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# Selecting and Estimating Optimum Passive Designs of Energy Efficiency in Educational Buildings in Turkey

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**Abstract:** The consumption of energy in building sector consists about 40% of energy consumptions by words. In this investigation we analysis using the passive design in educational buildings by selecting the Technology faculty building in Selçuk university at Konya city as example of Tik-tip project .To estimate the optimum case of passive designs, firstly proposal two new educational building envelopment ( cubic building with 1:1 aspect ratio and cylindrical building) at same floor area of original existing envelopment at same façades design and more compact by less outdoor walls and then analysis to use eight passive designs (orientation , double façades, window wall ratios, court yards, green-lands and environment's area, shading device, set temperature and building tightness) in each new envelopments by simulations each ones using Autodesk Revit 2020 and analysis optically same designs by Ecotect 2011 based on actually yearly weather data selecting it in NASA weather data web site .At the result of analysis the proposed the new envelopment's we have more energy efficient at each one about %16.7 decreasing in cooling load and %20.76 saving of heating load in cubic building with % 19.9 saving in cylindrical envelopment and then have saving in total yearly air-conditioning load about % 19.3 and % 18.75 in cubic and cylindrical envelopment respectively. A last when used the other passive designs in optimum case we have total energy saving in air conditioning load about %33.36 in cubic envelopment and %30.9 in cylindrical envelopment when compared it with existing building envelopment of technology faculty in Selçuk University.

**Keywords** energy efficiency, green energy, passive designs,

## 1. Introduction

The building sector is identified as the leading global consumer of energy. Adopting energy-efficient technology innovations has been recognized as the most promising approach to reduce energy consumption in buildings. However, the adoption of such technology is significantly lacking due to traditional techno-economic thinking that lacks a human focus. Energy culture has been identified as a field of research that successfully overcomes the traditional techno-economic focus of technology diffusion. However, current energy culture studies on the adoption of energy efficient technology innovations in buildings are limited to exploring specific energy cultures rather than investigating the holistic energy culture maturity that guides the gradual diffusion of energy efficient technology innovations. Conversely, cultural

maturity has been studied in other areas of cultural research, such as safety cultures (Soorige et all, 2022).
Today, buildings still account for almost half of global energy consumption and carbon emissions. This highlights the need to increase energy efficiency requirements worldwide in a concerted effort to reduce the construction industry's impact on the environment. Current energy policies are moving towards a design based on airtight and highly insulated envelopes. As a result, energy efficient homes have been found to have inadequate indoor air exchange rates, affecting indoor air quality and resulting in higher latent loads. Increased indoor humidity, combined with the increasing trend of using bio-based building materials, can easily support mold growth and facilitate indoor organic proliferation. The proportion of buildings damaged by mold is estimated to be 45% in Europe, 40% in the USA, 30% in Canada and 50% in Australia, highlighting the magnitude of this problem. Beyond the economic loss resulting from the remediation work required to correct building deterioration due to fungus, mold also has significant negative health effects on building occupants. Data shows that the incidence of asthma symptoms is higher in new, energy-efficient buildings with poor ventilation. This article explores the impacts of building sustainably on the indoor environment in relation to the risk of mold growth. Conducive conditions for growth, causes of growth, effects on health, and possible solutions are discussed. The results are a step towards a more precise and detailed understanding of mold growth to support policymakers and promote sustainable housing standards (Brambilla, 2020).
In general, the design process of a building; concept design, domestic design, advanced design and detailed design stages. During the concept design, a project group is formed to determine the needs of the building together with the stakeholders. At this stage, project goals and design requirements (site orientation, envelopment shape, initial services and building system) are determined and classified into 3 to 8 dimensions in terms of CAD software dimensions (Table 1).

**Table 1** The dimensions meaning in CAD software system.

| | Dimension | Meaning |
|---|---|---|
| 1- | 3D | Dimensions |
| 2- | 4D | + time |
| 3- | 5 D | + Cost |
| 4- | 6D | + Sustainability |
| 5- | 7D | +Time schedule |
| 6- | 8D | +Safety |

The aims to articulate a fundamental well-being framework that integrates thermal and photobiological needs with biophilic proposals to characterize positive links with Arctic climates for energy-efficient buildings. A scoping literature review was conducted to discuss the thermal and photobiological needs of building occupants in relation to biophilic recommendations and Arctic climatic conditions. As a case study, the shortcomings of current building practices in Cambridge Bay, Nunavut, Canada, related to well-being, indoor-outdoor connections, and energy efficiency needs are examined. The proposed well-being framework for positive indoor-outdoor connections in Arctic buildings integrates (i) thermal and (ii) photobiological indicators based on biophilic proposals. The integrated health framework enables the characterization of thermal and (photobiological) lighting adaptation scenarios that respond to Arctic weather, daylight and photoperiods, and energy efficiency. Intermediate spaces are also proposed as a proposed architectural solution to address integrated wellbeing framework energy efficiency in arctic buildings. Overall, the proposed framework can help architects, building designers, and stakeholders develop more architectural solutions for positive, energy-efficient indoor-outdoor connections for Arctic buildings and their inhabitants (Abazari et al, 2022). Using ground raw perlite through alkali activation to produce a variety of construction materials such as plaster, grout and concrete can provide economic and environmental advantages by reducing the consumption of Portland cement. The aim of this study is to produce cement-free pastes and cement-free mortars based on alkaline activation of raw perlite and standard sand. Experimental finding revealed that the addition of 0.25% $H_2O_2$ (perlite by mass) to the mixtures enabled the production of lightweight pastes and mortars with lower density and lower coefficient of thermal conductivity without a significant loss of ultimate strength. The developed perlite-based gas geopolymer is an environmentally friendly and energy efficient solution for buildings. Based on the results, more than 0.5% $H_2O_2$/Perlite and more than 45% water/Perlite should be avoided for both putty and mortars. To obtain optimum results in terms of workability, strength, density and thermal conductivity, it is recommended that the $H_2O_2$/Perlite ratio be 0.25% and the Water/Perlite ratio be 40% for all samples (Acar, 2023).

Phase change materials (PCMs) have great potential to improve building thermal comfort and save energy towards energy-efficient buildings. The current study sheds light on the passive use of PCM in a thin building envelope in an extremely hot location using EnergyPlus software. The thermal contribution of PCM to indoor thermal comfort was evaluated considering average temperature fluctuation reduction (ATFR), thermal load balancing reduction (TLLR), and operating temperature reduction (OTR). Additionally, total average heat gain reduction (AHGR) and equivalent $CO_2$ emissions and electricity cost savings (ECS) are discussed to measure energy savings. Simulation results demonstrated the effectiveness of PCM on the hottest summer days. Quantitatively, PCM contributed 5 ◦C- 6 ◦C to ATFR, along with TLLR and OTR, contributing an average of 38%-59% and 6 ◦C, respectively. According to the energy saving analysis, thanks to PCM integration, the total daily AHGR ranged from 66.6% to 76.5%, with the roof sharing the most. The results also demonstrated environmental and economic benefits, with a reduction in $CO_2$ emissions of up to 2 kg/day and ECS of up to 250 IQD/day. As a result, PCM can significantly improve building performance when passively integrated with thin envelope elements in extremely hot locations (Al-Yasiri,2023). When PCM with the possibility of phase change was used, annual energy use decreased by 28%, demonstrating that the possibility of phase change is very effective in reducing energy consumption. In addition to BioPCM M182/Q21, several BioPCMs with different enthalpy-temperature curves were used and it was observed that Q21 and Q23 BioPCMs fully met the heating needs of the building and reduced energy consumption in the building cooling section by 23.4% and 22.1%, respectively. Considering this, it has been found that there are more suitable options. Considering the effect of metabolic rate on PCM usefulness, in the range of 99-180 Watts per person, the addition of PCM to the building led to lower energy demand (Alharbey,2022).

Developing methods to recover waste heat and share it within a neighborhood can reduce that neighborhood's energy footprint and reduce its dependence on electrical grids. A mixed-use neighborhood consisting of retail, residential and greenhouse buildings was modeled to develop a holistic energy sharing strategy design. The waste heat recovery and distribution network at the neighborhood level is modeled in the EnergyPlus-DesignBuilder joint simulation platform. The energy sharing methodology is applied to different neighborhood configurations and neighborhood densities. Results show that by applying energy-efficient design and integrated energy sharing methodology with on-site solar, a net energy reduction of 74% was achieved in the mixed-use neighborhood compared to a design that complies with the minimum requirement of applicable energy codes. Similarly, a net 90.46% reduction in greenhouse gas (GHG) emissions is achieved by energy sharing and on-site carbon capture using a neighborhood greenhouse (Muslim, 2023).

