Bioclimatic Design and Advanced Strategies' Impacts on Energy Performance of Residential Buildings

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Abstract. The construction sector covers a significant percentage of the energy consumption in the world. Human actions on energy use are gradually being identified as the primary cause of climate change, global warming, and significant environmental changes. In response to these problems, the concept of sustainability has become one of the most crucial solutions for reducing the construction sector's high energy demand. Bioclimatic architecture is a sustainability approach that brings forward the strategies of vernacular architecture into the present by adapting the building systems to their climatic and topographic conditions. It is also an option for affecting the building sector in Turkey to prevent energy overconsumption by initiating efficiency improvements. This study examines the design requirements and physical characteristics of a building in the Marmara region (Turkey) and how these features impact its overall energy consumption. The case study building is a 9 storey apartment building in Erenköy, İstanbul, located in the humid-temperate climatic region of Turkey. Since that, the design scenarios consisting of different bioclimatic strategy combinations are chosen about this climatic region's features. The software DesignBuilder, empowered with an EnergyPlus simulation engine, is used to test the design scenarios' impacts on final energy consumption. The present condition of the case study building is monitored to calculate its energy consumption to evaluate the difference between the design scenarios. The impact on the primary energy use of different passive strategies, HVAC systems, electricity generation, and a bioclimatic set of standards implemented to the building was then assessed using parametric analysis of various scenarios. The results showed that the combination of passive strategies with earth pipe installation and thermal assisted radiant floors reduced the energy use by approximately 30%. Passive strategies significantly impact the residential building systems' energy efficiency showing how bioclimatic architecture criteria can meet the requirements of high-efficiency standards in the humid-temperate climatic region of Turkey.

Keywords. Bioclimatic Architecture, Residential Buildings, Building Energy Performance, Advanced Energy Efficiency Strategies
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1. Introduction

In Turkey, rapid population growth in the last two decades has resulted in a significant increase in energy demand. Nonetheless, Turkey's economy is still driven by fossil fuels, with considerable reliance on imports, particularly oil and gas (93% and 99%, respectively). As a result, Turkey's reforms and policies have focused on liberalization and domestic production. Turkey has made expanding local exploration and production a priority to lessen its reliance on imported oil and gas. Given the constraints on upstream supplies and the need to reduce emissions, Turkey should focus on cost-effective demand-side initiatives like efficiency improvements [1].

There are numerous ways to reduce the high energy consumption of the construction sector by following efficient passive system strategies on the buildings. Bioclimatic architecture is vital to increase the overall energy efficiency, achieve thermal occupancy comfort, use renewable energy sources and local materials while considering cost-efficiency.

Throughout history, people have been trying to adapt their buildings to the environment to form better living conditions [2]. Since each climatic region has its unique conditions, the bioclimatic design strategies vary in every location. Local environmental factors greatly influence the implementation of thermal design solutions for buildings.

A psychrometric chart is analyzed in ClimateConsultant with Istanbul's obtained weather data. The outside temperatures rise in the summer, whereas in winter, the temperatures may be low, with high precipitation creating discomfort. In temperate-humid climate regions, natural ventilation is possible throughout the year. However, heat recovery is recommended as a means of energy conservation. The earth can be utilized as a heat source for a heat pump or renewable cooling. Surface cooling systems may be proper to operate. Direct radiation accounts for a higher share of total radiation than diffuse radiation. Solar thermal systems can heat water and provide supplemental heating during transitional months. Integrated photovoltaic systems are also helpful [3].

In the literature, bioclimatic design strategies have been studied in different climate regions and locations. Buildings' energy performances and the impacts of passive cooling, heating, and ventilation strategies on occupants' comfort are analyzed for different locations. Bioclimatic research was done on traditional Turkish houses and outdoor spaces [4]. Other studies focus on feasible climate control approaches and techniques that have been used in vernacular architecture with bioclimatic methods and combining them with the innovative and parametric design processes, addressing current sustainability needs in case studies [5 and 6]. The use of passive system strategies' impacts on building energy performances is also studied [7].

This paper aims to assess the energy performance of a residential building located in the temperate-humid climate region, Istanbul, Turkey, by comparing the energy efficiencies between the existing situation of the building and the same building with bioclimatic strategies implemented. It is expected to see the impacts of bioclimatic strategies and innovative systems' assistance on building energy performance.

2. Research Methodology

This study uses DesignBuilder (v7.0.0.116) to analyze the effects of bioclimatic strategies and various building HVAC systems on the energy efficiency of a residential apartment in the Marmara region. The building model with envelope characteristics and HVAC systems is created to conduct energy simulations.

The obtained weather data for İstanbul, Turkey, is used. The thermal zones are based on the occupancy use, activity, and schedule (Figure 1.b); living room (lounge), kitchen, bedroom, and circulation area. The key characteristics assigned to each zone are (Figure 1.c.) HVAC zones are assumed: the living rooms and bedrooms are conditioned with radiator heating and PTAC; kitchens are conditioned only with radiator heating.

Occupancy activity is entered for using lighting and miscellaneous equipment as domestic family schedules, including 08:00-12:00 and 16:00-23:00 for weekdays and 08:00-23:00 for the weekends. According to Turkish regulations, the room temperatures in the independent sections heated by central systems should be adjusted to be at least 15 °C [8]. For heating, the night setback temperature is set at 15 °C, and during the day, the setpoint temperature is at 21 °C [9], [10]. The minimum supply air temperature for the cooling system operation (PTAC) is set at 15 °C, and the setback temperature is 28 °C to 25 °C. The internal doors of the floors are assumed to be open through the simulation hours.

