26. 07. 2021

PROJECT

PRO-ENERGY – PROMOTING ENERGY EFFICIENCY IN PUBLIC BUILDINGS OF THE BALKAN MEDITERRANEAN TERRITORY

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Activity:	*3.5 Joint Regional Analysis, Strategy and Framework - Energy audits in pilot public buildings*
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INTRODUCTION

PRO-ENERGY is a transnational cooperation project, co-financed by the Cooperation Programme "Interreg V-B Balkan Mediterranean 2014-2020", under Priority Axis 2, Specific Objective 2.2 Sustainable Territories. The project aims at promoting Energy Efficiency in public buildings in the Balkan Mediterranean territory and to create a practical framework of modelling and implementing energy investments interventions, through specific ICT monitoring and control systems, as well as through energy performance contracting (EPC). The specific objective of PRO-ENERGY is to reduce by more than 20% the energy spending in public buildings of the participating entities in one year after the implementation of pilot actions.

Based on the above, Work Package 3 (WP 3) "Joint Regional Analysis, Strategy and Framework" aims at formulating a Joint Strategy and Action Plan for the whole Balkan Med area regarding energy efficiency through behavioural change based on the analysis of the existing situation regarding energy efficiency in participating territories incorporating mapping of policies, initiatives and interventions, and the selection of good practices and benchmarking of participating authorities. More specifically, Activity 3.5 "*Energy audits in pilot public buildings*" aims to Aim to establish a benchmark for the pilot actions.

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SECTION 1

1. Purpose and Scope of the Energy Audit

The following report presents the methodology and results of the detailed inspection for energy efficiency of the building of the University of Agribusiness and Rural Development , located at 78 Dunav Blvd. in Plovdiv, Bulgaria.

The detailed energy audit was performed in accordance with the requirements of the Energy Efficiency Act (EEA), ORDINANCE № Е-РД-04-1 of 22.01.2016 for Inspection of energy efficiency, certification and assessment of energy savings of buildings and Ordinance and Ordinance №7 / 2004 for energy efficiency of buildings.

The purpose of the energy audit is: (1) identification of the building enclosing structures and elements and the systems for providing the microclimate, measurement and calculation of the energy characteristics, analysis and determination of the potential for reduction of the energy consumption; (2) developing measures to increase energy efficiency; (3) a feasibility study for energy efficiency improvement measures and a cost-benefit ratio; and (4) an assessment of the CO2 emissions that will be saved as a result of the implementation of energy efficiency improvement measures. The analysis is based on the available information from the documentation of the building, interview with administrative and technical staff, formation and systematization of the necessary database for assessment of energy consumption and energy systems of the building, thermal and economic calculations, simulation of energy performance.

Sequence and events:

- collection of primary information and processing of the database;
- analysis of the existing condition of the building;
- model study of the building with software product .

The technical calculations in the project were performed with the software product "EAB Software v. NS 1.0 ", developed by TU-Sofia.

The necessary information for the analysis was collected from:

- available project documentation provided by the building owner;
- available declarations of conformity of construction materials and certificates;

- recordings and measurements performed by the auditors;
- calculations;
- interview with administrative and service staff.

The evaluation of the potential for energy saving and the identified energy saving measures are performed on the basis of current and estimated prices of energy resources, current analysis of the market of the respective services provided by companies from different regions.

2. The building

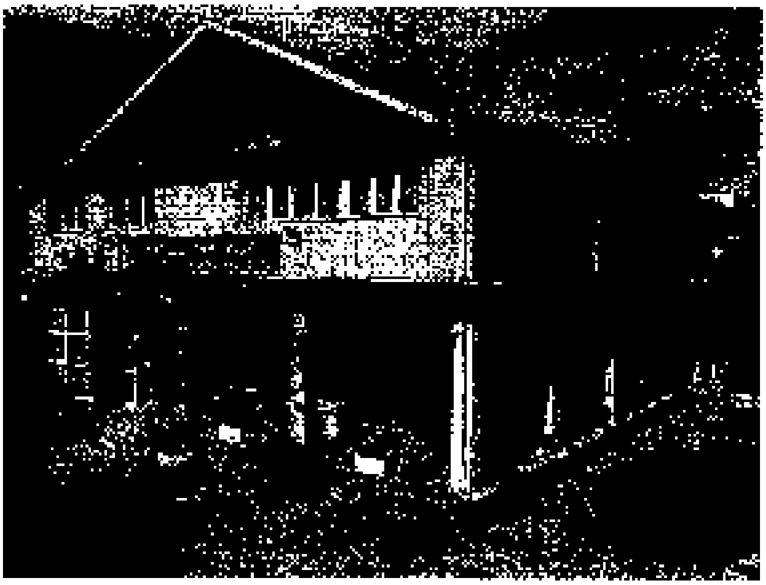

Figure 1 Front view of the building

The University of Agribusiness and Rural Development was established in 1992 by a decision of the Bulgarian government and accredited by the National Agency for Evaluation and Accreditation at the Council of Ministers as Higher School of Agricultural College. After 28 years of successful development and a number of accreditation procedures, now the University of Agribusiness and Rural Development is the largest private university in Bulgaria, which trains specialists in the field of agribusiness and rural development.

The main building of the University of Agribusiness and Rural Development is a monolithic two-storey building. It houses the main structural units such as the administration, service units such as libraries, centres, laboratories, training, experimental and production facilities, publishing houses, schools, administrative and economic structures.

2.1 General Information

Table 1 presents basic data about the building, and in Figure 1 shows the scheme and the orientation of the building.

Table 1 General information about the building

Main building data			
Name of the building	University of Agribusiness and Rural Development		
Address:	78 Dunav Blvd. Plovdiv		
Type of the building	Educational		
Ownership	Private		
Year of construction	1948-1949		
Number of inhabitants + staff	147		
Schedule to inhabitants - hours / day		Schedule for the heating mode - hours / day	
Working days hours / day	8	Working days hours / day	7
Saturday hours / day	8	Saturday hours / day	7
Sunday hours / day	8	Sunday hours / day	7

