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ASSESSING ENERGY CONSUMPTION IN PRIVATE RESIDENTIAL BUILDING AREA

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ABSTRACT

Energy consumption in residential buildings has been a crucial problem for many countries due to many different factors such as the location, building's size, design, appliances used, heating and cooling systems, and insulation. Recently, Albania as a developing country is facing of the problem of the energy consumption that comes from residential buildings. Most of the problems come from older buildings style years 1980 where the energy consumptions are very high in comparisons to the new ones. Based on it, our research work will be focused on the analysis of energy consumption of the older residential building style that is located in northeast part of Albania in the Kukes city. It has been analysed all the collected data during the years 2021 till 2023 and identification of the most consumed areas where energy efficiency needs to be implemented. Energy performance of this private apartment correspond to the B category.

Keywords: Energy consumption, HVAC, residential, efficiency, energy demand

1 INTRODUCTION

Many of European countries has been affected from significant energy crises during the Ukraine invasion. During this time the energy prices has been increased in the global market [1-6]. The current energy crisis is accelerating the energy transition by focusing on the increasement of investments in renewables and reducing the energy consumption. Furthermore, Albania as a developing country that want to join European Union (EU) has been affected from the global energy crises by influenced on the consumer prices and interrupting the production process in industry due to the higher electricity price that come from imports [7-9]. Albania is producing 60% of the total energy demand and importing 40% from European countries. Hydroelectric power accounts for approximately 95% of Albania's electricity generation, with the remaining 5% coming from solar energy. During the last three years, the higher energy consumption in Albania comes from two important sectors such as industry and residential buildings.

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Both sectors have been faced on the lack of energy efficiency analysis. Energy consumption in private residential building areas is a critical aspect of modern urban life, with significant implications for environmental sustainability, economic efficiency, and quality of life. As global concerns over climate change and energy security continue to rise, understanding and analysing the patterns of energy usage within these residential spaces becomes paramount. Efforts to improve energy efficiency in residential buildings often involve a combination of approaches such as using energy-efficient appliances, adopting renewable energy solutions, improving building design and insulation, employing smart technologies for energy management, and raising awareness among populations about energy-saving practices [10-16].

Based on it, our research work will be focused on the analysis of energy consumption in one residential building that is located in Kukes city. In this northeast area, most of the problems come from older buildings style years 1980 where the energy consumptions are very high in comparisons to the new ones that are located in centre part of Albania.

In this paper we will analyse all the collected data during the years 2021 till 2023 and identification of the most consumed areas where energy efficiency needs to be implemented.

Nevertheless, energy performance of this selected private apartment will be evaluated by focusing on heat demand classification [17-19]. Afterward, recommendations for improving energy efficiency of the selected apartment will be based on the most influenced energy consumption factors.

