TRANSLATION from the Romanian language

Energy Audit

Workshops building within the Technical Energy College from Electricienilor street, no. 1, Sibiu municipality

Beneficiary:
Sibiu City Hall
Illegible signature, Official stamp

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2025

Energy Audit Report of the building:
Workshops building within the Technical Energy College from Electricienilor street, no. 1, Sibiu

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Energy Audit Report of the building

Gf+2F Workshops building within the Technical Energy College from Electricienilor street, no. 1, Sibiu

A. ANALYSIS REPORT AND ENERGY CERTIFICATION

1. General information regarding the building

The scope of the works consists into the thermal-energy evaluation of the Workshops building within the Technical Energy College located in Sibiu municipality, Electricienilor street number 1. Its height regime is groundfloor and two floors.

The evaluation was carried out based on:

1. Survey of the studied building prepared by ALLBIZZ SRL
2. Cadastre of the studied building.
3. Inspections carried out during on-site visits.
4. Photo survey.
5. Investigations carried out on-site to establish the envelope structure.
6. The initial standard project carried out by IPCT in 1966

The results obtained based on the energy evaluation of the building and its heating, hot water preparation and lighting installations serve for the Energy Certification of the building, as well as for the preparation of the Energy Audit Report which includes the technical solutions for the refurbishment/modernization of the construction items and installations related.

The energy audit is carried out in order to evaluate the possibilities of improving the energy performance of the building, given the context of the refurbishment and modernization works of the Workshops building of the Technical Energy College.

1.1. Architectural and thermal insulation elements

The building is located in the municipality of Sibiu, Str. Electricienilor, no. 1, and was built in in 5 sections.

Workshops within the Technical College of Energy, located in str. Electricienilor, no. 1, the municipality of Sibiu is made up of three sections with the regime of Gf+2F. The building was designed by Electromontaj Trust in 1970 and was erected in the immediate period .

The Workshop building has a complex shape in plan that approaches the shape of an L with two blocks, which have the ground floor regime parallel to Vasile Aaron Street and the main block with the regime Gf+2F perpendicular to the street.

The Ground Floor is in two main areas, garage and electrical workshop.

The Garage is located towards Vasile Aron Street and has an opening of approximately 7.5 m and 4 bays (2.25+2x2.5+3.85 m). The garage is built in the first 3 bays while the sinks are organized in the last bay. The Electric Workshop Block has two openings of approximately 5 m and 5 bays (2.2 m + 4x3.4m). In the first bay, flammable materials are stored while the workshop is made in the 4 bays of 3.4 m. The garage and the workshop, Electric Workshop communicate through a hallway, which also provides access to the Gf+2F block. The Gf+2F block has an irregular shape in plan that can be classified as a rectangle with dimensions 32.70x 16.8 m. It is approximately 11 m further towards Vasile Aaron Street where the sanitary groups were organized in a 3.40 m span. Continuing the sanitary groups, a generous hall area was created with a with approximate dimensions of 11x 6.90 m. In this area is the staircase and the hall with dense ribs. From the hall area, access is made to the workshops on each level. The workshops are each organized in an opening of 7.20 m and are separated by a median wall. The workshop located towards the courtyard has 6 spans of 3.40 m. The workshop on the north side is made in 4 spans of 3.40 m and a span of 1.40 m. The workshop continues with a span of 6.80 m that houses the low voltage room, the transformer station, the distribution room and on the first floor various warehouses. On the 1st floor the laboratory from the inner courtyard was divided into two laboratories by introducing two separating walls according to the survey.

The building is equipped with a technical channel where the installations are located. In front of the classroom there are technical channels through which the pipes serving each classroom are passed.

The building was designed in 1970 and built in the immediate period. The main access to the building is on the SW side parallel to Electricienilor Street.

Height regime: ground floor for the garage block and for the electrical workshop block and ground floor and two floors for the workshop block.

The workshop block is an independent one that does not connect with other buildings . From architectural point of view, the envelope is made of:

- masonry walls with a thickness of 30 cm;
- PVC windows with double glazing;
- ground slab made of screed and reinforced concrete slab
- floor over the 2nd floor made of reinforced concrete.
- floor over the technical channel made of reinforced concrete.

The exterior walls are insulated with 10 cm polystyrene. This is depreciated and in some places it was even removed, remaining the wall initially exposed. On the heavily glazed windows of the workshop blocks (Gf + 2F) there are horizontal and vertical brice-soleils. These are cladded with 2 cm extruded polystyrene.

The strength structure of the building is made of a load-bearing masonry walls provided on both sides of the structure that collaborates with a reinforced concrete frame system.

The height regime of the electrical workshop block and the garage block is +7.87 m from the elevation +0.00 m, represented by the floor elevation. The floor elevation is about 30 cm above the elevation of the land arranged in the enclosure. The two blocks were covered with additional screed made with a wooden structure between the elevation +4.87 m and +7.87 m. The screed is provided with a ceramic covering.

The height regime of the workshop is +17.20 m from the +0.00 m elevation, represented by the floor quota. The floor elevation is about 30 cm above the elevation of the land arranged in the enclosure. and this block is covered with additional screed between elevations +14.20 and +18.25 m. The screed is provided with ceramic covering.

By the design topic, the beneficiary requires the implementation of energy efficiency measures, repairs on the damaged elements, fully refurbishment of the exterior finishes, replacement/repair of the heating system, current hot running water preparation and artificial lighting systems.

Works will lead to improving the operating conditions through:

- improvement in the interior comfort conditions;
- decrease in energy consumptions;
- decrease in maintainance costs for heating, hot running water, mechanical ventilation and lighting;
- rational use of the interior area according to the rules in force;
- increase in the hygrothermal comfort of the building;
- fulfilling the requirements specific for educational establishments

1.2 Strength structure items

The architectural part comprises three buildings. The garage and electric workshop blocks are regular with a rectangular shape in plan . They have a reinforced concrete frame structure that collaborates with the masonry walls . The garage block was initially provided as a locker room block and was later modified by creating a garage door.

For the workshop block Gf+2F, according to the technical expert report, the structural system is a dual one, made of load-bearing walls with reinforced concrete frames.

The frames are generally at a distance of 3.4 m and the masonry walls are located at the ends of the building.

The perimeter closures are 30 cm thick and the interior ones are 25 and 12.5 cm.

The additional screed has a strength structure in the form of a wooden structure, over which there is a ceramic tile opening .

The technical condition of the construction is corresponding, with some local deficiencies (degraded exterior plaster, sidewalks around the construction are detached from the building and have a reverse slope, the socket with infiltrations, detached polystirene). The construction screed was built subsequently to the construction.

1.3 Heating and hot running water systems

The building has all utilities: electricity, water and sewage, gas.
The building is equipped with internal heating systems. There is a special room in the building serving as a central heating plant between axes 23 and 24 and axes N-M where the heating and hot water production system is installed. The heating system consists of two Viessman Vitoplex 100 heating plants. The same heating plants are used for the production of hot water.
The heating distribution system consists of a network of pipes located in the technical channel that connect the heating plants to the steel radiators
The radiators in the rooms are equipped with classic taps**.**

1.4 Ventilation systems

The building is not equipped with organized ventilation systems.

1.5 Air conditioning/cooling systems

Not applicable. The building is not equipped with installations to ensure air conditioning.

1.6 Lighting systems

Artificial lighting is provided by fluorescent lighting fixtures..

2. Building energy performance evaluation

2.1 Determination of the corrected thermal strengthts of the construction elements of the building; how the thermal and energy performance requirements are met

2.1.1. Geometric characteristics of the building's thermal envelope

The geometric characteristics of the building were determined according to the methodology depending on the construction elements and are presented in the table below:

Construction element	S [sqm]
Exterior masonry wall 30 cm thick with 10 cm thermal insulation	815.1
Exterior masonry wall 30 cm thick with 2 cm thermal insulation	303.0
Ground slab	638.7
Floor over the technical basement	40.6
Floor over the last floor	679.2
Nevada brick	23.5
Exterior carpentry	488.1
Developed built area	2988.2

2.1.2. Thermal-technical characteristics of the construction materials

The thermal-technical characteristics of the building materials that make up the building elements are presented in the table below..