Phase Change Materials (PCMs) improve cementitious composites by exploiting latent heat capacity, reducing heating and cooling demands. Thermal Energy Storage Aggregates (TESAs) were created using Parafol 18–97 and Parafol 20Z PCMs. Sand was partially replaced by TESAs and cork granules. Analyzes evaluated physical, thermal and mechanical properties, revealing favorable phase change temperatures and remarkable latent heat values in TESA-A and TESA-B. While TESAs reduced mechanical properties, they outperformed cork granules. TESA-mortar samples exhibited acceptable properties, with TESA-50 showing the best energy-saving performance and longest time delay. These findings highlight the potential of PCM-inoculated fungal granules in energy-efficient cement mortar (Ates, 2024). Approximately 12% of greenhouse gas emissions in the EU come from buildings. More energy efficient technologies should be implemented to reduce emissions from buildings. To achieve this, drivers for the implementation of energy efficient technologies are important. Interviews were held with different actors within the scope of a city district development project to find drivers for the implementation of energy efficient technologies in buildings. These drivers were tied to different phases of a building project to see when they had the highest potential impact. Connecting drivers to various stages of the construction process has not been investigated before. As a result, they are the drivers that have the most impact on the Planning Program phase and the Project Planning phase. The most frequently mentioned drivers are cost reduction from lower energy use, greater knowledge in the construction industry, long-term perspective on the customer, both mentioned by ten out of 18 respondents, and National requirements and customer demands, both mentioned by eight out of 18 respondents. The most obvious driver appears to be economic gains, and LCC calculations are therefore a very important tool to demonstrate potential economic gains. Training with subsequent certification in working with energy-saving technologies and building techniques can be a driving force and will also combat the lack of knowledge within the business. In-house information on the Customer, Long-term perspective on the Customer and Customer demands are the three big driving forces. Therefore, clients on building projects should aim to have good in-house knowledge and a long-term perspective to be able to identify the right requirements and steer energy efficient technologies (Carlande, 2022).

Understanding and predicting the energy performance of existing buildings and new construction is crucial to decarbonization. Instead of using simulation software, multiple regression models are used to accelerate this process to predict building energy consumption while ensuring indoor thermal comfort. However, previous predictive models prioritize reducing energy demand with a limited focus on thermal comfort. This study aims to support decision-making during retrofit and new construction planning when developing a predictive model. An air-conditioned office building served as the reference building for simulation. 21 design parameters were analyzed, including weather, building envelope, internal loads, ventilation and temperature settings. Stepwise regression results revealed significant variables in the final model, with 8, 9, 13 and 6 variables remaining for peak cooling load, annual cooling load, overheating hours (WE) and Environmental Quality Index (EQITC) for thermal comfort in the perimeter and core 5, 6, 8 and 5 variables for regions respectively. Additionally, information was provided on important variables related to cooling load and thermal comfort, respectively. Weather- and envelopes-related variables such as cooling degree-days, global solar radiation, solar heat gain coefficient (SHGC), and U-value have the highest impacts on the cooling load. For thermal comfort, variables such as temperature set point, occupant activity level, and factors related to window sunlight transmission performance such as SHGC, window area ratio, and overhang projection ratio have proven to be effective. Overall, this study provided accurate models for evaluating optimal strategies for energy efficiency and thermal comfort in early design stages and advancing building performance practices (Chen X, 2022).

A new life cycle cost (LCC) analysis method is presented to evaluate the long-term cost-effectiveness of energy efficiency features in buildings by accounting for future costs associated with earthquake-induced damage to these features. Buildings located in a seismic zone are likely subject to lifetime earthquakes, and their nonstructural elements, such as energy efficiency features, may suffer varying levels of damage requiring repair or replacement to restore a satisfactory level of building energy efficiency. However, current LCC analysis methods have ignored such earthquake-related costs, potentially leading to unreliable cost-effectiveness assessment of energy efficient buildings. To address this issue, we propose a method to rigorously quantify the expected cumulative future cost due to repair/replacement of earthquake-damaged energy efficiency features and then integrate this cost into the LCC analysis. The new method is demonstrated using a medium-sized office building located in a high seismic area with a Mediterranean climate. The costs associated with the initial installation, as well as future energy consumption, environmental impacts and seismic damage of two alternative types of window installation with different levels of energy efficiency are calculated and compared. It has been found that when the cost of seismic damage is considered, the cost-effectiveness of energy efficiency features can be noticeably reduced and, equivalently, the payback period for building energy efficiency investment is extended (Liu, 2017).

So, in the relevant literature shown Table 2, the investigators research and optimizations the parameters of building envelopment and the passive design used in the different type of building and calculated the amount of energy consumptions in each iteration with energy saving to increase energy efficiency of buildings by using different building energy simulation or coding based on the actual or virtual weather data of the climate of it.

Lastly previous studies have extensively investigated parameters of passive design individual such as devices of shading, (WWR Window to wall ratio), and insulation materials, limited research has addressed the combined impact of building form compactness façade s and multiple passive strategies in educational buildings under specific climates such as Konya city. This study addresses this gap by integrating form optimization with passive design strategies by suggesting using two complementary simulation program tools with two.

**Table 2** Energy efficient parameters literature

| Year | Researchers | Climate | Parameters | Total Energy Efficiency Saving | Programming and Investigation Methods |
|---|---|---|---|---|---|
| 2024 | Soliman (Soliman, 2022 ) | Alexandria (Egypt) | Windows orientation and Shading devices<br>Windows glass<br>Vegetations<br>Green roof<br>Internal Temperature<br>Site | 4% | Revit and Design builder programs |
| 2024 | Naji Alhasnawi et all.(Alhasnawi, 2024 ) | Iraq | Smart Urban Buildings (SUBs) | %38 | mproved Sine Cosine Algorithm (ISCA) |
| 2024 | Reddy et all.(Reddy, 2024) | Virtual | PCM | %19-59 | A comprehensive review |
| 2023 | Cuce et all. (Cuce, 2023) | Virtual | Alternative novel insulation plaster (NIP) | %47.9 | Experimental |
| 2023 | Uzun(Long, 2023) | Vietnam | Pareto-optimal building envelope | %8.48 | AI optimization algorithms |
| 2023 | Wasim et all.(Wasim, 2023) | Virtual | Glazing type, Construction wal, Insulation layers WWR, floor and roof types | %28.7 | Revit, Matlab, Design builder and energy plus |
| 2023 | Müller et all.(Müller, 2023) | EU | new ventilation approache | %28 | Mathematical optimization |
| 2022 | Jakovic and Goia (Jankovic, 2022) | Virtual | Duable envelopment w | --- | Statistical DOE method |
| 2022 | Zhou and Razaqpurm(Zhou, 2022) | Virtual | Tromb wall with PCM | %20 | static |

| | | | | | |
|---|---|---|---|---|---|
| 2021 | Bui (Bui, 2021) | Texas Melbourne | Using Biomimetic adaptive electrochromic windows in shading and window materials | (19.3-23.5)% | python coded |
| 2020 | Geçimli (Geçimli, 2020) | Different climates | Technical solutions, façade, chimney, sound insulation, ventilation, light tube, solar panels, rainwater | 86% | Bee gaming |
| 2020 | Anwar et al. (Anwar, 2020) | Australia | Green roof | (13.6 -11.7)% | Simulation with practice |
| 2019 | Li and Wang (Li, 2019) | Chaina | Building direction, solar roofs, absorbability, WWR | --- | Wizard Coding |
| 2019 | Burratti et al.(Buratti, 2019) | Italy | Aro-gel on windows | 17% | TRYsis program |
| 2019 | Li et all. (Li, 2019) | Ningbo | Green roof, vertical landscaping | 2.8% | Design builder program |
| 2019 | Esen (Esen, 2019) | Antalya | Shading elements, TS-825 insulation | 56.70% | Green building studio |
| 2019 | Fabbri et al. (Fabbri, 2019) | Parma (Italy) | Microclatic with the color of the courtyard and interior walls | ---- | Envi-met simulations |
| 2019 | Rivera-Gomez et al. (Rivera-Gómez, 2019) | Spain | Courtyard aspect ratios | --- | Experimental |
| 2019 | Çimen (Çimen, 2019) | --- | Vermicute plant and normal wall insulation | 66.70% | Practical |
| 2019 | Koç (Koç, 2019) | Antalya | Shading elements, window-wall ratio | (6-14)% Primary energy savings | Matlab coding |
| 2019 | Koyun and Koç (Koyun, 2017) | Antalya | Wall and window ratio and material, Roof height | --- | Simulations |
| 2019 | Cüce et al.(Cüce, 2019) | --- | PV glasses, active glass systems | (16-22)% | Simulations |

## 2. Software and Program Selection

Today, energy efficient buildings are mainly concerned only with existing standards when defining their performance. This approach is correct only in terms of official competence to fulfill the requirements of legal rules and give people confidence. Beyond these facts, today's energy efficient buildings should be known not only in the context of current technology, but also in terms of the evolution of the equipment and design concept used in sync with the modernity of science. This article provides a historical and painstaking presentation of the evolution of techniques and concepts that led to energy efficient buildings as we know them today. An overview of the modern approach to the design of the main elements of such buildings is also presented. The article carries out a review of the current state of energy efficient buildings in terms of definitions and characteristics (Kishore,2022).

