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RESEARCH ARTICLE

The reduction of energy consumption in sustainable buildings for North Cyprus

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Abstract

Reducing energy consumption in buildings also can be referred to it as increasing the energy efficiency in a building. This study aims to examine the energy performance of buildings in North Cyprus. Three different case studies have been taken into consideration from North Cyprus: a normal villa without any renewable system, a flat with no renewable system, and a villa with a solar system for electricity generation. The energy efficiency of the buildings is evaluated using alternative clean energy systems such as photovoltaic systems. The founding of this study indicates a payback period of 4.5 years for the installation cost of the energy system. Using materials for minimizing the energy consumption in the buildings for example using insulation materials in the construction of a building will reduce the consumption of energy for cooling and heating. The case studies were simulated using SAM software and the obtained results have been compared. The environmental impact has been also taken into consideration where the effect of transforming buildings into sustainable ones is studied and how it would affect the numbers of the carbon footprints in buildings. The study found that the cost difference between insulating walls optimally and not insulating them at all is approximately 6000 euros. The payback period for this investment would be approximately 9 years. The research also calculated the amount of CO_2 emissions, finding that a villa would emit 2154 tons and a flat would emit 1675 tons per month. Increasing energy efficiency in buildings is a fast, cost-effective, and environmentally friendly way to reduce energy consumption.

1. Introduction

Energy is a crucial component of economic growth and development. In today's global marketplace, it is viewed as a vital commodity. As demand for energy continues to increase, it becomes increasingly profitable to shift to renewable sources. This not only helps to meet growing energy needs, but also helps to reduce our reliance on fossil fuels and mitigate the negative environmental impacts of energy production [1]. However, the economic feasibility of renewable energy sources can vary significantly depending on location. In the case of Northern Cyprus, the limited availability of traditional energy sources has resulted in a power generation system that relies heavily on imported fossil fuels. Energy availability is a key factor in determining human well-being, and its improvement is crucial for promoting overall quality of life. However, the rapid growth in energy

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demand is transforming the energy landscape. Conventional energy sources are struggling to keep up with this demand, leading to increased strain on these resources [1, 2]. To address climate change and environmental concerns associated with fossil fuel-based energy generation, governments and utilities are increasingly focusing on expanding the use of renewable energy in their electric systems [2]. The industrial revolution has led to significant changes in the behavior and societal structures of individuals worldwide, resulting in various environmental and socioeconomic trends. One of the major concerns arising from these trends is the potential long-term impacts of climate change and greenhouse gas emissions. To address this issue, the Kyoto Protocol aims to reduce GHG emissions by 5.2% from 1990 levels between 2008 and 2012, taking an important step towards addressing this pressing concern [3]. However, the construction industry has been identified as having significant potential for energy savings, with estimates suggesting that energy efficiency improvements in buildings could result in up to a 40% reduction in global energy consumption [4].

The use of passive and semi-passive technology, along with architectural designs that are tailored to local weather conditions, could be effective in achieving this energy savings potential. The envelope of a building separates the interior and exterior environments and incorporating energy-efficient features in this envelope can help to reduce energy consumption. To prevent overheating during the summer and thermal losses during the winter, it is important to optimize the building's envelope. This can be achieved using energy-efficient materials and construction techniques that help to regulate the temperature and airflow within the building [5, 6]. Maintaining a comfortable indoor environment requires the thermal insulation in the envelope to be evenly distributed [7, 8]. Thermal inertia, on the other hand, is the ability of a material or system to resist temperature changes, and it provide a stable and comfortable environment [7]. The exterior walls and floors of a building are known as the opaque walls. These walls are typically constructed using a combination of thermal insulation materials (such as polystyrene or air gaps) and structural elements (such as brick or reinforced concrete). The thermal conductivity, heat capacity, and density of these materials are important factors to consider when selecting materials for the opaque walls.

The thermal transmission coefficient, or U-value, is a measure of a wall's thermal insulation. It is expressed in units of $W/m^2/K$ and is used to ensure that the thermal insulation of a building meets regulatory standards [9, 10]. Heat-insulating materials can be broadly classified into two categories: traditional materials (such as cork and polystyrene) and new materials (such as vacuum insulators). New heat-insulating materials, such as vacuum insulators, work by reducing the volume and movement of gas molecules using confinement and pressure. Some contemporary insulators are transparent and can be used in a way that is visually unobtrusive, blending seamlessly with the front façade of a wall [8, 10, 11, 12]. While allowing solar radiation to penetrate, this form of insulation nonetheless provides excellent thermal insulation [10].

When it comes to achieving a balance between needs and self-sufficiency in a building under service conditions, the Zero Energy Building (ZEB) role has emerged as the gold standard reference point. Data on buildings, both global and local, show that existing buildings play an essential role in achieving the goal of total energy reduction for society, due to their large quantity and poor performance level. To promote energy efficiency and reduce its impact on the environment, economy, and society, certain policies have been put in place in different countries to encourage the restoration of existing buildings. New laws need a comprehensive assessment of the data acquired in relation to certain building types (residential, offices, schools, public buildings) to find strategies and solutions capable of satisfying those criteria.

