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Energy Audit of a Community Center

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Abstract: The aim of the study is to conduct an energy audit of the cultural center and museum at a community center in town of Mizia, Bulgaria. This audit includes a detailed analysis of existing condition of the building, as well as the energy systems used - heating, lighting and cooling. Energy-saving measures have been proposed such as installing thermal insulation on buildings' enclosing structures, replacing windows and doors in the building, installing high-efficiency VRF air conditioning systems, replacing old lighting fixtures with high-efficiency ones, installing a PV system for generating electricity. The total energy savings from the measures amount to 89273 kWh/year of electrical energy, with the environmental equivalent of the energy savings amounting to 51.64 t CO_2/year. After the audit, the building falls into class "B" on energy consumption scale. After implementing the prescribed energy savings measures, it can be summarized that it will meet energy consumption class "A" on the energy consumption scale.

Keywords: Energy audit, Energy efficiency, Energy-saving measures

Introduction

Energy efficiency is one of the main priorities of modern society, playing a crucial role not only in reducing energy costs, but also in sustainable development, environmental protection and reducing carbon emissions. In light of global efforts to tackle climate change and achieve sustainable development goals, improving energy efficiency in public and cultural buildings such as community centers is becoming increasingly necessary (Capehart et al., 2012; Doty, 2016; Kreith & Goswami, 2007). Community centers are institutions that play an important role in preserving cultural and social values, organizing significant social events and providing spaces for cultural events and education. Despite their importance, they often lack the necessary resources to modernize buildings and optimize their energy efficiency. Such a survey is essential not only for reducing energy costs and ensuring better comfort for visitors and employees of the cultural center and museum, but also for creating an example for other cultural and public institutions in the region. This study will contribute to the sustainable management of energy resources and will provide important guidelines for future improvements in other community centers and cultural sites. In addition, the results of the energy survey will have broad applicability, as they can serve as a basis for future research and practices to improve energy efficiency in public buildings, which is an important stage in the efforts to reduce energy dependence and environmental impact (Rasheva, 2011).

Energy efficiency is a set of measures and activities aimed at achieving optimal energy use in order to reduce costs, improve comfort and reduce carbon emissions. In Bulgaria, as a member state of the European Union, improving energy efficiency is not only an environmental necessity, but also an economic priority. The energy audit, defined in the Energy Efficiency Act, is a systematic analysis of the condition of a building and its energy systems. It identifies potential weaknesses and proposes specific measures for improvement (Directive 2002/91/EC; Directive 2006/32/EC; Energy Law; Energy Efficiency Act; Ordinance No.RD-02-20-3;

Ordinance No.E-RD-04-2/2022; Ordinance No.E-RD-04-1/2018; Ordinance No.E-RD-04-01/2022; Ordinance No.5; Ordinance No.15). Literature sources emphasize that the energy efficiency of buildings can be increased by implementing measures such as:

- Improving thermal insulation.
- Replacing window frames.
- Installing highly efficient heating and ventilation systems.
- Implementing intelligent energy management systems (Iliev et.al., 2024; Shapiro, 2016; Thuman & Younger; 2008; Turner, 1997).

Method

This paper focuses on energy audit of a cultural center and museum of a community center in the city of Mizia. The object of the study was chosen due to the existence of two important aspects – the cultural center as a social and cultural center of the community and the museum, which preserves part of the cultural heritage of the region. The existence of such buildings with different functions leads to significant energy consumption, mainly due to the need for heating, lighting and air conditioning of the different spaces. Despite their importance, these institutions often do not have the necessary resources to renovate the buildings and energy systems, which leads to unnecessarily high energy costs and possible inconvenience for visitors and employees.

This audit will include a detailed analysis of the existing condition of the building, as well as the energy systems used – heating, domestic hot water (DHW) system, ventilation, lighting and cooling. Based on the survey, the main problems and weaknesses in energy efficiency of the building will be identified and specific energy saving measures will be proposed to optimize energy consumption. This may include both technical solutions such as installing energy-efficient lighting, high-efficiency heating appliances and improving the building's insulation, as well as organizational approaches such as optimizing heating and lighting schedules. The energy efficiency audit is compiled based on a thorough analysis of both the energy and thermo-physical characteristics of the building. The survey process includes not only collecting data on energy consumption but also analyzing the condition of building elements that affect energy efficiency.

- The analysis of the condition of the building is a fundamental stage in the energy efficiency survey. It includes various subcategories that cover both the climatic conditions and thermo-physical characteristics of the building.
- Climatic conditions are an important factor in assessing the energy efficiency of the building. They directly affect energy consumption for heating and cooling. Among the main climatic data that are taken into account are temperature amplitudes, humidity, as well as other meteorological characteristics that can affect energy efficiency.
- A description of the site includes data on the location and purpose of the building, as well as general functional and operational characteristics.
- The main construction characteristics of the building include the materials of the building envelope, insulation and cladding. These factors determine how well the building retains heat and whether there is a need for improvements in thermal insulation. Enclosing elements such as walls, windows and roofs play a key role in energy efficiency. The analysis process includes calculations of heat losses that can be reduced by improving the insulation characteristics. Emphasis is placed on the use of modern materials and technologies that reduce heat losses and prevent cold penetration.
- Heating, cooling and ventilation of the building are major energy consumers in buildings. Their analysis includes the efficiency of heating installations, as well as the possibilities for optimizing consumption by modernizing existing systems and implementing new technologies for indoor temperature control and ventilation. Possibilities for using renewable energy sources such as solar panels and heat pumps are also considered in this context.
- Electrical installation - this part of the report analyzes the main electrical installations in the building. This includes existing lighting fixtures, electrical appliances used and the possibilities for replacing inefficient solutions with more energy-efficient technologies. The use of LED lighting and other modern solutions is a main focus of the energy audit.
- The building model study involves the use of simulation programs and software that allow for the calculation of energy losses and optimization of building energy costs. These simulations can include both winter and summer conditions in order to predict maximum energy savings. For this study a simulation software EECalc-Version 1.0.0.10201 is used.
- Energy-saving measures (ESM) for the project - this section of the report presents recommendations for energy saving measures that can be implemented in the building. This includes both improvements in thermal insulation

and changes in heating and lighting installations that will lead to significant energy savings. For this study simulation software PV Syst- Version 7.4.6 is used.
- The conclusion summarizes the results of the audit and highlights the main recommendations for improving the energy efficiency of the building. The goal is to achieve not only a reduction in energy costs, but also to improve the internal comfort of the building's occupants. All energy-saving measures have a positive ecological effect, which is characterized by saved carbon emissions into the environment.

