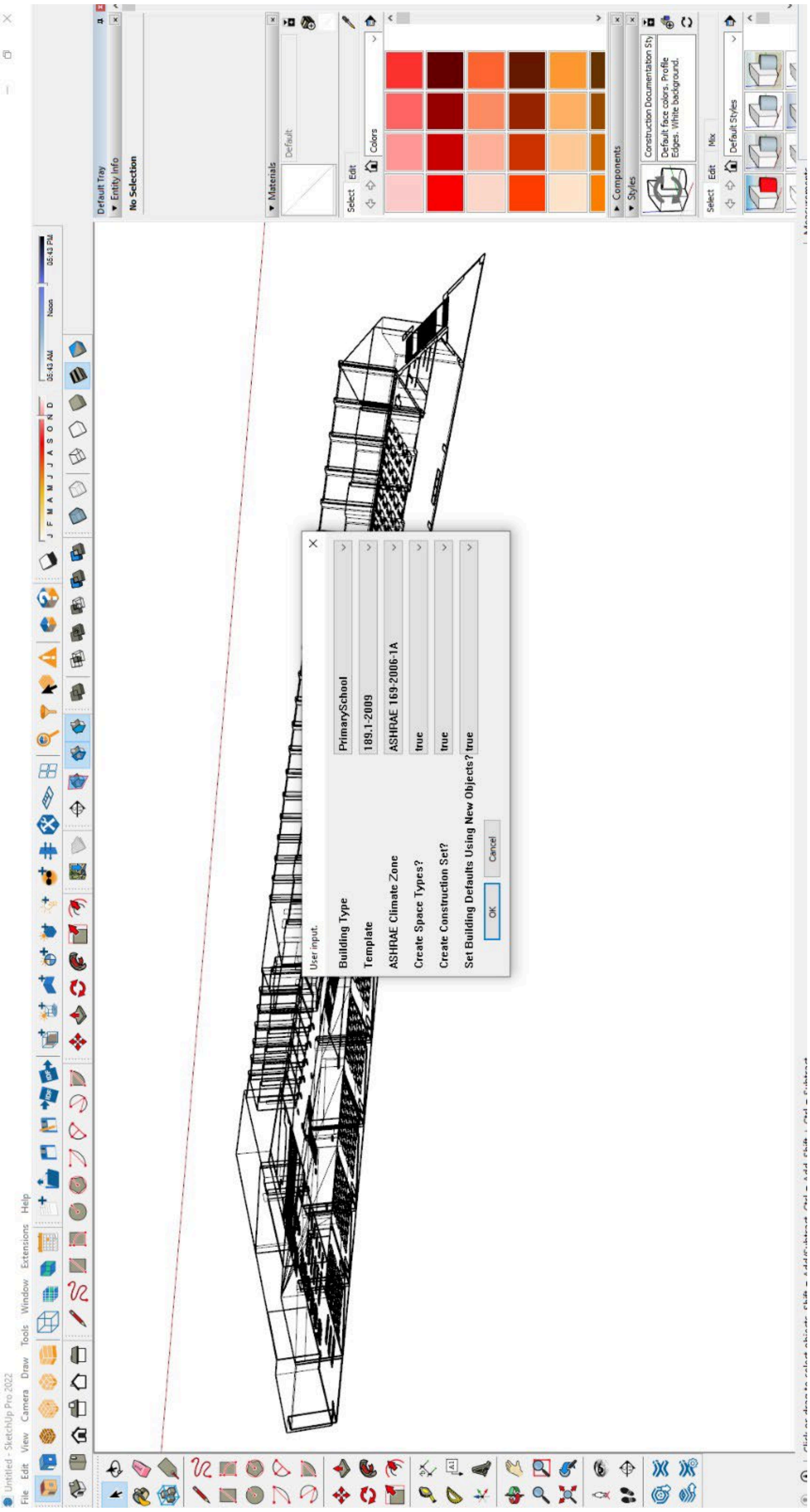
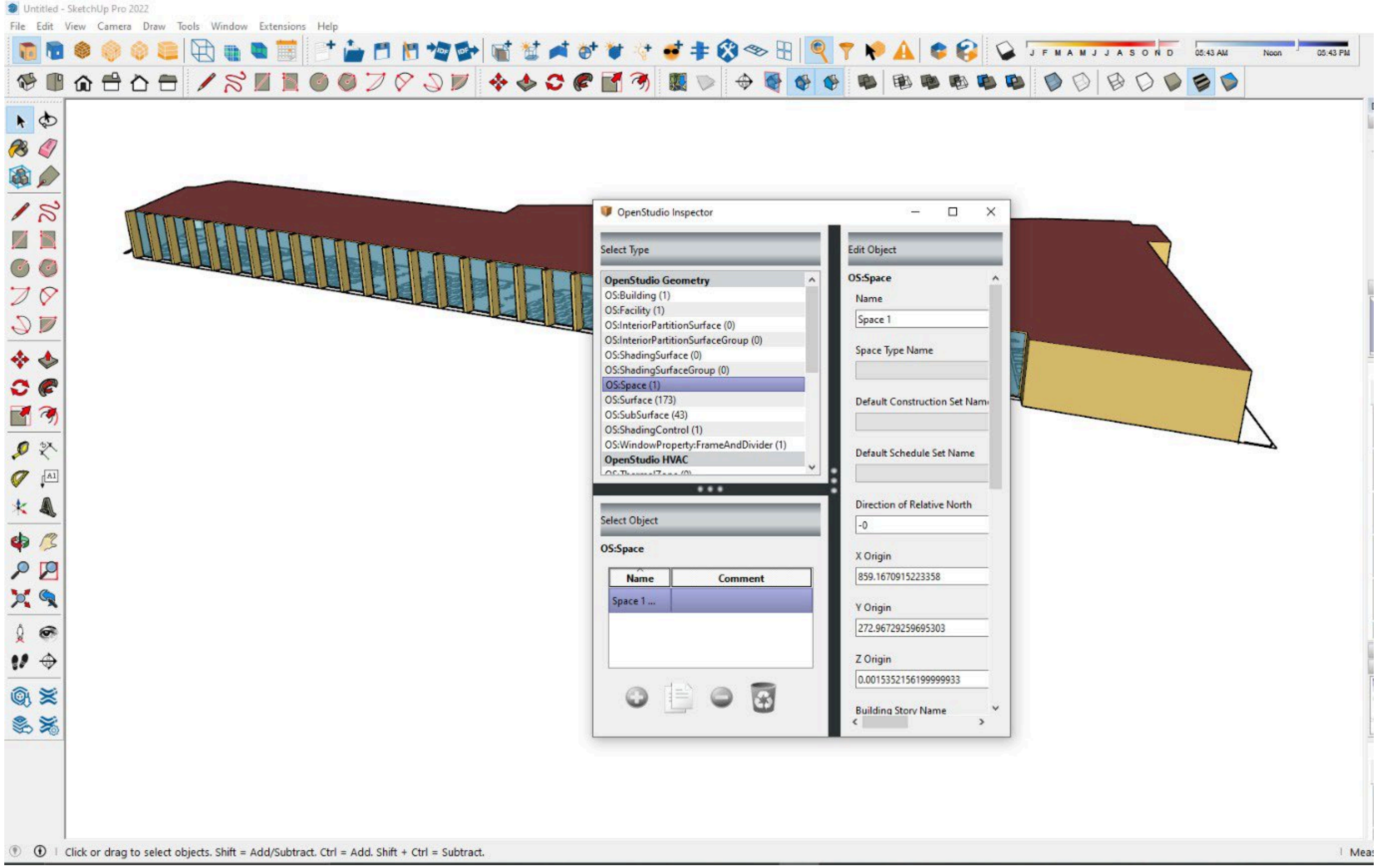
05:43 AM
Noon
05:43 PM