Situation of the building and orientation

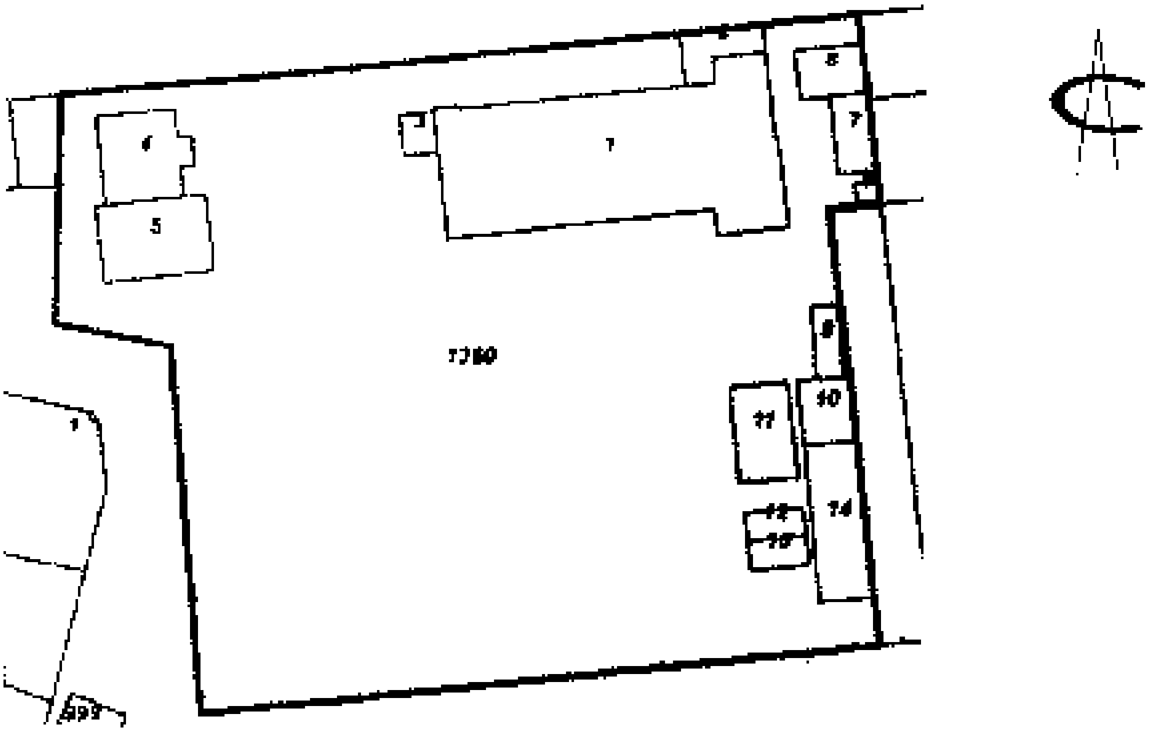

Figure 2 Situation of the building

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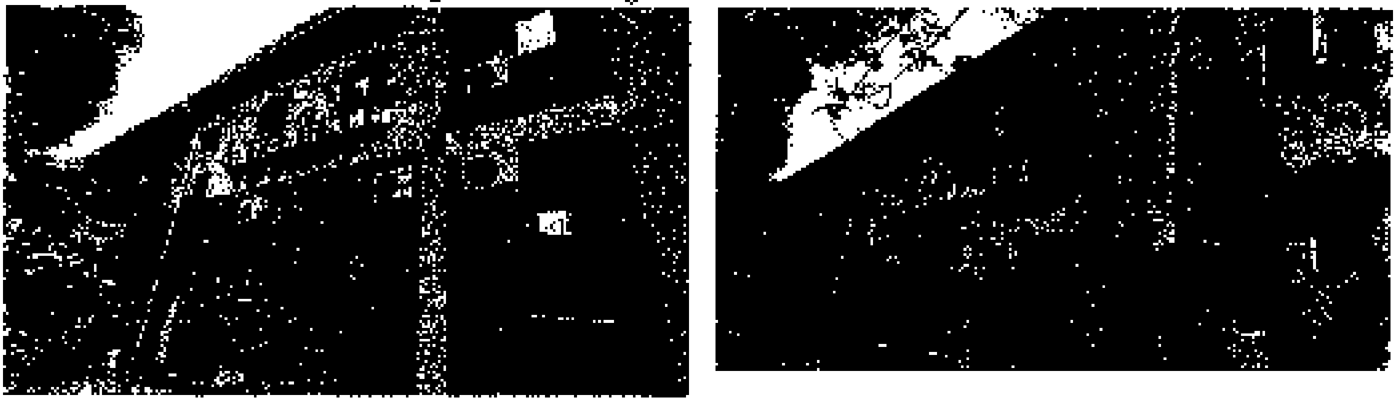
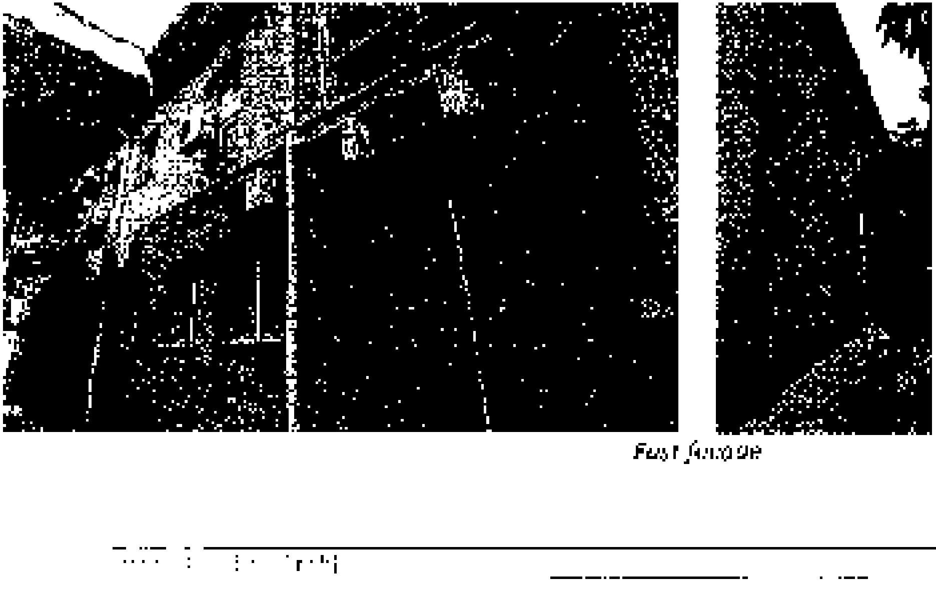
Figure 3 View of the building from above

Views of the building in the following directions:

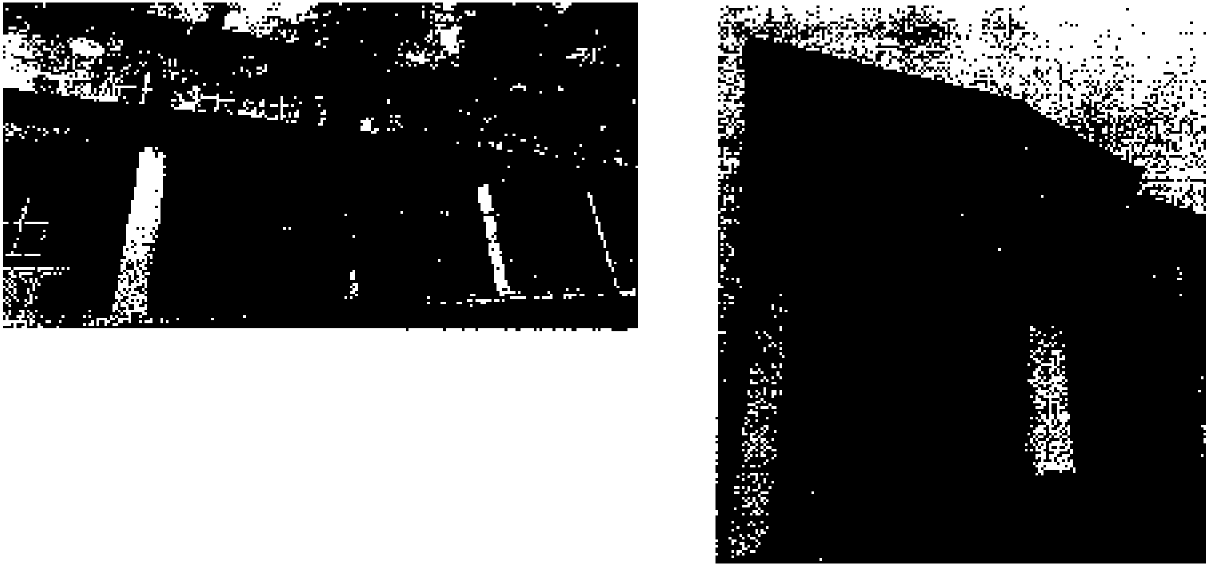


North facade



East facade

West facade



South facade

Figure 4 Views of the building by directions

2.2 Facilities, Building description

The building was built in 1948-1949 and was a nursery and kindergarten. It is built in a monolithic way, on two floors with clear heights of 3.3 m on the first floor and 3m on the second floor. The building is monolithic with reinforced concrete columns, beams and slabs, and the walls are brick masonry, the roof has a wooden roof structure with a slope height of 4.5 m. The building has a vertical structure - framed with brick washers and an internal staircase.

The building has been renovated in 2001 with new frame diaphragms, the windows are replaced with PVC joinery and 10 cm thick thermal insulation was implemeted. The slab between the two floors is concrete. The clear height of the premises on the first floor is 3.3 m, and on the second floor 3 m.

No cracks or deformations are noticed on the enclosing elements, as well as no leaks from the roof, gutters and plumbing installation

The premises have local air conditioning, which provides year-round maintenance of microclimate parameters.

2.3Area and Volume

Geometric characteristics of the building by floors are presented in the following tables:

Table 2 Geometric characteristics of the building

	Built-up area	Total Built-up area	Heated area	Gross volume	Net Volume
	m2	m2	m2	m3	m3
First floor	559,8	1226,3	539,9	1889,7	2511,7
Second floor	666.5		570,9	1789,9	1461,5

	Built-up area	Total built up area	Heated area	**Heated gross volume**	**Heated net volume**
	m2	*m2*	*m2*	*m3*	m3
Total	559,87	1226,3	1111	3680	2944

3. General Information for the Area

3.1 The Location

Plovdiv is the second largest city in Bulgaria with a population of 347,851. It is located in the western part of the Upper Thracian lowland, on both banks of the Maritsa River. It is 15 km north of the Rhodopes and 50 km south of the Balkan Mountains. The city is built at the foot of six syenite hills, which is why it is often called the "City under the hills". The climate is transitional-continental, typical of quite central southern parts of Europe.