ZEBs are supported by a few prestigious organizations around the world. There is a growing trend towards the development of near-ZEBs or ZEBs, which are highly energy efficient buildings that are designed to use little or no energy from the grid. These buildings are typically powered by renewable energy sources, including on-site or nearby energy production. Both near-ZEBs and ZEBs are being encouraged by city development and energy savings plans in Europe and the United States. Although substantial efforts have been made by major energy-consuming countries, such as China, India, and those in Latin America, they have not yet embraced this trend to the same extent.

2. Aims & significance of this research

This research focus on identifying ways to reduce energy consumption in buildings and green building. It aims to compare the energy consumption of green buildings with that of conventional buildings and to explore different construction materials that can be used to improve the energy efficiency of sustainable buildings. Overall, this research aims to contribute to the development of more energy-efficient and environmentally friendly building practices. This investigation was conducted for building in North Cyprus. This research might provide an opportunity by identifying and implementing effective strategies to improve the energy efficiency of buildings in North Cyprus.

The main objectives of this research given below guide the direction and focus of the research and is used to evaluate the success of the study in achieving its goals.

- To maintain the sustainability of the buildings to reduce the emissions of greenhouse gasses.
- To provide an overview of the future of sustainable buildings or green buildings towards a 100% renewable future.
- To increase knowledge of the types of materials used in the construction industry in terms of pros and cons in the sustainable era.
- To increase awareness of energy consumption, particularly in the construction industry.
- To suggest new methods for converting conventional buildings into sustainable buildings.

The analysis in this research is aligned with the overall aim of increasing energy efficiency in buildings in North Cyprus. The research clearly attempts to show the environmental possibilities of upcoming sustainable buildings, including energy efficiency and minimizing CO_2 emissions all being examined.

3. Literature review

Energy can be considered one of the most important factors that play a valuable role in the development and growth of countries. CO_2 emissions related to energy consumption have increased dramatically, especially in the past 20 years. Primary energy production estimates the number of primary energy resources generated or extracted. It addresses the use of oil, coal, electricity, gas, biomass, and heat generation. The production of geothermal, hydro, and nuclear electricity is regarded as vital. It is the sum of external commerce, primary production, maritime containers (fuel used by airplanes and ships for international transport), and stock markets for specialized energy items.

Energy consumption is normally decomposed into three different categories: i) industry, ii) transportation, and iii) other including different sub-categories such as agriculture, service sector, and residential. For that, it is somehow difficult to gather all the information related to energy consumption in buildings [11]. In total, the energy consumed in buildings could be summed to be around 20 to 40 % of the total energy consumption in countries [13]. With these huge percentages, the energy consumption in buildings should be considered on its own and should have its own sector as the third main sector, to study the energy consumption for residential and non-residential buildings [14].

With the dramatic increment in population, the comfort level in residential buildings has been transformed into a need as the building industry is focusing on enhancing building services and their comfort level [15]. Accompanied by the time spent inside the buildings, the levels of energy consumption have been increased to reach at least the levels of energy consumption in transportation as well as the energy consumed in the industry [16].

Consider the examples of different countries and regions that may be seen as the increment in energy consumption in buildings as an annual increment:

1. In the UK, the energy consumption in a building is found to be increased at the rate of 0.5% annually which is a little less than the increment in the EU where the ratio is approximately 1.5% on average. While in Spain only an annual increment of 4.2% can be seen and in the northern part of Europe as well as northern America the increment tends to be 1.9% per year can be seen. The reason behind all these increments is that services are provided in buildings such as HVAC or heating ventilation and air conditioning systems [17].
2. Between the years 2004 and 2018, the building consumption in the European Union tended to be between 37 to 44 %, which is higher than the industry sector, which reached 28%, and the transportation sector, which reached 32%. In the UK, the total energy used in buildings can reach 39% [17, 18].

One of the reasons behind this increase in energy consumption in buildings is that there was a shift from the heavy industry sector to the services sector after the industrial revolution ended, where the services sector gained more attention than the other sectors. These percentages are expected to rise and increase strongly with economic growth in all states and countries [19].

The service sector, which includes all commercial and public buildings, includes many different types of structures (schools, restaurants, hotels, hospitals, museums, etc.) with a wide range of uses and energy services (HVAC, domestic hot water (DHW), lighting, refrigeration, food preparation, etc.) [20]. Economic and population growth raise the demand for services (health, education, culture, leisure, etc.) as well as energy usage. Since the 1950s, the energy consumption in the service sector in the United States has increased from 11% to 18%. In 2004, service energy usage accounted for around 11% of total final energy use in the UK, which was comparable to the EU average. In comparison, the Spanish number was just 8%, but it has seen significant growth and has been compounded by 2.5 between 1980 and 2000 [21].

Size and location are major factors in residential energy use. Because there is less conditioning and transfer area as well as less occupancy, smaller apartments require less energy. Weather, architectural design, energy systems, and occupants' economic position all influence the amount and type of energy utilized in homes [17, 21]. In general, homes in developed countries use more energy than those in developing countries, and this tendency is expected to continue as new appliances are installed (air conditioners, computers, etc.). Residences account for 22% of total final energy consumption in the United States, compared to 26% in the EU. Due to a harsher environment and construction type, the percentage in the United Kingdom is 28%, which is much greater than the 15 percent in Spain (predominance of independent houses over blocks) [15, 17, 18, 22].