An analysis is conducted for various HVAC system designs and bioclimatic strategies' impacts on overall energy consumption. The measures for simulations are selected according to the climatic data input from the literature review. Firstly, the envelope characteristics and the HVAC systems are simulated. Subsequently, the passive design integrations (building volume/area, window/wall, and orientation variations) are combined with HVAC systems. Annual primary energy usage (kWh/m^2) and carbon dioxide emissions are calculated for scenarios' comparison. The site-to-source conversion factor is accepted as 2,36 for electricity end-use and 1,00 for natural gas end-use. The annual primary energy usage (EP) (kWh/m^2) in this study is calculated considering electricity end-use (EE), natural gas end-use (EG) as in the equation below;

$$EP=[(EEx2{,}36)+(EGx1{,}00)]/\text{net conditioned area}$$

The carbon dioxide emissions are calculated as the following equation;

$$CO_2=[(EEx0{,}626)+(EGx0{,}234)]/\text{net conditioned area}$$

2.1 Case Study Building Presentation

Güney Apartmanı (Fig. 2a) is a residential apartment building with 9 storeys and 16 flats located in Erenköy, Istanbul, Turkey. The layout is rectangular, with a fire staircase mass joined.

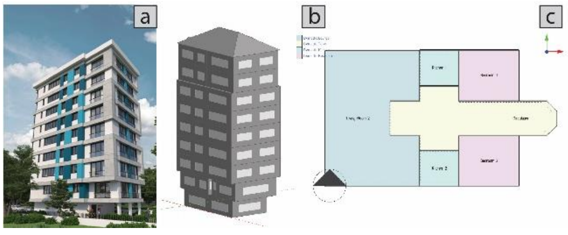


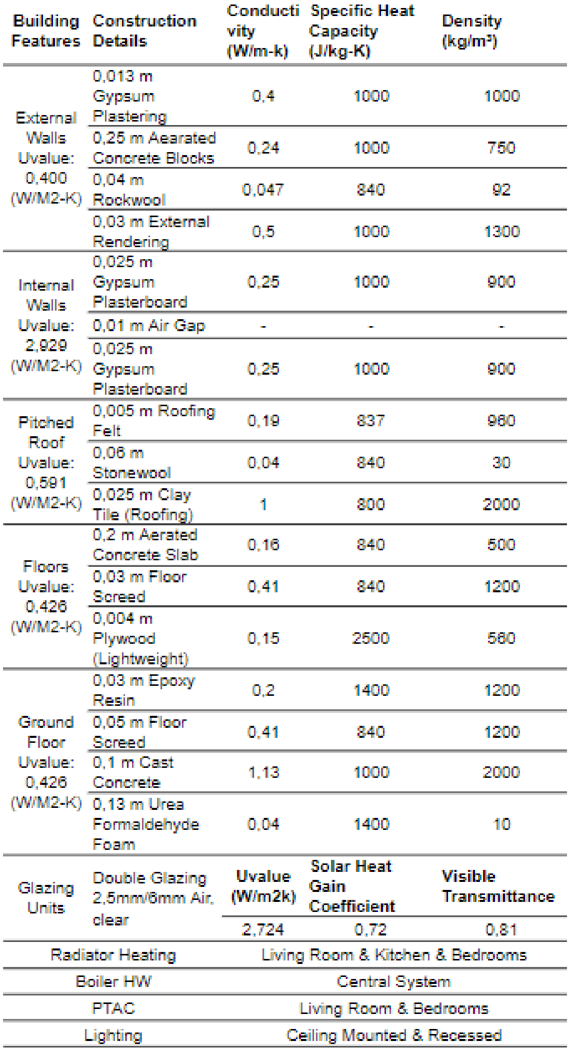
Fig. 1 - Case Study Building Render (a), Building Energy Model (b), Floor Zones in DesignBuilder (c).

The case study building was constructed in 2018 within the urban transformation process of Istanbul led by the municipality. The ground-level floor is being used as an entrance lobby. Each floor above the ground floor has two symmetrical flats consisting of one bedroom, one living room, one bathroom, and one kitchen. The total building area is 1496 m². The net conditioned building area is 1385 m² which was included in the calculations of primary energy usage of the building in energy simulations.

The window to wall ratio of the building is 30%. The building entrance (narrower façade) is oriented towards the west direction.

The rooms on the plan layout are concatenated towards the East and the West (Fig. 1.c). The humid weather can specify a temperate-humid climate in almost all seasons, rainy days in summers, and temperate winter months. The maximum temperature is around 28 °C in summer and 10 ° C in winter, whereas the minimum temperature is approximately 20 °C in summer and 5 °C in winter times [11].