In these studies, used mainly two simulation programs to optimization the perfect design of passive design in the new proposal building design of Selçuk university technology faculty based on annual weather conditions of Konya city.

### 2.1. Autodesk Revit 2020

The Autodesk revit2020 program, the building will be drawn exactly like the three-dimensional real one. It is a 3D building design and analysis program (Yori,2019). In selecting the objects related to the shell of the building and determining their thermal properties, either the elements will be loaded and used by using the ready data in the program, or a new thermal property definition will be made using the same substance.

The location and the weather files data (climate conditions) of the building selected if the values of some world cities were contained from the program or determined with the Google Earth program to use the exact climate of the building and automatically updated to the Revit program (Figure 1).


**Figure 1** The selection of the position of building from google-earth web sites (Earth, 2022).

NASA weather data were selected from NASA POWER web sites to their accessibility, because it was long-term consistency, with suitability for building simulations of energy at regions where high-resolution local meteorological data are limited weather characteristics or artificial data available. While national and global meteorological data were considered, the NASA data web-set provided a very comprehensive and actually annual weather data compatible with both Autodesk tools as Revit 2020 and Ecotect environment simulations program (Figure 2).

Finally, before calculating the cooling and heating energy consumption of the building, it is necessary to divide the building into different thermal areas (energy model). After division, the program will draw the energy model of the building, calculating the energy consumption for each area in one way or another.

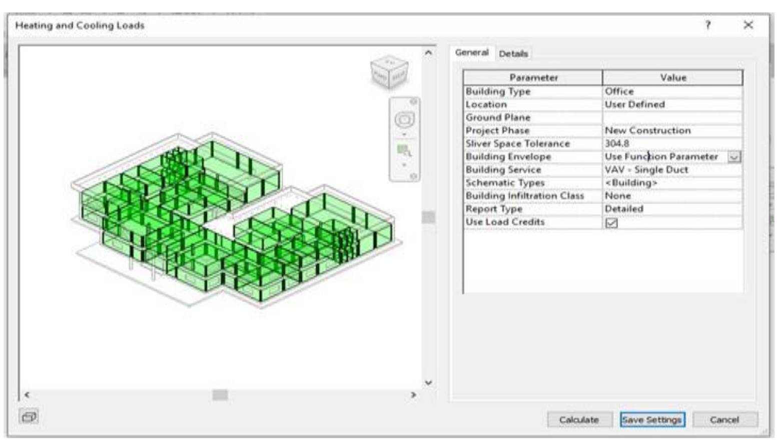


**Figure 2** Energy models of building (Tulukçu, 2021)

### 2.2. Ecotect 2011

It is a software program used for analysis purposes for environmentally friendly buildings in the early stages of the design of buildings (Figure 3). Although Ecotect 2011 is the latest version and after 2016 Autodesk has replaced energy simulation and alternative solutions with Revit with internet-based green building studio, it is still the Ecotect program in the design stages of the building. Due to the gradual behavior of passive designs, the fusion of the building with the climate, and the optimization of the daylight and shading parameters gained by the building, and the behavior of the designs very efficiently at the stage of characteristics of the designs, 3D drawing drawings are still used in passive design analysis in the market and in the relevant sector, although they are simple compared to Revit and other architectural programs.

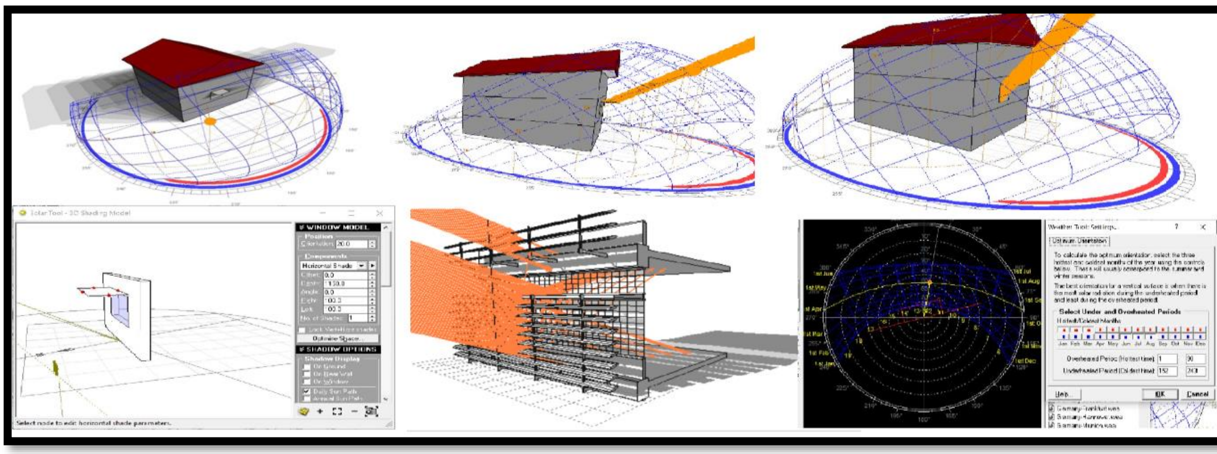

**Figure 3** Passive design analysis by ecotect 2011 (Issa et all, 2009).

## 3. Methodology

### 3.1. Proposed Inside of Shells program Energy efficiency portability analysis

The material used in the square and cylindrical shells of the proposed new technology faculty was analyzed on the web for energy efficiency realization in energy optimization trials, and the Autodesk-inside program analyzed the newly proposed shells through the Autodesk-inside program.

The was primarily for detailed energy modeling of each envelopment and annual heating and cooling with total load calculations by Autodesk Revit 2020, while employed in the early design stages of early design to evaluate solar analysis, daylight usefully, shading performance, and orientation sensitivity. The geometric models were kept consistent across both platforms to ensure comparability of results. The key assumptions were related to properties of material, schedules of occupancy, and gains of internal load were harmonized between the two programs.

As a result of the analysis of energy transport in the use of passive, active (shell and insulation materials) and renewable energy systems, we understood the possibility of obtaining a higher (plus) building at zero (-31.8 kW/m$^2$/year) in the square shell, but the possibility of obtaining a building close to the cylindrical building (10.2 kW/m$^2$/year).

### 3.2. Passive Designs Analysis

### 3.2.1 Orientation

To select the best direction of educational building we have two sets of iteration shown below:

#### 3.2.1.1. Normal Directions

In the first set of orientation analysis, we rotate the building to normal eight directions (North, Northeast, East, East South, South, West South, West, West North) for each proposal building (Figure 4 and 5).