User input.

Building Type	PrimarySchool
Template	189.1-2009
ASHRAE Climate Zone	ASHRAE 169-2006-1A
Create Space Types?	true
Create Construction Set?	true
Set Building Defaults Using New Objects?	true



OpenStudio Inspector

Select Type

OpenStudio Geometry
- OS:Building (1)
- OS:Facility (1)
- OS:InteriorPartitionSurface (0)
- OS:InteriorPartitionSurfaceGroup (0)
- OS:ShadingSurface (0)
- OS:ShadingSurfaceGroup (0)
- OS:Space (1)
- OS:Surface (173)
- OS:SubSurface (43)
- OS:ShadingControl (1)
- OS:WindowProperty:FrameAndDivider (1)

OpenStudio HVAC

Select Object

OS:Space

Name	Comment
Space 1 ...	

Edit Object

OS:Space

Name: Space 1

Space Type Name:

Default Construction Set Nam

Default Schedule Set Name:

Direction of Relative North: -0

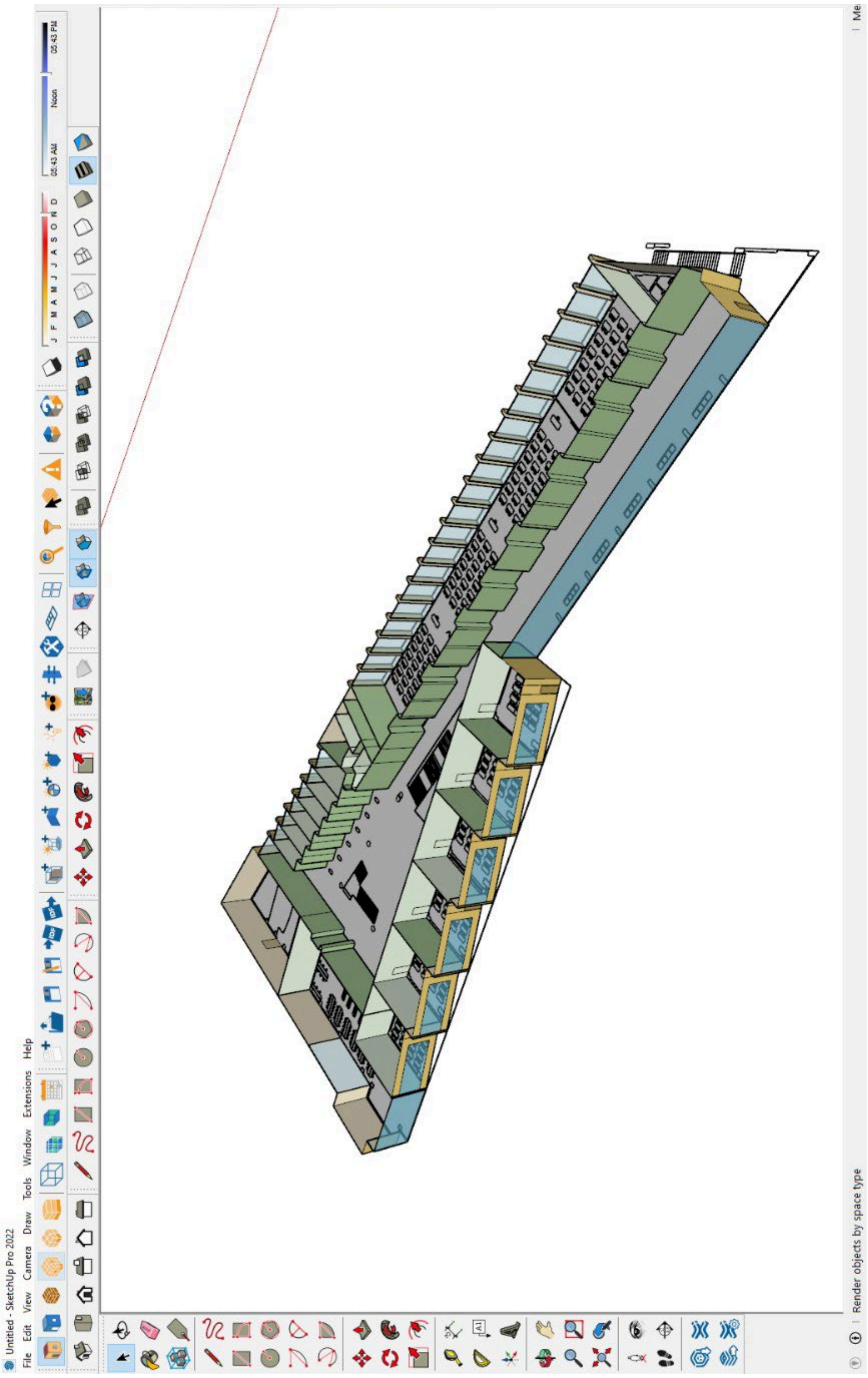
X Origin: 859.1670915223358

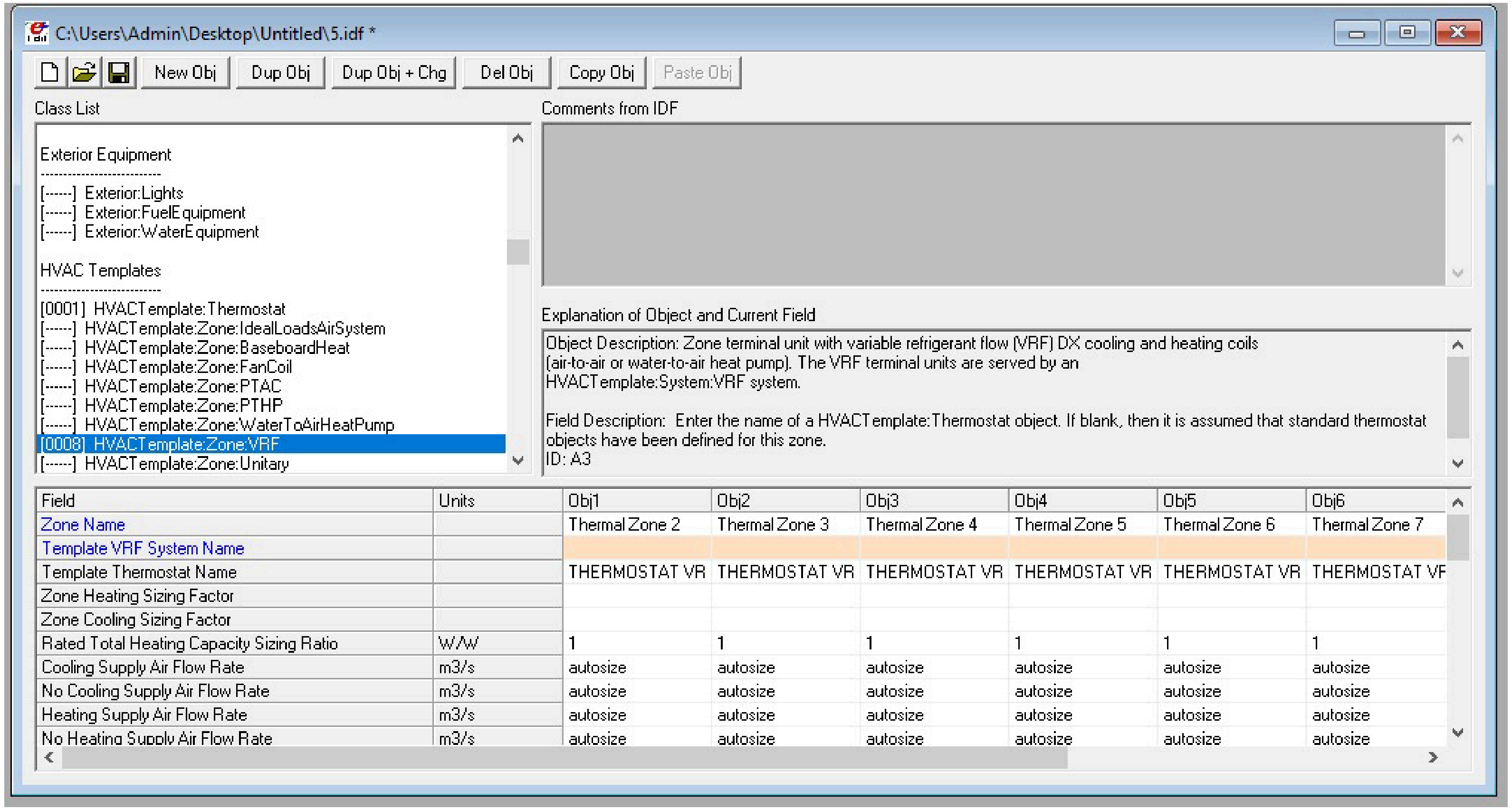
Y Origin: 272.96729259695303

Z Origin: 0.0015352156199999933

Building Story Name

Click or drag to select objects. Shift = Add/Subtract. Ctrl = Add. Shift + Ctrl = Subtract.