Figure 5 View of Plovdiv

Plovdiv is strategically important industrial, commercial, scientific, cultural and transportation-communications center on the Balkans region. The city is famous with the international fair, whose spring, autumn and other specialized exhibitions make it a center of economic and business. Plovdiv is a strategic railway junction and the airport "Plovdiv" recently established itself as an alternative to the airport "Sofia.

The preserved architectural, historical and cultural heritage have established the city as a major tourist center of Bulgaria. Plovdiv is older than Rome, Athens, Carthage or Constantinople, and is considered as a contemporary of ancient Troy. Today the town is built on the ruins of ancient cities and its culture has evolved from the legacy of many previous cultures

3.2 Climate and Temperature Data

According to the climatic zoning of the Republic of Bulgaria Ordinance 7 / 2004 for energy efficiency of buildings, the city of Plovdiv belongs to the sixth climate zone, which is characterized by the following parameters:

Figure 5 Climate zones map of Bulgaria

Average altitude - 164 m;

- Duration of the heating season 165 days (start: October 24; end: April 6)
- Heating dengrades (DD) 2400 at an average building temperature of 19 ° C
- Calculated outdoor temperature: 15 ° C

The measured average monthly outdoor air temperatures for the settlement for the period 2018 - 2020 according to Department of weather forecasts data at Bulgarian Academy of science, as well as representative average monthly outdoor air temperatures for the sixth climate zone are used as base values of the climatic factors.

The average annual temperature is 12.3 ° C. The average maximum temperature in July was 30.3 ° C, and the absolute maximum was measured on July 5, 2000: 45 ° C. The average annual minimum temperature is 6.5 ° C, and the absolute minimum is minus 31.5 ° C, measured in the morning of January 24, 1942 in a state of temperature inversion. The average annual relative humidity is 73%, with the highest in December (86%) and the lowest in August (62%). The average annual rainfall is 540 mm, with a maximum in May-June (69.2 mm) and a minimum in August (31 mm). The average annual number of days with snow cover in Plovdiv is 33. The average height of the snow cover is between 2 and 4 cm, and the maximum - between 6 and 13 cm. In the city of Plovdiv weak winds prevail (0 - 5 m / s), as the winds with speed up to 1 m / s are up to 95% per year. Fogs are common during the cooler months, with fog days a year averaging 33.

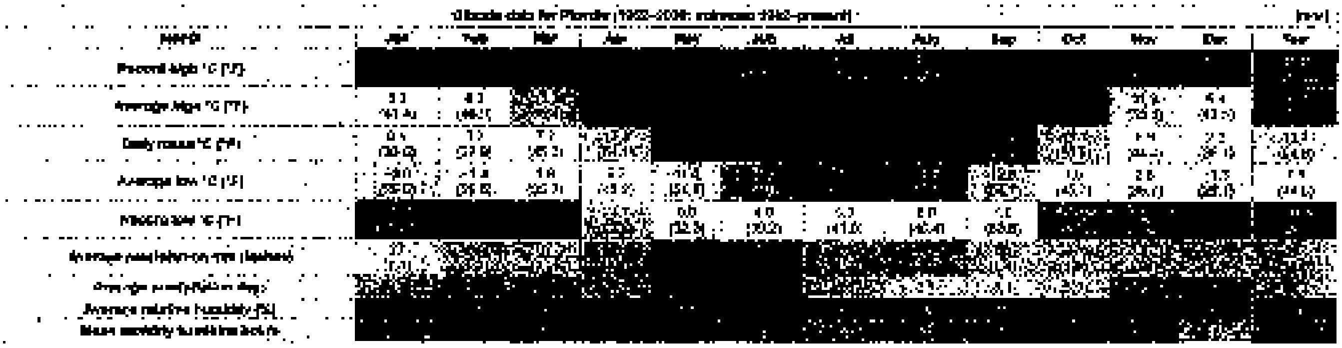


Figure 7 Climate data for Plovdiv

4. Building Envelope U values

Construction and thermophysical characteristics of the external walls:

After the inspection, two types of external walls are identified, which are in contact with the outside air. The thermophysical characteristics of the different types of walls are presented as follows:

- **Type 1** - brick wall with wall thickness δ = 40, lime-sand external and internal plaster with thickness δ - 2.5 cm, thermal insulation layer of expanded polystyrene EPS with thickness δ = 10 cm. The heat transfer coefficient of an external wall Type 1 is **U = 0,28W / m2K**.
- **Type 2** - brick wall with wall thickness δ = 45 cm, reinforced concrete wall with wall thickness δ = 25 cm; lime-sand exterior and interior plaster, thermal insulation

layer of expanded polystyrene EPS with thickness δ = 10 cm. The heat transfer coefficient of an external wall Type 1 is **U = 0.26W / m2K.**

Construction and thermophysical characteristics of floor structures:

Two types of floor constructions are identified in the building, floor on ground and floor in contact with outside air, differing in their construction and thermophysical characteristics.

The main initial and calculation data of the floor structures are analyzed and presented as follows:

- **Type 1: Floor of sub-bay window** - flooring (ceramic tiles) with thickness δ = 0.5 cm, cement sand mortar (screed) with thickness δ = 2 cm, reinforced concrete slab with thickness δ = 20 cm, thermal insulation layer of extruded polystyrene XPS with thickness δ = 10 cm, external lime-sand plaster with thickness δ = 2 cm, heat transfer coefficient of the bay window **U = 0.27 W/m2K.**
- Type 2: Floor **bordering the ground** - ceramic tiles with a thickness of δ = 0.5 cm, cement screed with a thickness of δ = 4 cm, reinforced concrete slab with a thickness of δ = 20 cm, coefficient of heat transfer of the floor to the ground U = **0 , 41 W/m2K.**

Construction and thermophysical characteristics of the roof structure of the building:

- **Type 1: Sloped roof with air layer height> 0.3 m**, **bitumen tiles** with thickness δ=0.35 cm, waterproofing layer 0.2 cm, air layer with medium thickness δ = 250 cm, wooden slats with thickness δ = 3 cm, reinforced concrete slab with thickness δ=20cm, internal lime-sand plaster with thickness δ = 2 cm, gypsum board with thickness δ = 1.5 cm. Heat transfer coefficient **U = 0.63 W/m2K.**
- **Type 2: Sloping roof with air layer height <0.3 m** bitumen tiles with a thickness of δ = 0.35 cm, a waterproofing layer with a thickness of δ = 0.2 cm, a wooden cladding with a thickness of δ = 5 cm, an air layer with a thickness of δ = 30 cm, a

thermal insulation layer of mineral wool with a thickness of δ = 12 cm., Plasterboard with thickness δ = 1.5 cm. Heat transfer coefficient **U = 0.25 W/m2K.**

- **Type 3: Ceiling terrace: Roof-terrace** - flooring (ceramic tiles) with a thickness of δ = 0.5 cm; cement sand mortar (screed) with thickness δ = 2 cm; thermal insulation layer of extruded polystyrene XPS with thickness δ = 10 cm, vapor barrier layer with thickness δ = 0.2 cm; lightweight slope concrete with medium thickness δsr. = 2 cm; reinforced concrete slab with thickness δ = 20 cm; internal lime-sand plaster with thickness δ = 2 cm; heat transfer coefficient **U=0.27W/(m2K)**

Table 3 Summary of the areas and heat transfer coefficient of the building envelope elements

Name	Heat transfer coefficient	Area
	[illegible]	[illegible]
Wall Type 1	0,28	537,61
Wall Type 2	[illegible]	[illegible]
Floor Type 1	0,27	61,70
Floor Type 2	[illegible]	[illegible]
Roof Type 1	0,63	909,48
Roof Type 2	[illegible]	[illegible]
Roof Type 3	0,27	65,40
Windows	[illegible]	[illegible]
Solid doors	2,2	4,5

5. Energy Systems

5.1 Heating and cooling

The indoor temperatures in all premises are maintained in accordance with the current regulatory requirements. Adopted as normative parameters of the microclimate in the premises, according to Ordinance № 15 of 28 July 2005 on technical rules and norms for design, construction and operation of sites and facilities for production, transmission and distribution of heat: for winter mode T indoor = 22 ° C; for summer mode Tindoor = 25-27 ° C. There is no centralized heating and cooling installation in the building. Local air conditioning has been developed for the premises, which ensures year-round maintenance of the microclimate parameters. Air conditioning heatpump SPLIT systems for direct evaporation. The indoor units are for wall mounting, and the outdoor units are mounted on the walls of the building, on metal frames with rubber pads, and their installation ensures good flow of external air. The connection between the individual elements of the air conditioning systems is provided by means of copper pipes and connecting elements. Condensation is drained from the air conditioning systems through PVC pipes.