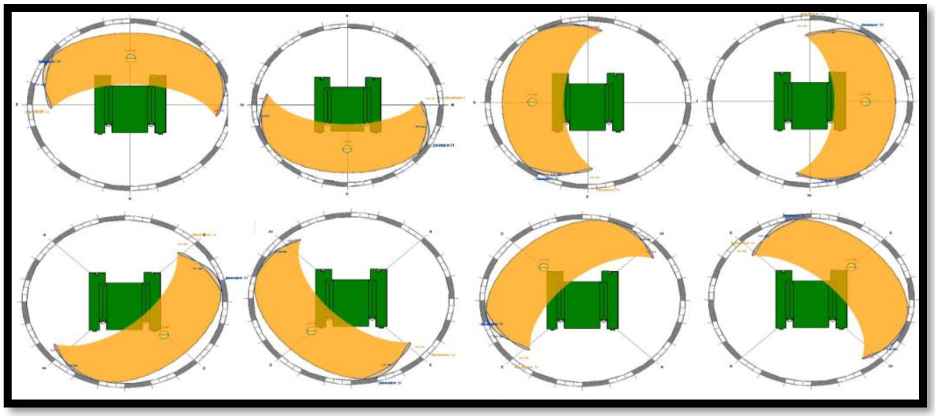

**Figure 4** Normal direction analysis of cubic shell

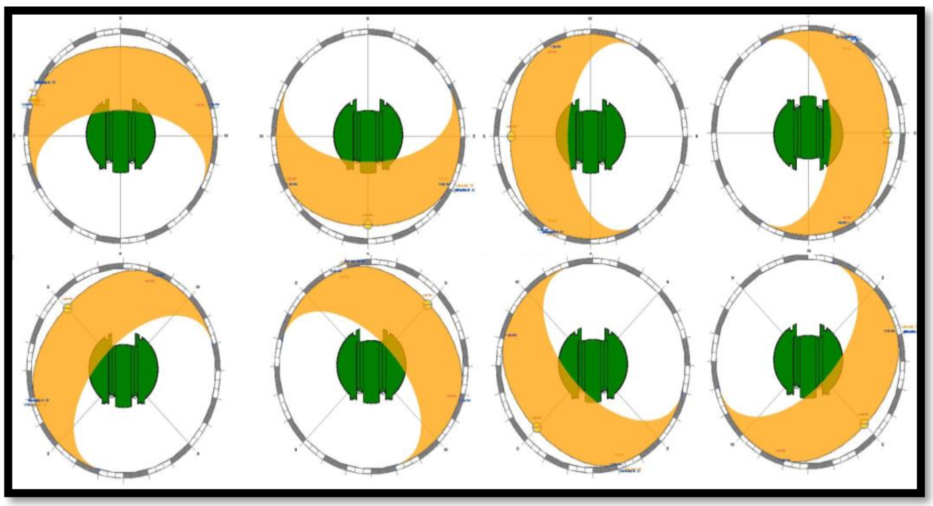

**Figure 5** Normal direction analysis of cylindrical shell

#### 3.2.1.2. Exact Directions

As a result of the optimum direction analysis in the Ecotect program, it was aimed to find the most productive direction by comparing the building with the most bearish direction (150 – 210) degrees and the energy consumption and south direction of 13 iteration construction with a difference of 5 degrees between these degrees (Figure 6 and 7).

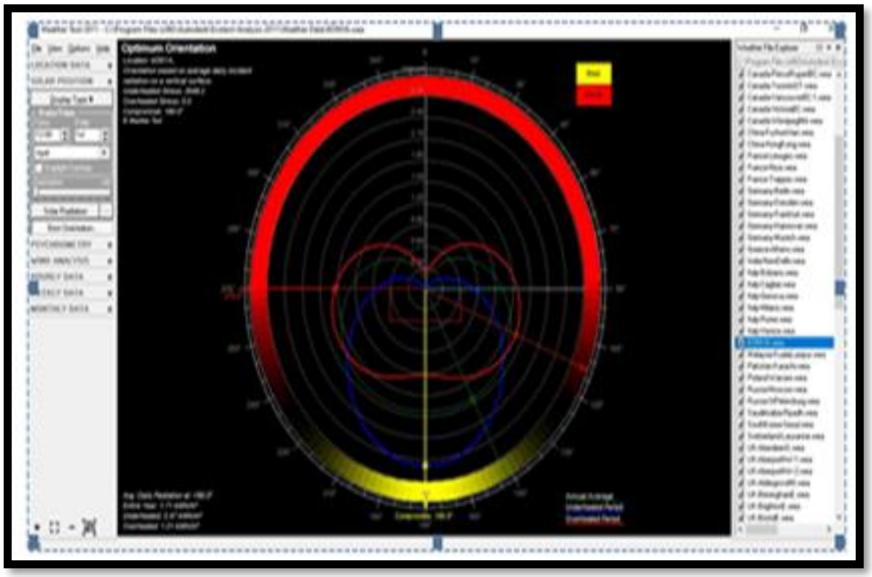

**Figure 6** Selection of the optimum orientation of buildings by Ecotect 2011

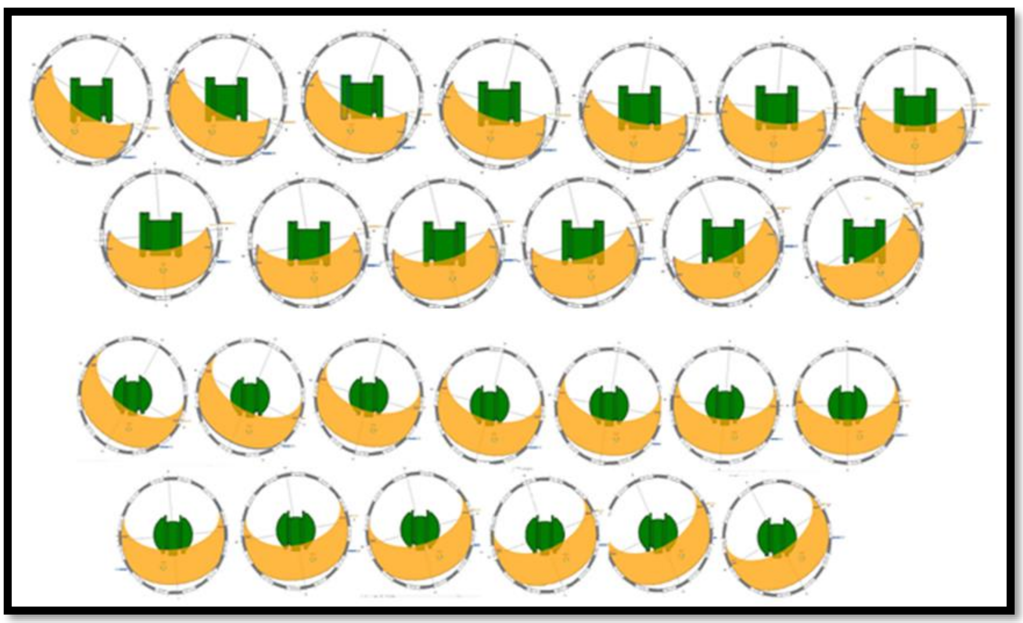

**Figure 7** The Analysis of the exact optimum direction between (150-210) degree

### 3.2.2. Double Shall Walls

To reduce the heat loss or gain from outside walls used two types of double walls to achieved increasing in thermal resistance by utilizations the air buffered between walls by two methods, firstly by direct air gape (23 mm) between two walls because generally the walls thickness in turkey cannot be excess 64 mm, secondly by installed the greenhouse façade on building walls (Figure 8).

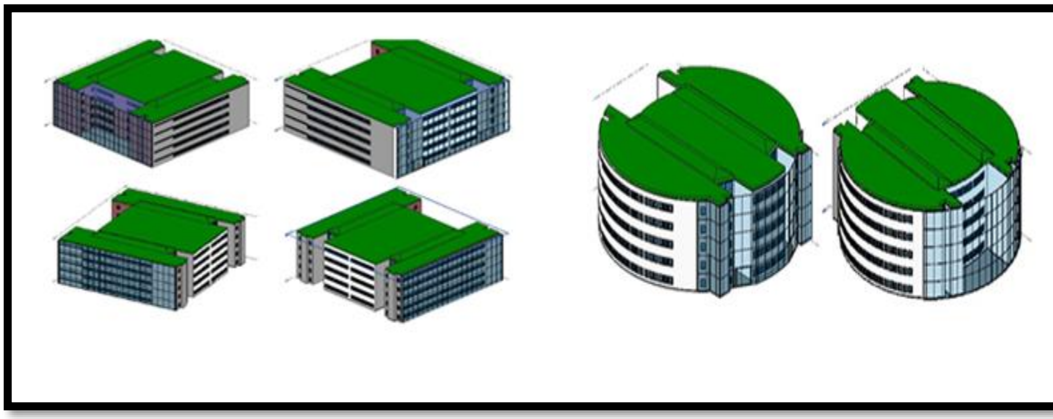

**Figure 8** The green house wall installed in buildings model.

In the last stage, since the air-tampered walls between the air walls are more efficient, both shells connected in terms of efficiency level in the walls used the attach certification on the double facades.

1. Less efficient composition of two
2. Least + most bearish efficient combination
3. Best + second moment less efficient combination
4. Top month two-yielding combination
5. Second efficient + second bad combination
6. Second best + worst efficient combination

### 3.2.3. Window wall ratios (WWR)

In order to select the most efficient window-to-wall ratio in the four directions in the proposed shells, the amount of energy saving with the original shell window-to-wall ratio was calculated after placing the same type of window volumes used in the old building in the wall-to-window ratio on each façade (0%, 25%, 50%, 75%, 100%) in accordance with the ratios and analyzing the energy consumption (Figure 9 and 10).