Tab. 1 – Base Case Envelope and HVAC System Features



Building Features	Construction Details	Conductivity (W/m-k)	Specific Heat Capacity (J/kg-K)	Density (kg/m³)
External Walls Uvalue: 0,400 (W/M2-K)	0,013 m Gypsum Plastering	0,4	1000	1000
	0,25 m Aearated Concrete Blocks	0,24	1000	750
	0,04 m Rockwool	0,047	840	92
	0,03 m External Rendering	0,5	1000	1300
Internal Walls Uvalue: 2,929 (W/M2-K)	0,025 m Gypsum Plasterboard	0,25	1000	900
	0,01 m Air Gap	-	-	-
	0,025 m Gypsum Plasterboard	0,25	1000	900
Pitched Roof Uvalue: 0,591 (W/M2-K)	0,005 m Roofing Felt	0,19	837	960
	0,06 m Stonewool	0,04	840	30
	0,025 m Clay Tile (Roofing)	1	800	2000
Floors Uvalue: 0,426 (W/M2-K)	0,2 m Aerated Concrete Slab	0,16	840	500
	0,03 m Floor Screed	0,41	840	1200
	0,004 m Plywood (Lightweight)	0,15	2500	560
Ground Floor Uvalue: 0,426 (W/M2-K)	0,03 m Epoxy Resin	0,2	1400	1200
	0,05 m Floor Screed	0,41	840	1200
	0,1 m Cast Concrete	1,13	1000	2000
	0,13 m Urea Formaldehyde Foam	0,04	1400	10
Glazing Units	Double Glazing 2,5mm/6mm Air, clear	**Uvalue (W/m2k)**	**Solar Heat Gain Coefficient**	**Visible Transmittance**
		2,724	0,72	0,81
Radiator Heating		Living Room & Kitchen & Bedrooms		
Boiler HW		Central System		
PTAC		Living Room & Bedrooms		
Lighting		Ceiling Mounted & Recessed		

The building design is a synthesis of many decisions analyzed from the characteristics of the weather conditions that can be aimed at lowering energy use of the building by additional passive strategies and innovative tactics.

2.2 Model Calibration

For the calibration of the simulations and the present energy consumption of the case study building, the accessible electricity bill of February-March 2021 and the gas bill of August-September 2020 are obtained.

In the yearly analysis of the base energy simulation in DesignBuilder, electricity end-use per conditioned building area accounts for 33,18 kWh. The conditioned area of each flat of the case study building is 70 m². The electricity end-use of a flat is 2310 kWh in a year. For a month, it equals 192,5 kWh. The actual electricity use on the bill is 202,29 kWh. The accuracy difference between simulation and bill of electricity is 4,79%.

The natural gas end per condition conditioned building area accounts for 35,98 kWh. For each flat, the natural gas end-use for a year equals 2518 kWh and 209,9 kWh for a month. The obtained natural gas use on the bill is 221,89 kWh. The accuracy difference between simulation and bill of natural gas is 5,03%.

2.3 Case Study Building's Energy Consumption

The base case is simulated in current conditions (base simulation), including all energy performance indicators to compare each scenario's efficiency. The envelope features are entered (Table 1). The heating system of the building is a radiator heating system. The cooling system is packaged terminal air conditioner (PTAC). The glazing system is double glazing (3 mm panels- 6 mm air gap). The electricity end-use (EE) for the current situation is 38331,83 kWh. The natural gas end-use (EG) is 41575,94 kWh. The total energy for heating with natural gas is more than the total energy for cooling and lighting demand. The net conditioned area for the building is 1155,36 m².

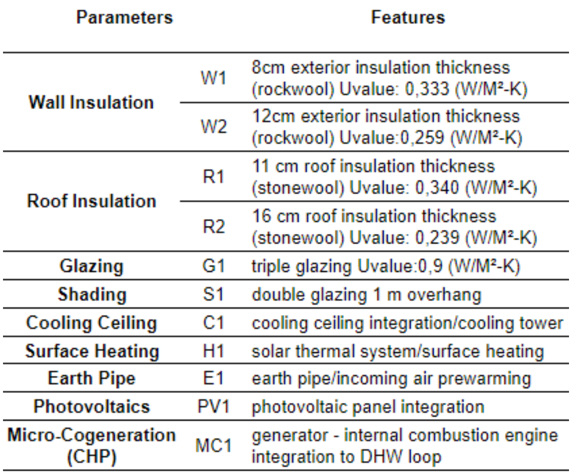
For the current situation's calculation, the annual primary energy usage (EP) is equal to 114,283 kWh/m². The simulations after are compared with this primary energy consumption (EP) value.

3. Results and Discussion

3.1 Envelope and HVAC System Scenarios

Different envelope characteristics and HVAC systems were tested after determining the case study building's energy performance (Table 2). Initially, building envelope characteristics, the exterior wall, roof insulations' thickness variations, and glazing unit type were indicated and simulated separately.
Among advanced energy systems, the shading panel integration, cooling ceiling with cooling tower, solar thermal system assisted surface heating, heating and

cooling with earth pipe installation are selected to be analyzed in the study [3]. Additionally, power generator systems, electricity generation with photovoltaics, and micro-cogeneration system (CHP), which produces electricity and provides heat recovery, are modeled and tested [12].