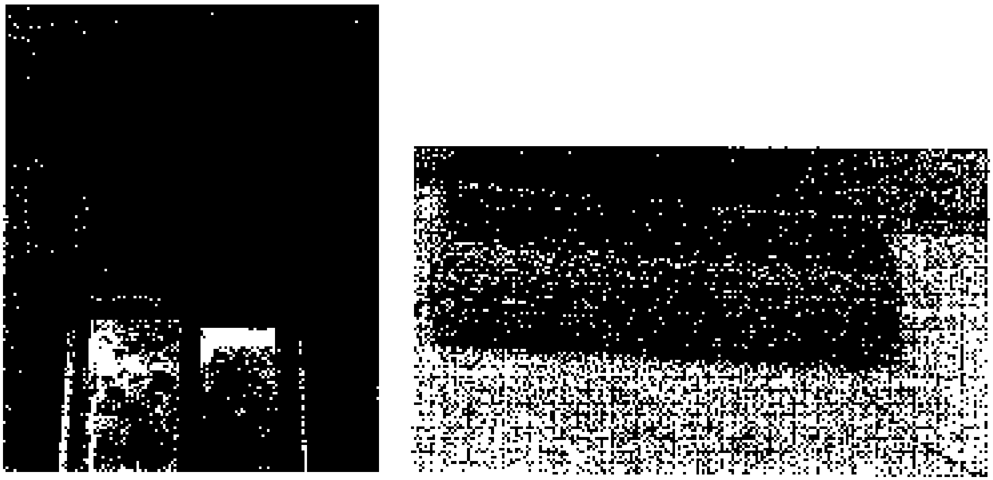


Figure 8 Local air conditioning in the rooms

The hours of operation of the heating and cooling appliances are shown in section 8.4 and 8.5.

5.2 Ventilation

There is no common exchange ventilation system in the building. The bathrooms are naturally ventilated through openable windows.
Due to the lack of an area with cooking equipment / ovens, deep fryers, etc./ it is not necessary to provide local mechanical ventilation

5.3 Hot Water System

There is no central system for domestic hot water in the building. Hot water for domestic needs in the sanitary areas and the dining room is provided by local electric water heaters, respectively 1 pc. - 80 l., 1pc -40l., 1pc.-5l., 1pc. instantaneous water heater. The hours of operation and electricity consumption for domestic hot water are given in section 8.3.

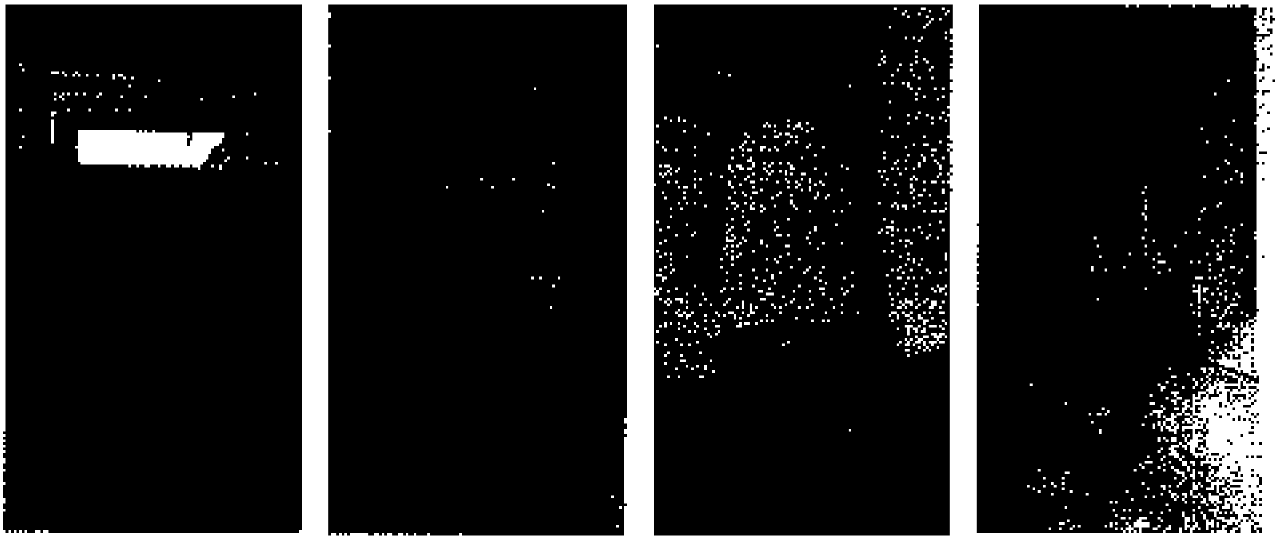


Figure 9 Domestic water heaters

The table below shows the annual hot water consumption, depending on the number of users of the building.

Table 4 DHW consumption

Persons	Number	l/day	Total	Days	l/y
Staff	36	5	180	360	64800
Students	106	8	848	327	277296
Teachers	5	5	25	327	8175
Total	147				350271
Litres/m2					315,28

5.4 Lighting

The lighting in the classrooms, offices and corridors is solved with fluorescent ceiling lights 2x36W and 3x36W, IP-20. In the bathrooms, as well as in the warehouses and the staircase, the lighting is solved with 40W bulbs. The power supply of the lighting fixtures is made with SVT cables, drawn in corrugated PVC pipes above suspended ceilings and laid in PVC cable ducts on ceilings and walls. There is no automation system for lighting.

The table below describes the types of building luminaires and their operation hours:

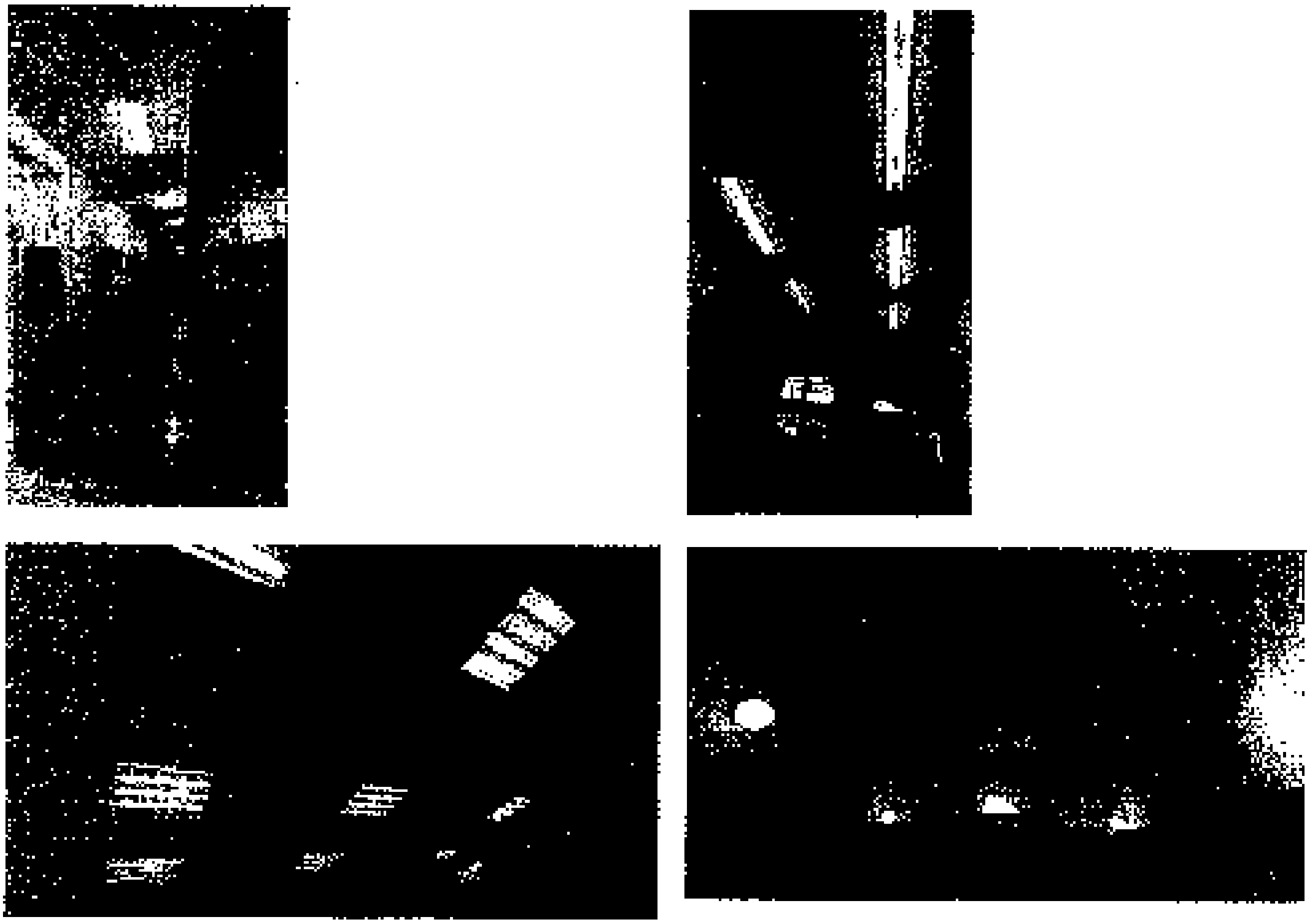


Figure 10 Different types of lamps

Table 5 Types of lamps and their characteristics

Type	Number	Unit power	Total power	Coefficient of simultaneous work	Power consumption	Working hours per day	Working hours per week	Days
			P_i	$k_{s.s.}$	P_{nav}			
		W	kW		kW	number	number	number
Incandescent bulbs 40W	40	40	1,60	0,33	0,53	8	56	360
Fluorescent lamps 2x36W	100	72	7,20	0,33	2,38	8	56	360
Fluorescent lamps 3x36W	35	108	3,78	0,33	1,25	8	56	360
Fluorescent lamps 4x18W	18	72	1,30	0,33	0,43	8	56	360
Total			13,88		4,58			

6. Integration of Renewable Energy Sources

There are no integrated renewable energy systems in the building.

7. Description of Electrical Installation

Electricity is measured by main switchboard through a three-phase electricity meter installed in an existing electrical panel located at elevation +0.00 of the building. The power supply is three-phase. The power allowed in advance for the site is not exceeded. The board is for 4 buildings in total - the inspected one and two more, located in the school yard. According to an expert assessment and after an interview with representatives of the building, it is estimated that 60% of the energy on invoices falls on the inspected building.

The power supply of the contacts is made of PVVM wire, hidden under plaster. The lighting is controlled with switches mounted at 1 m. height, and the contacts are 0.5m high from the floor.

It is necessary to install new measuring devices in order to individually measure the electricity for each building, as well as for different branches of the electrical installation.

8. Energy Consumptions (available energy data)

Analysis of the energy bills is performed in order to determine the baseline energy consumption of electricity. Data on the consumption of electricity in the building are provided for the period 2018, 2019 and 2020.

Table 6 Electricity consumption by months for 2018, 2019 and 2020

	2018		2019		2020	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JANUARY	7274,6	1595,6	10008,8	1992,6	7661,2	1654,2
FEBRUARY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MARCH	7364,1	1416,5	5001,5	984,1	4865,5	1005,7
APRIL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAY	3135,1	610,4	2836,5	564,1	2577,5	544,6
JUNE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JULY	3782,1	742,7	4123,4	868,1	3630,4	782,7
AUGUST	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SEPTEMBER	3951,1	788,4	3887,6	817,7	4112,7	890,8
OCTOBER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NOVEMBER	5634,8	1125,1	4891,6	1068,3	4322,3	1001,7
DECEMBER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	62434,6	12204,9	67957,8	12702,9	52879,9	11321,4

Monthly electricity consumption for 2018, 2019 and 2020

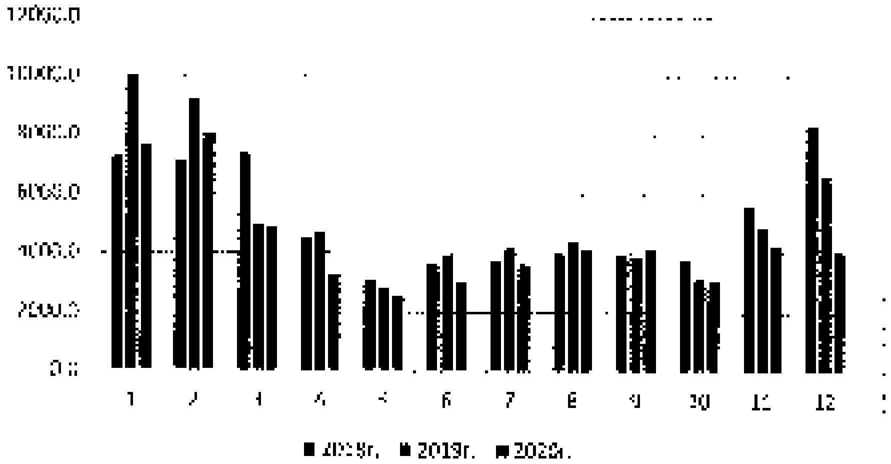


Figure 11 Monthly electricity consumption for 2018, 2019 and 2020

The following sections provide detailed information on the distribution of electricity consumption:

8.1. Electricity for lighting

The table below describes the types of building lamps and the annual electricity consumption for lighting:

Table 7 Annual electricity consumption for lighting

Type	Number	Unit power	Total power	Coefficient of simultaneous work	Power consumption	Working hours per day	Working hours per week	Days per year	Consumed energy	Consumed energy
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
		W	kW	-	kW	h/d	h/w	days	kWh	MWh
Incandescent bulbs 40W	40	40	1,60	0,33	0,53	8	56	327	1381,25	1,38
Fluorescent lamps 2x36W	100	72	7,20	0,33	2,38	8	56	327	6215,62	6,22
Fluorescent lamps 3x36W	35	108	3,78	0,33	1,25	8	56	327	3263,20	3,26
Fluorescent lamps 4x18W	18	72	1,30	0,33	0,43	8	56	327	1118,81	1,12
Total			[illegible]		4,58				11978,87	11,98

The analysis show that the total power consumption of the lighting appliances, according to the specified coefficients of simultaneity is P installed = 4.58 kW.

To calculate the annual electricity consumption for lighting, it is assumed that the building's lamps light an average of 8 hours a day, 56 hours a week and 327 days a year. The annual electricity consumption for lighting, in the current state, is estimated at 11.98 MWh / year.

8.2. Electricity consumption for equipment

Electricity consumers in the building are divided into two parts: affecting and not affecting the heat balance. Their influence is determined by their own heat radiation and their location in the building. Influential consumers in this case are office equipment such as computers, printers, scanners and multifunction printer devices. Summary data on the energy consumed by appliances that affect and do not affect the energy balance in the building are given in the following table:

Table 8 Annual consumption of electricity from appliances affecting and not affecting the energy balance

Type	Number	Unit power	Total installed power	Coefficient of simultaneous operation of the device	Consumed power	Working hours per day	Working hours per week	Working weeks	Consumed energy per year	Consumed energy per year
		kW	kW		kW	number	number	number	kWh	MWh
Appliances affecting energy balance										
Refrigerator with freezer	3	0,8	2,4	0,2	0,48	6	42	50	1008	1,008
Coffee machine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14	50	560	0,560
TV	2	0,5	1	0,1	0,1	2	14	50	70	0,070
Computer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27,300
Printer small	15	0,6	9	0,2	1,8	1	7	50	630	0,630
Multifunctional printer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,326
Multimedia projector	3	0,25	0,75	0,2	0,15	1	7	50	52,5	0,053
Water dispenser	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,210
Appliances that do not affect the energy balance										
Outdoor lamps 40W	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total			72,47		14,46	3,56	24,22		30655,70	30,66

The total installed power of all appliances, according to the specified coefficients of simultaneity is $P_{installed}$ = 14.46kW.

The annual electricity consumption of the specified equipment, according to the data in the table above, is 30.66 MWh / year.