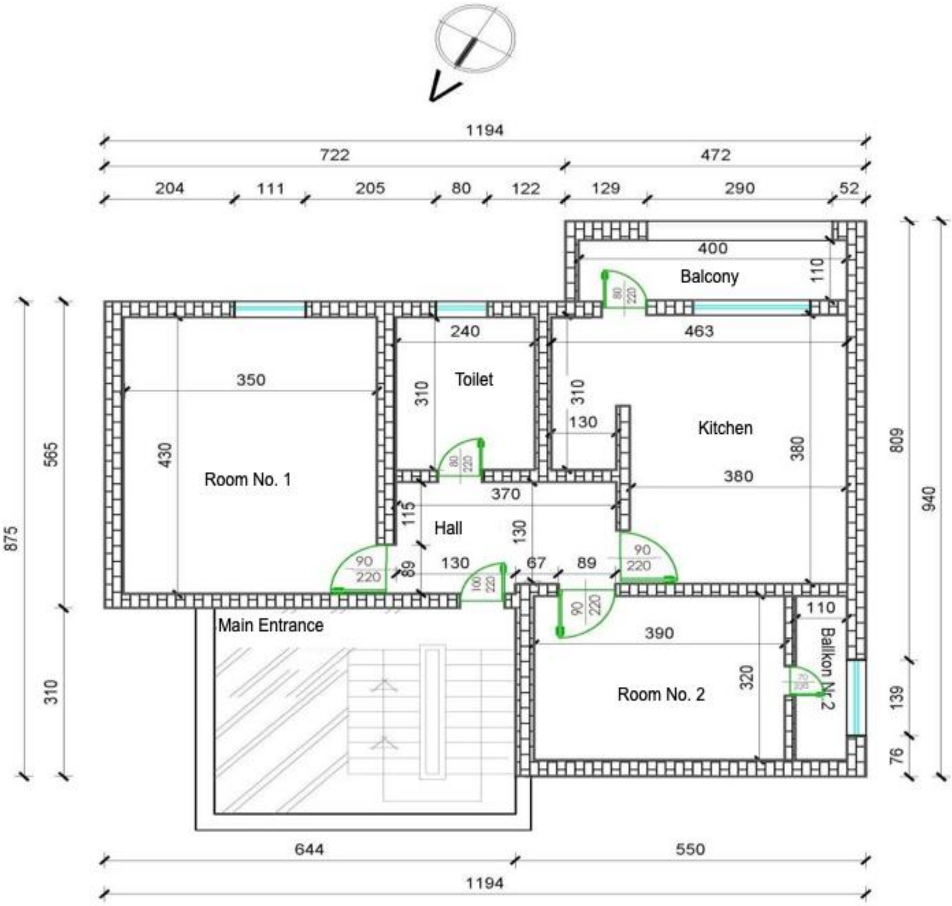

Figure 1 Floor plan of the selected apartment in Kukes city.

2 APARTMENT TYPOLOGY AND ENERGY CONSUMPTION DEVICES

The apartment is located on the fifth floor of a residential building, with a height of 5 floors in the Kukes city. The building is positioned in the northeast of Albania and it was built in the year 1980. The apartment is of type 2+1 with a total area of 82.2 m^2 where 77.7 m^2 are usable. The footprint of the apartment tends towards the square shape and its floor-to-ceiling height is 2.55 m. Figure 1 depict the current floor plan of the apartment and their dimensionsThe building's structural framework is constructed using a beam-column system crafted from reinforced concrete. The flooring consists of beam-type foundations filled with lightweight ceramic bricks featuring perforations. The envelope of the building is made with ceramic bricks without holes with a thickness of 20 cm and in some places, its role is played by concrete walls with a thickness of 40 cm, which replace the perimeter columns of the building.

The windows and doors of the balconies are made of plastic glass and are closed with elements made of aluminium boxes and elements with a thickness of 76 mm and 2 sheets of transparent, simple glass, each with a thickness of 4 mm.

The interior finishes of the apartment are as follows:

- Except for the floor of the sanitary unit, and the Kitchen, which is laid with porcelain tiles, the rest of the floor of the two rooms is laid with wooden parquet;
- The refinishing of the rooms walls is partially done with mortar plaster patinated with the corresponding patination putty and partially covered with wall paper with the possibility of ventilation;
- The walls of the sanitary unit are covered with porcelain tiles up to a height of 2.0 m;
- The ceiling of the entire apartment is of the type with 10 mm plastered panels.

All the apartments of the selected residential buildings have the same typology and configuration.

During the years 2021 till 2023, apartment is inhabited in the whole months and during all days, except for the half of the month of July due to the summer holidays. Most of the devices were working in the afternoon during the hours of 16:00-24:00 where the energy consumption is in this time band. In the transit periods of the year such as spring and autumn, the air conditioning system stays on for a few hours as long as the atmospheric air temperatures do not have large differences from the thermal comfort temperatures. While during the winter, the heating is done with firewood because it is not done with the current air conditioner due to the big difference in temperature.

The apartment uses as a source electricity from the city network, firewood for the winter period and gas for cooking. Heating is done with a firewood system and air conditioners. Cooling is done with air conditioners and small portable fans. Hot water is obtained from an 80-litre electric boiler. Cooking is also done with electric appliances and a gas oven. Lighting is generally covered by LED lamps and some spots. All of these, as mentioned above, have been operating since 2021 and have been newly installed as can be seen in the Table I.