Parameters		Features
Wall Insulation	W1	8cm exterior insulation thickness (rockwool) Uvalue: 0,333 (W/M²-K)
	W2	12cm exterior insulation thickness (rockwool) Uvalue:0,259 (W/M²-K)
Roof Insulation	R1	11 cm roof insulation thickness (stonewool) Uvalue: 0,340 (W/M²-K)
	R2	16 cm roof insulation thickness (stonewool) Uvalue: 0,239 (W/M²-K)
Glazing	G1	triple glazing Uvalue:0,9 (W/M²-K)
Shading	S1	double glazing 1 m overhang
Cooling Ceiling	C1	cooling ceiling integration/cooling tower
Surface Heating	H1	solar thermal system/surface heating
Earth Pipe	E1	earth pipe/incoming air prewarming
Photovoltaics	PV1	photovoltaic panel integration
Micro-Cogeneration (CHP)	MC1	generator - internal combustion engine integration to DHW loop

Tab. 2 - Envelope and HVAC System Scenarios

For the shading panel integration (S1), the glazing units are kept as double glazing, U-Value: 2,724, 3 mm panels, and 6 mm air gap with 1 m overhangs integrated. With this method, the simulated total electricity end-use is 32855,53 kWh, whereas the total natural gas end-use is 49221,5 kWh. The calculated primary energy use is 109,7 kWh/m^2. This method performs more efficiently than the base simulation (114,28 kWh/m^2) (Figure 2).

For the cooling system, instead of the packaged terminal air conditioner (PTAC), the cooling ceiling integration (C1) with the cooling tower had been used with a regular radiator heating system. The cooling ceiling usage simulation resulted in the total electricity end-use of 38257,02 kWh total natural gas end-use of 43845,98 kWh. The calculated primary energy use is 116,09 kWh/m^2. This system performs less efficiently than the base simulation.

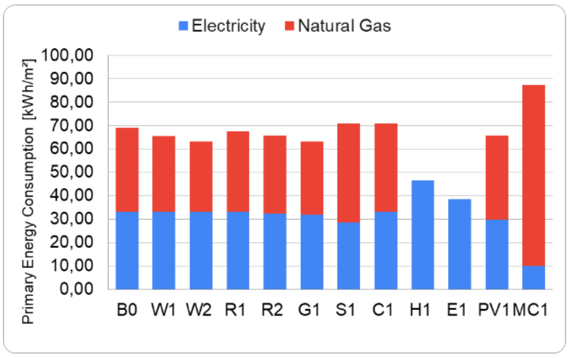


Fig. 2 – Natural Gas and Electricity Primary Energy Consumptions under different Envelope and HVAC Scenarios

Another strategy for bioclimatic architecture is to use renewable energy sources. In this context, solar energy is selected for the simulation H1. This simulation tests surface heating instead of radiator heating with a central hot water system with a boiler. The hot water source for surface heating corresponds with solar thermal energy. Compared to the base simulation, there is no need for natural gas for heating besides electricity. A solar thermal panel on the South facing roof surface and storage are used. The system resulted in 53.639 kWh total electricity end-use and zero natural gas use. In this case, the primary energy calculation resulted in 109,99 kWh/m^2.

The simulation with earth pipe integration (E1) is selected to compare the radiator heating system's energy efficiency and earth pipe usage's energy efficiency. The pond heat exchanger template is selected in the earth pipe scenario (E1) for the ground heat exchanger. The pipes are connected to a chilled water plant loop with a chiller system and a hot water loop with a heat pump system. The supply pipes are connected to the radiant surfaces conditioned zones. In this way, the heating and cooling demand corresponded with a passive system strategy of using the temperature difference of earth and outside temperature. The earth pipe integration simulation (E1) resulted in 44481,69 kWh total electricity end-use and zero natural gas consumption. It is the common conditioning system for heating and cooling demand. The calculated primary energy use is 90,86 kWh/m^2. This method performs much more efficiently than the base simulation.

The photovoltaic panel integration (PV1) and five photovoltaic panels (5m x 0,548m) were placed on the South facing roof surface. These panels generate 3889,389 kWh of electricity. It is reduced from the total electricity end-use (38.467 kWh). The remaining electricity used is 34578 kWh for the building. The calculated primary energy use is 106,62 kWh/m^2 for this case. Compared to the base simulation, this method performs efficiently but not significantly by itself (Figure 3).

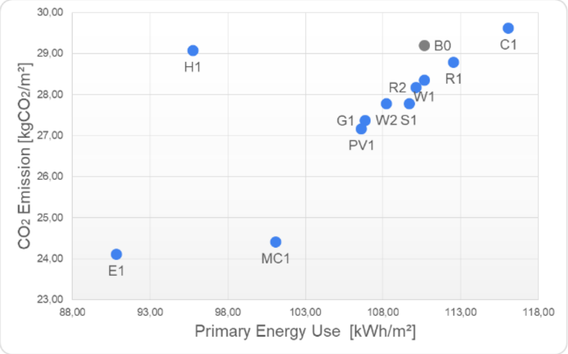


Fig. 3 – Primary Energy Consumptions vs. CO_2 Emissions under different Envelope and HVAC Scenarios

The micro-cogeneration system (MC1) is a DHW loop hot water tank heated by a hot water loop with a natural gas sourced generator incorporated and functioning as a heating source. Suppose the heat produced by the generator is insufficient to fulfill the heating load. In that case, the hot water tank contains an internal built-in gas boiler that provides backup heating for the building heat requirement. The generator type in this study is an internal combustion engine. The generator is operated to supply the building's thermal demand and generates electric energy as a product [13]. This method consumes more natural gas than a boiler system (Figure 4). However, the satisfied electricity load is %76,22 from fuel-fired power generation, and water-side heat recovery is %24,34. Consequently, the primary energy use is 101,12 kWh/m², and CO2 emission is 28198,47, which is an efficient system (Figure 3).