The EIA analyzes and estimates future trends in building energy usage based on its International Energy Outlook. Energy consumption in the built environment will increase by 34% during the next 20 years, at a 1.5% annual pace. Consumption related to homes and non-domestic sectors will be 67% and 33%, respectively, in 2030 (Approximately). Spread throughout Southeast Asia, and hence the expansion of development will increase energy consumption in the residential sector. Forecasts indicate that by 2010, both developed and developing countries will have achieved a balance in the use of energy in housing. Economic, trade, and population expansion in developing nations will increase demand for education, health, and other services, as well as energy usage. Energy consumption in the service sector in non-developed nations is predicted to treble over the next 25 years, with an annual average growth rate of 2.8% [23].

Energy consumption is rapidly increasing because of population growth and urbanization. Residential energy requirements vary by region, depending on climate, house type, and level of development [7, 8]. Every year, building activities utilize 38% of all energy consumed worldwide.

There is growing concern about the usage of building energy and its possible environmental repercussions. These are problems that all building professionals across the globe must address [19].

For EU (European Union) admission, the "Energy Efficiency Law" was approved in Turkey in 2007. Increasing a building's energy efficiency has been the goal of the "Regulation of Energy Performance in Buildings" since 2010. The primary goal of this rule is to provide "Energy Identity certificates" to all the newly built buildings. Additionally, there is a standard that sets building heat isolation requirements. As of May 22, 2008, the TS 825 standard, first released in February 1970 as "The Rules of Protection against Heat Effects in Constructions," has been amended several times. Aiming to reduce greenhouse gas emissions, Turkey ratified the UN Framework Convention on Climate Change (UNFCCC) in 2004 in addition to existing norms and regulations governing the energy sector. As a result of these standards, energy must be conserved and utilized efficiently in both the building and transportation, and service sectors [24].

Buildings use energy in different phases and for different purposes.

1. In the manufacturing phase of construction, energy is consumed for the transportation and construction of construction materials.
2. In the use phase, energy is consumed to provide proper internal air quality in accordance with indoor visual, thermal, and acoustic comfort conditions, as well as to maintain, restore, and renew the condenser.

"Energy Efficient Design Approaches" have been created to reduce the energy consumption of buildings during their lifespan. The distinguishing characteristics of energy-efficient design are that it aims to minimize the amount and cost of energy while considering individual and social benefits in accordance with all construction standards in a wide range of areas, from the production of all materials and components that comprise the construction to the use of construction as well as its design, maintenance, and operation, to the selection and management of climatic conditions [20, 25].

Building energy consumption has been reduced by 30%–90 percent in developed countries such as the Netherlands, Germany, Canada, Australia, and Singapore during the last decade because of the deployment of energy-efficient techniques. According to US experience, a well-designed structure of the same size using solar energy saves approximately 50% more energy than conventional structures, with a 5–10% initial investment [20, 25].

The use of energy-efficient building materials is important in energy-efficient building design because construction materials may positively support the construction in which they are employed by reflecting their environmental aspects along with their other qualities in the structure. Consequently, in order to conserve energy, it is vital to incorporate energy-efficient building materials early in the design phase [17, 18].

4. Methodology and case study

4.1. Methodology of the study

Three real case studies in North Cyprus were investigated to understand the energy consumption of the buildings. The examinations conducted in this research provide insights into how energy consumption can be minimized, and energy efficiency can be improved in buildings in North Cyprus.

4.2. General Overview

The first case study considered is a villa located in Hamitkoy-Nicosia / North Cyprus. This villa is composed of 3 rooms, 2 salons, 1 office, 1 kitchen, 1 living room, and 3 toilets. Four persons are living in this villa, where there are air conditioners (ACs) in all rooms as well as in the salons. The ACs in rooms are 9 BTU, and the ACs in the salons are 18 BTU and in total 7 ACs are available. The villa is illustrated in Fig. 1.

The second case study (Fig. 2) is a normal flat in an apartment located in Kizilbas- Nicosia, North Cyprus having 3 bedrooms, 1 living room, 1 kitchen, and 2 toilets. In this flat, 3 peoples are living together, bedrooms contain AC systems with 9 BTU and there is an additional AC in the living room with the size of 18 BTU.

Fig.1.The first case study villa in Hamitköy-Nicosia / North Cyprus

Fig.2. Second case study of the flat.

The third case study (Fig.3) is a villa located in Hamitkoy- Nicosia / North Cyprus that has already a solar system. The purpose of using this villa as a case study is to examine how energy consumption can be minimized using more sustainable construction materials. In addition, the research aims to identify opportunities for minimizing energy consumption in electricity through the application of simple restoration measures. The installed solar energy system contains 18 solar panels that generate 5 kW of electricity. For this case study, the calculations are made in the next section where insulation and material used for the building are considered.

4.3. Energy consumption of the villa vs. flat

The energy consumption of villas, in general, is more than flats especially during the summer months as is obvious in the diagram, showed in Fig.4. Where we can see that the difference between flats and villas occurs between May and September.