Table I - Electrical/electronic devices and usage profile

Devices	Power (kW)	Usage
Heating	2.8	7 days - months / 5 months
Gas stove	1.7	6 days – months / 1 year
Aspirator	0.5	4 times - week / 10.5 months
Cooking stove	1.3	5 times - week / 10.5 months
Oven	2.6	2 times - week / 10.5 months
Microwaves	0.5	7 times - week / 10.5 months
Fridge (A+)	0.8	24 hours / day / 1 year
Air Condition	2.3	3 hours / 7 days / 6 months
Washing machine	2.3	6 times – week / 10.5 months
Boiler	1.4	1 hour / day / 11 months
Hair dryer	1.4	7 times - week / 10.5 months
Ironing	1.8	2 times - week / 10.5 months
LCD TV	0.6	5 hours / 7 days / 10.5 months
Carpet-sweeper	1.8	2 times - week / 10.5 months
LED Lamps	0.4	9 hours / 7 days / 1 year

3 ENERGY CONSUMPTION ANALYSIS

Energy consumption analysis during the years 2021, 2022 and 2023 has been based on three important steps which are:

- Energy consumption from invoices
- Apartment heat loss
- Energy needs for heating and cooling

3.1 ENERGY CONSUMPTION FROM INVOICES

Energy consumption analysis from invoices in the selected apartment has been focused on the energy usage during the years 2021 till 2023. During these periods we will consider the energy consumption that come from electronic devices, heating and cooling system in different areas and sanitary water. Table II depict the energy consumption of the last three years.

In the Figure 2 is shown the annual energy consumption that come from invoices during the years 2021, 2022 and 2023.

Table II - Electricity invoices during the years 2021-2023

Months	2021 (kWh)	2022 (kWh)	2023 (kWh)
January	411	536	418
February	405	426	353
March	351	378	502
April	320	395	523
May	302	448	442
June	343	397	374
July	301	258	365
August	337	339	268
September	323	327	275
October	378	321	298
November	407	310	475
December	486	475	602

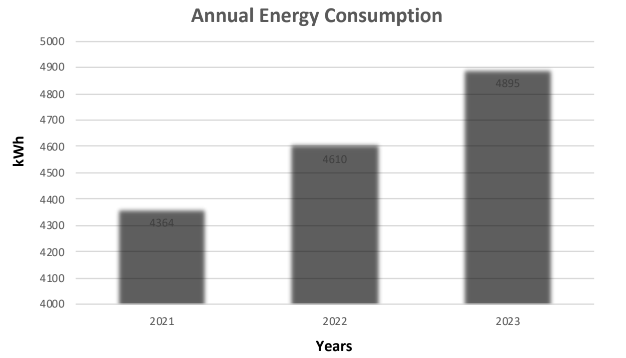

Figure 2 Annual energy consumption for the years 2021, 2022 and 2023, data collected from invoices.

Our analysis will continue by using energy consumption evaluation only for heating and cooling. To assess the typical electrical energy usage for heating and cooling within the apartment, we will focus on the months exhibiting the lowest energy consumption levels. Specifically, we will regard the month of July as a benchmark, attributing zero energy consumption due to its historically minimal usage. This approach involves deducting the energy consumption recorded in July, presumed to be solely for heating and cooling, from the consumption data of all other months. Notably, July stands out as the month with the least energy consumption within the apartment, as it remains uninhabited for half of its duration. The results are shown in Table III.

Table III - Energy consumption for heating and cooling during the years 2021-2023

Months	2021 (kW/h)	2022 (kW/h)	2023 (kW/h)
January	152	274	161
February	144	169	95
March	96	117	25
April	57	138	262
May	43	186	183
June	85	138	116
July	0	0	0
August	78	81	6
September	64	64	14
October	122	62	43
November	148	45	212
December	227	217	45

3.2 APARTMENT HEAT LOSS

Heat loss Q_T of the apartment has been calculated by focusing on the sum of the apartment fabric element Q_f and air infiltration Q_v, see equation 1.

$$Q_T = Q_f + Q_V \quad (1)$$

The total heat loss of the apartment fabric element has been calculated by using the equation 2.

$$Q_f = ((U_1 \cdot A_1) + (U_2 \cdot A_2) + (U_3 \cdot A_3) + (U_4 \cdot A_4)) \cdot \Delta t \quad (2)$$

Where, U-values for individual elements are the heat transfer values of the external fabric apartment such as respectively floor U_1, roof U_2, walls U_3, windows & doors U_4, A-values are their respective areas, Δt are the differences between indoor t_i and outdoor t_o temperatures.

In the winter the designed outdoor temperature corresponds to -9ºC and indoor to 20ºC. U_1, U_2, U_3 and U_4 has been calculated by using equation 3.

$$U = \frac{1}{R} \tag{3}$$

Where R respectively is thermal resistance of the floor, roof, walls and windows & doors.