No. crt.	Material name	Characteristics		Increase percentage	calculation thermal conductivity
		p [kg/m³}	γ [W/mK]		
1	Reinforced concrete	2400	1.62	1.1	1.782
2	Lime-cement mortar	1700	0.87	1.1	0.957
3	Cement mortar	1800	0.93	1.1	1.023
3	Solid brick masonry	1800	0.80	1.15	0.92
4	Simple concrete screed	2000	1.16	1.03	1.195
5	Fir wood	550	0.17	1.1	0.187
6	Gravel filler	1800	0.70	1	0.70
7	Top soil	1800	1.160	1	1.16
8.	Coal ash and slag	650	0.290	1.1	0.319
9.	Polystirene	80	0.044	1.6	0.070

2.1.3. Unidirectional thermal strenghts and corrected with the effect of thermal attics, construction elements of the building thermal envelope

The unidirectional thermal strengths are determined by using the following formula:

$$R = R_{si} + \sum \frac{\delta_j}{a_j \lambda_j} + R_{se} = \frac{1}{h_i} + \sum \frac{\delta_j}{a_j \lambda_j} + \frac{1}{h_e} \left[\frac{m^2 K}{W}\right]$$

- h_i - internal surface heat transfer coefficient [W/m^2K];
  h_e - external surface heat transfer coefficient **[W/m^2K];**
- a - thermal conductivity increase coefficient depending on the condition and age of the materials, acc.to page 2.2, Mc001 Chapter 2.1.;
- γ – regulated thermal conductivity

The calculation of the corrected thermal strength is carried out according to the formula:

$$R' = rR$$

- R - the unidirectional specific thermal strength related to the area *A*,
- R' – corrected thermal strength ;
- r - correction coefficient for thermal attics;
- S= envelope elements area

Construction element	S [sqm]	R [sqmK/W]	R [-]	R' [sqmK/W]	R'_{min} [sqmK/W]
NE masonry exterior wall	196.3	1.927	0.62	1.19	3.00
NW masonry exterior wall	259.0	1.927	0.65	1.25	3.00
SW masonry exterior wall	115.4	1.927	0.61	1.18	3.00
SE masonry exterior wall	244.4	1.927	0.67	1.29	3.00
Ground slab	638.7	0.545	0.95	0.52	4.50
Floor over technical basement	40.6	0.357	0.92	0.33	4.50
Floor over the last floor under the attic	679.2	0.623	0.97	0.60	5.00
NE masonry exterior wall	140.2	0.624	0.45	0.28	3.00
NW masonry exterior wall	162.9	0.624	0.45	0.28	3.00
PVC NE Exterior windows	156.2	0.43	1	0.43	0.83
Metal NE exterior doors	3	0.15	1	0.15	0.77
PVC NW Exterior windows	36.4	0.43	1	0.43	0.83
PVC SW Exterior windows	203.8	0.43	1	0.43	0.83
Metal SW exterior doors	7.4	0.15	1	0.15	0.77
PVC SW Exterior doors	30.5	0.41	1	0.41	0.77
PVC SE Exterior windows	42.3	0.43	1	0.43	0.83
PVC SE Exterior doors	1.9	0.41	1	0.41	0.77
Glass brick	23.5	0.17	1	0.17	0.83
Metal SW exterior doors	6.8	0.15	1	0.15	0.77

The last column in the table with R'min represents the minimum required strength provided by the norm for buildings with school function - Corrected thermal strenghts recommended for the renovation of existing non-residential buildings (according to page 2.9.b Mc00l-2022). It is noted that the thermal strengths of the envelope elements are lower than the minimum strengths requested by the rule.

2.1.4 Operating schedule, definition of the calculation formula and zoning

The building functions as workshops with an operating schedule of 8 hours per day, 5 days per week, from Monday to Friday according to the table below:

Energy Audit Report of the building:

Workshops building within the Technical Energy College from Electricienilor street, no. 1, Sibiu

Operating scenario (Building / building unit / apartment occupancy schedule)

		Number of usage hours per day [h]								Total hours [h]	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
January											
	W1	10	10	10	10	10			15	50	
	W2	10	10	10	10	10				50	150
	W3	10	10	10	10	10				50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
February	W3			10	10	10				30	
	W4	10	10	10	10	10				50	
	W5	10	10	10	10	10				50	
									15		150
	W6	10	10							20	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
March	W6			10	10	10				30	
	W7	10	10	10	10	10				50	
	W8	10	10	10	10	10				50	230
	W9	10	10	10	10	10			23	50	
	W10	10	10	10	10	10				50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
April	W10										150
	W11	10	10	10	10	10				50	
	W12	10	10	10	10	10				50	
	W13	10	10	10	10	10			15	50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
May	W13	10	10	10	10	10				50	
	W14	10	10	10	10	10				50	
	W15	10	10	10	10	10			25	50	250
	W16	10	10	10	10	10				50	
	W17	10	10	10	10	10				50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
June	W17				10	10				20	
	W18	10	10	10	10	10				50	
	W19	10	10	10	10	10				50	220
	W20	10	10	10	10	10			22	50	
	W21	10	10	10	10	10				50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
July	W21										
	W22	10	10	10	10	10				50	
	W23	10	10	10	10	10				50	150
	W24	10	10	10	10	10			15	50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
August											
									0		0

		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
	W24										
	W25	10	10	10	10	10				50	
	W26	10	10	10	10	10			20	50	200
September	W27	10	10	10	10	10				50	
	W28	10	10	10	10	10				50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
	W28										
	W29	10	10	10	10	10				50	200
	W30	10	10	10	10	10			20	50	
October	W31	10	10	10	10	10				50	
	W32	10	10	10	10	10				50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
	W32	10	10	10	10	10				50	
	W33	10	10	10	10	10				50	
	W34	10	10	10	10	10				50	
	W35	10	10	10	10	10			25	50	250
November	W36	10	10	10	10	10				50	
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No.of days	Week	Month
	W36	10	10	10	10	10				50	
	W37	10	10	10	10	10				50	150
	W38	10	10	10	10	10			15	50	
December											

2.1.5 The need of air for ventilation

The building is not equipped with an organized ventilation system. Manual ventilation of the rooms, especially the classrooms, is carried out by unscheduled opening of the windows. At the same time, ventilation will also be carried out by air infiltration from the outside.

2.1.6. How the recommended thermal performance requirements are met in terms of thermal strength and hygrothermal comfort

The building does not comply with the recommended thermal performance requirements in terms of thermal strength and hygrothermal comfort.

2.2 Determination of the annual primary energy consumption for heating

The annual energy consumption for heating is determined according to Chapter 3 of MC00l-2022, depending on the external and internal climatic parameters.

External climatic parameters

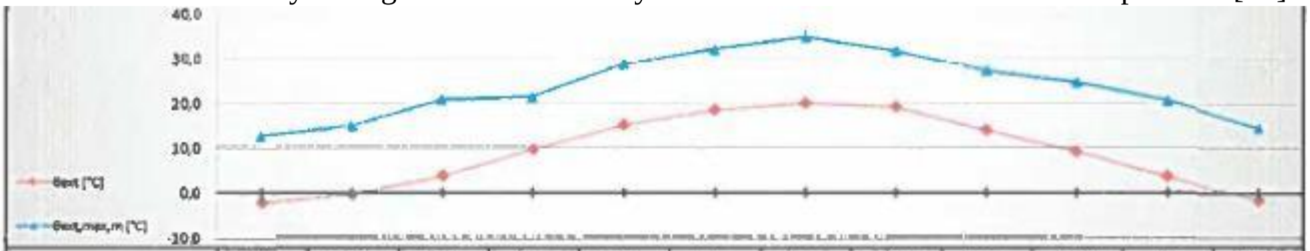
Conventional external calculation temperature

For winter, the conventional calculation temperature of the external air is considered depending on the climatic zone where the locality Sibiu is located (zone III), according to the MC00l-2022 Methodology, Chapter 2.1.1, as follows:

$$\Theta_e = -18°C$$

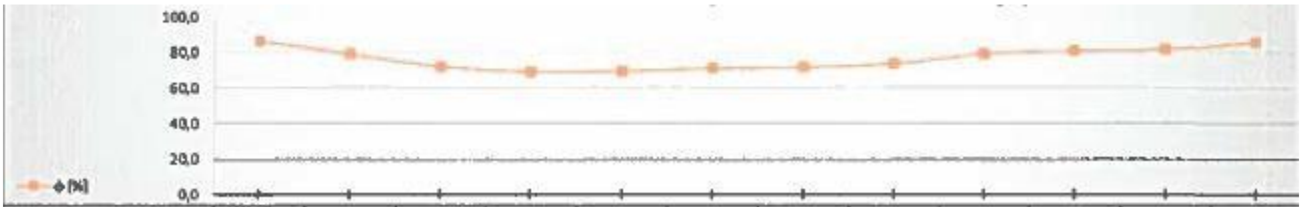
CLIMATE DATA for Sibiu

Monthly average values & monthly maximum values of the exterior temperature [°C]



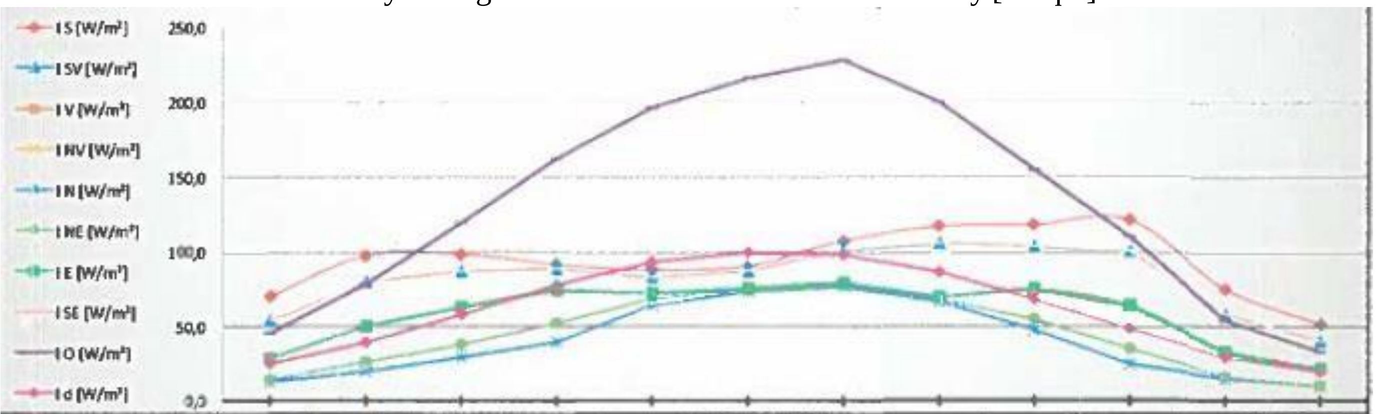
	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
θ ext [°C]	-2,3	-0,3	3,8	9,7	15,2	18,5	20,1	19,2	14,0	9,2	3,6	-1,5
θ ext,max,m [°C]	12,8	15,0	20,9	21,5	29,0	32,5	35,1	32,1	27,4	24,8	20,7	14,7