The recommendations propose specific actions for implementing energy-saving measures that will provide long-term benefits for the building. These may include investments in new technologies as well as optimization of existing installations.

Results and Discussion

Situation Analysis

Basic Climatic Data for the Area

According to the climatic zoning of the Republic of Bulgaria, the town of Mizia belongs to Climate Zone 3, which is characterized by the following climatic features:

- Duration of the heating season is 175 days; start: October 23; end: April 15;
- Heating degree days DD = 2600 at an average temperature in the building of 19 ºC
- Calculated outdoor temperature: - 17 ºC
- Altitude of the site 54 meters

Climatic zones in Republic of Bulgaria are shown on Figure 1. The measured average monthly outdoor air temperatures for the settlement for the period 2021 - 2023, according to data from the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences, as well as representative average monthly outdoor air temperatures for Climate zone 3, were used as basic climate data.

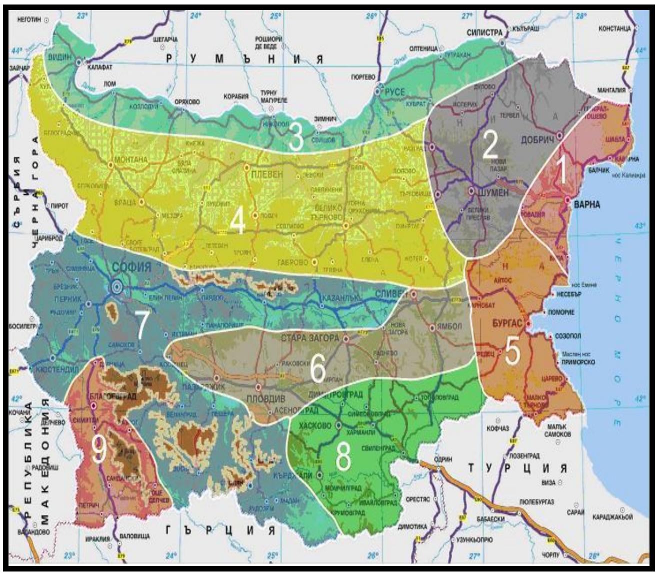


Figure 1. Climatic zones in Republic of Bulgaria

Description of the Object

The building is a collection of several sections with different storeys, which are functionally interconnected. The roof structure is designed with a flat roof without an air gap, with only the area above the audience hall identifying an under-roof space. The window frames have been completely replaced with PVC frames and double glazing. Measures to increase energy efficiency have been implemented on the facade, basement and roof. General data about the building are presented in Table 1. Exterior facades of the building are shown on Figure 2.

Table 1. General data about the building

Building (name)		Cultural Center and Museum at the "Prosveta 1915" Community Center, Mizia	
Address		Mizia, 18A Georgi Dimitrov Street	
Building type		Massive	
Ownership		Municipal	
Year of construction		1973	
Number of residents + Staff		15+36	
Residents schedule hour/day		Heating schedule hour/day	
Weekdays, hour/day	8	Weekdays, hour/day	8
Saturday, hour/day	8	Saturday, hour/day	8
Sunday, hour/day	8	Sunday, hour/day	8


a) North-east (NE) b) North-west (NW)


c) South-east (SE) b) South-west (SW)

Figure 2. Exterior facades of the building

General Construction Characteristics

Data for area and heated volume of the building are presented in Table 2.

Table 2. Area and heated volume of the building

Built-up area, m^2	Surveyable area, m^2	Heated area, m^2	Heated volume, gross, m^3	Heated volume, net, m^3
1 820	3 591	2 489	13 383	10 706

Analysis of the Enclosing Elements

The main enclosing walls of the structure are made of brick walls. Some of them are thermally insulated with external thermal insulation of expanded polystyrene foam with a thickness of 100 mm. On the southwest facade, part of the enclosure is finished with limestone slabs. The basement walls are made of monolithic reinforced concrete with a thickness of 400 mm. The building's windows were replaced more than 10 years ago. There are failures in the opening parts, as well as damaged and missing seals, which is why there is serious infiltration. All windows and doors are equipped with standard white-white glazing. General data about enclosing elements of the building are presented in Table 3.