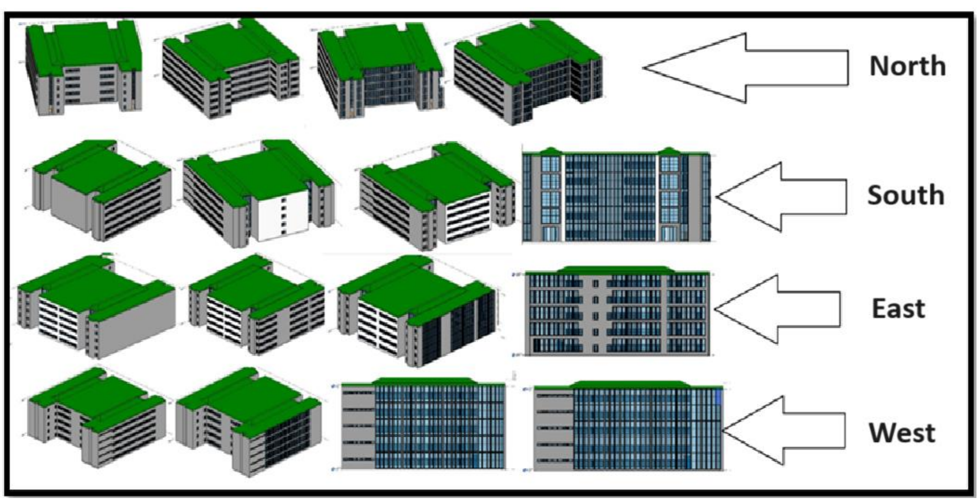


**Figure 9.** Images of sample trials on wall window proportions cubic shells

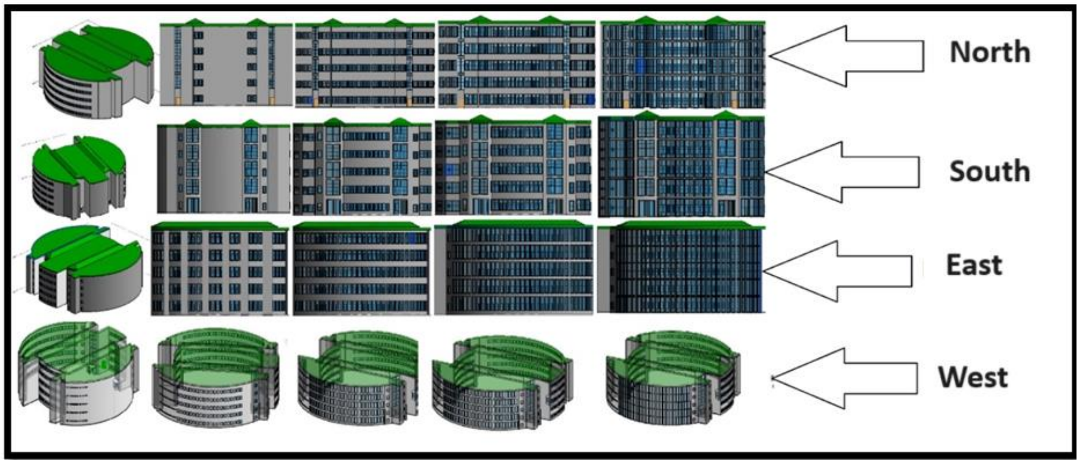


**Figure 10** Images of sample trials on wall-window proportions in cylindrical shell

### 3.2.4. Courtyard

In the proposed cubic and cylindrical buildings, the new building was modeled and used in two ways, using the area of approximately (25 × 6.3) m, which is the middle part of the original building, as a courtyard to increase the natural daylight and passive air conditioning of the building, and taking the aspect ratio of approximately 2:1 (Figure 11)

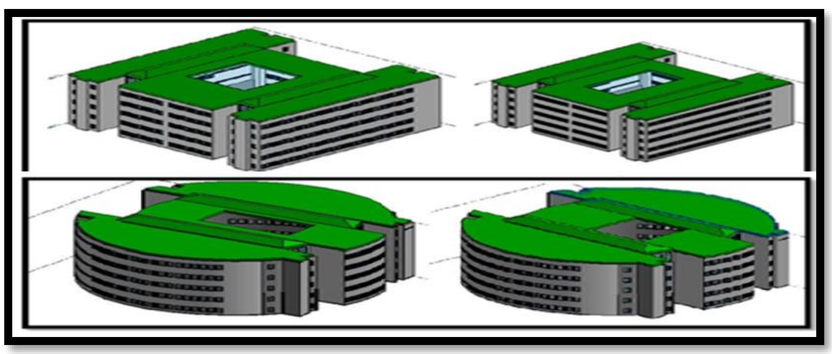

**Figure 11** The shapes of courtyard

### 3.2.5. Landscaping and Surrounding Area

Since Selçuk University is in the south/west part of Esentepe and generally pine trees are grown in the green areas and gardens of Selçuk University, the height of the pine trees will be between (1.5 - 4.35) m by placing them as green and garden areas in the north and east directions around the newly proposed Technology Faculty. In our study, the average height of the trees was taken as 3m, with a gap of 2.75m between the trees in four rows of zigzag shape. The simulation was made to ensure that pine trees provide windbreaks in the winter and shade unwanted solar radiation in the mornings in the summer. On the other hand, the western perimeter of the building was chosen as a parking area for vehicles and areas for students to sit and do other activities between classes.

### 3.2.6. Shading Elements

Windows and controls, including shading systems, are among the most critical building components that affect both energy consumption and occupant comfort. With the increasing demand for fully glazed facades, designers and researchers are actively developing advanced control strategies to address the challenges posed

by excessive sunlight penetration and heat transfer. These strategies aim to align the benefits of natural light with the need for comfortable indoor environments and reduced energy consumption(Nazari, 2023).
Extended shading elements are used on the horizontal window, which is most conveniently used on the south facade. The following formula is used to obtain the optimum length (Woh) of window shading elements.

$$\text{Who} = \frac{H\ oh}{SLF} \quad (1)$$

### 3.2.7. Internal Conditions Parameters

#### 3.2.7.1. Internal Temperature

In order to understand how much increase or decrease is possible in the internal temperature levels used, the comfort temperature levels that can be kept in annual, winter and summer seasons were analyzed in the psychometrics chart (weather characteristics chart) in the Konya climate in the Ecotect program.
After analyzing the air internal temperature comfort levels with Ecotect, reducing the adjustment level from 21.11°C to 20,19,18 and 17°C in winter and increasing the internal temperature from 23.33°C to 24 and 25°C in summer, energy saving in square and cylindrical buildings is achieved. analysis was made.

#### 3.2.7.2 Building Tightness

In all experiments carried out in the Revit program, the density level of the building was taken as medium. Since the building density level is an important parameter in the air conditioning energy of the building's internal air due to its direct effect on the air leakage rate in the shell, square and cylindrical building shells were analyzed as dense (tied) and poor (lose) shells reaching the middle level.

## 4. Results and Discussion

This part presents the investigation results by simulation tools of the proposed envelopes of building and passive design parameters strategies, focusing on their energy consumptions impact like annual heating, and annual cooling with total air-conditioning energy loads demand.

### 4.1 Orientation

#### 4.1. 1.Normal Directions

The results of the experiments, as a result of comparing the buildings with the original south orientation, were obtained as the South/North direction in the total air conditioning energy savings of the two shells shown in Figure 12 and 13 , and although the total energy savings between the north and south directions were 1.69% in the square shell and 0.42% in the cylindrical shell, the north direction in heating energy was achieved. and the same amount of consumption was obtained in the southern regions.

In both shells, the worst directions were the west and north-west and northwest directions, with energy consumption increases between -9.82% and -8.78% in the square shell and -11.16% and -9.56% in the cylindrical shell, respectively.

In the second stage, after obtaining the best direction for heating, optimum direction analysis was carried out in the Konya climate with the Ecotect program to find the exact direction in the energy efficiency of the building.