In these initial scenarios, the earth pipe installation and micro-cogeneration system result efficiently compared to buildings' existing situation (approximately %10 decreases in final energy end-use).

3.2 Bioclimatic Design Parameters Scenarios

A quantitative study is performed to determine the influence of alternative HVAC system configurations and bioclimatic parameters used in the building on overall energy consumption. After the envelope combinations (W1R1G1, W2R2G1), these two packages (P1, P2), and other passive strategies; the building volume/area ratio (P3, P4), building orientation (P5, P6), window to wall ratio (P7, P8) are combined with advanced system scenarios (Figure 4). Seventy final scenarios are combined and analyzed for the comparison of different configurations.

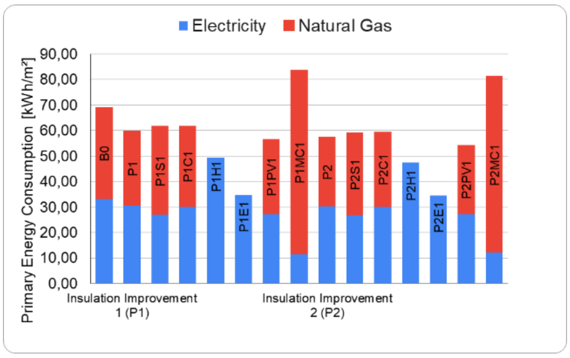


Fig. 4 - Natural Gas and Electricity Primary Energy Consumptions under different Building Envelope Improvements

The shading devices integration with first envelope parameters (P1S1), which uses shading panels (1m overhang), resulted in 18,81% less total electricity end-use and 2,83% less total natural gas end-use. The thicker insulation (P2S1) resulted in 19,53% less total electricity end-use and 9,39% less total natural gas end-use. In comparison, the difference is minor between the scenarios. The differentiation between these packages is the insulation thicknesses. Natural gas demand is more reduced with a thicker insulated envelope than the base simulation. The shading devices provide a reduction in building cooling energy demand causes a decrease in electricity usage. Thus, the thicker insulation may be efficient for heating and cooling energy demand with shading devices used in buildings.

The chilled ceiling with a cooling tower is tested instead of air conditioning units for cooling the building (P1C1, P2C1). The system combined with the first insulation scenario resulted in 9,15% less electricity end-use and 11,89% less natural gas end-use. In contrast, the second scenario resulted in 9,69% and 18,17% fewer end uses. The electricity reductions are not high compared to the present condition for the cooling need. If this system is chosen for cooling interiors, thicker insulations may be required in terms of energy saving.

For analyzing the envelope measures with heating system variations, the heating floor with the solar thermal system usage (P1H1, P2H1) is tested instead of natural gas sourced radiators. This system resulted in more (42,94% and 42,94% respectively) electricity use, but no natural gas consumption. This scenario's primary energy uses are 116,72 and 111,92 kWh/m². Compared to base case conditions, the primary energy calculation of P1H1 is slightly more. In early design phases, heating floor systems with solar thermal assistance with a well-insulated envelope can be considered instead of radiator heating for this climatic region.

Earth pipe integration (P1E1, P2E1) resulted in similar electricity end-use as the base conditions. The advantage of the system is that it does not consume natural gas. The primary energy use calculations for these simulations' results are 82,22 and 81,45 kWh/m². Compared to the building's present condition, the energy consumption is dramatically reduced. Providing the heating and cooling need of the building, the system can be considered in the early phases of building design for energy efficiency.

Power generative systems' analysis with envelope parameters (P1PV1, P2PV1, P1MC1, and P2MC1) results in less electricity end-use. Photovoltaics' integration reduces the electricity demand by 18,14%, whereas the micro-cogeneration system corresponds to 65,77% of the electricity load. The envelope improvements can be considered since these systems do not reduce heating demand. Overall, the building envelope's insulation improvements positively impact primary energy use and carbon dioxide emissions (Figure 5).

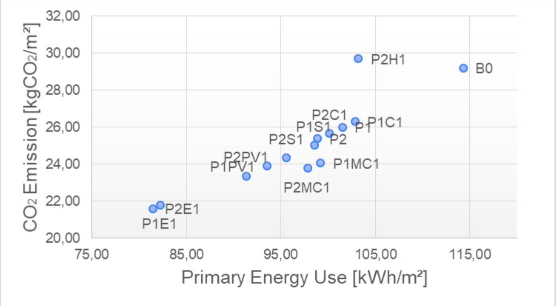


Fig. 5- Primary Energy Consumptions vs. CO_2 Emissions under different Building Envelope Improvements

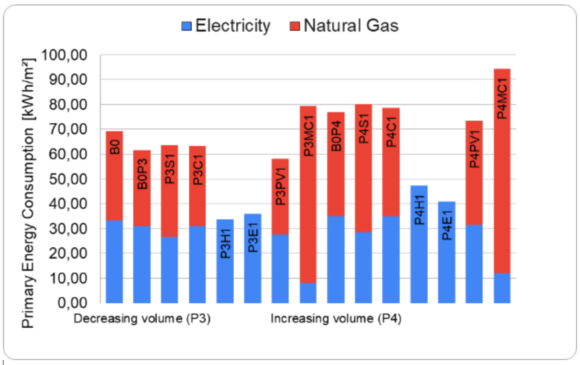


Fig. 6- Natural Gas and Electricity Primary Energy Consumptions under different Building Volume to Area Ratios (V/A)