Table 3. General data about enclosing elements of the building

Type	Facades - celestial orientation			
	NE	NW	SW	SE
Area, m^2 Type 1 - brickwork 380 mm	146.84	124.29	110.28	91.18
U, W/m²K	1.57	1.57	1.57	1.57
Area, m^2 Type 2 - brickwork 380 mm + thermal insulation	244.78	432.87	207.57	333.65
U, W/m²K	0.30	0.30	0.30	0.30
Area, m^2 Type 3 - brickwork 380 mm + overlay	0.00	5.16	51.14	5.16
U, W/m²K	1.51	1.51	1.51	1.51
Area, m^2 Type 4 - brickwork 250 mm + thermal insulation	4.00	9.84	4.65	9.84
U, W/m²K	0.31	0.31	0.31	0.31
Area, m^2 Type 5 - reinforced concrete 400 mm	72.63	47.36	11.24	50.75
Area, m^2 Type 1 Door with PVC frame and thermal panel /old/	0.00	2.00	0.00	0.00
U, W/m²K (g = 0.47)	-	2.40	-	-
Area, m^2 Type 2 Door with PVC frame and 50% thermal panel + 50% glass /old/	0.00	2.80	0.00	0.00
U, W/m²K (g = 0.23)	-	2.40	-	-
Area, m^2 Type 3 Window with PVC frame and thermal panel /old/	0.00	2.66	0.00	0.00
U, W/m²K (g = 0.47)	-	2.40	-	-
Area, m^2 Type 4 Window with PVC frame and double glazing /old/	13.57	3.94	0.00	4.00
U, W/m²K (g = 0.47)	2.40	2.40	-	2.40
Area, m^2 Type 5 Window with PVC frame and double glazing /old/	103.30	64.97	111.32	193.07
U, W/m²K (g = 0.47)	2.40	2.40	2.40	2.40
Area, m^2 Type 1 Floor on unheated basement	256.31			
U, W/m²K	0.40			
Area, m^2 Type 2 Floor on unheated basement	99.96			
U, W/m²K	0.37			
Area, m^2 Type 3 Floor on unheated basement	508.50			
U, W/m²K	0.36			
Area, m^2 Type 4 Floor to outside air	23.16			
U, W/m²K	0.33			
Area, m^2 Type 5 Floor to ground	955.31			
U, W/m²K	0.33			
Area, m^2 Type 1 Flat "warm" roof	1146.20			
U, W/m²K	0.26			
Area, m^2 Type 1 Flat "warm" roof	1146.20			
U, W/m²K	0.26			
Area, m^2 Type 2 Flat "warm" roof	140.44			
U, W/m²K	0.26			
Area, m^2 Type 3 Flat roof with air gap	541.70			
U, W/m²K	0.27			

Heating, Domestic Hot Water, Ventilation and Air Conditioning of the Building

The heating of the building is carried out locally, through electrical appliances. The heating is carried out with individual air conditioners, fan convectors and electric heaters. A large part of the premises are not heated. Electrical appliances for heating of the building are shown on Figure 3.

Figure 3. Electrical appliances for heating of the building

The building has six air conditioners, one electric heater, six fan coils and one electric radiator. Air conditioning systems are used for both heating and cooling the rooms in the building. The air conditioners and conventional electrical appliances are low efficiency and need to be replaced. In Table 4 are shown general data for annual electrical energy consumption for heating.

Table 4. General data for annual electrical energy consumption for heating

Heating	Quantity	Installed power, W	Working hours per year	Simult. Coefficient, -	Load factor, -	Annual consumption, kWh/y
Air Conditioner 12000Btu/hr	6	1150	2000	0.25	1	3450
Radiator	1	4000	900	0.15	1	540
Fan Coil	6	2000	1500	0.15	1	2700
Electric Radiator	1	2000	1500	0.15	1	450
Total:						7140
Heated area, m^2	Installed power, W	$P_{work,}$ kW	Usability, hours per week		P simult, W/m^2	
2 489.00	24900	4.43	18.35		1.78	

DHW in the building is provided year-round by one instantaneous and one volumetric electric boiler. The reference value for the specific amount of hot water for sanitary and domestic purposes in the building is calculated according to Appendix No.3 to Regulation No. 4/2005 on the design, construction and operation of building, water supply and sewage installations according to the norms for administrative buildings - standard hot water consumption 5 liters per employee, norms for theaters for 120 seats (spectators) - 5 liters per spectator and norm for artists - 25 liters per artist. In Table 5 are shown general data for consumption of hot water in the building.

Table 5. General data for consumption of hot water in the building

Average daily consumption by benchmark	Value for office	Value for spectators in theaters	Value for artists in theaters
Norm, l/day	5	5	25
Indicator, number of residents with standardized consumption	51	600	5
Coefficient for uneven load	0.1	0.01	0.1
Temperature of heated water, t˚C	55	55	55
Temperature of drawn water, t˚C	37.5	37.5	37.5
Temperature of cold water, t˚C	10	10	10
Heated area, m^2	2489	2489	2489
Working days (shifts)	261	261	261
Total, l/m^2 per year of heated water	1.34	3	1
Total, l/m^2 per year of mixed water	2.2	5	1

Table 6. General data for annual electrical energy consumption for DHW

Domestic Hot Water (DHW)	Quantity	Installed power, W	Working hours per year	Simult. Coefficient, -	Load factor, -	Annual consumption, kWh/y
Instantaneous water heater	1	2500	250	0.15	1.00	94
Volume water heater	1	3000	250	0.25	1.00	188
Total:						281
Heated area, m^2	Installed power, W	P_{work}, kW	Usability, hours per week		P simult, W/m^2	
2 489.00	5500	1.13	8.35		0.45	

In Table 6 are shown general data for annual electrical energy consumption for DHW. There are no ventilation installations in the building.

Electrical Installation and Consumers

Table 7. General data for electrical consumers affecting heat balance

Consumers affecting the balance	Quantity	Installed power, W	Working hours per year	Simult. Coefficient -	Load factor -	Annual consumption, kWh/y
Laptop	1	65	1200	0.25	1.00	20
Computer system	12	300	2000	0.45	1.00	3240
Printer	1	250	350	0.05	1.00	4
Refrigerator	1	120	8760	0.25	1.00	263
Coffee maker	1	1500	150	0.05	1.00	11
Scanner	1	35	150	0.15	1.00	1
Microwave oven	2	900	150	0.15	1.00	41
Multimedia	1	350	360	0.15	1.00	19
Refrigerated display case	1	150	8760	0.25	1.00	329
Television	1	120	1800	0.50	1.00	108
Sound system	1	300	350	0.25	1.00	26
Total:						4061
Heated area, m^2	Installed power, W	P_{work}, kW	Usability, hours per week			P simult, W/m^2
2 489.00	8290	2.25	34.01			0.91