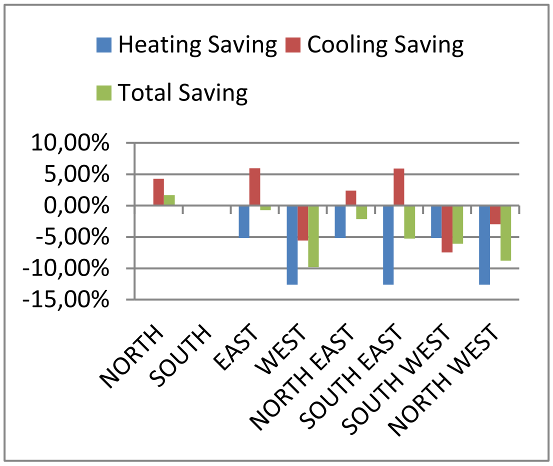


**Figure 12** The energy saving of exact direction analysis in Cubic Shape Building

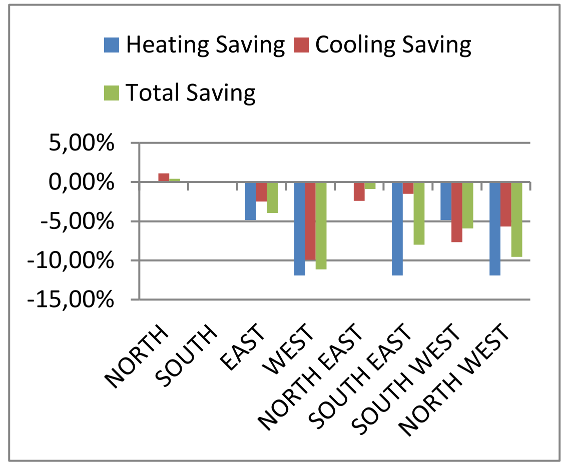


**Figure 13** The energy saving of exact direction analysis in Cylindrical Shape Building

### 4.1.2 Exact Direction

As a result of the directional analysis in the square shell Show in Figure 7, there is a difference between the savings increase in the cooling load in the minus direction of 180 degrees (East direction) depend in suggestion at Figure 6 and the increase rate in every 5 degrees in the direction of increasing to 180 degrees (West direction) without any change in the heating load (0.7-1.15). It was calculated as (0.38-0.238).

Likewise, the cylindrical shell (150-210) degrees does not see any difference in the heating load or savings load, and even though there is a small difference in the energy consumption for every 5 degrees in cooling, the total energy saving, and increase is calculated between (0.34 - 1.84) %. He realized that there was little difference in the rate of energy consumption between the degrees (Figure 14 and 15).

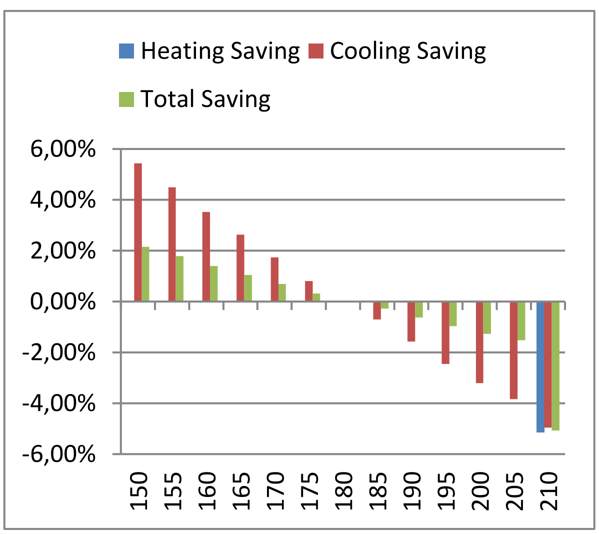


**Figure 14** The energy saving in exact directions angle between (150-210) of Cubic Shell

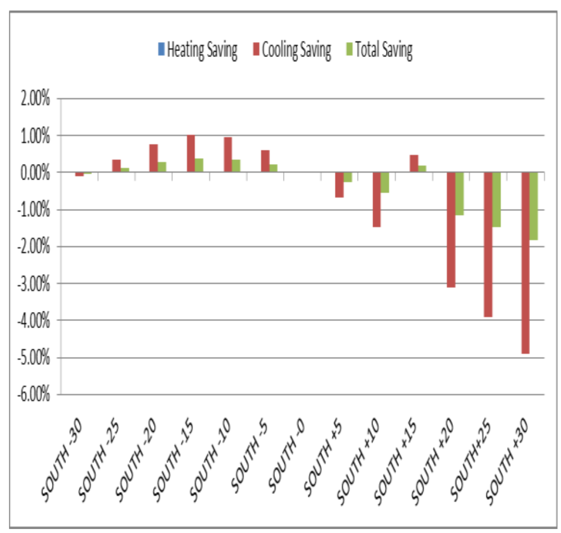


**Figure 15** The energy saving in exact directions angle between (150-210) of Cylindrical Shell

### 4.2. Double Shall Walls

The highest energy efficiency in the square shell is on the south facade, where the total air-conditioning energy saving was 15.3% in the use of air-buffered walls, and in the use of greenhouses, the total savings on the south facade decreased by 8.23%. On the other facades, in the use of air-buffered double walls in the north 14.74%, in the east 10.24% and in the west 7.89%. They ranked second, third and fourth by achieving total energy savings.

On the other hand, the maximum total air conditioning energy savings on the other facades, except for the south facade, did not exceed 3.87% on each facade. In the Cylindrical Shell, the maximum savings in the double walls with air buffers were 14.36%, and in the northern, eastern and western walls, it was calculated as 11.99%, 8% and 7.05% (Figure 16 and 17)

In the last stage, since the air buffered walls between the air walls are more efficient was shown in figure 8, the results were obtained when the analysis was performed on the double facades of both shells depending on the efficiency level in the walls.

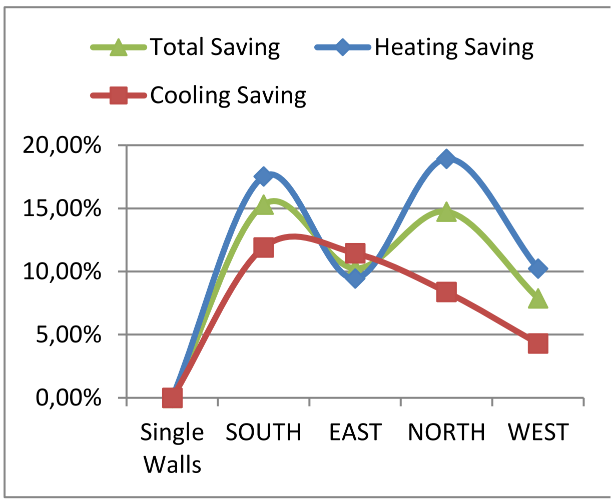


Figure 16 Energy saving in air-buffered double shell on facades of Cubic Shell

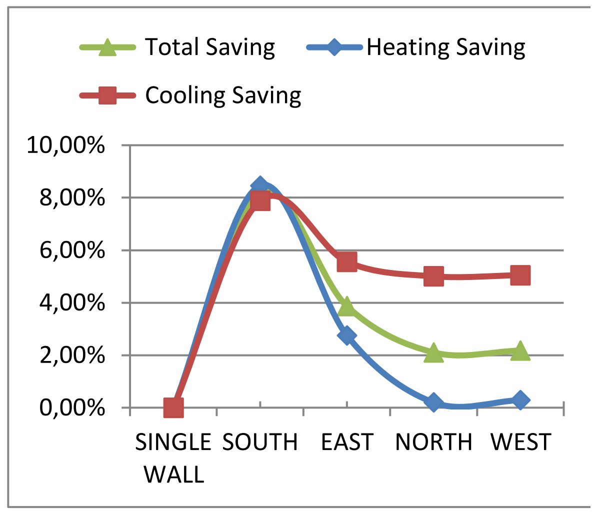


Figure 17 Greenhouse on the facades of the square shell energy-saving in the Double Shell

### 4.3. Window Wall Ratio (WWR)

As a result of the experiments, among the five wall ratios, the maximum energy savings were 2.86% and 0.97%, respectively, with 75% wall and window ratio on the south walls of buildings with square shown in figure 9 and cylindrical shown in figure 10 acceptances. At the second level, on the western walls, with a window wall ratio of 25%, the total energy saving is 1.68% in the square shell and 0.78% in the cylindrical shell, and on the eastern walls, with a similar window-wall ratio on the western walls, it is 0.39% and in the cylindrical shell it is 0.69%. savings in energy have been achieved. Finally, savings of 0.1% to 1.01% were calculated for square and cylindrical shells on walls without windows in the north direction.

### 4.4. Court-Yard

According to the analysis results, the heating loads in square and cylindrical shells are 3 times higher than the cooling load amounts in Konya, and since the courtyard is generally used in hot and hot dry regions, if the courtyard is used in Konya, it causes an increase in the total annual consumption energy due to the increase in heating energy. It was understood that the use of the courtyard was inefficient like shown in Figure 11.