8.3. Electricity for DHW

Electricity for DHW is calculated in the following table:

Table 9 Annual electricity consumption for DHW

Type	Number	Unit power	Total installed power	Coefficient of simultaneous operation of the device	Consumed power	Working hours per day	Working hours per week	Working weeks	Consumed energy per year	Consumed energy per year
	[illegible]									
		kW	kW	-	kW	бр	бр	бр	kWh	MWh
Water heater 50 l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1534,08	1,53
Water heater 80 l	1	2,88	2,88	0,6	1,728	4	32	47	2598,912	2,60
Water heater 5l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	1015,2	1,02
Flow mixer - heater	1	3,2	3,2	0,3	0,96	4	24	47	1082,88	1,08
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6231,07	6,23

The total installed capacity of all boilers, according to the coefficients of simultaneity, given in the table above is 4.38 kW, and the annual electricity consumption of the boilers is 6.23 MWh / year.

8.4. Energy for cooling

The annual electricity consumption for cooling is calculated in the following table:

Table 10 Annual energy consumption for cooling

Type	Number	Unit power	Total installed power	Coefficient of simultaneous operation of the device	Consumed power	Working hours per day	Working hours per week	Working weeks	Consumed energy per year	Consumed energy per year
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		kW	kW		kW	бр	бр	бр	kWh	MWh
Air conditioner for cooling 9000 BTU	8	0,79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20	[illegible]	0,9[illegible]
Air conditioner for cooling 12000 BTU	25	1,25	31,25	0,15	4,6875	7	49	20	4593,75	4,59

Air conditioner for cooling 18000 BTU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20	882	0,88
Total			37,41	0,51	[illegible]		49,00		6382,27	6,38

The annual consumption of electricity for cooling is 6.38 MWh / year.

8.5. Energy for heating

The annual electricity consumption for heating is calculated in the following table:

Table 11 Annual energy consumption for heating

Type	Number	Unit power	Total installed power	Coefficient of simultaneous operation of the device	Consumed power	Working hours per day	Working hours per week	Working weeks	Consumed energy per year	Consumed energy per year
	[illegible]		[illegible]	[illegible]						
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	kWh	MWh
Air conditioners 9000 BTU	0,88	8	7,04	0,15	1,07	7,0	49	20	1052,68	1,05
Air conditioners 12000 BTU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5046,98	5,05
Air conditioners 18000BTU	2,2	3	6,6	0,15	0,99	7,0	49	20	970,20	0,97
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7069,86	7,07

The annual consumption of electricity for heatingis 7,07 MWh / year.

8.6. Summary of the annual energy consumption by consumers

From the figure below for the distribution of the annual electricity consumption by items, it can be seen that the largest share of electricity consumption is in the electrical appliances in the building - 49%, followed by lighting - 19%. and heating appliances - 12%.

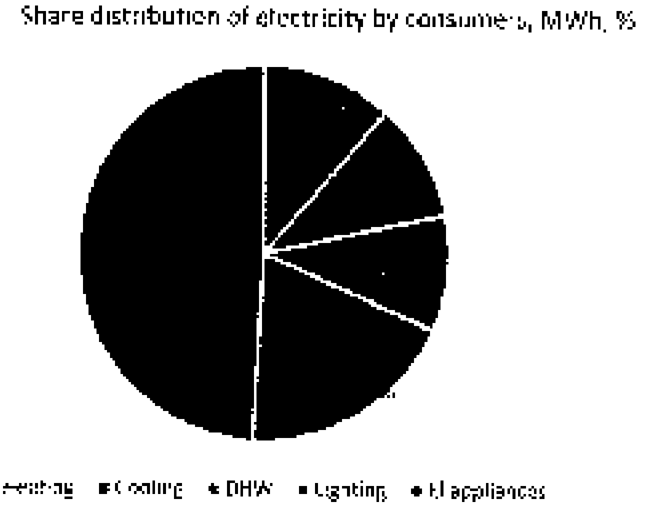


Figure 12 Share distribution of electricity by consumers

8.7. Energy balance of the building

To determine the calibration energy consumption, the degrees of the climatic zone at an internal temperature of 20°C are calculated:

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	31	0,2	613,8
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	31	6,9	406,1
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			0
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			0
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			0
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	30	7,4	378
[illegible]	31	[illegible]	561,1
[illegible]			2571,8

The heating day degrees in the above tables are calculated at an average indoor temperature in the building of 20 ° C and the reported average monthly outdoor air temperature in Plovdiv.

Based on the data from the above tables, the specific energy consumption for heating, related to the heating area, is calculated.

The specific Heating energy consumption is calculated by the following formula.

$$q_h = \frac{Qh \cdot D_{d\,climate\,zone}}{D_r \cdot A_H}$$

where,

q_h - specific annual energy consumption for heating for 2019, kWh/m2

Qh - annual heating energy consumption, kW

$D_{d\,zone}$ – Heating day degree, according to climate zone of the city. For Plovdiv, they are calculated for 20°C as 2571,8.

D_r – Heating degree days for the year, at an average internal temperature of the building - 20°C.

A_H – Heated area, m2

Table 12 Calculation of reference energy consumption

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1111	7264,7	2384,17	2571,8	7,1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1111	5530,2	2074,5	2571,8	6,2

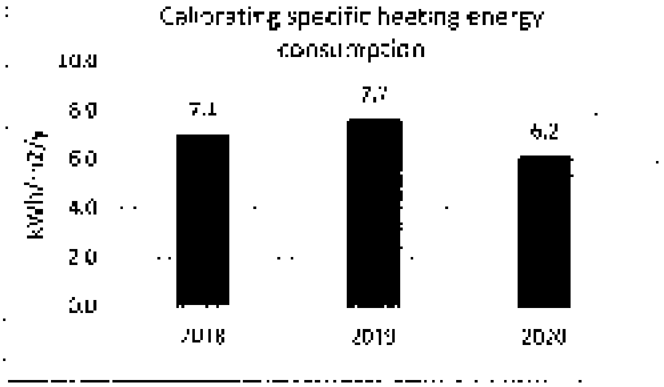


Figure 13 Specific energy consumption related to the heated area for 2018, 2019 and 2020.

2019 was chosen as base year, as it is characterised with the highest specific energy consumption for heating, related to the heating area. The reference energy consumption is q_H = 7.7 kWh / m2.

To estimate the annual energy consumption and accurate assessment of energy savings, computer modeling and simulation of the site is applied through the software product "EAB software". The program considers the building as an integrated system with one thermal zone consisting of:

- Building components;
- Energy systems;

- Residents and living regime of the building;
- Local climate

A benchmark of the building meets the legal requirements in force for the year of entering the building in operation and current regulatory requirements. The input data of the building are entered, which include climatic data (geographical area), the type of the building, mode of use, characteristics of all enclosing elements with their thermophysical parameters - heat transfer coefficients.

All geometric data on the facades are entered and generalized information about the building is obtained - the heated area, the area of the enclosing elements, as well as the living regime and the heating regime. The building operates on 8 hours of operation and is used by 147 people, incl. teachers, students and staff.

For the final creation of the building model (calibration of the model) the reference heating consumption was calculated for the selected base year 2019. According to the calculations, the reference specific heating energy consumption is q_H – 7.7 kWh / m2. Based on the obtained reference consumption, a model of the existing condition of the building is created.

The model of the building thus created shows that with the existing heating appliances and the requirements for maintaining the temperature mode in the main part of the premises, the average volumetric temperature is 20°C, which corresponds to the normative one, and the infiltration is 0.5 h-1.

Table 13 Calculation of annual primary energy consumption and ecological equivalent of CO2 emissions

ЕНЕРГИЯ ПРЕДИ ECM							
PARAMETER	**ENERGY DEMAND**			**PRIMARY ENERGY**		**CO_2 EMISSIONS**	
	Ql	Ql	e_p	Qp	Qp	f_e	t CO_2
	kWh/m2	kWh/y		kWh/m2	MWh/y	gCO2/kWh	
HEATING	7,7	8554,7	3,0	23,1	25,7	819	7,0
DHW	5,8	6443,8	3,0	17,4	19,3	819	5,3
LIGHTING	10,8	11998,8	3,0	32,4	36,0	819	9,8
EQUIPMENT	27,5	30552,5	3,0	82,5	91,7	819	25,0
COOLING	6,10	6777,1	3,0	18,3	20,3	819	5,6
TOTAL	57,9	64326,9		173,7	193,0		52,7

According to the energy performances classes for universities scale from Annex №10 of Ordinance №7 / 2004 for energy efficiency of buildings, the building energy class is "B", as the condition is fulfilled: 91kWh/m2 year <173.7 kWh/m2 year <180 kWh/m2 year.