Building volume to area ratio (V/A) is combined with initial scenarios to evaluate the impact of building volume changes on advanced building systems' energy performance. Firstly, the V/A ratio is decreased by %15. This method is applied to the base scenario (B0P3). The total electricity end-use and the natural gas end-use slightly decreased (6,25% and 15,37%, respectively). Conversely, the increase in V/A with no advanced system used increases energy uses (5,57% EE and 16,11% EG). Next, the method is applied to the HVAC scenarios (Figure 6).

The decrease in the V/A ratio results in 19,62% end-use electricity reduction with shading panels (P3S1) but a 2,91% increase in natural gas end-use. The decline in electricity demand is mainly from the cooling demand. Compared with B0S1, a reduction in the V/A ratio reduces the need for cooling by 9,37%.

The heating and cooling systems, chilled ceiling, radiant heated floors, earth pipe integration performs more efficiently in decreased volumes since the temperature conditioning of interiors need less energy in fewer volumes. The chilled ceiling integration to the base scenario (B0C1) has not affected the primary energy use. On the contrary, the system performs 7,47% less energy consumption in decreased volumes. The P3H1 scenario resulted most efficiently with a 30% decrease in primary energy use. Similarly, the P3E1 scenario outcome presents a reduction of 25,58% primary energy use compared to the base simulation (Figure 7).

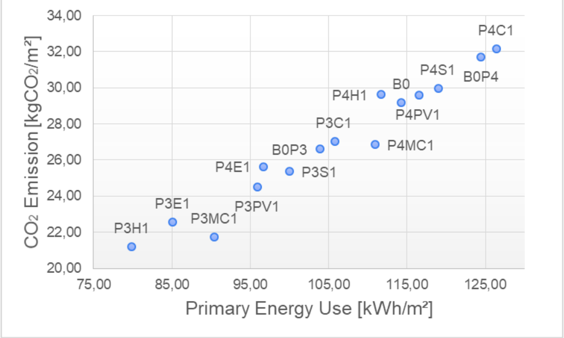


Fig. 7 - Primary Energy Consumptions vs. CO2 Emissions under different Building Volume to Area ratios (V/A)

The photovoltaic panel integration into the V/A ratio reduced model results in 16,40% electricity end-use reduction and 15,37% natural gas reduction. The micro-cogeneration system provides 70,36% of the electricity load. Compared with B0MC1, the system performs 18,89% more efficiently in decreased volume.

Ultimately, the volume decreases resulted in fewer primary energy end-uses and carbon dioxide emissions. On the contrary, the 15% increase in volume has increased the building's primary energy end-use. Higher volume residential buildings may be more efficient with HVAC system improvements (Figure 7).

Another passive strategy tested on advanced systems in this study is the orientation of the building. At the current stage, the building's larger façade is facing the South direction. To examine the HVAC strategies performances, the building is rotated between 30°-90° angles in four steps. The significant differences that occurred (45° and 90°) are presented in Figure 8. Initially, the 45° change in orientation is applied to the base simulation. The electricity end-use is almost resulting no change. In contrast, the heating demand of the building is slightly increased and caused a minor (4,14%) increase in natural gas end-use.

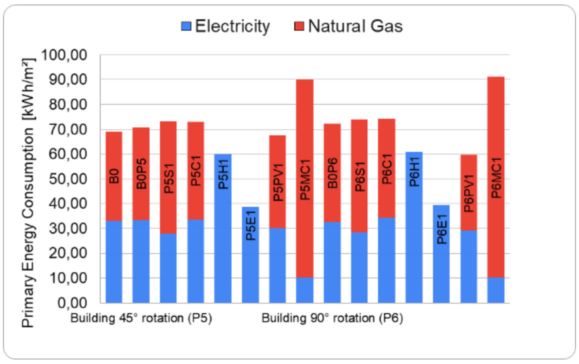


Fig. 8 - Natural Gas and Electricity Primary Energy Consumptions under different Building Orientations (45°, 90°)

The shading device applied South-West facing façade (P5S1) results in a 15,67% decrease in EE and a 25,60% increase in EG. On the other hand, the 90° rotation (P6S1) resulted in similar outcomes (-14,25%, +26,42%). Hence, the heating demand is in correlation with the building orientation. The Southern orientation performs more efficiently with

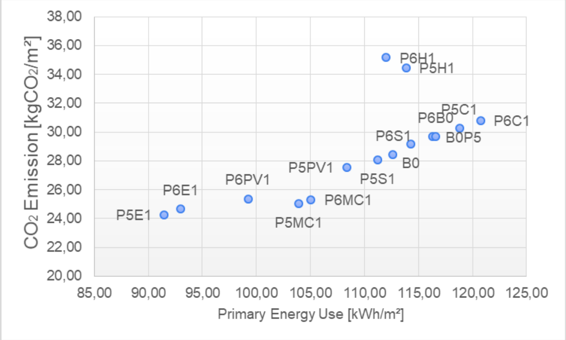


Fig. 9 - Primary Energy Consumptions vs. CO2 Emissions under different Building Orientations (45°, 90°)