### 4.5. Landscaping and Surrounding Area

In the use of landscape design, a 2.6% - 3.38% increase in heating load and a 7.27% - 8% increase in cooling energy were observed in square and cylindrical shells, resulting in a 4.787% - 4.98% increase in the annual air conditioning total energy.

### 4.6. Shading Elements

As a result of the analysis of the use of south facade shading systems, although the most efficient shading element in the square shell is the most efficient with a roof extension with a saving of 7.69% in terms of cooling load, the most efficient shading element in terms of total annual air conditioning load is 2.12% in terms of total annual air conditioning load, due to a -2.02% consumption increase in heating load. has provided.

### 4.7. Visual Analysis

In order to understand the effect of the sun path on the building in winter and summer seasons, Revit sun path feature is utilized, and it is seen that the landscape distribution is utilized as shading elements on all windows on the first floor of the square building, and a lower shading area is provided due to the rounding of the cylindrical facades on the south / north side (Figure 19).

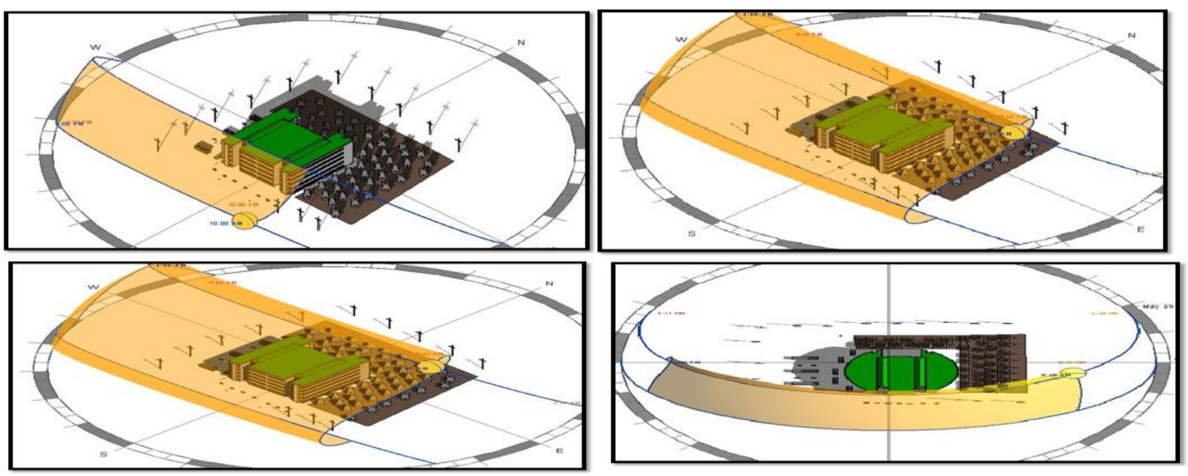

**Figure 19** The visual analysis of landscape shading effect by Ecotect

### 4.8. Internal Condition Parameters

#### 4.8.1. Temperature

By keeping the cooling and heating at two degrees each (19 °C, 25 °C) and (18 °C, 24 °C) at the indoor air settings, 12.47% and 9.68% savings were achieved in the total air conditioning energy of the building.

#### 4.8.1. Tightness

As a result of the analysis, when making a mid-level comparison in the square shell, a -4.698% consumption increase in total air conditioning energy was calculated due to a -7.26% increase in energy consumption in the heating load in the poor shell and a -0.809% increase in cooling. At the strict level, total air conditioning energy was obtained as 1.65% due to a 3.023% saving in heating load and a -0.437% increase in energy consumption in cooling.

### 4.9. Discussion and Validating the Result with Similar Studies in Literature

Saffar, in his study conducted by he worked on a $100m^2$ detached house model in the local architectural conditions used in Konya and Kirkuk, using the Design Builder drawing program and energy plus energy calculation simulation programs in nearly zero energy buildings. In the study, they calculated the savings in heating, cooling and lighting energy and proved that the maximum annual consumption fell below 44 kWh (Saffar, 2022).

In our study, in the square shell in its original form (513.184 kWh), it showed a decrease in annual energy consumption of approximately 41kWh, whereas in the cylindrical shell we proposed, we calculated that it was decrease of approximately 46 kWh was achieved. Although there was little difference in the study by Sarah Waleed SAFFAR based on weather conditions in 2021, the results were very close, and the building used was due to the square shell.

In the Bolu Gülezler Mansion reconstruction by (Akşit & Metin, 2022), they first worked on modeling in terms of heating energy and saving the energy consumed through the Design Builder program. In their study, they achieved 25% savings in total heating energy because of optimization of the building's form, orientation and spacing (surrounding land) (Akşit, 2022).

In our study, since Konya and Bolu are in the same 3rd geographical region in Turkey, the building shape (square 20.76%, cylindrical 99%), the building perimeter (square 2.6%, cylindrical 3.38%) and the internal temperature drop of the building in terms of heating savings in the same parameters were affected. Savings between (1.7-2.35) % were achieved. In the study conducted in Bolu, results showing interconnectedness were obtained due to the gain in heating load between (25.06-25.63) in the same scenarios used in this thesis. Since building shape is also effective in geographical regions, it would be a correct approach to choose building shapes according to geographical regions.

Yazgan and Koçak Soylu, compared the energy and cost savings in an anonymous hotel in Antalya in order to increase energy efficiency, considering the internal comfort parameters. By calculating a maximum of 7452250 kWh/year and a minimum of 500524 kWh/year in the energy consumed for 5 years in the occupancy rates and internal parameters in the years 2017, 2018, 2109, 2020 and 2021, they calculated a cost saving of 33256 TL/year in the hotel due to approximately 7% energy saving in interior comfort ((Yazgan & Koçak Soylu, 2022)).

In our study, energy savings in interior comfort parameters (indoor temperature, heating and building density ratio) were achieved between 2.07% and 4.245%, and the total annual energy saving was calculated as approximately 6%. The reason why it is 1% lower than the study conducted in Antalya is due to the fact that Antalya is a hot and humid region, and the cooling load is higher, and it plays a big role in the calculations. Accordingly, optimizing cooling loads in such climates would be a more accurate approach.

## 5. Conclusion

The early-stage decisions at results demonstrate related to building shape and form by using integration of passive designs technology can significantly increase saving in energy demand to cooling and heating process in educational buildings, offering by guidance practically for architect's design and planners in same climatic regions.

In the cubic shell passive design optimization made after the optimization of the parameters in the shell, it is understood that it will contribute to savings in total air conditioning energy of 33.36% in the square shell and 30.9% in the cylindrical shell, as seen in the chart below.

The passive designs are in their optimum state (Facade direction, air buffered double wall, window to wall ratio, building density ratio, shading with landscaping) and in their worst case when the internal air conditioning parameters are used in their optimum form (Internal temperature, Frequency ratio). We can save approximately 86-92% of air conditioning energy and classify it as a building with class B energy or close to zero energy.

Similarly, in the cylindrical shell, 83-91% savings can be achieved in the worst cases when the shell parameters, passive designs and internal air conditioning parameters are used in their optimum forms, and in the square shell, a building proposal with 1-3% lower savings can be achieved.
For future studies if needed to may extend this investigation work firstly by incorporating life-cycle cost analysis and thein occupant behavior modeling, and lastly validation using measured operational data from existing and proposal buildings.

**Declaration of Ethical Standards**

As the authors of this study, we declare that he complies with all ethical standards.

**Credit Authorship Contribution Statement**

A.N.Hussein: Software, Validation, Formal analysis, Writing -Original Draft, Visualization.
M.Acaroğlu: Investigation, Resources, Writing, Review & Editing, Supervision, Funding acquisition.

**Declaration of Competing Interest**

The authors declared that they have no conflict of interest.

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**Data Availability**

No datasets were generated or analyzed during the current study.

## References

Abazari T, Potvin A, Demers CM, Gosselin L. A biophilic wellbeing framework for positive indoor-outdoor connections in energy-efficient Arctic buildings. Building and Environment. 2022; 226:109773.

Acar MC, Celik AI, Kayabaşı R, Şener A, Özdöner N, Özkılıç YO. Production of perlite-based-aerated geopolymer using hydrogen peroxide as eco-friendly material for energy-efficient buildings. Journal of Materials Research and Technology. 2023; 24:81-99.