Monthly average values of the relative humidity of the external air [%]



	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
φ [%]	86,2	78,8	72,1	69,0	69,5	70,9	71,4	73,7	79,0	80,5	81,4	86,1

Monthly average values of the solar radiation intensity [w/sqm]



	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
I S [W/m²]	69,9	97,2	98,3	91,7	87,6	90,6	107,2	116,9	118,0	121,1	75,1	51,7
I SV [W/m²]	54,0	79,6	86,9	88,7	82,5	87,1	101,0	105,5	103,3	100,3	58,5	40,1
I V [W/m²]	28,3	49,4	62,8	73,8	72,2	75,5	78,9	69,3	74.8	63,6	33,2	21,3
I NV [W/m²]	13,7	26,0	37,3	51,5	68,0	74,3	77,6	67,6	54.4	34,9	16,0	10,3
I N [W/m²]	12,5	19,4	29,0	38,9	63,9	73,2	76,3	65,9	47,1	24,2	14,8	9,9
I NE [W/m²]	13,7	26,0	37,3	51,5	68,0	74,3	77,6	67,6	54,4	34,9	16,0	10,3
I E [W/m²]	28,3	49,4	62,8	73,8	72,2	75,5	78,9	69,3	74,8	63,6	33,2	21,3
I SE [W/m²]	54,0	79,6	86,9	88,7	82,5	87,1	101,0	105,5	103,3	100,3	58,5	40,1
I O [W/m²]	45,4	78,3	119,1	162,0	195,9	216,1	228,1	199,8	154,7	109,9	54,1	32,9
I d [W/m²]	25,0	38,9	57,9	77,7	92,7	99,8	97,9	86,4	68,3	48,3	29,5	19,9

Interior climate parameters

The interior temperature for calculating the building while using has the following value: $\Theta_{i,u}$ = 20 [°C]

Calculation of heat loss coefficients Htr and Hve

Calculation of the building's heat loss coefficient through ventilation, Hve

$$H_{ve} = \frac{\rho_a c_a n_a V\, b_{ve}\, f_{ve}}{3.6}$$

- p_a- air density;
- c_a- specific air heat;
- n_a - average number of air changes
- V - heated volume
- b_{ve} air inlet temperature is the outside air temperature
- f_{ve} correction factor for monthly calculation.

Calculation of the heat loss coefficient of the building, by transmission, Htr

$$H_{trfinal} = H_d + H_g + H_{iu} + H_a$$

H_d -direct heat transfer coefficient between heated spaces and the exterior through the building envelope $\left[\frac{W}{K}\right]$

Hg -heat transfer coefficient through the ground $\left[\frac{W}{K}\right]$

H_{iu} -heat transfer coefficient through transmission through unheated spaces $\left[\frac{W}{K}\right]$

H_{ve} - Heat transfer coefficient through ventilation $\left[\frac{W}{K}\right]$

H_a- heat transfer coefficient through transmission to adjacent buildings $\left[\frac{W}{K}\right]$

1	ZTC1.1	θ int;inc [°C]	θ int;rac [°C]	A use;day [m²]	q [m³/h]		Thermal inertia class	Average
		20,0		1498,2	9087,4	9087,4	Cm;zi/Ause;zi[J/m²K]:	165000

	Cod	A e;i carpentry Nr.	[m²]	[m²]	A e;i [m²]	Orientation	r [-]	R' [m²K/W]	U'i [W/m²K]	Type of adjacent area	Adjacent area code	H g [W/K]	H d [W/K]	H iu [W/K]	H ve [W/K]
1	PE1				196,3	NE	0,62	1,19	0,84	Ext.			164,30		
2	PE1				259,0	NV	0,65	1,25	0,80	Ext.			206,78		
3	PE1				115,4	SV	0,61	1,18	0,85	Ext.			98,19		
4	PE1				244,4	SE	0,67	1,29	0,77	Ext.			189,31		
5	PL attic				679,2	ORIZ	0,97	0,60	1,65	ZT	ZTU1			1123,94	
6	Pl – ground				638,7	ORIZ	0,95	0,52	1,93	Sol		345,39			
7	Pl [illegible]				40,6	ORIZ	0,92	0,33	3,04	ZT	ZTU2			123,49	
8	FE-PVC		156,2	156,2		NE		0,43	2,33	Ext.			363,17		
9	UE-metal		3,0	3,0		NE		0,15	6,79	Ext.			20,36		
10	FE-PVC		36,4	36,4		NV		0,43	2,33	Ext.			84,56		
11	FE-PVC		203,8	203,8		SV		0,43	2,33	Ext.			474,03		
12	UE-metal		7,4	7,4		SV		0,15	6,79	Ext.			50,23		
13	UE-PVC		30,5	30,5		SV		0,41	2,43	Ext.			74,09		
14	FE-PVC		42,3	42,3		SE		0,43	2,33	Ext.			98,33		
15	UE-PVC		1,9	1,9		SE		0,41	2,43	Ext.			4,60		2998,86
16	PE2				140,2	NE	0,45	0,28	3,56	Ext.			499,15		
17	PE2				162,9	SV	0,45	0,28	3,56	Ext.			580,02		
18	[illegible]		23,5	23,5		NV		0,17	5,80	Ext.			136,42		
19	UE-metal		6,8	6,8		SE		0,15	6,79	Ext.			45,82		
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															
30															
												345,39	3089,35	1247,44	2998,86

Legend: PE – exterior wall; PL – floor; FE – exterior windows; UE-exterior doors

LOSS TO THE GROUND		Thermal features				Thermal flow features						
Exposed area [m]	Walls thickness [m]	ɰ wf [W/mK]	γg [W/mK]	P c [W/mK]	Ʊ {m}	α	ß	r	Θint [C]	Θint [K]	Θe [C]	Θe [K]
174.17	0.30	1.68	0.3	1.26E+0.6	2.20	0	1	1	18.0	2.7	9.1	11.4

	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	
θ int;inc [°C]	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	HEATING
θ int;rac [°C]													COOLING
θ int;adj [°C]													
θ ext [°C]	-2,3	-0,3	3,8	9,7	15,2	18,5	20,1	19,2	14,0	9,2	3,6	-1,5	
b [-]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
H ia [W/K]													Max
H a [W/K]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,0
H g [W/K]	351,37	359,47	363,80	363,19	357,81	349,11	339,40	331,30	326,98	327,58	332,96	341,67	
H u [W/K]	388,73	388,73	388,73	388,73	388,73	388,73	388,73	388,73	388,73	388,73	388,73	388,73	388,7
H tr [W/K]	3829,44	3837,54	3841,87	3841,26	3835,89	3827,18	3817,48	3809,38	3805,05	3805,66	3811,03	3819,74	3841,9

HEATING Decreased night		HEATING Decreased day		HEATING Decreased weekend	
$\Delta t_{H;red;y}$	12	$\Delta t_{H;red;y}$		$\Delta t_{H;red;y}$	48
$n_{rep;red;y}$	5	$n_{rep;red;y}$		$n_{rep;red;y}$	1
$f_{H;red;y}$	0,36	$f_{H;red;y}$	0,00	$f_{H;red;y}$	0,29

COOLING	
$\Delta t_{C;red;wknd}$	
$n_{rep;red;y}$	
$f_{C;red;wknd}$	0,00
$b_{C;red;wknd}$	
$a_{C;red;wknd}$	1,00

$\eta_{HU;rvd}$	
$(\Delta x \cdot t)_{a;sup}$	
$\varphi_{V;comf2}$	
$f_{DHU;C;ss}$	

Low	
$a_{H;0}$	0,8
$\tau_{H;0}$	70
H final [W/K]	6840,72

Internal intakes

Next, internal intakes are calculated based on the occupants and equipment located in the building.