Untitled - SketchUp Pro 2022
File Edit View Camera Draw Tools Window Extensions Help
J F M A M J J A S O N D
05:43 AM
Noon
05:43 PM
Render objects by space type
Me



Exterior Equipment

[------] Exterior:Lights
[------] Exterior:FuelEquipment
[------] Exterior:WaterEquipment

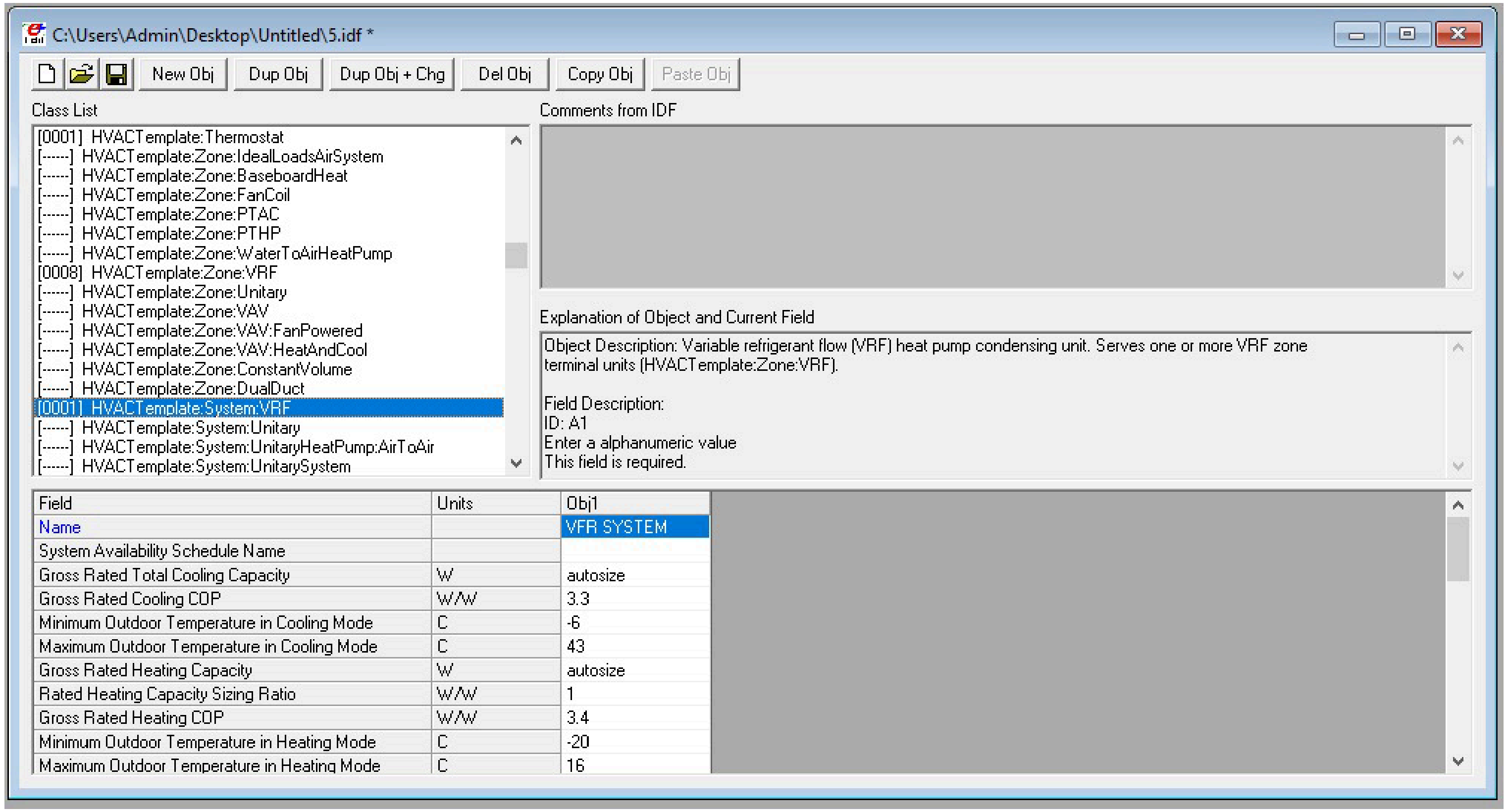
HVAC Templates

[0001] HVACTemplate:Thermostat
[------] HVACTemplate:Zone:IdealLoadsAirSystem
[------] HVACTemplate:Zone:BaseboardHeat
[------] HVACTemplate:Zone:FanCoil
[------] HVACTemplate:Zone:PTAC
[------] HVACTemplate:Zone:PTHP
[------] HVACTemplate:Zone:WaterToAirHeatPump
[0008] HVACTemplate:Zone:VRF
[------] HVACTemplate:Zone:Unitary

Object Description: Zone terminal unit with variable refrigerant flow (VRF) DX cooling and heating coils (air-to-air or water-to-air heat pump). The VRF terminal units are served by an HVACTemplate:System:VRF system.

Field Description: Enter the name of a HVACTemplate:Thermostat object. If blank, then it is assumed that standard thermostat objects have been defined for this zone.
ID: A3

Field	Units	Obj1	Obj2	Obj3	Obj4	Obj5	Obj6
Zone Name		Thermal Zone 2	Thermal Zone 3	Thermal Zone 4	Thermal Zone 5	Thermal Zone 6	Thermal Zone 7
Template VRF System Name							
Template Thermostat Name		THERMOSTAT VR	THERMOSTAT VR	THERMOSTAT VR	THERMOSTAT VR	THERMOSTAT VR	THERMOSTAT VF
Zone Heating Sizing Factor							
Zone Cooling Sizing Factor							
Rated Total Heating Capacity Sizing Ratio	W/W	1	1	1	1	1	1
Cooling Supply Air Flow Rate	m3/s	autosize	autosize	autosize	autosize	autosize	autosize
No Cooling Supply Air Flow Rate	m3/s	autosize	autosize	autosize	autosize	autosize	autosize
Heating Supply Air Flow Rate	m3/s	autosize	autosize	autosize	autosize	autosize	autosize
No Heating Supply Air Flow Rate	m3/s	autosize	autosize	autosize	autosize	autosize	autosize