Akşit ŞF, Metin CA. Isıtma Enerjisi Korunumunda Etkili Olan Tasarım Değişkenlerinin Değerlendirilmesi: Bolu Gülezler Konağı. 2022.

Al-Yasiri Q, Szabó M. Numerical analysis of thin building envelope-integrated phase change material towards energy-efficient buildings in severe hot location. Sustainable Cities and Society. 2023; 89:104365.

Alharbey RA, Daqrouq KO, Alkhateeb A. Energy exchange of inserting eco-friendly bio phase change material into the vertical walls to make the buildings energy efficient. Journal of Building Engineering. 2022; 56:104777.

Alhasnawi BN, Jasim BH, Alhasnawi AN, Hussain FFK, Homod RZ, Hasan HA, et al. A novel efficient energy optimization in smart urban buildings based on optimal demand side management. Energy Strategy Reviews. 2024; 54:101461.

Anwar M, Rasul M, Khan M. Performance Analysis of rooftop greenery systems in Australian subtropical climate. Energy Reports. 2020; 6:50-6.

Ates F, Woo B-H, Jang C, Kim HG. Enhancing cementitious composites with PCM-impregnated cork granules for sustainable and energy-efficient building elements. Construction and Building Materials. 2024; 416:135071.

Brambilla A, Sangiorgio A. Mould growth in energy efficient buildings: Causes, health implications and strategies to mitigate the risk. Renewable and Sustainable Energy Reviews. 2020; 132:110093.

Bui D-K, Nguyen TN, Ghazlan A, Ngo TD. Biomimetic adaptive electrochromic windows for enhancing building energy efficiency. Applied Energy. 2021; 300:117341.

Buratti C, Moretti E, Belloni E, Zinzi M. Experimental and numerical energy assessment of a monolithic aerogel glazing unit for building applications. Applied Sciences. 2019;9(24):5473.

Carlander J, Thollander P. Drivers for implementation of energy-efficient technologies in building construction projects—Results from a Swedish case study. Resources, Environment and Sustainability. 2022; 10:100078.

Chen X, Abualdenien J, Singh MM, Borrmann A, Geyer P. Introducing causal inference in the energy-efficient building design process. Energy and Buildings. 2022; 277:112583.

Cuce E, Cuce PM, Alvur E, Yilmaz YN, Saboor S, Ustabas I, et al. Experimental performance assessment of a novel insulation plaster as an energy-efficient retrofit solution for external walls: A key building material towards low/zero carbon buildings. Case Studies in Thermal Engineering. 2023; 49:103350.

Cüce APM, GÜÇLÜ T, BEŞİR AB, Erdem C. Enerji Verimli Binalar İçin Sürdürülebilir Ve Çevre Dostu Pencere Ve Cam Teknolojileri: Son Gelişmeler Ve Uygulamalar. Uludağ Üniversitesi Mühendislik Fakültesi Dergisi. 2019;24(3):503-22.

Çimen S. Investigation of The Availability of Vermiculite In Thermal Insulation Technologies. Sürdürülebilir Mühendislik Uygulamaları ve Teknolojik Gelişmeler Dergisi. 2019;2(2):87-93.

Earth g, cartographer selcuk university teknology faculty, Konya, Turkey. Konya2022.

Esen S. Enerji etkin bina tasarım modeli: yüksek lisans tez, Eğitim Enstitüsü; 2019.

Excel SGb. The Graph gemneration by excel program based on simulation data. 2020 ed2022.

Fabbri K, Pretelli M, Bonora A. The study of historical indoor microclimate (HIM) to contribute towards heritage buildings preservation. Heritage. 2019;2(3):2287-97.

Geçimli M. Tasarım Sürecinin Deneyimlenmesinde Oyun ve Oyun-Tabanlı Uygulamalar. Mimarlık Planlama ve Tasarım Alanında Araştırma ve Değerlendirmeler- I: Gece Kitaplığı; 2020 2021. 21-42 p.

Issa RR, Suermann PC, Olbina S, editors. Use of building information models in simulations. Proceedings of the 2009 Winter Simulation Conference (WSC); 2009: IEEE.

Jankovic A, Goia F. Characterization of a naturally ventilated double-skin facade through the design of experiments (DOE) methodology in a controlled environment. Energy and Buildings. 2022; 263:112024.

Kishore P, Selvam N, Didwania S, Augenbroe G. Understanding BIPV performance with respect to WWR for energy efficient buildings. Energy Reports. 2022; 8:1073-83.

Koç SG. Sıcak-nemli iklim bölgelerinde gölgeleme elemanı kullanımının bina enerji performansına etkisinin incelenmesi: Fen Bilimleri Enstitüsü; 2019.

Koyun T, Ersin K. Bir Binanın Değişken Cam ve Dış Duvar Tiplerine Göre Pencere/Duvar Alanı Oranlarının Bina Isı Kayıplarına Etkisi. Mühendis ve Makina. 2017;58(688):1-14.

Liu MM, Mi B. Life cycle cost analysis of energy-efficient buildings subjected to earthquakes. Energy and buildings. 2017; 154:581-9.

Li H, Wang S. Coordinated optimal design of zero/low energy buildings and their energy systems based on multi-stage design optimization. Energy. 2019; 189:116202.

Li Z, Chow DH, Yao J, Zheng X, Zhao W. The effectiveness of adding horizontal greening and vertical greening to courtyard areas of existing buildings in the hot summer cold winter region of China: A case study for Ningbo. Energy and Buildings. 2019; 196:227-39.

Long LD. An AI-driven model for predicting and optimizing energy-efficient building envelopes. Alexandria Engineering Journal. 2023; 79:480-501.

Müller TM, Sachs M, Breuer JH, Pelz PF. Planning of distributed ventilation systems for energy-efficient buildings by discrete optimisation. Journal of Building Engineering. 2023; 68:106205.

Muslim SA, Hachem-Vermette C. Towards the development of energy sharing methodology between different buildings for high efficient neighborhood design. Energy Conversion and Management. 2023; 283:116901.

Nazari S, MirzaMohammadi PK, Sajadi B, Ha PP, Talatahari S, Sareh P. Designing energy-efficient and visually-thermally comfortable shading systems for office buildings in a cooling-dominant climate. Energy Reports. 2023; 10:3863-81.

Reddy VJ, Ghazali MF, Kumarasamy S. Advancements in phase change materials for energy-efficient building construction: A comprehensive review. Journal of Energy Storage. 2024; 81:110494.

Rivera-Gómez C, Diz-Mellado E, Galán-Marín C, López-Cabeza V. Tempering potential-based evaluation of the courtyard microclimate as a combined function of aspect ratio and outdoor temperature. Sustainable Cities and Society. 2019; 51:101740.

Saffar SWA. Yaklaşık Sıfır Enerjili Bir Bina tasarımı için enerji performansı modellemesi ve simülasyonu: Necmettin Erbakan Üniversitesi Fen Bilimleri Enstitüsü; 2022.

Self Di. Drawing of Selcuk university teknology faculty by autodesk revit 2020. Auto desk Student version. [Drawing an simulation]. In press 2022.

Soliman A, editor Minimizing Energy Consumption of Educational Buildings by Testing Alternatives of Green Envelopes in Alexandria. International Conference on Green Urbanism; 2022: Springer.

Soorige D, Karunasena G, Kulatunga U, Mahmood MN, De Silva L. An energy culture maturity conceptual framework on adopting energy-efficient technology innovations in buildings. Journal of Open Innovation: Technology, Market, and Complexity. 2022;8(2):60.

Stine DJ. Autodesk Revit for Architecture Certified User Exam Preparation (Revit 2020 Edition): SDC Publications; 2019.

Tulukcu DA. Örnek Bir Binanın Isıl ve Çevresel Performansının Autodesk Revit Simülasyon Programı ile Analizi. Avrupa Bilim ve Teknoloji Dergisi. 2021(23):197-206.

Wasim M, Wang K, Yuan Z, Jin M, Abadel A, Nehdi ML. An optimized energy efficient design of a light gauge steel building. Case Studies in Construction Materials. 2023;19:e02398.

Yazgan SÖ, Koçak Soylu S. Otellerde enerji verimliliğini iyileştirmeye yönelik çeşitli yaklaşımların tasarruf oranlarına etkisinin karşılaştırılması: Antalya örneği. 2022.

Yori R, Kim M, Kirby L. Mastering Autodesk Revit 2020: John Wiley & Sons; 2019.

Zhou S, Razaqpur AG. Efficient heating of buildings by passive solar energy utilizing an innovative dynamic building envelope incorporating phase change material. Renewable Energy. 2022; 197:305-19.