All the prices were calculated according to the price of kWh in North Cyprus, which is 0.25 euros. The consumption in the villa is 5400 kWh per year. On the other hand, the flat is engaged with a prepaid system where the price of electricity in that system is slightly higher and on average the flat needs 350 kWh in a month which makes it in total 4200 kWh/year.

Fig.3. The third case study villa with a PV system installed

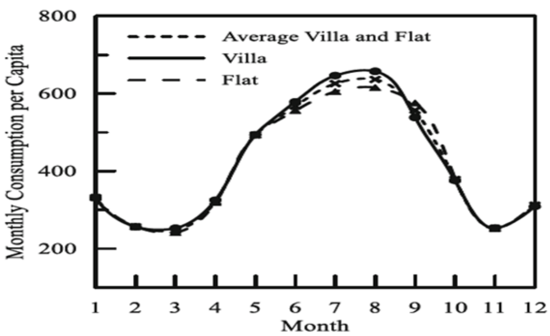


Fig.4. Monthly consumption per capita in flats and villas

4.4. Solar energy offers

In this section of the research, the installation of 5kW of solar energy systems by three different companies will be analyzed. This is the maximum amount of energy that can be installed in a residential villa and connected to the grid without batteries with smart meters, as per the rules in place.

4.4.1. Companies and offers for villa

The offers for the installation of 5kW solar energy system were obtained from three different companies, and all the offers were based on the specifics of the villa in the case study. These companies are 1) Akbar Ltd., 2) Derin energy solar, and 3) Ekrem Gunes solar Ltd. Tables 1-3show the details of the offers of each company, respectively.

Table 1. Villa offer from Akbar Ltd.

Product	Brand	Price per unit (euro)	Quantity	Warranty	Total (euro)
395 W solar panel Monocristalline quantom cell	Qcells	200	14	25 years	2800
6 kW inverter	Fronius primo	1500	1	7 years	1500
Aluminum frame	--	350	1	25 years	350
Tile roof construction	--	250	1	--	250
Ac electrical equipment	--	200	--	--	200
DC electrical equipment (connectors)	--	200	--	--	200
Design of the project	--	150	--	--	150
Kib-tek control	--	150	--	--	150
Installation workmanship	--	500	--	--	500
Total			6100		

Table 2. Villa offer from Derin Energy Ltd.

<table>
<tr><th>Product</th><th>Brand</th><th>Price per unit (euro)</th><th>Quantity</th><th>Total (euro)</th></tr>
<tr><td>500 W solar panel Monocristalline quantom cell</td><td>Trina</td><td>245.5</td><td>11</td><td>2700</td></tr>
<tr><td>6 Kw inverter</td><td>SMA</td><td>1400</td><td>1</td><td>1400</td></tr>
<tr><td>Aluminum frame</td><td>--</td><td rowspan="6">--</td><td rowspan="6">1</td><td rowspan="6">1800</td></tr>
<tr><td>Galvanized foot</td><td>--</td></tr>
<tr><td>Solar cables (ac-dc)</td><td>--</td></tr>
<tr><td>Engineering design of the project</td><td>--</td></tr>
<tr><td>Kib-tek control</td><td>--</td></tr>
<tr><td>Installation workmanship</td><td>--</td></tr>
<tr><td>Total</td><td colspan="4">5900</td></tr>
</table>

Table 3. Villa offer from Ekrem Gunes Solar Ltd.

Product	Brand	Price per unit (euro)	Quantity	Total (euro)
530 W solar panel	Luxor	236.5	11	2600
5.0 Kw inverter	SMA	1500	1	1500
Aluminum frame	--			
Galvanized foot	--			
Solar cables (ac-dc)	--			
Engineering design of the project	--	--	1	1700
Kib-tek control	--			
Installation workmanship	--			
Total	5800			

4.4.2. Companies and offers for flat

The offers were obtained from the same companies for the flat of the case study. Tables 4-6 shows each offer detail, respectively.

5. Results and discussion

5.1. Economical savings for villa

According to the consumption of the villa, if its total consumption per year is 5400 kWh and if we multiply it by the average feed-in tariff that is equal to 0.25 euro cents per kWh, the total energy price is 1350 euros per year. If the solar system that will be installed is 5kWp then the average production per year could reach to 4500kWh. For that, the amount of money that is needed to be paid per year is around 39.12 euros which is the rental price of the smart meter according to Kib-tek. The amount of saving per year R is equal to 1310.88 euros.

5.1.1. Simple Payback Period (SPP) for villa

To calculate SPP, the following formula was used:

$$SPP = \frac{C}{R} \quad (1)$$

where C is the capital cost of the solar power system, R is the amount saved in the first year. Eq. (1) was used to calculate the SPP values of all case studies.

Table 7 gives the simple payback period information for the villa. The results show that the clean energy system is provided for approximately 4.5 years for payback of the system cost. On the other hand, every company has its own price system, that's why it is not the same as seen in Table 7.