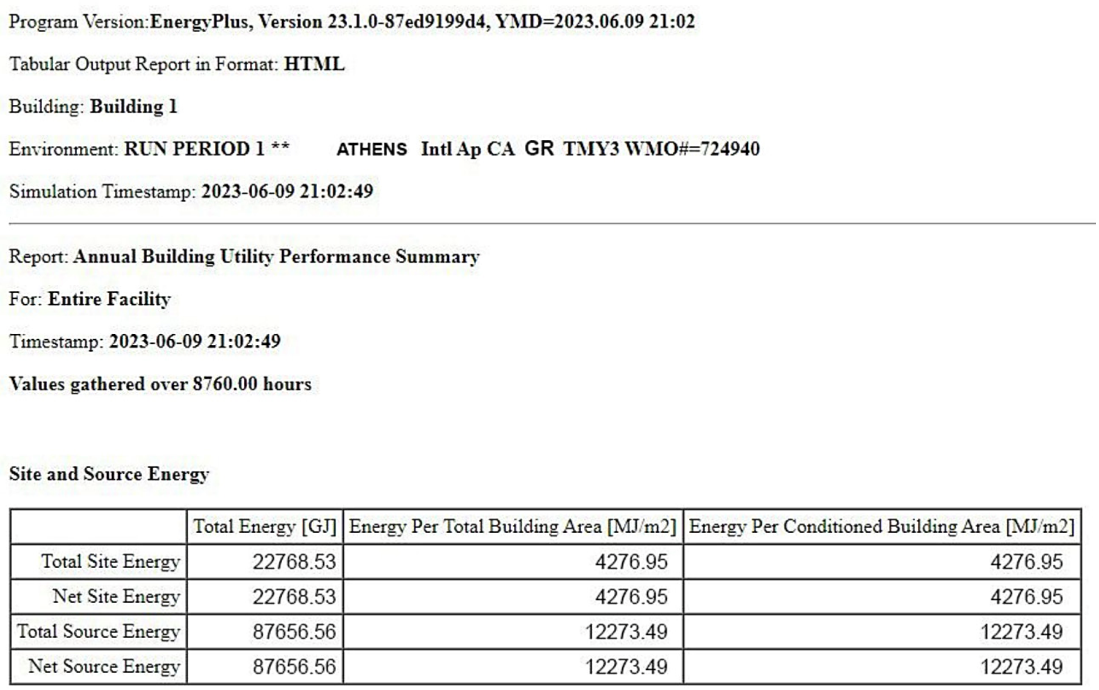


[0001] HVACTemplate:Thermostat
[------] HVACTemplate:Zone:IdealLoadsAirSystem
[------] HVACTemplate:Zone:BaseboardHeat
[------] HVACTemplate:Zone:FanCoil
[------] HVACTemplate:Zone:PTAC
[------] HVACTemplate:Zone:PTHP
[------] HVACTemplate:Zone:WaterToAirHeatPump
[0008] HVACTemplate:Zone:VRF
[------] HVACTemplate:Zone:Unitary
[------] HVACTemplate:Zone:VAV
[------] HVACTemplate:Zone:VAV:FanPowered
[------] HVACTemplate:Zone:VAV:HeatAndCool
[------] HVACTemplate:Zone:ConstantVolume
[------] HVACTemplate:Zone:DualDuct
[0001] HVACTemplate:System:VRF
[------] HVACTemplate:System:Unitary
[------] HVACTemplate:System:UnitaryHeatPump:AirToAir
[------] HVACTemplate:System:UnitarySystem

Object Description: Variable refrigerant flow (VRF) heat pump condensing unit. Serves one or more VRF zone terminal units (HVACTemplate:Zone:VRF).

Field Description:
ID: A1
Enter a alphanumeric value
This field is required.

Field	Units	Obj1
Name		VFR SYSTEM
System Availability Schedule Name		
Gross Rated Total Cooling Capacity	W	autosize
Gross Rated Cooling COP	W/W	3.3
Minimum Outdoor Temperature in Cooling Mode	C	-6
Maximum Outdoor Temperature in Cooling Mode	C	43
Gross Rated Heating Capacity	W	autosize
Rated Heating Capacity Sizing Ratio	W/W	1
Gross Rated Heating COP	W/W	3.4
Minimum Outdoor Temperature in Heating Mode	C	-20
Maximum Outdoor Temperature in Heating Mode	C	16



Program Version:**EnergyPlus, Version 23.1.0-87ed9199d4, YMD=2023.06.09 21:02**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