It is clear from the table that at baseline the building enters energy class "B".

Figure 14 Energy performances classes for Universities

9. Energy Upgrade Scenarios

In order to optimize the electricity consumption and perform energy management in the building, it is planned to be installed 10 pcs. smart electricity meters with ICT platform for decision-making to measure the electricity consumption in the building. This will increase the energy efficiency through real-time monitoring and analysis of energy consumption at various points in the building.

It is planned to install 10 pcs. Meter, as the location of the measuring points, is recommended to be considered at the stage of investment technical design process by licensed designer.

It is recommended to optimize the operating hours of the lighting and the equipment, by reducing them as following: for lighting - 49 hours per week, and for the equipment 40 hours per week.

Table 14 Description of the energy upgrade scenarios

Nº	Activity	Unit	Quantity	Price	Total price, BGN
[illegible]	Delivery and installation of 10 pcs. electricity meter with a platform for monitoring and decision making	Number	10	1000	10000
[illegible]	[illegible]			[illegible]	[illegible]

The following table presents the annual energy consumption after the implementation of energy saving measures:

Table 15 Calculation of annual primary energy consumption and ecological CO2 equivalent after interventions

ENERGY AFTER

PARAMETER	ENERGY DEMAND			PRIMARY ENERGY		CO$_2$ EMISSIONS	
	Ql	Qi	e_f	Qp	Qp	fi	t CO$_2$
	kWh/m2	kWh/y		kWh/m2	MWh/y	gCO2/kWh	
HEATING	7,4	8221,4	3,0	22,2	24,7	819	6,7
DHW	5,5	6110,5	3,0	16,5	18,3	819	5,0
LIGHTING	9,4	10443,4	3,0	28,2	31,3	819	8,6
EQUIPMENT	24,4	27108,4	3,0	73,2	81,3	819	22,2
COOLING	5,80	6443,8	3,0	17,4	19,3	819	5,3
TOTAL	52,5	58327,5		157,5	175,0		47,8

Table 26 Economic efficiency of the proposed interventions

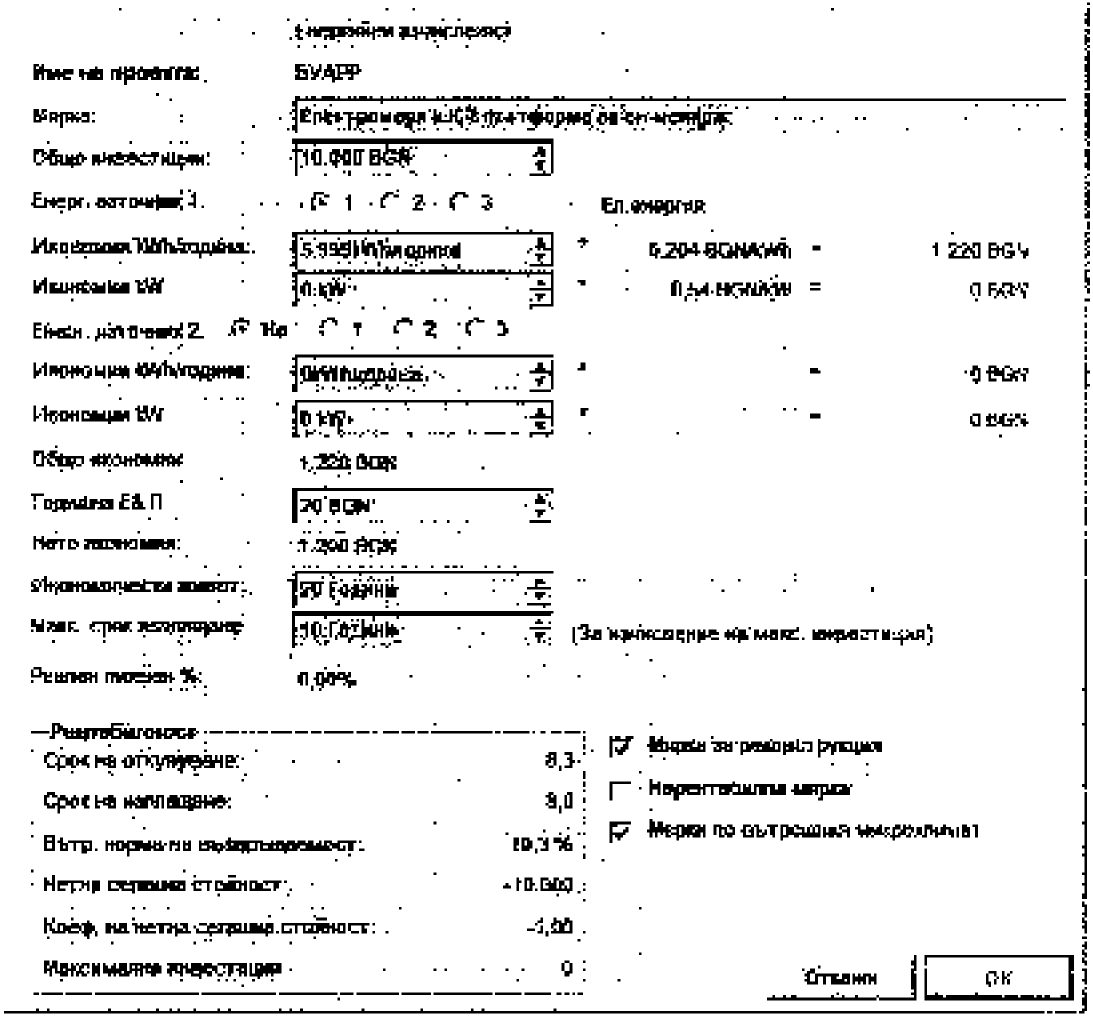
Intervention	*Energy source*	Before	After	Energy savings		Investment costs	Savings	Payback period	CO$_2$ savings	
		kWh/y	*kWh/y*	*kWh/y*	*%*	*BGN*	*BGN/y*	*y*	fi	t CO$_2$
ICT decision making platform	Electricity	64 327	58 328	5 999	9,33%	10 000,00	1223.9	8,2	819	4,9

The technical and economic analysis of the effect of the implementation of the planned energy saving measures was performed by economic software "Financial Calculations" of ENSI at an accepted interest rate of 0.3% and annual inflation of 0.5%.

The evaluation of the introduction of the measures was performed according to the following indicators:

- required investments (Io) - BGN;
- net annual savings (B) - BGN / year.
- payback period (PB) - years;
- repayment period (PO) - years;
- Internal rate of return (IRR) - %;
- net present value (NPV) – BGN

After entering detailed information about the measures in the software the results are as follows:



Енергийни анализи

Име на проекта: БУАПР

Мярка: [illegible]

Общо инвестиции: 10.000 BGN

Енерг. източник 1: ● 1 ○ 2 ○ 3 Ел.енергия

Икономия kWh/година: 5.999 kWh/година * 0,204 BGN/kWh = 1 220 BGN

Икономия kW: 0 kW * 0,54 BGN/kW = 0 BGN

Енерг. източник 2: ● Не ○ 1 ○ 2 ○ 3

Икономия kWh/година: 0 kWh/година * = 0 BGN

Икономия kW: 0 kW * = 0 BGN

Общо икономии: 1.220 BGN

Годишни Е& П: 20 BGN

Нето икономия: 1.200 BGN

Икономически живот: 20 години

Макс. срок изплащане: 10 години (За изчисление на макс. инвестиция)