5.2. Economical savings for flat

According to the consumption of the flat, if its total consumption per year is 4200 kWh and if multiplied by the average feed-in tariff that is equal to 0.25 euro cents per kWh, the total energy price is 1050 per year. If the solar system that will be installed is 2.5 kWp then the average production per year could reach 4000 kWh, for which the amount of money that needs to be paid per year is around 39.12 euros which is the rental price of the smart meter, according to the Cyprus Turkish Electricity Department (Kib-tek). The amount of saving per year R is equal to 1010.88 euros.

5.2.1. Simple Payback Period (SPP) for flat

Table 8 shows the SPP calculation for the flat. The results showed that the clean energy system provided approximately 3.4 years for payback of the system cost.

Table 4. Flat offer from Akbar Ltd.

Product	Brand	Price per unit (euro)	Quantity	Warranty	Total (euro)
395 W solar panel Monocristalline quantom cell	Qcells	200	7	25 years	1400
3 kW inverter	Fronius primo	800	1	7 years	800
Aluminum frame	--	200	1	25 years	200
Tile roof construction	--	250	1	--	250
Ac electrical equipment	--	200	--	--	200
DC electrical equipment (connectors)	--	200	--	--	200
Design of the project	--	150	--	--	150
Kib-tek control	--	150	--	--	150
Installation workmanship	--	350	--	--	350
Total			3700		

Table 5. Flat offer from Derin Energy Ltd.

Product	Brand	Price per unit (euro)	Quantity	Total (euro)
500 W solar panel Monocristalline quantom cell	Trina	245.5	5	1227.5
3 Kw inverter	SMA	750	1	750
Aluminum frame	--			
Galvanized foot	--			
Solar cables (ac-dc)	--			
Engineering design of the project	--	--	1	1350
Kib-tek control	--			
Installation workmanship	--			
Total		3327.5		

Table 6. Flat offers from Ekrem Gunes Solar Ltd.

Product	Brand	Price per unit (euro)	Quantity	Total (euro)
530 W solar panel	Luxor	236.5	5	1182.5
3 kW inverter	SMA	850	1	850
Aluminum frame	--			
Galvanized foot	--			
Solar cables (ac-dc)	--			
Engineering design of the project	--	--	1	1250
Kib-tek control	--			
Installation workmanship	--			
Total	3282.5			

Table 7. SPP for all offers

Company	Ekrem Gunes Solar ltd.	Derin Enerji Solar ltd.	Akbar Electric ltd.
SPP (years)	4.4	4.5	4.6

Table 8. SPP for all offers (flat)

Company	Ekrem Gunes Solar ltd.	Derin Enerji Solar ltd.	Akbar Electric ltd.
SPP (years)	3.6	3.3	3.2

5.3. Simulation results

The offers obtained from the companies were simulated using SAM software (SAM 8.2 version for analysis and constrained optimization of linkage mechanisms), and the solar irradiation data was obtained from the SAM software for the location of Nicosia, North Cyprus. The simulation parameters are presented for the villa and then for the flat respectively (Tables 9-10)

After simulating, we could clearly see that the SPP obtained through manual calculation matched with the simulation results. The SPP values for the villa were 4.6, 4.5, and 4.4 while the SPP values for the flat were 3.6, 3.3, and 3.2.

5.4. Applying the construction materials

In this part, the third case study is considered, where the villa has an already installed PV system. Thermal and mechanical characteristics of materials must be characterized to reveal the suitability of a material choice for the implementation of energy-efficient construction. The thermos-physical characteristics of these materials are the ones that may be used to determine their energy efficiency (see the details in Table 11).

5.4.1. Calculations for building materials

In this case, which is considered the main difference, we focus on the outer walls of the villa, where if we change normal concrete conventional bricks to fly ash bricks, the thermal conductivity will be less. The thermal conductivity of conventional bricks, fly ash bricks and double-walled concrete with foam are presented in Table 4. If considering the area of the villa is 350m^2 the outer walls covering this

The area was calculated to be 499.2 m^2 and accordingly, we calculated the prices of each material if it was used to build external walls to maintain sustainability (given in Table 12).

5.4.2. Simple Payback Period (SPP)

After insulation using concrete, one layer of glass wool was added to increase the thermal insulation. The price of m^2 of glass wool in North Cyprus is 97 TL, which is equivalent to approximately 5 euros. If needing to calculate all the outer walls to be insulated with the glass wool insulation, we need 500 m^2 of material. The price needed is 2500 euros. With the optimal insulation the total amount of money needed will be 2500+6125.2+2915 ≈ 11 500 euros. While using the conventional concrete block that is already available in the villa, the total amount will be 2625+2915 ≈ 5500 euros. After the made calculation for the walls with the optimal insulation and the calculations done for the walls without any insulation, the difference in the price between both methods is approximately 6000 euros (given the details in Table 12). The SPP value of the solar system can be derived using Eq. (1). Alternatively, in Eq. (1), the capital can be obtained through summation of solar system and insulation costs as shown in Eq. (2).

$$\text{SPP} = \frac{\text{Solar system cost} + \text{insulation cost}}{\text{Calculated 1st year saving amount}} \quad (2)$$

$$SPP = \frac{6000 + 6000}{1310.88}$$

For example, the SPP value was found as approximately nine years in response to using the sample values given in Eq. (2).