Environment: **RUN PERIOD 1 ** ATHENS Intl Ap CA GR TMY3 WMO#=724940**

Simulation Timestamp: **2023-06-09 21:02:49**

Report: **Annual Building Utility Performance Summary**

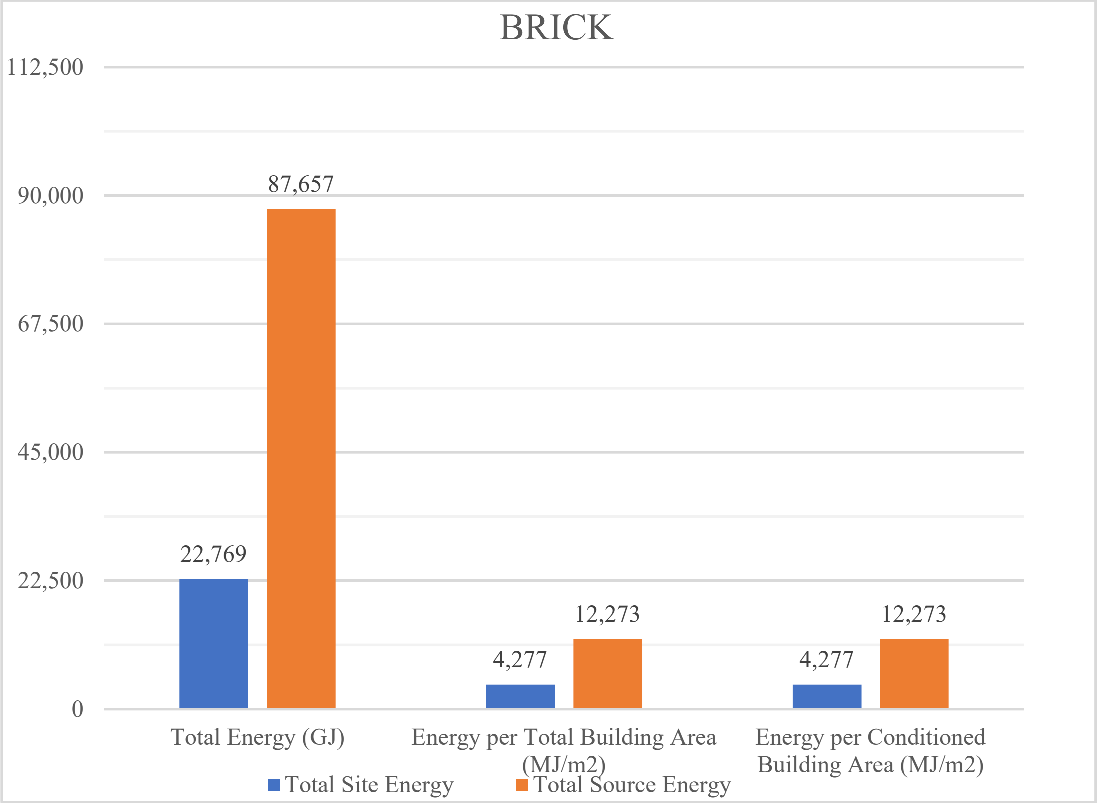
For: **Entire Facility**

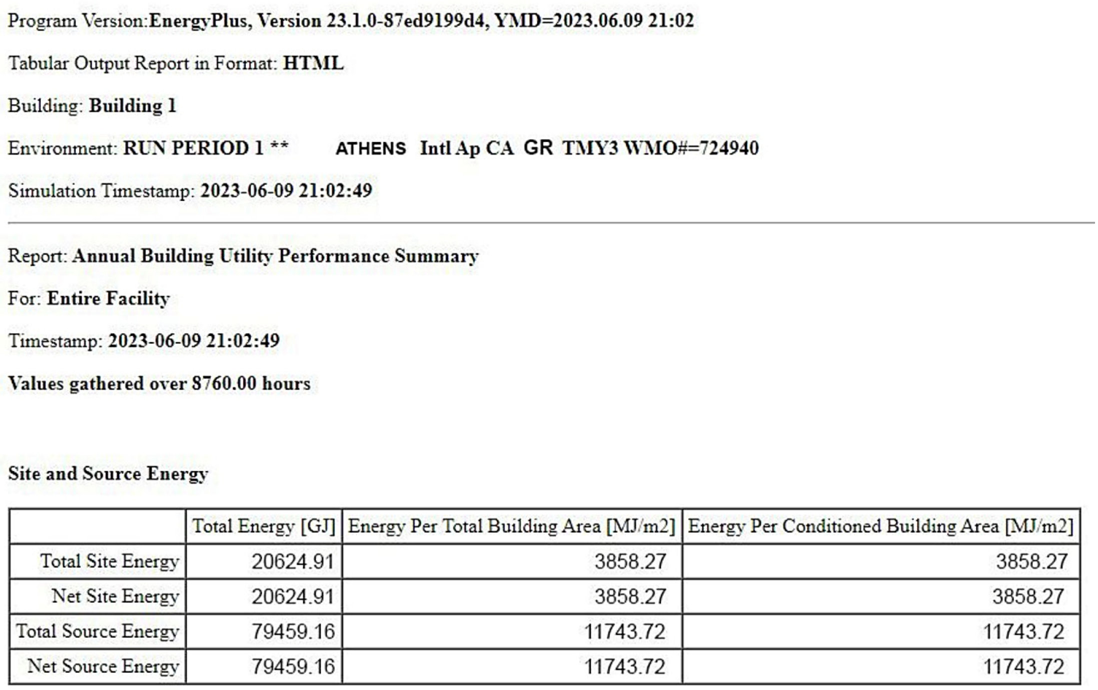
Timestamp: **2023-06-09 21:02:49**

Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	22768.53	4276.95	4276.95
Net Site Energy	22768.53	4276.95	4276.95
Total Source Energy	87656.56	12273.49	12273.49
Net Source Energy	87656.56	12273.49	12273.49





Program Version:**EnergyPlus, Version 23.1.0-87ed9199d4, YMD=2023.06.09 21:02**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