Реален лихвен %: 0,00%

Рентабилност

Срок на откупуване: 8,3

Срок на изплащане: 8,0

Вътр. норма на възвращаемост: 10,3 %

Нетна сегашна стойност: +10.000

Коеф. на нетна сегашна стойност: -1,00

Максимална инвестиция: 0

☑ Мерки за реновиране

☐ Нерентабилни мерки

☑ Мерки по вътрешния микроклимат

Figure 15 Economic calculations for the envisaged measure

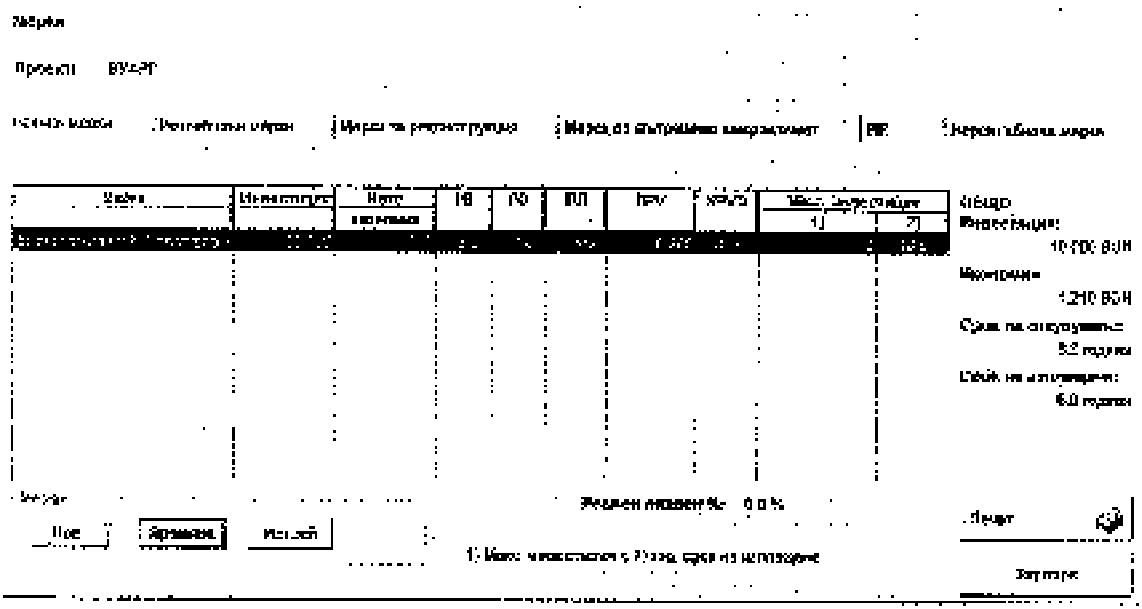


Figure 16 Results of economic calculations for the envisaged measure

The results are as follows:

- necessary investments (Io) - BGN 10,000 with VAT.
- net annual savings (B): BGN 1210 / year.
- redemption period (FB): 8.3 years;
- repayment period (PO) 8.0 years;
- internal rate of return (IRR) : 4%;
- net present value (NPV) : -10000 BGN

Conclusion

The values for primary energy according to the performed energy audit are:

- primary energy at the current condition of the building - 173.7 kWh/m2y
- primary energy after the interventions 157.5 kWh/m2y
- energy savings - 5999 kWh/ y.
- CO2 emissions saved — 4.9 tCO2/y
- Simple redemption period of 8.3 years.

Based on the conducted energy audit, the following was established:

• The energy performance class in the existing condition of the building and after the interventions is "B".

10. Legislative Framework, Bibliography

The main legislative framework for energy efficiency in Bulgaria covers the following documents.

- Energy Efficiency Act, amended and supplemented. issue 21 of March 12, 2021
- Ordinance № 7 of 2004 on energy efficiency of buildings
- Ordinance № E-РД-04-1 of 2016 on energy efficiency inspection, certification and assessment of energy savings of buildings (SG, issue 10 of 2016)
- Ordinance № E-РД-04-1 of 22.01.2016 for energy efficiency audits, certification and assessment of energy savings of buildings
- Ordinance № E-РД-04-2 of 2016 on the indicators for energy consumption and the energy characteristics of the buildings (SG, issue 10 of 2016)
- Ordinance № E-РД-04-2 of 22.01.2016 on energy consumption indicators and energy performance of buildings
- Ordinance № 15 of 2005 on technical rules and norms for design, construction and operation of the sites and facilities for production, transmission and distribution of thermal energy (promulgated, SG No. 68/2005; amended and supplemented.)
- Design standards;
- Construction manual;
- Handbook "Heating, ventilation and air conditioning" by Stancho Stamov

11. Conclusions and Suggestions

The performed energy audit of the building shows that the energy performances meet the current minimal regulatory requirements.

It is possible to optimize and manage the electricity flows in the building by installing electricity meters and ICT platform for decision making. In this way, the electricity consumption of the inspected building will be measured individually, and not as present - by a common electricity meter for several buildings. It is also recommended to optimize the operating hours of the lighting and equipment.

The energy savings after these measures as estimated as 5999 kWh, the environmental equivalent of energy savings is 4.9 tons of reduced CO2 emissions per year.

The necessary investment for the implementation of all defined and analyzed energy saving measures is 10,000 BGN inc. VAT with payback period of 8.3 years and a repayment period of 8.0 years.

26. 07. 2021

12. References

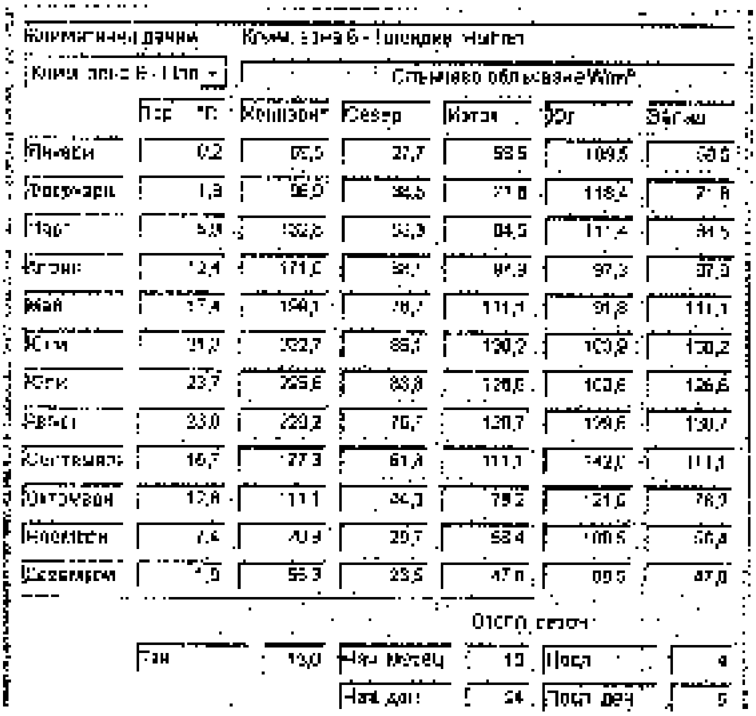
Software "EAB software" of Technical university of Sofia was used for the model study of the building at current stage and after the interventions. All requirements of EAB software of TU Sofia have been used for the model examination of the building. The requirements of ORDINANCE № Е-РД-04-2 from 22.01.2016 for the energy performances indicators and energy characteristics of the buildings and ORDINANCE № Е-РД-04-1 from 22.01.2016 for inspection for energy efficiency, certification and evaluation of energy savings of buildings are met.

SNSI Financial Calculations software was used for the economic analysis.

13. Annexes

(Building's drawings, Measurements results, tables, photos, energy audit team background information, legislation, calibration certificates)

Climate data for Plovdiv



Климатични данни Клим. зона 6 - Пловдив [illegible]

Клим. зона 6 - Плов

Слънчево облъчване W/m²

	Ср. т. °C	Хоризонт	Север	Изток	Юг	Запад
Януари	0,2	65,5	27,7	58,5	109,5	58,5
Февруари	1,3	96,0	34,5	71,6	118,4	71,6
Март	5,9	132,6	53,3	84,5	111,4	84,5
Април	12,4	171,0	[illegible]	97,3	97,3	97,3
Май	17,4	194,1	[illegible]	111,1	91,8	111,1
Юни	21,2	222,7	85,1	130,2	100,9	130,2
Юли	23,7	225,6	88,0	126,6	100,6	126,6
Август	23,0	220,2	76,7	130,7	129,6	130,7
Септември	16,7	177,3	61,8	111,1	142,0	111,1
Октомври	12,8	111,1	34,3	79,2	121,6	78,9
Ноември	7,6	70,9	29,7	58,4	100,5	58,4
Декември	1,5	55,3	23,5	47,0	99,5	47,0

Отопл. сезон

Тгр	15,0	Нач. месец	10	Посл.	4
		Нач. ден	24	Посл. ден	5

26.05.2021

26. 07. 2021