5.5. Insulation types in building

In this section, a brief explanation of insulation type used on the walls and roofs in case studies is provided. Fig. 5 illustrates the potential locations for installation of insulation components. The types of insulation are presented in the following Table 13.

5.6. Environmental impact

Internationally, the climate change is considered as the biggest environmental challenge. According to the Intergovernmental Panel on Climate Change (IPCC) worldwide emissions of greenhouse gases increased by 70% between 1970 and 2004 [27]. Correspondingly, the impact of construction industry on climate change has been extensively studied. Construction industry is responsible for considerable global greenhouse gas emissions (30%) and the world's total energy consumption (40%) [27]. It is projected that between 1971 and 2004, the amount of CO_2 emitted by commercial buildings rose by 2.5% each year whereas the amount of carbon dioxide released by residential structures rose by 1.7% per year. There are, however, many unknowns about the impact of climate change on the construction business. Understanding the impacts of climate change on built environments will be crucial, as it will significantly influence these environments.

Table 9. Simulation results for villa study-case

Energy Companies Metric	Akbar Company	Derin Company	Ekrem Company
Annual Energy (year 1)	8,545 kWh	9,419 kWh	9.128 kWh
Capacity Factor (year 1)	17.6%	19.5%	18.9%
Energy Yield (year 1)	1,545 kWh/kW	1,711 kWh/kW	1,658 kWh/kW
Performance Ratio (year 1)	0.72	0.80	0.78
Levelized COE (nominal)	6.24 $/kWh	5.47 $/kWh	5.56 $/kWh
Levelized COE (real)	4.98 $/kWh	4.37 $/kWh	4.44 $/kWh
Electricity Bill without System (year 1)	$818	$818	$818
Electricity Bill with System (year 1)	$-154	$-150	$-150
Net Savings with System (year 1)	$972	$968	$968
Net Present Value	$5,986	$6,208	$6,250
Simple Payback Period (SPP)	4.6 years	4.5 years	4.4 years

Table 10. Simulation results for flat study-case

Energy Companies Metric	Akbar Company	Derin Company	Ekrem Company
Annual Energy (year 1)	4,566 kWh	4,167 kWh	4,186 kWh
Capacity Factor (year 1)	18.8%	19.0%	19.1%
Energy Yield (year 1)	1,651 kWh/kW	1,666 kWh/kW	1,673 kWh/kW
Performance Ratio (year 1)	0.77	0.78	0.78
Levelized COE (nominal)	7.08 $/kWh	6.98 $/kWh	6.85 $/kWh
Levelized COE (real)	5.65 $/kWh	5.57 $/kWh	5.47 $/kWh
Electricity Bill without System (year 1)	$664	$664	$664
Electricity Bill with System (year 1)	$-231	$-947	$-530
Net Savings with System (year 1)	$895	$1,611	$1,194
Net Present Value	$4,823	$2,927	$2,802
Simple Payback Period (SPP)	3.2 years	3.3 years	3.6 years

Table 11. Thermal conductivity of different types of material

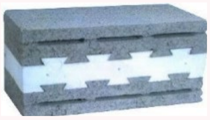
	Type: Concrete block Thermal Conductivity: 1.25 – 1.35 W/m^2 ºC conventional concrete block with dimensions(15,30,20)
	Type: Fly ash block Thermal Conductivity: 0.90-1.05 W/m^2 ºC Fly ash concrete block with dimensions (20, 20, 60)
	Type: Double concrete block with foam Thermal Conductivity: 0.04-0.06 W/m^2 ºC
	Type: Glass wool insulation Thermal Conductivity: 0.023-0.04 W/m^2 ºC

Table 12. Prices of external walls isolation

Type	Dimensions m^2	Quantity	Price/m^2 (euros)	Total (euros)
Fly ash concrete blocks	499.2	4160	11.67	5825.7
Double concrete walls with foam	499.2	16640	12.27	6125.2
Conventional concrete block	499.2	8320	5.26	2625.8
Workability	499.2	--	6	2915.3