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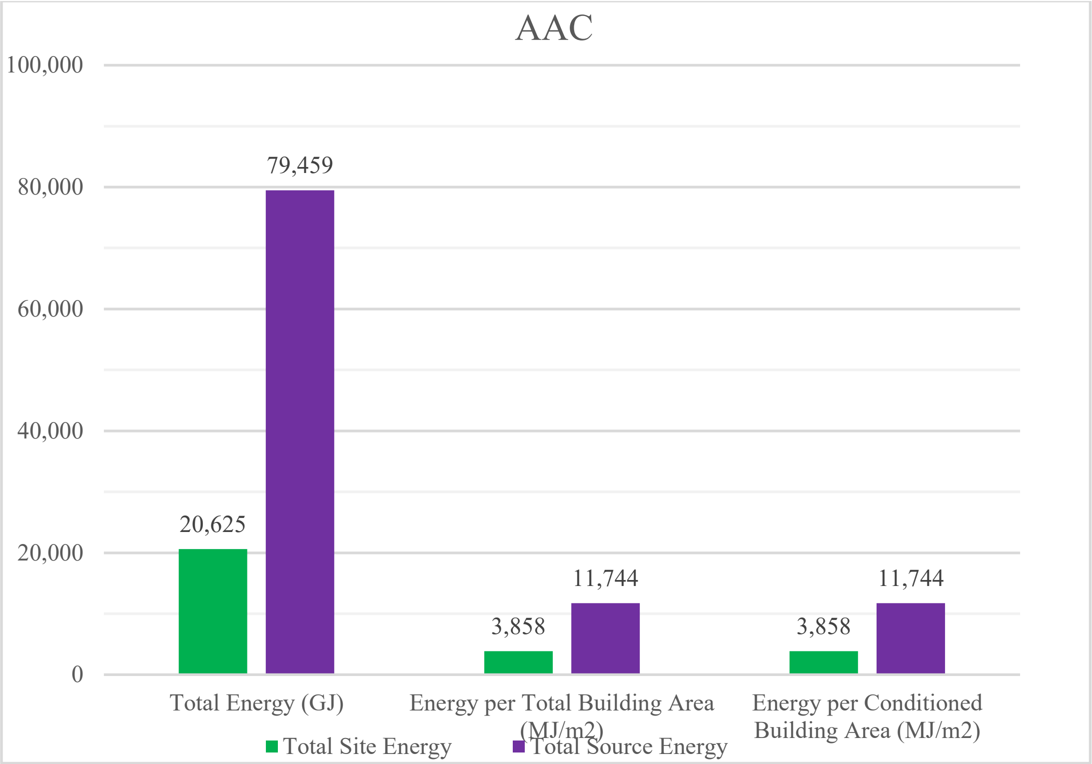
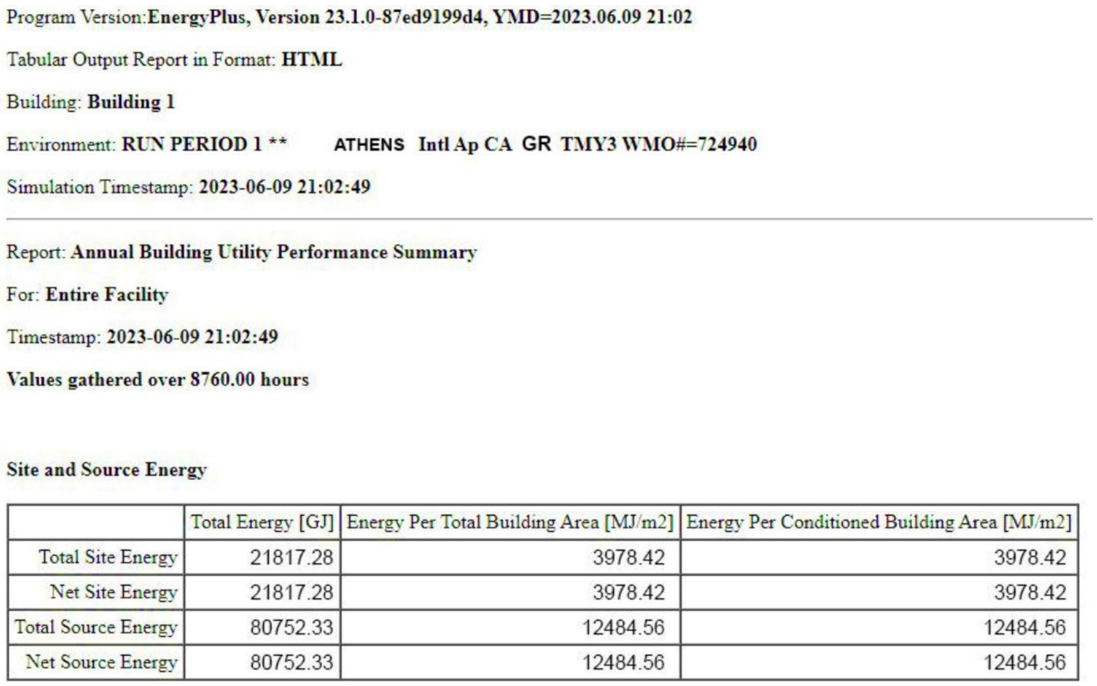
Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	20624.91	3858.27	3858.27
Net Site Energy	20624.91	3858.27	3858.27
Total Source Energy	79459.16	11743.72	11743.72
Net Source Energy	79459.16	11743.72	11743.72





Program Version:**EnergyPlus, Version 23.1.0-87ed9199d4, YMD=2023.06.09 21:02**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