Table 8. General data for electrical consumers non affecting heat balance

Consumers non affecting the balance	Quantity	Installed power, W	Working hours per year	Simult. Coefficient, -	Load factor, -	Annual consumption, kWh/y
Lighting fixture unheated volume	24	60	250	0.10	1.00	36
Air conditioner 12000 Btu/h	6	1150	450	0.065	1.00	202
Outdoor lighting	8	150	900	0.10	1.00	108
Outdoor lighting	2	8	900	0.10	1.00	1
Total:						347
Heated area, m^2	Installed power, W	$P_{work,}$ kW	Usability, hours per week		P simult, W/m^2	
2 489.00	9556	0.71	9.50		0.29	

The facility is supplied with electricity with a three-phase voltage of 400/230 V from an existing steel pole of an overhead power distribution network of "Elektrorazpredelenie Zapad" Ltd to the facade of the building with a power cable 4x35 mm^2. The measurement of the electricity consumed in the building is carried out by 2 electricity meters installed in main distribution board (MDB), located on property boundary wall. MDB, using power cables of type 4x10mm^2, supplies power to the MDB of the library block with the small hall, the MDB of the cinema hall with the ritual hall and the municipal club-disco. The technical condition of the MDB is good. In Table 7 are shown general data and annual consumption for electrical consumers affecting heat balance. In Table 8 are shown general data and annual consumption for electrical consumers non affecting heat balance (this includes air-conditioners, operating in cooling mode).

The lighting installation throughout the building dates from the time of its construction. It is equipped with 2x1.5mm^2 cables. The lighting fixtures in the cinema are wall lamps with incandescent lamps, in places they have been replaced with LED bulbs with missing protective glass. There are exposed cables and wires and missing wall lamps. The lighting fixtures in the hall next to the cinema are square ceiling lamps and date from the time of the construction of the building. There are exposed junction boxes with missing protective caps and unsecured electrical connections. In the cinema above the exit doors, there are evacuation lights with fluorescent lamps installed. They do not function; their batteries are damaged. The lighting fixtures on the second floor in the cinema are old type pendant lamps with incandescent lamps, with open sockets and with broken protective glass. Open sockets with incandescent lamps light bulbs are installed on the walls. The lighting fixtures in the warehouses are incandescent lamps ceiling lamps with missing protective glass. The stage lighting is implemented with spotlights, which are old and energy inefficient.

Table 9. General data for lighting fixtures in the building

Lighting	Quantity	Installed power, W	Working hours per year	Simult. Coefficient, -	Load factor, -	Annual consumption, kWh/y
Luminiscent lamp 4x18W	5	72	1200	0.25	1.00	108
Luminiscent lamp 2x42	15	84	1200	0.25	1.00	378
Luminiscent lamp 2x18	10	36	1200	0.25	1.00	108
Lamp LED bulb	41	9	1200	0.25	1.00	111
Lamp incandescent	35	60	900	0.30	1.00	567
Stage spotlights	4	250	350	0.25	1.00	88
Lamp incandescent (missing)	65	60	900	0.00	1.00	0
Total:						1359
Heated area, m^2	Installed power, W	$P_{work,}$ kW	Usability, hours per week		P simult, W/m^2	
2 489.00	9349	1.47	18.35		0.59	

The lighting fixtures in the library block and the municipal club are 2x36W fluorescent lamps and pendant lamps with open sockets with incandescent lamps. In the inner courtyard of the building, park lighting fixtures of the "globe" incandescent lamps have been installed. In the ritual hall and in the entrance lobby, the lighting fixtures are chandeliers with incandescent lamps. There are open junction boxes with missing protective caps. Additionally, power cables have been laid in PVC cable ducts. In the toilets, the lighting is implemented everywhere with LNC incandescent ceiling lamps and wall lamps. In the basement of the library block, the lighting is depreciated. The lighting control everywhere is carried out by electric switches mounted on the walls at a height of 1.3m from the floor. They are old from the time the building was built, broken and in places missing. The lighting control for the stage is carried out by the local switchboard on the second floor in the technical room by means of electric switches. In Table 9 are shown general data for lighting fixtures in the building. Data on the building's electricity consumption for the period 2021-2023 were requested. The building's electricity consumption data for 2021 and 2022 were deemed irrelevant due to the fact that the building was not visited in connection with the global COVID-19 pandemic. The distribution of electrical energy consumed for 2023, taken as the reference year, is shown on Figure 4.

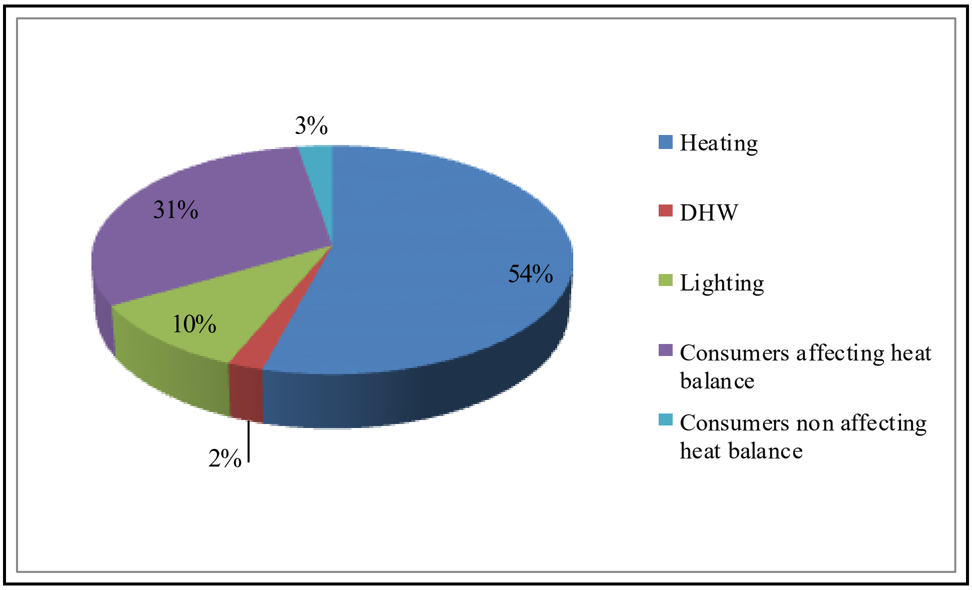


Figure 4. Distribution of electrical energy consumed for reference year 2023

Data for average monthly outdoor air temperature, heating DD, and electricity costs for 2023 in kWh/month and ₠+VAT are shown in Table 10. Average price for 1 kWh of electricity is 0.2219 ₠ +VAT.