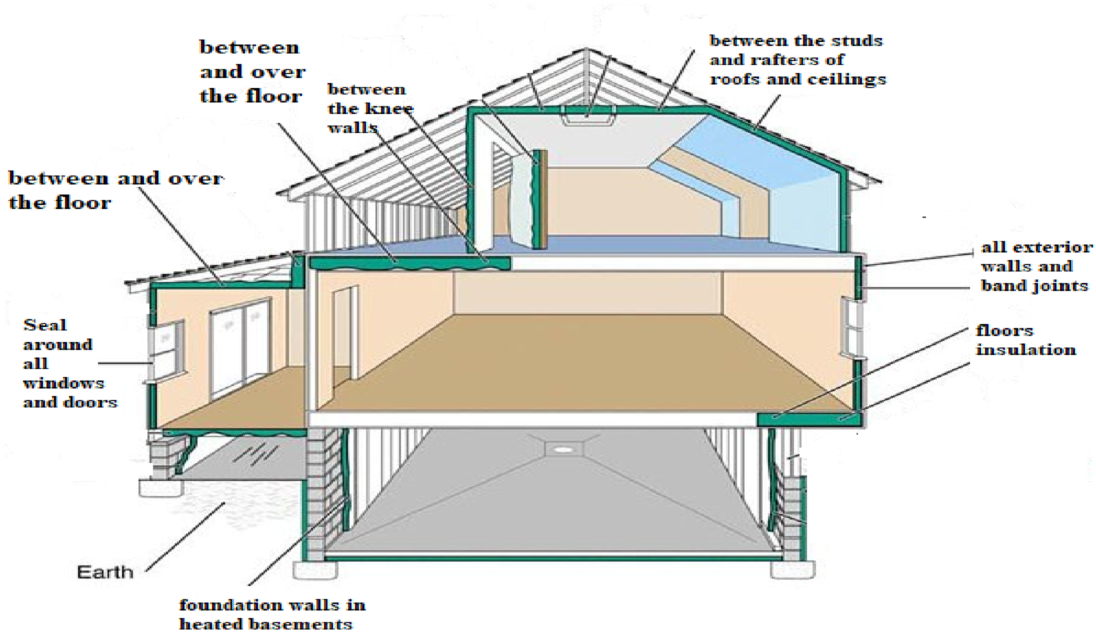


Fig.5. Places of insulation in a villa

Table 13. Type of Insulation and application

Type	Material	Application	Methods of installation
Blanket: bat and rolls	Fibers Wool	Ceilings and walls	Between studs, beams, joist
Concrete block	Foam boards to be installed inside of walls	Walls containing concrete blocks	Specialized skills are required and can be installed without mortar
Rigid foam	Phenolic, polystyrene, polyurethane	Floors and ceilings including foundation walls	Interior with fire safety material, Exterior with weatherproof on top of it
Insulating concrete forms	Foam blocks or foam board	Unfinished walls	Part of the structure of the buildings.
Blown-in	Cellulose mineral wool Fiber	Enclosed wall or wall cavities, hard to reach places	Blown using special tools.
Reflective system	Plastic films, cardboard, polyethylene bubbles	Walls, ceilings, and floors	Between wood frame studs rafters and beams
Rigid fibrous insulation	Fiberglass or mineral wool	Stick in some spaces	Prefabricated ducts
Sprayed foam	Cementitious, Polyurethane	Attic floors, new walls cavities	Small spray containers with high pressure

5.6.1. CO_2 emissions for the case studies

Fig. 6 shows that the average efficiency of generators in North Cyprus for electricity is 36% (42% diesel generators and 30% steam turbine generators), and 1 kg of fuel generates 11.233 kWh, producing 3.114 $kgCO_2$. Since in the case study of the villa the generation needed is 5400 kWh per year it means that in total 1335 kg of fuel is needed.

Fig. 7 shows the case study of flat, which required 4200 kWh/year, 1038.6 kg of oil needed to generate the amount of 4200 kWh/year. To calculate the total amount of CO_2 emissions, the following formula was used:

$$\text{Total amount of } CO_2 = \text{Total fuel Needed} \times \text{emission per 1 kg fuel} \quad (5)$$

The corresponding results for the villa and flat were obtained as of 4157 tons of CO_2 and 3233 tons of CO_2, respectively, by applying Eq. (5).

These amounts could be minimized if solar energy generation is installed, and renewable sources are considered. Thus, the case studies considered could be energy efficient and tend to be environmentally friendly as solar energy has no GHG emissions, particularly CO_2 emissions (see Figs. 8-9).