Due to the usage of polystyrene it has been found that thermal resistance of the floor correspond to the value 2.00 $m^2 \cdot K/W$. In case of the roof it has been found that thermal resistance were 1.55 $m^2 \cdot K/W$. Equation 4 has been used to calculate the thermal resistance of the walls.

$$R = \frac{1}{\alpha_1} + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3} + \frac{1}{\alpha_2} \tag{4}$$

Where, coefficient of thermal conductivity of the thin wall λ_2 with thickness 0.25m correspond to the value 0.36 $W/m \cdot K$, as well as coefficient of thermal conductivity for the two layers of internal and external plaster 0.025m thickness were λ_1=0.9 and λ_3=0.9 $W/m \cdot K$. In the calculation of the overall thermal resistance of the wall, the convection coefficients were accepted respectively α_1=5.1; α_2=12 $W/m^2 \cdot K$. Based on our data and calculation the thermal resistance of the walls correspond to the value 1.029 $m^2 \cdot K/W$.

The building's windows are crafted from duralumin and are equipped with double glazing, which is filled with argon gas. These windows were fitted during the initial year of construction and were installed according to standard procedures, ensuring uniform placement throughout the building. The internal doors of the apartment were made from wooden. Thermal resistance of the windows and doors correspond to the value 2 $m^2 \cdot K/W$. Furthermore, the equation 5 has been used for calculation of total contribution of the heat loss coefficient R_f from apartment fabric element.

$$R_f = Q_f / \Delta t \tag{5}$$

Table IV depict the apartment fabric elements and the overall heat loss.

Table IV - Overall apartment fabric element heat loss

Elements	U-value ($W/m^2 \cdot K$)	A (m^2)	R_f ($W \cdot K^{-1}$)
Floor	0.50	35	17.5
Roof	0.65	35	22.8
Walls	0.97	50	48.5
Windows - doors	2.00	30	60.00
Total			148.8

Air infiltration will take into account the heat ventilation loss which has been calculated by using equation 6.

$$Q_v = 0.33 \cdot n \cdot V \cdot \Delta t \tag{6}$$

Where n is the number of air changes per hour and V is the volume of the house. In our case the air change rate corresponds to the value 0.5 and the volume of the house correspond to 205.5 m^3. The ventilation contribution to the overall heat loss coefficient Rv is given by equation 7.

$$R_v = Qv / \Delta t \tag{7}$$

The overall coefficient heat loss coefficient correspond to the value 33.91 $W \cdot K^{-1}$. The total apartment heat loss coefficient R_T has been calculated by using equation 8.

$$R_T = R_f + R_v \tag{8}$$

The total heat loss coefficient correspond to the value 182.71 $W \cdot K^{-1}$. The necessary heating system size Q for apartment has been calculated by equation 9.

$$Q = R_T \cdot \Delta t \tag{9}$$

The necessary heating system correspond to the value 5298.59 W.

3.3 ENERGY NEEDS FOR HEATING AND COOLING

In this section, conduct a comparison between the energy required for heating in its present condition and following the suggested thermal insulation measures, it's essential to compute the building's air conditioning needs under the current environmental conditions, considering the energy demands for heating as well. Figure 3 depict the percentage breakdown of the heat loss coefficient in the whole apartment.

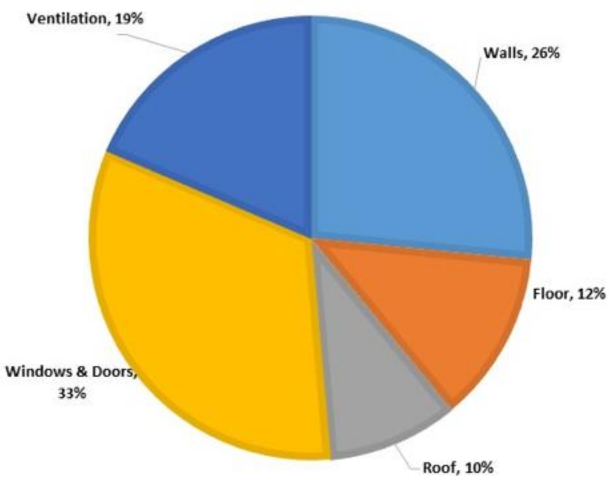

Figure 3 Percentage breakdown of the apartment heat loss coefficient

In accordance with the decision of the Albanian Council of Ministers No. 38, dated 16.01.2003 "On the approval of norms, rules and conditions of design and construction, production and storage of heat in buildings" otherwise known as the Energy Code of Buildings we have calculated the loss coefficient volume G_v by using equation 8 [20-22].