1	ZTC1.1

	Type	Thermal power Predefined N	Thermal power Predefined [W]	Thermal power User [W]	Operating period Ian [zile]	Feb [zile]	Mar [zile]	Apr [zile]	Mai [zile]	Iun [zile]	Iul [zile]	Aug [zile]	Sep [zile]	Oct [zile]	Noi [zile]	Dec [zile]	No.of hrs/ day (hrs)
1	Occupants - soft activity	[illegible]	50820		21	21	31	21	31	30	21	0	28	28	30	21	10
2	Lighting - T26 fluorescent linear	70	2520		21	21	31	21	31	30	21	0	28	28	30	21	10
3	Desktop-type computers	10	3500		21	21	31	21	31	30	21	0	28	28	30	21	10
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
	Total power and operating hours		56840	0	210,0	210,0	310,0	210,0	310,0	300,0	210,0	0,0	280,0	280,0	300,0	210,0	2830,0

	Indoor heat intakes Ian [kWh]	Feb [kWh]	Mar [kWh]	Apr [kWh]	Mai [kWh]	Iun [kWh]	Iul [kWh]	Aug [kWh]	Sep [kWh]	Oct [kWh]	Noi [kWh]	Dec [kWh]	TOTAL Source type [kWh]	TOTAL Annual [kWh]
1	10672,20	10672,20	15754,20	10672,20	15754,20	15246,00	10672,20		14229,60	14229,60	15246,00	10672,20	143620,60	
2	529,20	529,20	781,20	529,20	781,20	756,00	529,20		705,60	705,60	756,00	529,20	7131,60	
3	735,00	735,00	1085,00	735,00	1085,00	1050,00	735,00		980,00	980,00	1050,00	735,00	9905,00	
4														
5														
6														
7														
8														160857,20
9														
10														
11														
12														
13														
14														
15														
	11936,40	11936,40	17620,40	11936,40	17620,40	17052,00	11936,40	0,00	15915,20	15915,20	17052,00	11936,40		

Legend: zile = days

Solar gains

Solar gains were calculated based on:

$a_{sol,k}$ radiation absorption coefficient

$g_{gl,n,wt}$ total solar energy transmission coefficient at normal incidence

$g_{gl,wt}$;- total average solar energy transmission coefficient

$F_{fr,win}$-window frame surface fraction

$F_{sky,k}$. -visibility factor between element and sky

$F_{sh,dir}$ shading factor for direct solar radiation intensity

1	ZTC1.1

	Code	Type	A_{el} [m²]	U_{el} [W/m²K]	Orientation	Inclination angle Introduced	Inclination angle [°]	$\alpha_{sol;k}$ [-]	$g_{gl;n;w}$ [-]	$g_{gl;w}$ [-]	$F_{f;w}$ [-]	$F_{sky;k}$ [-]	$F_{sh;dir}$ [-]
1	PE1	PLIN	196,30	0,84	NE		90	0,60				0,50	0,70
2	PE1	PLIN	259,01	0,80	NV		90	0,60				0,50	0,90
3	PE1	PLIN	115,42	0,85	SV		90	0,60				0,50	0,90
4	PE1	PLIN	244,41	0,77	SE		90	0,60				0,50	0,90
5	PL attic	INTERIOR	679,21	1,65	ORIZ								
6	Pl ground	GROUND	638,65	1,93	ORIZ		0						
7	[illegible]	INTERIOR	40,56	3,04	ORIZ								
8	FE-PVC	TRANSPARENT	156,16	2,33	NE		90		0,60	0,54	0,21	0,50	0,60
9	UE-metal		3,00	6,79	NE		90					0,50	0,70
10	FE-PVC	TRANSPARENT	36,36	2,33	NV		90		0,60	0,54	0,21	0,50	0,90
11	FE-PVC	TRANSPARENT	203,83	2,33	SV		90		0,60	0,54	0,21	0,50	0,80
12	UE-metal	PLIN	7,40	6,79	SV		90					0,50	0,90
13	UE-PVC	TRANSPARENT	30,47	2,43	SV		90		0,60	0,54	0,56	0,50	0,90
14	FE-PVC	TRANSPARENT	42,28	2,33	SE		90		0,60	0,54	0,21	0,50	0,90
15	UE-PVC	TRANSPARENT	1,89	2,43	SE		90		0,60	0,54	0,56	0,50	0,90
16	PE2	PLIN	140,16	3,56	NE		90	0,60				0,50	0,70
17	PE2	PLIN	152,87	3,56	SV		90	0,60				0,50	0,90
18	brick-glass	TRANSPARENT	23,52	5,80	NV		90		0,85	0,77	0,25	0,50	0,90
19	UE-metal	PLIN	6,75	6,79	SE		90					0,50	0,90

	Monthly solar intake by elements							- Qsol;ell [KWH]						
	Dec.(0)	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
1	0,68	0,91	1,63	3,03	2,75	6,09	18,18	12,88	0,00	13,36	2,98	1,61	0,68	
2	1,10	1,47	2,64	4,91	4,44	9,86	29,42	20,84	0,00	21,62	4,82	2,61	1,10	
3	14,22	19,23	26,86	38,02	25,43	39,77	38,03	23,61	0,00	35,74	46,08	31,71	14,22	
4	27,41	37,07	51,78	73,30	49,03	76,67	67,89	45,52	0,00	68,91	88,84	61,13	27,41	
5														
6														
7														
8	6,16	8,20	15,56	34,23	30,82	67,62	196,65	139,32	0,00	130,22	27,85	15,96	6,16	
9	0,14	0,19	0,34	0,63	0,57	1,26	3,76	2,66	0,00	2,76	0,62	0,33	0,14	
10	2,15	2,86	5,43	11,96	10,76	23,69	68,33	48,66	0,00	45,46	9,73	5,57	2,15	
11	292,36	393,76	580,34	971,46	646,68	1002,47	731,76	576,57	0,00	788,98	976,00	710,84	292,36	
12	12,12	16,40	22,90	32,42	21,68	33,91	29,60	20,13	0,00	30,48	39,29	27,03	12,12	
13	27,16	36,57	53,91	90,24	60,07	93,12	67,98	53,74	0,00	73,29	90,67	66,03	27,16	
14	68,22	91,87	135,43	226,70	150,91	233,93	170,77	135,01	0,00	184,12	227,52	165,88	68,22	
15	1,68	2,27	3,34	5,60	3,73	6,78	4,22	3,33	0,00	4,55	5,62	4,10	1,68	15167,0
16	2,06	2,76	4,96	9,22	8,34	18,51	55,24	39,12	0,00	40,59	9,06	4,90	2,06	
17	83,99	113,69	158,67	224,58	150,22	234,91	177,36	139,40	0,00	211,14	272,21	187,30	83,99	
18	1,88	2,50	4,74	10,42	9,38	20,65	58,56	42,41	0,00	39,64	8,48	4,86	1,88	
19	11,06	14,96	20,89	29,57	19,78	30,93	23,36	18,36	0,00	27,80	35,84	24,66	11,06	
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
	552,4	744,5	1089,4	1766,3	1194,6	1869,4	1719,1	1323,6	0,0	1718,7	1844,5	1314,5	552,4	

The heat lost as a result of thermal radiation to the sky is:

$$Q_{sky,eli} = 9252.8 \text{ KWh/year}$$

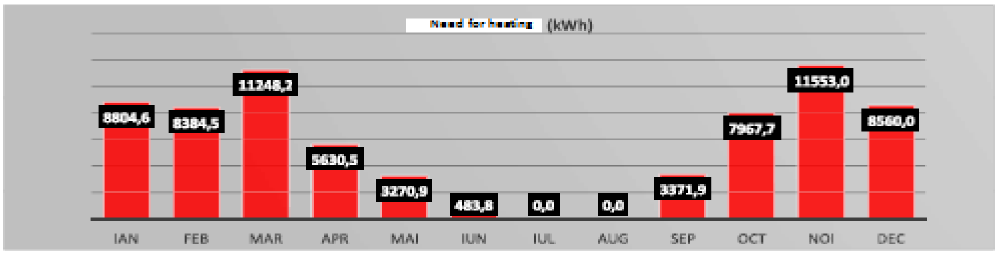
Need for heating

The table below presents the heating requirements for the highschool building for each month.

Need for heating [kWh]

	ZTC code	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
1	ZTC1.1	8804,6	8384,5	11248,2	5630,5	3270,9	483,8	0,0	0,0	3371,9	7967,7	11553,0	8560,0	69275,1

	ZONE	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
1	ZT1	8804,6	8384,5	11248,2	5630,5	3270,9	483,8	0,0	0,0	3371,9	7967,7	11553,0	8560,0	69275,1
	Total ZT	8804,6	8384,5	11248,2	5630,5	3270,9	483,8	0,0	0,0	3371,9	7967,7	11553,0	8560,0	69275,1



Determining the heating period

Next, the number of degree days for the winter period is established. The following graph shows the average monthly and external equilibrium temperatures. The external equilibrium temperature Θ_e is the external temperature for which it is not necessary to start the heating.