Table 10. Data for average monthly outdoor air temperature, heating DD, and electricity costs for 2023

Month	Number of days in month	Average monthly outdoor air temperature		Electrical energy 2023	
		ºC	DD	kWh/month	₠+VAT
1	31	4.4	452.6	1408	312.44
2	28	4.5	406.0	1501	333.07
3	31	8.3	331.7	1317	292.24
4	15	10.8	123.0	1152	255.63
5	-	-	0	908	201.48
6	-	-	0	712	157.99
7	-	-	0	802	177.97
8	-	-	0	824	182.85
9	-	-	0	701	155.55
10	9	15.3	33.3	948	210.36
11	30	8.3	321.0	1215	269.61
12	31	5.1	430.9	1700	377.23
Total:			2098.5	13188	2926.43

Model Study of the Building

The model study of the building is carried out using the software product EECalc-1.0.0.1201. The purpose of the model study is to obtain the values of the actually required energy to maintain the microclimate in the building, compared to the reference energy consumption, determine possible energy saving measures and issue an energy efficiency certificate in the presence of the conditions provided for in the regulatory framework. The software has entered areas and heat transfer coefficients of the building's enclosing structures, as well as specific energy costs for heating, DHW, lighting, etc. The reference energy consumption of the building has been calculated, after which the building model has been calibrated and normalized using the software. The results for energy costs for current state and normalized state of the building are shown on Figure 5.

Потребна енергия										
Енергия за:	Реф. с-ти 1 kWh/m²	Реф. с-ти 2 kWh/m²	Текущо състояние kWh/m²	Текущо състояние kWh/year	Нормализирано съст. kWh/m²	Нормализирано съст. kWh/year	След ЕСМ kWh/m²	След ЕСМ kWh/year	в т.ч. ЕВИ kWh/year	Общо ЕВИ kWh/year
Отопление			3.467	8 629.011	50.911	126 717.793	50.911	126 717.793	0	123 676.566
Охлаждане			0	0	0	0	0	0	0	0
Вентилация (отопление)			0	0	0	0	0	0	0	0
Вентилация (охлаждане)			0	0	0	0	0	0	0	0
БГВ			0.110	274.845	0.385	957.968	0.385	957.968	0	0
БГВ(Помпи)			0	0	0	0	0	0	0	0
Помпи и вентилатори			0	0	0	0	0	0	0	0
Осветление			0.532	1 324.358	0.967	2 406.877	0.967	2 406.877	0	0
Уреди влияещи на топлинния баланс			1.646	4 097.468	1.646	4 097.468	1.646	4 097.468	0	0
Уреди невлияещи на топлинния баланс			0.139	345.799	0.139	345.799	0.139	345.799	0	0
Други			0	0	0	0	0	0	0	0
Общо			5.895	14 671.481	54.048	134 525.905	54.048	134 525.905	0	123 676.566

Разпределение на потребната енергия по енергийни ресурси					
Енергиен ресурс	Реф. стойности 1 kWh/m²	Реф. стойности 2 kWh/m²	Текущо състояние, kWh/m²	Нормализирано състояние, kWh/m²	След ЕСМ kWh/m²
Електричество			5.895	54.048	54.048
Природен газ			0	0	0
Пропан-бутан			0	0	0
Черни каменни въглища			0	0	0
Лигнитни/кафяви каменни въглища			0	0	0
Дървени пелети, брикети и дърва			0	0	0
Брикети			0	0	0
Промишлен газьол, петрол и дизел			0	0	0
Централизирано топлоснабдяване			0	0	0
Мазут			0	0	0
Антрацитни въглища			0	0	0

Figure 5. Energy costs for current state and normalized state of the building

Potential Energy Saving Measures

- ESM 1 Thermal insulation of external walls

The measure includes external thermal insulation with expanded polystyrene foam (EPS) with a thickness of 120 mm and a thermal conductivity coefficient not higher than $\lambda = 0.030$ W/m.K on the facade walls. The measure for the walls of Type 1 and Type 3 with a total area of 534.05 m^2 + 55 m^2 for zones around windows and doors includes the delivery and installation of thermal insulation material type "EPS". Value for the implementation of ESM 1 is 56242.00 € including VAT.

- ESM 2 Replacement of windows

The measure includes replacing the old windows (478.4 m^2) with new PVC windows with triple glazing with one low-energy glass, one K-glass and one float in the middle with a heat transfer coefficient of 1.10 W/m^2K. The large glass window on the NE facade (23.6 m^2) is planned to be replaced with an aluminum one with a interrupted thermal bridge and a glass package with one low-energy glass with a heat transfer coefficient of 1.60 W/m^2K. It is planned to replace the windows in the unheated volume (28.97 m^2) of the building with new PVC windows with double glazing with one low-energy glass, with a heat transfer coefficient of 1.40 W/m^2K. Value for implementation of ESM 2 is 102258.00 € including VAT.

- ESM 3 Thermal insulation of floor (adjacent walls)

Different types of floor structures are identified in the building. Some of the sections have a basement floor, while others are directly located on the ground. Thermal insulation of extruded polystyrene foam with a thickness of 5 cm is laid on the ceilings of the unheated basements. This measure provides for the thermal insulation of the adjacent walls of the basement bordering the outside air (the plinth) - 181.98 m2 with external thermal insulation EPS with a thickness of 120 mm and a thermal conductivity coefficient not higher than $\lambda =$ = 0.030 W/mK. The cost of implementation of ESM 3 is 4602.00 € including VAT.