Environment: **RUN PERIOD 1 ** ATHENS Intl Ap CA GR TMY3 WMO#=724940**

Simulation Timestamp: **2023-06-09 21:02:49**

Report: **Annual Building Utility Performance Summary**

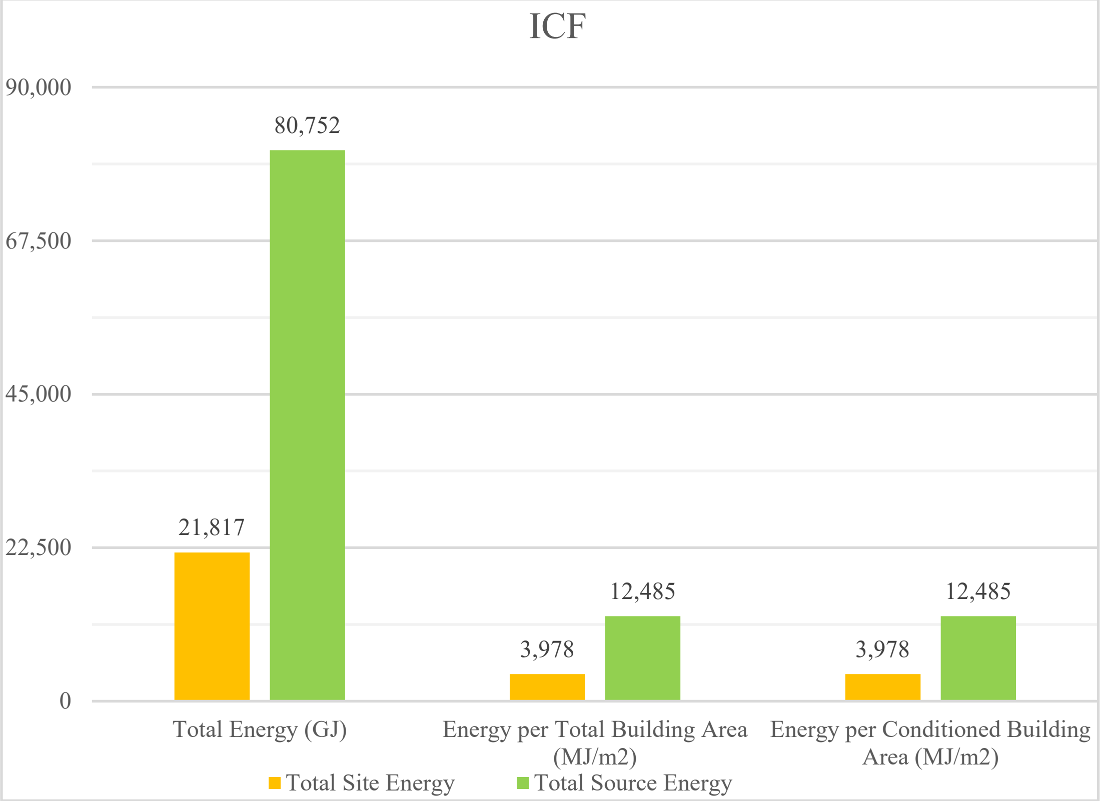
For: **Entire Facility**

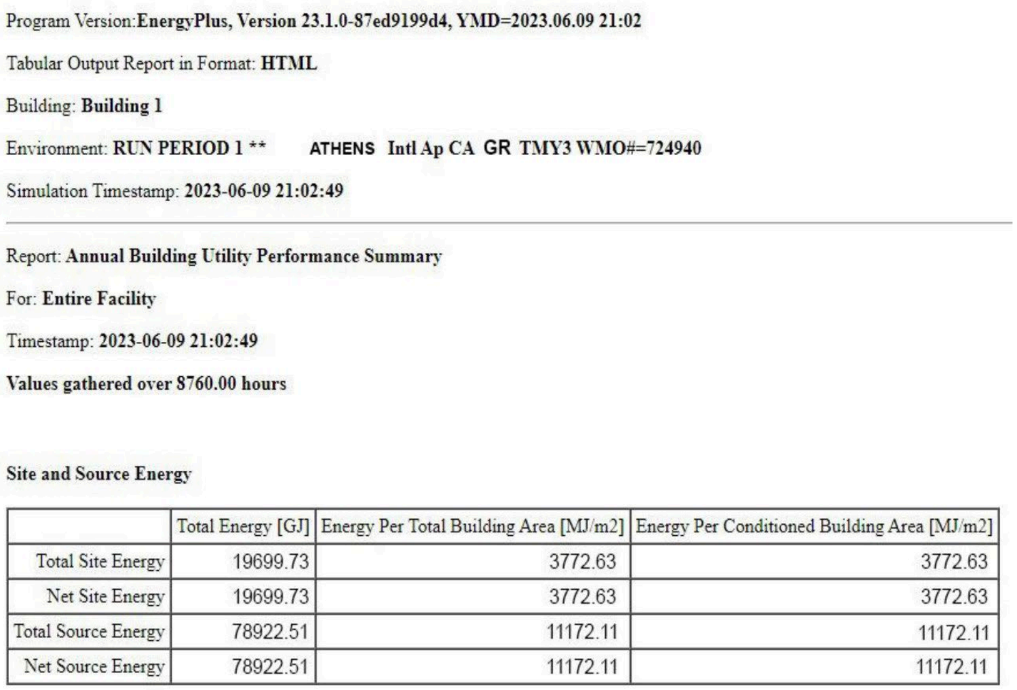
Timestamp: **2023-06-09 21:02:49**

Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	21817.28	3978.42	3978.42
Net Site Energy	21817.28	3978.42	3978.42
Total Source Energy	80752.33	12484.56	12484.56
Net Source Energy	80752.33	12484.56	12484.56





Program Version:**EnergyPlus, Version 23.1.0-87ed9199d4, YMD=2023.06.09 21:02**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

Environment: **RUN PERIOD 1 **   ATHENS Intl Ap CA GR TMY3 WMO#=724940**

Simulation Timestamp: **2023-06-09 21:02:49**

Report: **Annual Building Utility Performance Summary**

For: **Entire Facility**

Timestamp: **2023-06-09 21:02:49**

Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]	Energy Per Conditioned Building Area [MJ/m2]
Total Site Energy	19699.73	3772.63	3772.63
Net Site Energy	19699.73	3772.63	3772.63
Total Source Energy	78922.51	11172.11	11172.11
Net Source Energy	78922.51	11172.11	11172.11

Site and source energy SIPs