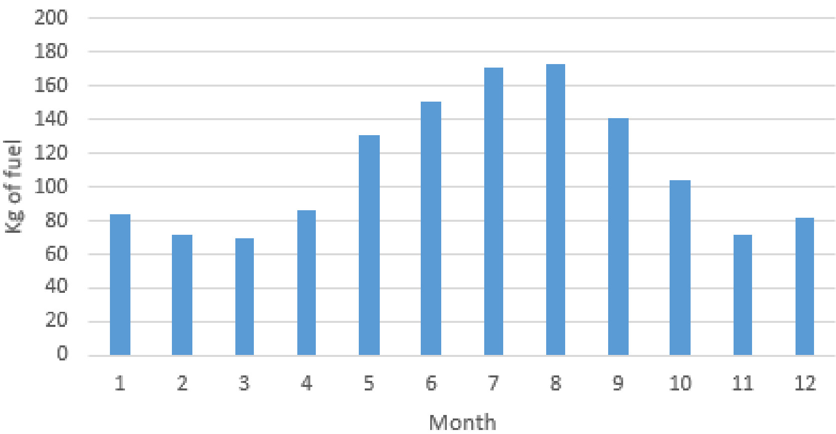


Fig. 6. Kg of fuel needed for villa per month

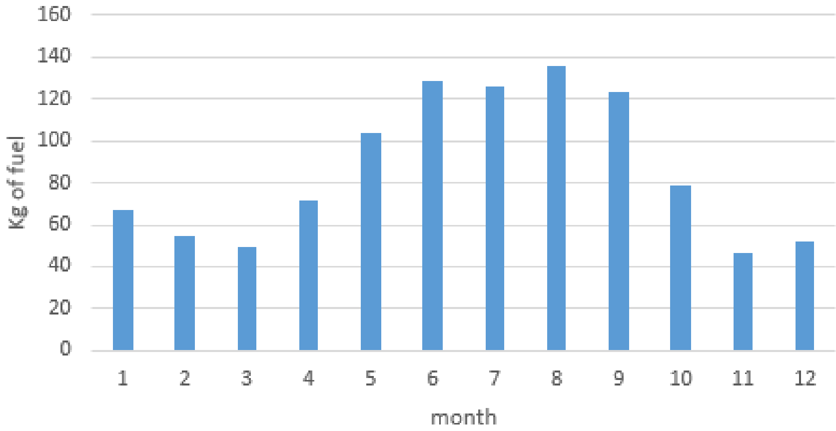


Fig. 7. Kg of fuel needed for flat per month

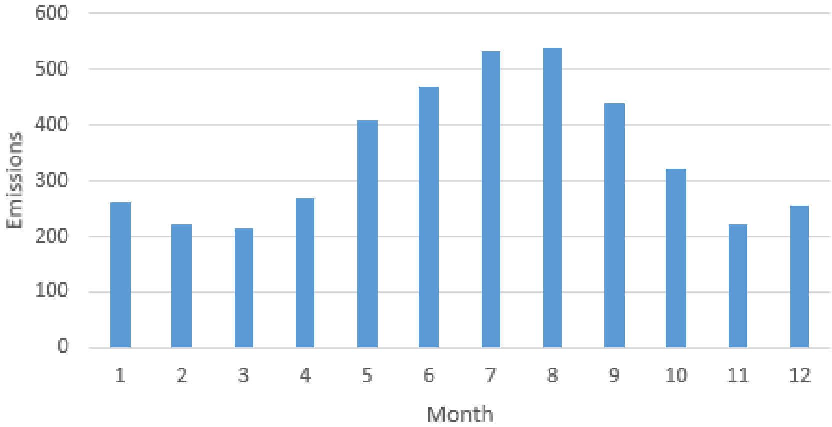


Fig. 8. Emissions of CO_2 per month for villa

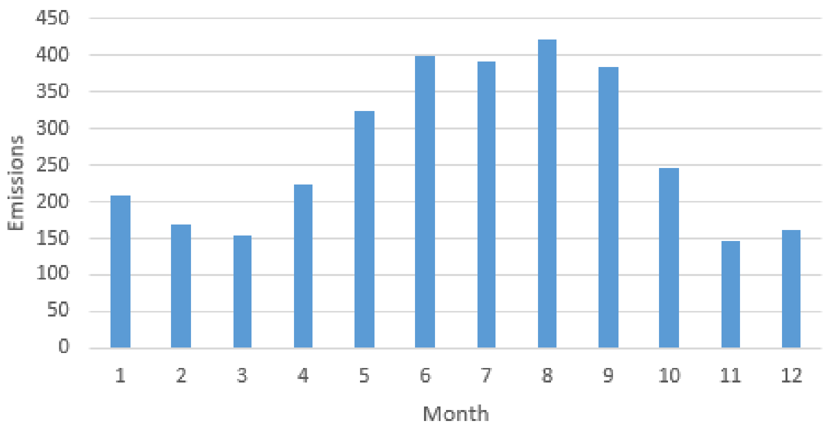


Fig. 9. Emissions of CO_2 per month for flat

6. Conclusion

This study extensively examined case studies in North Cyprus. The energy consumption of buildings is examined and provided alternative energy resources for improving the sustainability and energy efficiency in buildings at North Cyprus. The main findings of the work are summarized in the following points:

- The study found that applying an alternative energy system decreased the energy cost and minimized damage to the environment. Based on the historical data collected by the various metrological stations are received solar radiation around 7 kWh/m^2 in normal condition and 3 kWh/m^2 in winter. That's why photovoltaic panels have the potential for use. The cost of installation is to be recouped in about 4.5 years. After that, the energy cost for the buildings is minimized while also reducing CO_2 emissions by utilizing a clean energy system.
- Building materials are important for sustainable buildings. This study examined alternative materials for using in the building components to minimize the energy consumption. Among them, fly-ash concrete blocks have better thermal conductivity. Since the thermal conductivity of double-layered concrete blocks with foam is the most convenient, it is to be the best choice for isolation purposes in the external walls of the villa. it was found in this study that the difference in the construction cost between the walls with optimal insulation and those without any insulation is approximately 6000 euros. For this choice, the SPP is approximately 9 years.
- The total monthly emissions for a villa and flat were calculated as 2154 tons of CO_2 and 1675 tons of CO_2, respectively. Northern Cyprus' un-consideration of renewable energy is a big concern to achieve sustainable environmental-friendly buildings.

Given the high cost of fuel and high demand for energy, particularly in the residential sector, generating electricity and energy from renewable sources like solar energy is one of the most effective solutions. Using renewable energy resources can improve the air quality index and reduce the environmental impact, as it will minimize or eliminate most emissions from the residential and construction sectors. Governments should implement a new plan that provides incentives to the population and guides them toward a 100% renewable future. This plan should also address other industries in addition to construction to ensure a transition to a toxicant-free future. As part of future work, old buildings should be analyzed for their energy consumption and retrofitted to become zero-energy buildings. This will establish a criterion for all buildings to follow to transition to sustainable buildings safely.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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