$$G_v = \frac{Q}{V \cdot \Delta t} \tag{8}$$

Based on our apartment the loss coefficient volume correspond to the value 0.7 $W/m^3 \cdot K$. Based on the energy losses through equation 10 it has been calculated the annual energy consumption in kWh of our apartment E_{year}.

$$E_{year} = Q \cdot G_{RD} \cdot 24/1000 \tag{10}$$

Where G_{RD} is degree days which for Kukes corresponds to the value 2300-degree days.

Based on our data and calculation the value of annual energy consumption was 10,085.6 kWh/year. Afterward, “Termolog” software for generating the certificate of the energy performance has been used by taking into account the whole apartment data [17]. This software has the capability to factor in financial considerations and risk assessments if there arises a necessity for enhancements and refurbishments of residential buildings. Through our measurements data like energy consumption, invoices for the years 2021, 2022 and 2023, and annual energy needs from “Termolog” software we have calculated that the selected apartment is classified type B with energy class that correspond to the value 81.65 kWh/m^2 in year as can be seen in the Figure 4.

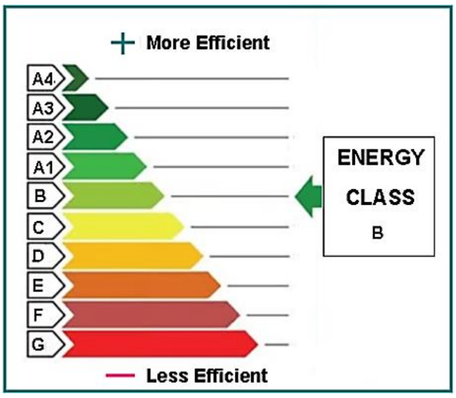

Figure 4 Energy performance certificate for apartment located in Kukes city [13].

4 OPTIMUM ENERGY CONSUMPTION STRATEGY

Energy consumption in private residential buildings in north-eastern part of Albania stands as a critical component in this pursuit. The strategy for achieving the optimum energy consumption in this area needs efficiency, affordability, and environmental responsibility. Based on it, our proposal for optimum energy consumption are as follows:

- **Current scenario analysis.** This analysis will be focused on the current data on energy usage, identifying inefficiencies and assessing the impact in residents by including the environment.
- **Identifying the most key area improvement**. This could include enhancing insulation, upgrading appliances to energy-efficient models, optimizing heating and cooling systems, and promoting behavioral changes among residents to reduce energy wastage.
- **Technological integration**. Integrating smart technologies will contribute to optimize energy consumption [15, 23, 24].
- **Community engagement and education**. Conducting awareness campaigns, workshops, and educational programs can empower residents to adopt sustainable practices
- **Financial incentives and support.** Offering financial incentives such as subsidies, tax credits, or low-interest loans can encourage adoption of different renewable energy sources [7, 10, 16, 25-28].
- **Monitoring and evaluation.** Regular and ongoing monitoring and assessment are vital to determine the efficacy of enacted measures. This involves tracking energy consumption data, conducting periodic audits, and soliciting feedback from residents.

For achieving optimum energy consumption in private residential buildings is a multifaceted endeavor that requires a combination of technological innovation, policy support, community engagement, and long-term planning.

5 SUMMARY AND CONCLUSIONS

In this paper it has been briefly described an energy efficiency analysis of the apartment during the years 2021 to 2023 which is located in northeast part of Albania at Kukes city. The results from invoices have shown that energy consumption has been increased from the year 2021, 2022 and 2023 with respectively values 4364, 4610 and 4895 kWh. Most of the losses are coming from outdoor walls, windows, and air infiltrations. “Termolog” software has been used to generate the certificate of the energy performance of the selected apartment. The class energy results have shown that this apartment is B class and corresponds to the value of 81.65 kWh/year with good energy efficiency. The results were in accordance with Albanian law and European standards. As an energy efficiency measure for the apartment taken in this research work, we recommend:

- Thermal insulation of the floor
- Thermal insulation of the terrace
- Thermal insulation of external walls
- Installation of solar panels

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