- ESM 4 Heat generation measures – Mounting a VRF direct evaporation air conditioning systems

The measure requires the preparation of a project in accordance with the new load of the building, namely after laying thermal insulation and joinery on the enclosing elements. It is planned to replace the old inefficient electrical heating appliances with highly efficient VRF systems with minimal value of coefficient of performance COP = 3.80. Five VRF direct evaporation air conditioning systems are planned for the building. For the premises on the first floor in the western part of the complex - ritual hall, pensioner's club, admin. premises and lobby, a VRF direct evaporation system with $Q_{heat} = 24.00$ kW; $Q_{cool} = 22.4$kW; $P_e = 6.12$ kW is selected, with an outdoor unit mounted on the roof above the entrance to the inner courtyard in the northeastern part of the building. The indoor units in the ritual hall are console type mounted in height 300 mm from the floor and for high wall mounting in the other premises.

For the premises on the second floor - library, computer room, reading room and office, a VRF direct evaporation system with Q_{heat} = 24.00 kW; Q_{cool} =22.4 kW; P_e = 6.12 kW is selected, with an outdoor unit mounted on the roof above the entrance to the inner courtyard. The indoor units are for high wall mounting.

For the conference halls (first and second floor) in the southeastern part of the complex, a VRF direct evaporation system with Q_{heat} = 18.00 kW; Q_{cool} = 16.00 kW; P_e= 4.75 kW is selected, with an outdoor unit mounted on the flat roof above the hall. The indoor units are console type mounted in height 300 mm from the floor.

For the lobby and the staircase in front of the theater hall, a VRF direct evaporation system with Q_{heat} = 24.00 kW; Q_{cool} = 22.40 kW; P_e = 6.12 kW is selected, with an outdoor unit installed in the southern part of the flat roof above the staircase. The indoor units are for high wall installation.

For the dressing rooms, rehearsal halls and corridors, a VRF direct evaporation system with Q_{heat} = 35.00 kW; Q_{cool} = 33.50 kW; P_e = 9.57 kW is selected, with an outdoor unit installed on the flat roof above the municipal club. The indoor units are for high wall installation.

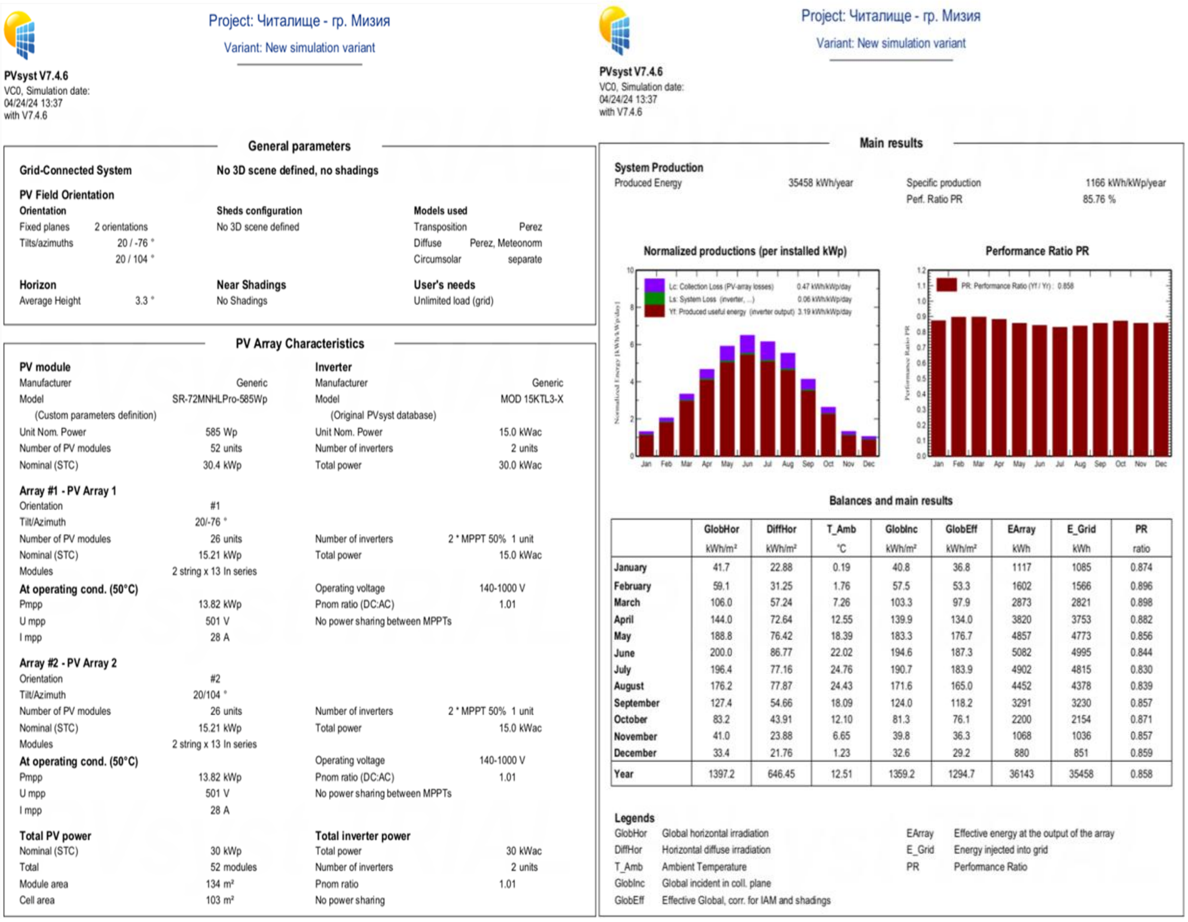
Cost of implementation of ESM 4 is 127823.00 € including VAT.