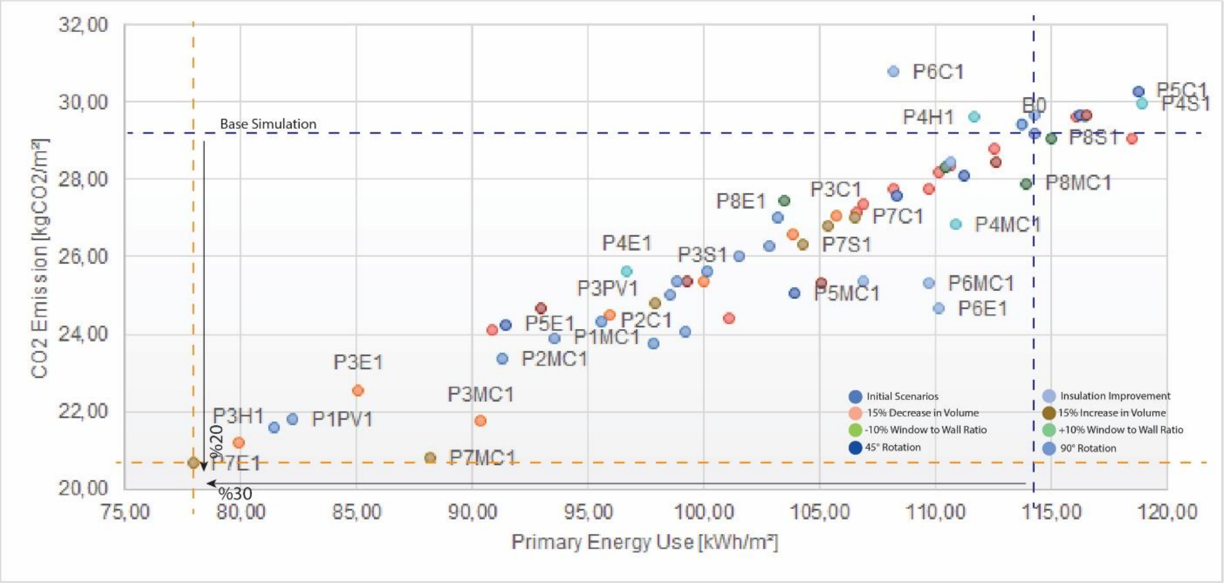


Fig. 12 – Bioclimatic Strategies Impacts on Primary Energy Use and C0$_2$ Emissions

shading elements. That being the case, this method presents more significant outcomes with HVAC system variations.

The chilled ceiling systems result in minor differences in electricity end-use. However, the natural gas end-use outcomes 15,18% less demand for heating energy than shading device scenarios. Compared to B0P5 and B0P6, the chilled ceiling implementation scenarios result in 3,97% and 5,68% more primary energy end-use. This cooling system method should be considered with optimum building orientation. The earth pipe integrated scenarios (P5E1, P6E1) result in 16,80% and 18,74% more electricity end-use. Indeed, the primary energy uses in both scenarios are approximately 20% less than the base scenario since the thermal loss is more with increased window dimensions. Given these points, the 45° and 90° rotation from the South direction lead to more primary energy end-use and CO$_2$ emissions. Despite this result, some systems in this study, like shading elements, earth pipe usage, and generative power systems, still present less primary energy use than the base simulation (Figure 9).

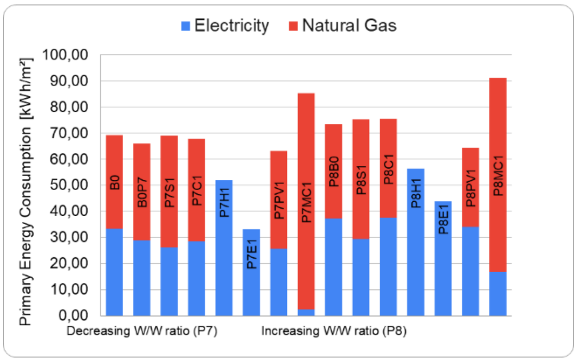


Fig. 10 – Natural Gas and Electricity Primary Energy Consumptions under different Window to Wall Ratios (±10%)

The window to wall ratio differentiations' impacts on energy performance is analyzed as a final step. The case study building has a 30% window to wall ratio. First, this ratio is decreased by 10% (P7). This method decreased 7,82% in electricity end-use and 8,23% in natural gas end-use. Second, the ratio is increased by 10% (P8). The obtained outcomes present an 8% increase in energy end-uses. These variations are applied to initial system simulations (Figure 10). The shading devices' combinations with the first window to wall ratio (P7S1) have a 21,72% decrease in electricity end-use, whereas this scenario results in a 19,54% more natural gas end-use. When the ratio is increased to 40% (P8S1), the decrease in electricity end-use is smaller (11,65%). In this scenario, the natural gas end-use is 27,33% more.

The chilled ceiling integration scenario's (P7C1) outcome presents a 14,11% decrease in electricity end-use compared to the base scenario, and the natural gas end-use differs 9% more. If the window-wall ratio is increased (P8C1), these differentiations are not majorly changed. The earth pipe integrated scenarios (P7E1, P8E1) result in 16,80% and 18,74% more electricity end-use. Indeed, the primary energy uses in both scenarios are approximately 20% less than the base case (Figure 11). The CHP system performs best when the thermal loss by windows is minimized.