Θh(tr,ve;sol,int,)-Heat transferred by transmission for heating, ventilation, solar gains, internal gains

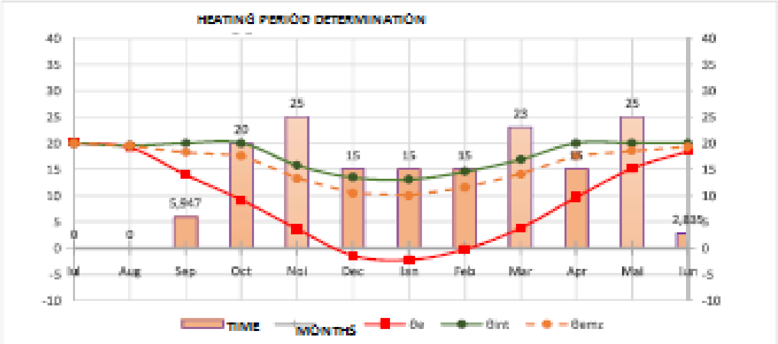
T_H-time constant of the heated area

Intermittent heating is taken into account through the γ coefficients

1	ZTC1.1	$H_{gr,H,adj}$	214,42 [W/K]

Month	Hours	$Q_{H,tr,cont}$	$Q_{H,ve,cont}$	$Q_{H,ht,cont}$	τ_H	$Q_{H,sol}$	Q_r	$Q_{H,sol}$	$Q_{H,int}$	$Q_{H,gn}$	$Q_{H,tr}$	$Q_{H,ve}$	$Q_{H,ht}$	$\gamma_{H,gn,cont}$	γ_H	a_H	$\eta_{H,gn}$	$Q_{H,nd}$	f_H	f_{HU} (Humidification)	$Q_{HU,nd}$ (Humidification)
[-]	[h]	[kWh]	[kWh]	[kWh]	[h]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[-]	[-]	[-]	[-]	[kWh]	[-]	[-]	[kWh]
Dec	150	12676	9671	22348	9,6	552	664	-112	11959	11847	9327	6744	16071	0,53	0,74	0,94	0,56	8560	1,00	0,12	0,0
Ian	150	13112	10031	23143	9,6	745	661	83	11959	12042	9556	6932	16487	0,52	0,73	0,94	0,56	8805	1,00	0,13	0,0
Feb	150	12101	9132	21232	9,5	1089	641	449	11956	12405	9288	6686	15973	0,58	0,78	0,94	0,54	8385	1,00	0,12	0,0
Mar	230	15242	11174	26416	9,5	1766	868	898	17643	18540	12769	9026	21795	0,70	0,85	0,94	0,52	11248	1,00	0,16	0,0
Apr	150	6783	4633	11416	9,5	1195	606	588	11958	12546	6783	4633	11416	1,10	1,10	0,94	0,46	5631	1,00	0,08	0,0
Mai	250	5651	3599	9250	9,5	1899	1080	819	17643	18462	5651	3599	9250	1,98	2,00	0,94	0,32	3271	1,00	0,05	0,0
Iun	220	2010	990	2999	9,6	1719	1017	702	17073	17775	2010	990	2999	5,92	5,93	0,94	0,14	484	0,10	0,01	0,0
Iul	150	0	0	0	9,6	1324	701	623	11959	12581	0	0	0	0,00	0,00	0,94	0,00	0	0,00	0,00	0,0
Aug	0	0	0	0	0,0	0	0	0	22	22	0	0	0	0,00	0,00	0,80	0,00	0	0,00	0,00	0,0
Sep	200	5477	3599	9075	9,6	1719	974	744	15937	16681	5477	3599	9075	1,84	1,84	0,94	0,34	3372	0,30	0,05	0,0
Oct	200	9399	6478	15876	9,6	1845	966	878	15937	16815	9399	6478	15876	1,06	1,06	0,94	0,47	7968	1,00	0,12	0,0
Noi	250	16500	12295	28795	9,6	1315	1074	241	17073	17314	12897	9138	22035	0,60	0,79	0,94	0,54	11553	1,00	0,17	0,0
Dec	150	12676	9671	22348	9,6	552	664	-112	11959	11847	9327	6744	16071	0,53	0,74	0,94	0,56	8560	1,00	0,12	0,0
		98859		176551		15167	9253	5914	161118	167032	83156	57823	140978					69275			0

.



	θ_e	θ_{int}	θ_{emz}	TIME (DAYS)
Iul	20,10	20,00	20,00	0,00
Aug	19,20	19,49	19,49	0,00
Sep	14,00	20,00	18,26	5,95
Oct	9,20	20,00	17,59	20,00
Noi	3,60	15,79	13,23	25,00
Dec	-1,50	13,49	10,44	15,00
Ian	-2,30	13,11	9,99	15,00
Feb	-0,30	14,58	11,48	15,00
Mar	3,80	15,89	14,09	23,00
Apr	9,70	20,00	17,65	15,00
Mai	15,20	20,00	18,54	25,00
Iun	18,50	20,00	19,30	2,84

The graph above shows:

Θ_e = monthly average external temperature, in Celsius degrees

Θ_{int}= monthly average internal temperature, in Celsius degrees

Θemz- monthly average equilibrium temperature, in Celsius degrees

From the intersection of the two graphs, the number of heating days is determined, namely 212.28 days.

Energy consumption for heating

The heating consumption is calculated according to the type of source, the regulation, distribution and transmission of the heating system. The heat losses through emission for the heating elements were calculated. The following table shows the results for the energy consumption through emission. Additionally, the auxiliary energy consumption given by the circulation pumps was taken into account.

Total calculation heating energy

Heating emission energy consumption: 69922.540 kWh/year

Specific heating emission energy consumption: 46.67 kWh/sqm.year

Total floor reference area: 1498.22 sqm

	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
ZT1	5060,8	5294,1	8899,8	7006,8	8734,5	4134,2	0,0	0,0	7203,4	9456,3	9029,5	5103,3	**69922,540**
TOTAL	**5060,8**	**5294,1**	**8899,8**	**7006,8**	**8734,5**	**4134,2**	**0,0**	**0,0**	**7203,4**	**9456,3**	**9029,5**	**5103,3**	**69922,540**

Equipments electric consumption

ZT1	0,000
TOTAL	**0,000**

Considering the previous data and the energy system, one calculated the energy consumption for heating:

	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
QH;dis;in [kWh]	13922,489	13733,240	20224,640	12680,798	12071,103	4624,944	0,000	0,000	10591,242	17482,444	20667,320	13719,516
QW;dis;in [kWh]	2317,680	2317,210	3551,710	3858,501	3857,227	3702,204	2313,353	0,000	3086,004	3086,893	3860,843	2317,519
QV;dis;in [kWh]	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
QC;dis;in [kWh]	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Qge;out;tot [kWh]	0	0	0	0	0	0	0	0	0	0	0	0

The table shows the monthly calculation for heating, hot water consumption, ventilation, air conditioning and the total.

Total specific annual primary energy consumption for heating

Based on the heating consumption, the specific primary energy consumption of the building for heating can be calculated as:

$$q_{inc} = 122{,}1 \left[\frac{kWh}{\text{year}\ m^2}\right]$$

The building, from a heating point of view, falls into class C, with a specific annual primary energy consumption of 122.1 kWh/sqm per year.

2.3 Determination of annual primary energy consumption for cooling

The building is not equipped with an organized air conditioning system, in this case it is not mandatory to calculate the energy requirement for cooling (the building has no energy consumption for cooling). However, a calculation was made to determine the energy requirement for air conditioning and the overheating indicator.

1	ZTC1.1	$H_{gr;C;adj}$	893,53	[W/K]

Luna [-]	Ore [h]	$Q_{C;tr}$ [kWh]	$Q_{C;ve}$ [kWh]	$Q_{C;ht}$ (kWh)	τ_C [h]	$Q_{C;sol}$ [kWh]	Q_r [kWh]	$Q_{C;sol}$ [kWh]	$Q_{C;int}$ [kWh]	$Q_{C;gn}$ [kWh]
Dec	150	15764	12370	28135	8,9	0	0	0	0	0,0
Ian	150	16208	12730	28939	8,9	0	0	0	0	0,0
Feb	150	15205	11830	27035	8,9	0	0	0	0	0,0
Mar	230	20007	15312	35319	8,9	0	0	0	0	0,0
Apr	150	9890	7332	17222	8,9	0	0	0	0	0,0
Mai	250	10822	8097	18919	8,9	0	0	0	0	0,0
Iun	220	6549	4948	11497	8,9	1719	1017	702	17057	17759,5
Iul	150	3827	2654	6481	8,9	1324	701	623	11942	12564,6
Aug	0	0	0	0	0,0	0	0	0	0	0,0
Sep	200	9576	7197	16774	8,9	1719	974	744	15921	16665,0
Oct	200	13499	10076	23575	8,9	0	0	0	0	0,0
Noi	250	21633	16794	38427	8,9	0	0	0	0	0,0
Dec	150	15764	12370	28135	8,9	0	0	0	0	0,0
		142981		252322		4761	2692	2069	44920	46989

Luna [-]	$\gamma_{C;gn;cont}$ [-]	a_C [-]	$\eta_{C;ht}$ [-]	$Q_{C;nd;cont}$ [kWh]	$a_{C;red;wknd}$ [-]	$Q_{C;nd}$ [kWh]	f_C [-]	Dehumidification: f_{DHU} [-]	Dehumidification: $Q_{DHU;nd}$ [kWh]
Dec	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Ian	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Feb	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Mar	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Apr	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Mai	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Iun	1,54	0,93	0,58	11037,2	1,00	11037,2	0,87	0,39	0,00
Iul	1,94	0,93	0,64	8440,1	1,00	8440,1	1,00	0,30	0,00
Aug	0,00	0,80	0,00	0,0	1,00	0,0	1,00	0,00	0,00
Sep	0,99	0,93	0,48	8620,2	1,00	8620,2	0,70	0,31	0,00
Oct	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Noi	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
Dec	0,00	0,93	0,00	0,0	1,00	0,0	0,00	0,00	0,00
				28097		28097			0,00