- ESM 5 Lighting measures

It is necessary to replace the old inefficient lighting with new LED ones. Old incandescent lamp 60 W will be replaced with new LED 6 W – 100 pieces, 42 W fluorescent tubes will be replaced with 18 W LED tubes – 30 pieces, 18 W fluorescent tubes will be replaced with 9 W LED tubes – 20 pieces, 250 W stage spotlights will be replaced with 35 W LED. The measure includes the development of an investment project by a designer with the relevant qualification for the replacement of the lighting installation. The new lighting must meet the following indicators and technical data:

• Energy class – A;
• Color temperature: CCT≤ 5000K;
• Light output of the luminaire: $\chi \geq 110$ lm/W;
• The power supply unit must provide a light flux ripple coefficient: KP ≥ 10%

All lighting parameters of the luminaire are certified by a test laboratory report. Value for the implementation of ESM 5 is 4857.00 € including VAT.


Project: Читалище - гр. Мизия
Variant: New simulation variant
PVsyst V7.4.6
VC0, Simulation date:
04/24/24 13:37
with V7.4.6

General parameters

Grid-Connected System — No 3D scene defined, no shadings

PV Field Orientation
Orientation: Fixed planes 2 orientations; Tilts/azimuths 20 / -76 °, 20 / 104 °
Sheds configuration: No 3D scene defined
Models used: Transposition Perez; Diffuse Perez, Meteonorm; Circumsolar separate
Horizon: Average Height 3.3 °
Near Shadings: No Shadings
User's needs: Unlimited load (grid)

PV Array Characteristics

PV module: Manufacturer Generic; Model SR-72MNHLPro-585Wp (Custom parameters definition); Unit Nom. Power 585 Wp; Number of PV modules 52 units; Nominal (STC) 30.4 kWp
Inverter: Manufacturer Generic; Model MOD 15KTL3-X (Original PVsyst database); Unit Nom. Power 15.0 kWac; Number of inverters 2 units; Total power 30.0 kWac

Array #1 - PV Array 1: Orientation #1; Tilt/Azimuth 20/-76 °; Number of PV modules 26 units; Nominal (STC) 15.21 kWp; Modules 2 string x 13 In series; Number of inverters 2 * MPPT 50% 1 unit; Total power 15.0 kWac
At operating cond. (50°C): Pmpp 13.82 kWp; U mpp 501 V; I mpp 28 A; Operating voltage 140-1000 V; Pnom ratio (DC:AC) 1.01; No power sharing between MPPTs

Array #2 - PV Array 2: Orientation #2; Tilt/Azimuth 20/104 °; Number of PV modules 26 units; Nominal (STC) 15.21 kWp; Modules 2 string x 13 In series; Number of inverters 2 * MPPT 50% 1 unit; Total power 15.0 kWac
At operating cond. (50°C): Pmpp 13.82 kWp; U mpp 501 V; I mpp 28 A; Operating voltage 140-1000 V; Pnom ratio (DC:AC) 1.01; No power sharing between MPPTs

Total PV power: Nominal (STC) 30 kWp; Total 52 modules; Module area 134 m²; Cell area 103 m²
Total inverter power: Total power 30 kWac; Number of inverters 2 units; Pnom ratio 1.01; No power sharing

Main results

System Production: Produced Energy 35458 kWh/year; Specific production 1166 kWh/kWp/year; Perf. Ratio PR 85.76 %

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	41.7	22.88	0.19	40.8	36.8	1117	1085	0.874
February	59.1	31.25	1.76	57.5	53.3	1602	1566	0.896
March	106.0	57.24	7.26	103.3	97.9	2873	2821	0.898
April	144.0	72.64	12.55	139.9	134.0	3820	3753	0.882
May	188.8	76.42	18.39	183.3	176.7	4857	4773	0.856
June	200.0	86.77	22.02	194.6	187.3	5082	4995	0.844
July	196.4	77.16	24.76	190.7	183.9	4902	4815	0.830
August	176.2	77.87	24.43	171.6	165.0	4452	4378	0.839
September	127.4	54.66	18.09	124.0	118.2	3291	3230	0.857
October	83.2	43.91	12.10	81.3	76.1	2200	2154	0.871
November	41.0	23.88	6.65	39.8	36.3	1068	1036	0.857
December	33.4	21.76	1.23	32.6	29.2	880	851	0.859
Year	1397.2	646.45	12.51	1359.2	1294.7	36143	35458	0.858

Legends
GlobHor Global horizontal irradiation
DiffHor Horizontal diffuse irradiation
T_Amb Ambient Temperature
GlobInc Global incident in coll. plane
GlobEff Effective Global, corr. for IAM and shadings
EArray Effective energy at the output of the array
E_Grid Energy injected into grid
PR Performance Ratio

Figure 6. Simulation report for PV system

- ESM 6 RES measures: Installation of a photovoltaic plant FPP for own needs 30.42 kWp

Due to the large area of unusable roofs and the geographical location with intense solar radiation, the installation of a photovoltaic installation for own needs is planned for the building, which will be able to cover an average of 37.55% of the building's electricity annually. The photovoltaic plant will be located on the roof of the building and will be sized in the technical phase according to the load capacity of the structure and the practical possibility of implementing the installation. For this purpose, it is necessary to prepare a structural statement and, if necessary, provide for structural reinforcement in order to safely install the facilities. The total capacity is sized based on the calculated energy consumption/power of the building from the electrical appliances used.

Annual production from the photovoltaic installation is within 35457 kWh, which according to the geographical location and the preliminary simulation made is equivalent to an installation of 30.42 kWp. After analysis of the energy consumption in the building and the production from the photovoltaic plant, it was established that the building will not be able to absorb all the electrical energy produced. The amount of energy that will be absorbed in the building is in the order of 16990 kWh. A simulation of the site has been prepared based on polycrystalline modules. The energy yield of the installation has been calculated based on 52 photovoltaic modules, with a nominal power of 585 Wp and a total installed power of 30.42 kWp, their type and type should be determined after the selection of a contractor and approval of the project. For this study an simulation software PV Syst - Version 7.4.6 is used. The results of simlation are shown on Figure 6. Value for the implementation of ESM 6 is 30678.00 € including VAT.

Energy Budget

On Figure 7 are shown data for annual energy consumption and specific energy consumption before and after energy saving measures. On Figure 8 are shown data for energy savings.