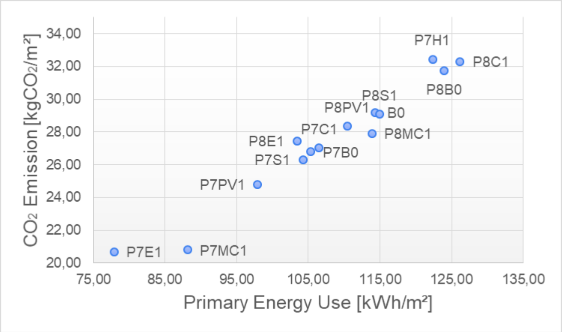


Fig. 11 – Primary Energy Consumptions vs. CO$_2$ Emissions under different Window to Wall Ratios

(±10%)

The most efficient scenario in envelope improvements is earth pipe installation (P2E1) with 28,72% reduction in primary energy use and 25% reduction in C02 emission. In -10% V/A scenarios, solar-assisted radiant floor usage (P3H1) performs the best with reducing primary energy usage by 30% and C02 emission by 27,82%. The building orientation efficiency is the best when the larger façade is oriented towards the South. The variations in degrees may increase the primary energy by 4% (P5C1). In -10% W/W scenarios, the earth pipe usage decreases the primary energy by 31,81% and C02 emission by 29,19%. Overall, amongst the bioclimatic strategies, the decrease in the W/W ratio performs the best (Figure 12).

4. Conclusion

One of the most critical challenges in contemporary architecture is to design high-performance buildings. Bioclimatic strategies can harmonize buildings with the climate, thus conveniently improving building performance. The analyzed parameters by bioclimatic principles influence the control of all factors related to energy conservation. As a result, there is a need for optimizing and estimating the performance of the bioclimatic design criteria, particularly during the early design phase. The dynamic simulation calculations performed for the case study reveal that a suitable design for a bioclimatic building may easily lead to achieving the requirements for an energy-efficient building. The findings also highlight the need to analyze passive methods with building systems to optimize energy savings. Variations in window dimensions and building volume among bioclimatic strategies create the most significant changes. It was also shown that, notably in a humid-temperate climate, renewable solar energy could be a critical source in lowering the energy demand for heating. The solar-assisted radiant floor integration and surface heat exchanger (earth pipe installation) reduced the primary energy use, around 30%. The contributions of photovoltaic panels and savings in micro-cogeneration systems are also significant in reducing energy consumption by power generation. This framework, however, solely pertains to building energy performance analysis. The bioclimatic strategies' impacts on thermal comfort and cost efficiency should be considered in future studies.

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6. References

[1]Turkey 2021. IEA. Available from: https://www.iea.org/reports/turkey-2021

[2]El-Masry D, Farag E, Salem L, Katafygiotou M. Bioclimatic principles towards sustainable, comfortable and energy-efficient societies. Qatar Green Building Conference 2015 - The Vision. Hamad bin Khalifa University Press. Doi: 10.5339/qproc.2015.qgbc.7

[3] Hausladen G, Saldanha Mde, Liedl P. Building to suit the climate: A Handbook. Basel: Birkhauser; 2012.

[4]Özdeniz MB. Bioclimatic analysis of traditional Turkish houses. Vol. 17, Environment International. Elsevier BV; 1991. p. 325–36. Doi: 10.1016/0160-4120(91)90019-M

[5]Chronis A, Liapi KA, Sibetheros I. A parametric approach to the bioclimatic design of large scale projects: The case of a student housing complex. Vol. 22, Automation in Construction. Elsevier BV; 2012. p. 24–35. Doi: 10.1016/j.autcon.2011.09.007

[6] Convertino F, Di Turi S, Stefanizzi P. The color in the vernacular bioclimatic architecture in Mediterranean region. Vol. 126, Energy Procedia. Elsevier BV; 2017. p. 211–8. Doi: 10.1016/j.egypro.2017.08.142

[7] Ashrafian, T. & Moazzen, N. & Karagüler, M. Wind-catchers' Impact on the Energy Performance of Buildings in Hot & Arid Climate of Iran; 2017.

[8] Heating And Sanitary Hot Water Expenses In Central Heating And Sanitary Hot Water Systems Regulation On Sharing. Official Gazette of the Republic of Turkey. No: 26847.

[9]European Standards. BS EN 16798-1:2019 Energy performance of buildings. Ventilation for buildings Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting, and acoustics.

[10]Turkish Standards Institute. TS 825 - Thermal insulation requirements for buildings. 2008, TSE, Ankara.

[11]Weather Observation Station Data Set - İBB: https://data.ibb.gov.tr/tr/dataset/meteorology-observation-station-data-set

[12]Filoğlu E. Türkiye'de Mikro Kojenerasyon. [retrieved at 2022 Mar 1]. Available from: https://www.emo.org.tr/ekler/1d7156ffb1bc9a4_ek.pdf

[13]Generators - modeling guide. Available from: https://designbuilder.co.uk/helpv6.0/Content/GeneratorsModellingGuide.htm [retrieved 2022 Mar 1]