	θ_e	θ_{int}	θ_{emz}	TIME (DAYS)
Ian	-2,30	26,00	26,00	0,00
Feb	-0,30	26,00	26,00	0,00
Mar	3,80	26,00	26,00	0,00
Apr	9,70	26,00	26,00	0,00
Mai	15,20	26,00	26,00	0,00
Iun	18,50	26,00	23,13	0,00
Iul	20,10	26,00	22,75	0,00
Aug	19,20	26,00	26,00	0,00
Sep	14,00	26,00	23,57	0,00
Oct	9,20	26,00	26,00	0,00
Noi	3,60	26,00	26,00	0,00
Dec	-1,50	26,00	26,00	0,00

This calculation showed that the temperature graphs do not intersect, which leads to the conclusion that currently the building does not need an air conditioning system

CALCULATION OF THE NUMBER OF OVERHEATING HOURS

Area with the highest overheating risk is: ZT C1.1.
Reference floor area: 1498.22 sqm
Reference interior volume: 6442.346 m^3

Area infiltrations ratio: 0.46 vol/h
Ground thermal transfer coefficient calculated in stationary mode: 363.8 W/K
Thermal transfer coefficient through transmission: 3478.1 W/K
Specific thermal capacity: 45.8 Wh/m^3K
Internal intakes: 23683.3 W

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
11936.4	11936.4	17620.4	11936.4	17620.4	17052.0	11936.4	0,0	15915.2	15915.2	17052.0	11936.4

Solar intakes: 2.6 KWh/day

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sвp	Oct	Nov	Dec
744.5	1089.4	1766.3	1194.6	1899.4	1719.1	1323.6	0,0	1718.7	1844.5	1314.5	552.4

Does the mechanical ventilation system exist? No

Fresh air flow provided by the ventilation system from the building: m^3/h
0,00 vol/h

Ventilation system yield: %
Temperature range during the summer: 15.00 K
Ventilation ratio due to opening the windows during the night: vol/h
Number of overheating hours (temperature > 26 degrees) : 441 hours
Percentage of total yearly number of hours: 5.03%

2.4 Determination of the primary energy consumption for preparing the hot running water
Energy consumption evaluation for preparing the hot running water is made starting from the hot running water consumption for one person per day and depending on the activities carried out by such persons.

HOT RUNNING WATER ENERGY CONSUMPTION CALCULATION

General data

Water temperature data
Hot running water temperature: 60°C
Cool water temperature: 10°C
Temperature difference allowed: 5°C
Average temp: 57.5°C
Hot running water accumulation temp: 60°C
Burried pipes depth: (m)

Recirculation pipe: does not exist
General heating meter: does not exist
Does the hot running water system exist: Yes, it works
Thermal power for preparing the hot running water: 10 kW
Maximum thermal power installed for preparing the hot running water: 10 kW

1. ZT1 Reference area: 1498.2 m2
Livable area: 0.0 m2
Recirculation pump: NO

Energy source for preparing the hot running water:
own source – own thermal plant – natural gas
District heating with connection to a thermal point: local central

Debit metres on the consumption points: do not exist
Sanitary items: WC: 5 urinals: 2 basins: 4 washer: 1
Hot running water consumption points: 5 Cold water consumption points: 12
Daily hot running water operating schedule: 10 hrs/day Number of uses of the sanitary items: 100 l/day
13 – Schools without showers or bathrooms
a. schools without showers or bathrooms (for one student per program)

V_{day}	Days											
$l/_{day}$	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
2668,1	15	15	23	25	25	24	15	0	20	20	25	15

- f average number ofdaily consumption units 462.00 Number ofstudents: 462
- V w, f, day– specific need for one consumer 5.00 l/units/day
- V w,day– necessary hot consumption water volume 2310.00 l/day
- V w,l,s day– volume corresponding to water loss 358.05 l/day

	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
Hot running water consumption hours - no recirculation	150	150	230	250	250	240	150	0	200	200	250	150
Recirculation pump operating hours												
$Q_{w,nd,monthly}$ [kWh/l month]	2303,5	2303,5	3532,0	3839,2	3839,2	3685,6	2303,5	0,0	3071,3	3071,3	3839,2	2303,5

Qw, nd, annualy, ZT1 : 34091.716 kWh/year Qw, nd, annualy, spec ZT1 : 22.75 kWh/year

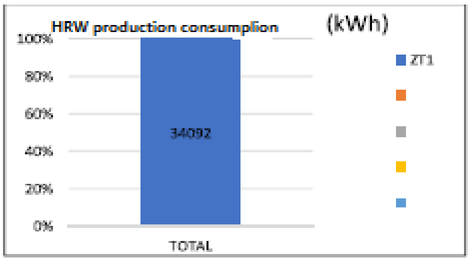
Total HRW energy supply –SUMMARY

Total need for energy for hot water consumption – 34091.716 [kwh/year]

Specific need for energy for hot water consumption – 22.75 [kwh/sqm.year]

Total reference area of the floor: 1498.22 sqm

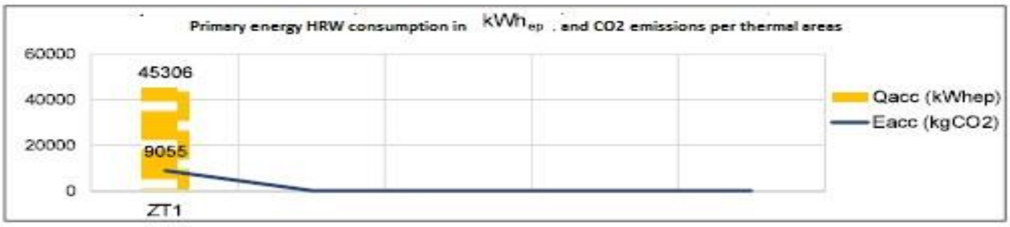
	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
ZT1	2303,5	2303,5	3532,0	3839,2	3839,2	3685,6	2303,5	0,0	3071,3	3071,3	3839,2	2303,5
TOTAL	2303,5	2303,5	3532,0	3839,2	3839,2	3685,6	2303,5	0,0	3071,3	3071,3	3839,2	2303,5



Energy consumption for preparation, distribution, storage and generation of hot running water

#	ZONE	Qw,nd	Qw,dis,tot	Qw,sto	Qw,g	Qw,total	Ww	Qw,total	Ww	Qacc	Eacc
um	[-]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh_{ep}]	[kWh_{ep}]	[kWh_{ep}]	[$kgCO_2$]
1	ZT1	34091,716	177,429	0,000	3578,419	37847,564	409,814	44281,650	1024,534	45306,184	9054,518
TOTAL		34091,716	177,429	0,000	3578,419	37847,564	409,814	44281,650	1024,534	45306,184	9054,518

#	ZONE	Qw,max
um	[-]	[kW]
1	ZT1	0,332
TOTAL		0,332



$Q_{W,in,total}$	45306,184	[kWh/ yr]	$Q_{W,in,spec}$	30,24	[kWh/m^2, yr]
CO2 emissions	9054,518	[$kgCO_2$/yr]	Specific CO2 emissions	6,04	[$kgCO_2/m^2$, yr]

The building, in terms of the preparation of hot running water, falls into class D, having a specific annual primary energy consumption of 30.24 kWh/sqm/year

2.5 Determining the annual primary energy consumption for mechanical ventilation

The building is not equipped with a mechanical ventilation system. According to Mc00l-2022, for non-residential buildings for which ventilation is not provided by a dedicated centralized mechanical ventilation system, a virtual consumption of electricity for ventilation is required corresponding to a classification into energy efficiency class E - the maximum consumption limit, namely 39kWh/sqm/year in case of educational establishments.

2.6 Determining the annual primary energy consumption for lighting

The calculation of the energy requirement for lighting, in case of the building analyzed, is carried out starting from the power installed, which was estimated.