Потребна енергия										
Енергия за:	Реф. с-ти 1	Реф. с-ти 2	Текущо състояние		Нормализирано съст.		След ЕСМ		в т.ч. ЕВИ	Общо ЕВИ
	kWh/m^2	kWh/m^2	kWh/m^2	kWh/year	kWh/m^2	kWh/year	kWh/m^2	kWh/year	kWh/year	kWh/year
Отопление			3.467	8 629.011	50.911	126 717.793	15.818	39 371.684	0	110 240.717
Охлаждане			0	0	0	0	0	0	0	0
Вентилация (отопление)			0	0	0	0	0	0	0	0
Вентилация (охлаждане)			0	0	0	0	0	0	0	0
БГВ			0.110	274.845	0.385	957.968	0.385	957.968	0	0
БГВ(Помпи)			0	0	0	0	0	0	0	0
Помпи и вентилатори			0	0	0	0	0	0	0	0
Осветление			0.532	1 324.358	0.967	2 406.877	0.192	479.072	0	0
Уреди влияещи на топлинния баланс			1.646	4 097.468	1.646	4 097.468	1.646	4 097.468	0	0
Уреди невлияещи на топлинния баланс			0.139	345.799	0.139	345.799	0.139	345.799	0	0
Други			0	0	0	0	0	0	0	0
Общо			5.895	14 671.481	54.048	134 525.905	18.181	45 251.991	0	110 240.717

Figure 7. Data for annual energy consumption and specific energy consumption before and after energy saving measures

Енергоспестяващи мерки		
Параметър	**kWh/m^2**	**kWh**
Осветление		
Едновременна мощност	0,775	1928,975
Общо	**0,775**	**1928,975**
Отопление		
U външни стени	5,673	14120,097
U прозорци	5,102	12698,878
U под(НПЕ/ОПЕ/външен въздух/земя)	0,345	858,705
Инфилтрация	4,463	11108,407
Ефективност на генератора на топлина ЕИ1	19,509	48557,901
Общо	**35,092**	**87343,988**

Figure 8. Data for energy savings

Determination of the values of equivalent primary energy before and after ESM is presented in Table 11 and Table 12.

Table 11. Values of equivalent primary energy before ESM

Energy	Q_i, kWh/y	$f_{P,nren}$, -	K_{CO2e}, g CO_2/kWh	$E_{we,del;an}$, kWh/m^2.y	EP_{CO2e}, t CO_2/y
Heating	126718	2.3	486	117.10	61.58
DHW	958	2.3	486	0.89	0.47
Lighting	2407	2.3	486	2.22	1.17
Others	4443	2.3	486	4.11	2.16
Total:	134526			124.31	65.38

Table 12. Values of equivalent primary energy after ESM

Energy	Q_i, kWh/y	$f_{P,nren}$, -	K_{CO2e}, g CO_2/kWh	$E_{we,del;an}$, kWh/m^2.y	EP_{CO2e}, t CO_2/y
Heating	39372	2.3	486	36.38	19.13
DHW	958	2.3	486	0.89	0.47
Lighting	479	2.3	486	0.44	0.23
Others	4443	2.3	486	4.11	2.16
PV	-16990	2.3	486	-15.7	-8.26
Total:	45252			26.12	13.74

Based on the obtained primary energy values for EP = 124.31 kWh/m^{2}y and EP_{ESM} = 26.12 kWh/m^{2}y and scale of energy consumption classes for types of building categories, the energy consumption class of the building in its current state for buildings in the field of culture and arts is determined. From the correlation of the obtained EP value and the scale, it follows that at the time of the survey the building has a specific primary energy consumption EP = 124.31 kWh/m^{2}y and belongs to energy consumption class "B".

After implementation of all energy saving measures, the building will have a specific primary energy consumption of EP_{ESM} =26.12 kWh/m^{2}y, which will meet the requirements for energy consumption class "A". Energy consumption classes are defined according to Appendix No.2 of Ordinance No. RD-02-20-3 of November 9, 2022 on technical requirements for energy performance of buildings for energy consumption indicators and energy performance of buildings in the field of culture and arts.

Economic and Ecological Analysis of ESM

An economic and ecological analysis showing the energy savings (ES) of individual ESM in kWh/year, %, €/year, as well as the investments (I), simple payback periods (PB) and saved emission carbon dioxide for each of the measures are presented in Table 13.

Table 13. Economic and ecological analysis of ESM

Energy saving measures	Q_i, kWh/y	Q_{iESM}, kWh/y	ES, kWh/y	ES, %	I, € +VAT	ES, € +VAT/year	PB, years	t CO_2/y
Thermal insulation of external walls	134526	120406	14120	10.5	56242	3133.27	18.0	6.86
Replacement of windows	134526	110719	23807	17.7	102258	5282.87	19.4	11.57
Floor insulation	134526	133667	859	0.6	4602	190.55	24.2	0.42
Heat generation measures	134526	85968	48558	36.1	127823	10775.06	11.9	23.60
Lighting measures	134526	132597	1929	1.4	4857	428.05	11.4	0.94
RES measures: Photovoltaic power plant	-	-	-	-	30678	3770.10	8.1	8.26
Total:	134526	45253	89273	66.3	326460	23580.00	13.8	51.64

Conclusion

The existing condition of the building before energy saving measures indicates that the building falls into energy class "B" of the energy consumption scale. The current state established is EP = 404.52 kWh/m²y, falling within the limits of class "F", namely: EP_{min} > 110 kWh/m²y and EP_{max} >220 kWh/m²y. After implementing the prescribed energy saving measures, it can be summarized that the building will be in class "A" of the energy consumption scale.The established condition after implementing the prescribed energy saving measures is EP_{ESM} = 26.12 kWh/m²y, falling within the limits of class "A", namely: $EP_{max} \leq$ 110 kWh/m²y. The total energy savings from the measures amount to 89273 kWh/year of electrical energy, with the environmental equivalent of the energy savings amounting to 51.64 t CO_2/year.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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