ZT code: ZT1 ZT area category: 04 – educational establishments ZT area destination: a - classroom
power estimated: yes

Floor reference area: 1498.22 sqm
Length, L: 149.82 [m]
Width, W: 10.00 [m]
Height, h_m: 4.30 [m]
Room index, K: 2.180 [-]
Lighting source distribution, UFF: 10%
Type of flow: direct
Power density per flow: 0.0236 [W/x]
Power density: 8.98 W/sqm
Estimated lighting power: 13458.73 W
Correction factor, Fmf: 1.33 [-]
Absence factor, Fa: 0.25 [-]
Power decrease factor, F_{CA}: 1.00 [-]
Sourse efficiency factor, F_L: 0.95 [-]

Lighting power known: [W]
Lighting level, E_m: 300 [lx]
Maintainance factor, FM: 0.6[–]
Lighting area percentage: 100% [%]
Lighting charging batteries: No
Stand-by for lighting control: No
Type of lighting source: T26 linear fluorescent lamp
Occupation control: 1 – Manual On/Off
emergency light battery consumption: 0 [kWh/sqm.year]
stand-by energy consumption: 0 [kWh/sqm.year]
constant lighting factor, Fc: 1 [-]
control II dependency factor, Foc: 1 [-]
occupation dependency factor, F_c: 0.95 [-]

Type of natural light control: Manual
Constantly controlled system: No

Natural light dependency factor
Natural light dependency factor, Fd: 0.544 [-]

- Usage hours/day: 1800
- Usage hours/night: 200
- Total usage hours: 2000
- Total electricity lighting annual consumption: 15078.940 [kWh/year]
- LENI (Preliminary) indicator: 10.06 [kWh/sqm.year]

Thermal area results – ZT1
Safety lighting charging power, Pem: 0.0 W
power lighting controls- Ppc: 0.0 W

Wtotal: 37697.350 [kWh/year]
CO2 emissions: 4033.616 [kgCo2/year]

Energy consumption for lighting
LENI: 25.16 [kWh/sqm.year]
Specific CO2 emissions: 2.69 [kgCo2/sqm.year]

The building, from lighting point of view, falls into class C, with a specific annual primary energy consumption of 25.16 kWh/sqm. year.

2.7 Determining the annual consumption of primary energy from renewable energy sources

Not applicable

2.8 Determining the annual primary energy consumption, quantities of equivalent CO2 emitted and RER indicator

Energy consumption before refurbishment

Consumer	HEATING	HRW	VENTILATION	COOLING	LIGHTING	Energy from renewable sources	TOTAL
Final thermal energy consumption [MWh/year]	154.019	37.848	0.000	0.000	0.000	0.000	191.867
Final electricity consumption [MWh/year]	1.090	0.410	23.372	0.000	15.079	19.975	39.951
Primary energy consumption [MWh/year]	182.926	45.306	58.431	0.000	37.697	19.975	324.380
Specific energy consumption [kWh/sqm.year]	122.1	30.24	39	0	25.16	13.33	218.50
ENERGY EFFICIENCY CLASS	C	D	E	-	C	-	C

The primary energy consumed to ensure comfort in the building is determined, 216.5 kWh/sqm, year - CLASS C.
Based on the total annual consumption of thermal and electrical energy, the annual CO2 equivalent emissions are determined. The specific amount of CO2 is 37.4 kg/sqm. year – CLASS C.
The RER indicator is determined with the relationship

$$RER = \frac{E_{p,regen}}{E_p} \cdot 100 = 6.16\%$$

3. Drafting of the energy performance certificate

The building's energy performance certificate is drafted according to Mc00l-2022. The actual building falls into energy efficiency class E.

3.1 Mentioning the energy features of the reference building

- The reference building is a virtual building associated with the real building that is being analyzed from the energy performance point of view. This concept allows the comparison of the thermotechnical and energy characteristics of the real building with the "reference" values.
- The reference building is defined as follows:

  - for the construction elements that are part of the building envelope, the recommended values of the corrected thermal strengths indicated in MC001-2022 table 2.9b for the current refurbished non-residential buildings are chosen (chapter 2.2.2.)

  - from the energy point of view, by the maximum primary energy consumption value indicated in MCOOI-2022 table 2.10b (chapter 2.3.) for buildings intended for the education system, climate zone III (82.70 kWh/sqm.year), considering the building equipped with all technical systems (heating, hot running water, lighting, ventilation and cooling)

  - from the pollution level point of view, by the value of equivalent CO2 emissions indicated in MC001-2022 table 2.10b (chapter 2.3.), for buildings intended for the heating system. climate zone III (13.10 kgCO2/sqm. year), considering the building equipped with all technical systems (heating, hot running water, lighting, ventilation and cooling)

Reference building		
Primary energy consumption [kWh/sqm.year]		CO2 emissions [kgCO2/sqm.year]
Heating	82.70	13.10
Hot running water		
Cooling		
Ventilation		
Lighting		
Class	B	B

3.2 ENERGY PERFORMANCE CERTIFICATE

drafted according to the Calculation Methodology of the Buildings Energy Performance no.001

DATA REGARDING THE CPE AND THE ENERGY AUDITOR IDENTIFICATION

CPE number 000132/550311 Valid 10 years until 13.05.2025 if no major changes appear

Cruciat Radu-Iuliu Energy auditor
Certificate SSA/02258 grade I

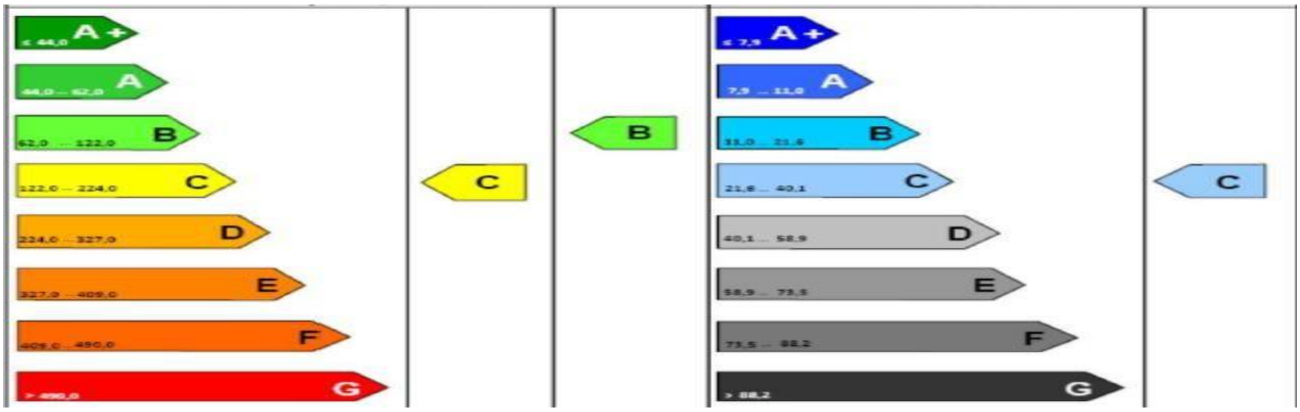
DATA REGARDING THE BUILDING/BUILDING BLOCK CERTIFIED NZEB NO

Building category: school/highschool/college
Year of building/major refurbishment: 1970
Building address: Sibiu, Electricienilor street no.1 , Sibiu county
Floor reference area: 1498.22 sqm
GPS coordinates (lat x long): 45.78470x 24.16853
Built/developed area: 741.29/1571.63 sqm
Height regime: Gf+2F
Reference interior volume: 6442.35 m3
CPE drafting purpose: Information
Calculation programme used: ENERG+ version 04/2024

ENERGY PERFORMANCE TRUE BUILDING REFERENCE BUILDING CO2 EMISSIONS LEVEL

kWh/sqm.year – total primary energy
High energy performance

kgCo2/sqm.year
Low pollution level



Total annual specific energy consumption (kWh/sqm.year)	Final	128.1	26.7	CO2 equivalent emissions level (kgCo2/sqm.year)	37.4
	primary	216.5	82.7		

low energy performance high pollution level

Annual specific energy consumption from renewable sources (Kwh/sqm.year)	Thermal solar	Electric solar	Heat pumps	Biomass	Other SRE type	Total SRE
	0.0	0.0	0.0	0.0	13.3	13.3

Type of installation system of the real building	Energy class/Annual specific consumption of primary energy per facility [kWh/m², yr]*							
	A+	A	B	C	D	E	F	G
Heating	≤ 25	25 ... 36	36 ... 71	122.1	144 ... 218	218 ... 272	272 ... 327	> 327
Hot running water	≤ 7	7 ... 10	10 ... 19	19 ... 26	30.2	33 ... 41	41 ... 49	> 49
Cooling***	≤ 4	4 ... 6	6 ... 13	13 ... 22	22 ... 31	31 ... 38	38 ... 46	> 46
Mechanical ventilation	≤ 4	4 ... 6	6 ... 11	11 ... 21	21 ... 31	39.0	39 ... 46	> 46
Lighting	≤ 7	7 ... 10	10 ... 21	25.2	33 ... 45	45 ... 57	57 ... 68	> 68

*values calculated ***number of hours of a year when the interior temperature exceeds the comfort temp.
**t/e thermal/electric in free regime, during the summer = 441h (is 0 if the cooling consumption is calculated)

Auditor's signature and stamp

B. ENERGY AUDIT REPORT

4. Description of the thermal refurbishment/modernization solutions

Following the assessment of the current situation, one observes that the envelope elements do not comply with the minimum requirements set out in the Methodology for calculating the indicative energy performance of buildings Mc 001-2022, approved by ordinance no. 16/2023.

The measures provided by the energy audit aim to bring the construction within the minimum requirements established by Mc00l-2022 and to meet the eligibility conditions requested for accessing funds through the Swiss-Romanian Cooperation Program for Energy Efficiency and Renewable Energy, namely Supporting the Transformation of Current Public Buildings into NZEBs.

According to the specific guide - Conditions for accessing funds are:

• In order to ensure the energy performance of the building, the financing will target the in-depth energy renovation of public buildings (primary energy savings of over 60%).

• Upon the investment completion, the building refurbished should obtain the A or B energy performance certificate

According to the specific guide - the eligible intervention works are: thermal refurbishment works of the building envelope elements;

thermal refurbishment works of the building envelope

thermal refurbishment works of the heating system/hot running water supply system;

installation of alternative systems for producing electricity and/or heat for own consumption; use of renewable energy sources;

installation/refurbishment/modernization of air conditioning systems to ensure indoor air quality;

refurbishment/modernization works of lighting systems in buildings;

integrated energy management systems for buildings;

intelligent shading systems for the hot season;

modernization of technical systems of buildings;

provision of charging stations for electric cars, according to the provisions of Law no. 372/2005 on the energy performance of buildings, republished;

4.1. Presentation of solutions and packages for the thermal refurbishment of the building

Solution 1. This solution will improve the thermal strength of the envelope elements, namely exterior walls and floor above the last floor.

The thermal insulation of the exterior walls with a layer of fireproof expanded polystyrene or mineral wool 15 cm thick on the exterior. It is recommended that the thermal insulation used has a thermal conductivity of $\gamma<0.038$ W/mK

By applying the solution, an increase above the minimum level of thermal transfer strength of the opaque part of the envelope will be achieved. Also, applying the solution will lead to the correction of thermal attics. The base of the structure will be thermally insulated with fireproof extruded polystyrene boards at least XPS300 thick of 5-10 cm.

Thermal insulation of the floor above the last floor with natural sheep wool insulation with a thickness of 25 cm and a minimum thermal strength of γ<0.038 W/mK.

Solution 2. Replacing the external double-glazed windows and doors with aluminum or PVC carpentry, with frames and sashes provided with pentachamber profiles and galvanic metal reinforcement profiles, triple thermal insulation windows treated on the outside with low-e. Two sealing gaskets will be provided between the frame and the sashes and on the contour of the thermal insulation windows.

By replacing the carpentry, the final strength of the windows and doors will be increased above the minimum level, cold air infiltration will be reduced, and thermal attics at the contact between the window and door frames with the closing walls will be improved. The new windows will have a minimum thermal strength of Rmin=0.83 sqm K/ W (or a transfer coefficient lower than U = 1.2 W/sqm K) and respectively Rmin 0.77 sqm K/ W (or a transfer coefficient lower than U = 1.3 W/sqm K) for doors.

Solution 3. The solution refers to the building's installations.

3.1. In order to increase the efficiency of the heating system,a condensing gas boiler will be installed in the highschool block. The new thermal plants will serve the highschool building, the workshops building and the gym hall.

3.2. Also in the heating plant adjacent to the high school, an air-water pump will be installed that will be used for heating and to prepare the hot running water for workshops, the gym hall and the high school building. The heating plant will be used to take over the consumption peaks during winter and will be adapted to prioritize as much as possible the use of the heat pump. The calculation considered a heat pump with a COP4. We recommend changing the distribution network of the thermal agent and also replacing damaged static bodies with new ones.

3.3. A system of photovoltaic solar panels will be installed on the workshop building trusses and if there is no space, on the high school truss if necessary, on SW and/or SE directions that will produce electricity for lighting, the heat pump andfor preparing the hot running water. The photovoltaic panels will be connected to the national network in order to benefit from compensation in accordance with the regulations in force.

3.4. The ventilation will be carried out in an organized manner, by arranging a ventilation system in each classroom. According to SR EN 16798-1, the minimum fresh air flow set for one occupant from schools is 15 m^3/h/person. We recommend the ventilators to be automatically operated depending on the CO2 level. The calculation considered the thermal transfer efficiency of 72%.

3.5 The lighting fixtures will be replaced with new led-type lighting sources. Once with these changes, one will inspect the electrical system condition and if it shows any damages, they will be remedied. We recommend to use the presence sensors for circulation areas.

Related works. The following is a brief description of the related works that will be carried out together with the main thermal refurbishment works:

• Local repair of the existing envelope elements that pose a risk of detachment.

• Repair of any leaks in the framework. If necessary, the framework elements will be replaced or reinforced.

• The rainwater collection systems of the framework will be repaired or replaced.

• The installations and equipment installed on the building facades will be dismantled and reassembled.

• The protective sidewalks around the building will be repaired or replaced in order to remove any infiltrations to the foundations and basement of the building.

• Water losses from the installations will be removed. If necessary, the cold water distribution installations, household and rainwater sewer collectors up to the connection/connection shaft will be repaired/replaced.

• The current thermal and waterproofing layers will be removed.

• The brice-soleils from the building facade will be removed

• The current polystirene thermal insulation will be removed.

For the economic calculation, the following packages are proposed:

Package 1 is a package consisting into the implementation of solutions 1 and 2. Within the package, the thermal insulation of the exterior walls with a 15 cm thermal insulation layer is carried out, the thermal insulation of the floor above the ground floor with a 25 cm thermal insulation layer, the thermal insulation of the floor above the technical channel with a 10 cm thermal insulation layer and the replacement of the existing carpentry.

The corrected, recalculated thermal strengths of the construction elements in case of applying package 1 are synthetically presented in Table 1.

Table 1

Construction element	S [sqm]	R [sqmK/W]	R’min [sqmK/W]	Criteria Fulfilled
NE exterior masonry wall PE1	327.9	3,12	3.00	YES
NW exterior masonry wall	266.8	3.03	3.00	YES
SW exterior masonry wall	261.9	3.03	3.00	YES
SE exterior masonry wall	244.4	3.08	3.00	YES
Ground slab	638.7	1.93	4.50	NO
Floor over the last floor below the attic	679.2	6.54	5.00	YES
Floor over the technical channel	40.6	2.6	2.50	YES
NE exterior windows	164.7	0.77	0.77	YES
NE exterior doors	3	0.83	0.83	YES
NW exterior windows	52	0.77	0.77	YES
NW exterior doors	0	0.83	0.83	YES
SW exterior windows	220.2	0.77	0.77	YES
SW exterior doors	7.4	0.83	0.83	YES
SE exterior windows	49.1	0.77	0.77	YES
SE exterior doors	8.7	0.83	0.83	YES

The ground slab does not observe the minimum strength requested by the code. Works related to the energy improvement of these parts of the envelope are with payment and are not economically justified.

Package 2 is a package consisting of the implementation of solution 3. This package consists of the refurbishment of the installations, namely: heat pumps, a new heating plant, a ventilation system with heat recovery and a photovoltaic panel system were installed. Additionally, the package includes measures to improve the lighting system. In order for the solution package to meet the minimum requirements given by the calculation methodology, the use of renewable sources and the introduction of a mechanical ventilation system for the investigated building are requested.

A photovoltaic panel system with an installed power of 20 kWh is implemented. The calculation considered a number of 50 photovoltaic panels on the roof of the high school to reduce the consumption of electricity for the operation of heat pumps, a hot running water preparation plant and the lighting system. Polycrystalline photovoltaic panels with a maximum power of 400 W were used for the calculation. The photovoltaic panels are mounted on the SE or SW side of the roof of the high school building. To determine the electrical energy produced by the photovoltaic panels, the position of the building, the cardinal orientation on which the panels are mounted and their inclination to the horizontal were taken into account.

The following table presents in order:

$I_{1\ Solar}$ radiation on a horizontal surface;

f_{head}- correction factor of the global intensity of solar radiation function of the inclination angle of the solar collectors and the angle of deviation from the cardinal direction SOUTH

It inclined- solar radiation on an inclined surface;

E_{li} total lunar energy

CALCULATION OF ENERGY PRODUCED BY THE PHOTOVOLTAIC PANELS

Thermal area related to the photovoltaic solar system: ZT1

Entry data photovoltaic system

Type of panel: 400 Wp Monocrystalline Yield = 21%

Maximum electrical power: 400 W

Nominal yield: 21%	Installation method: on the building
Solar panel area: 2.11 sqm	Calculation method: complex
Number of solar panels: 50	Panels orientation: SW
Total electrical power: 20.000,0 W	Inclination angle: 35%

Total panels area: 105.68

Nominal temperature: 45°C

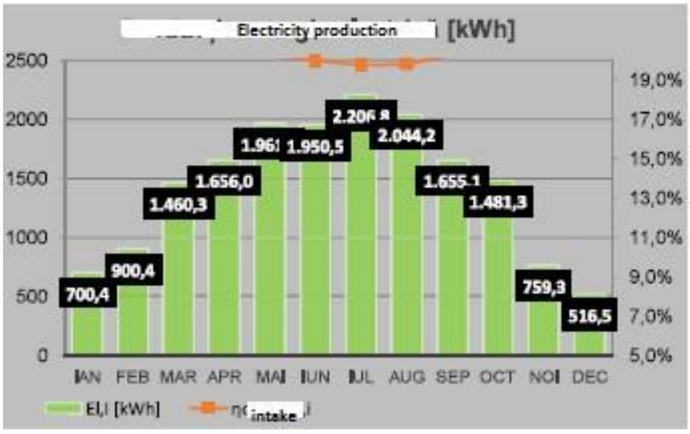
Module temperature coefficient: 0.4%

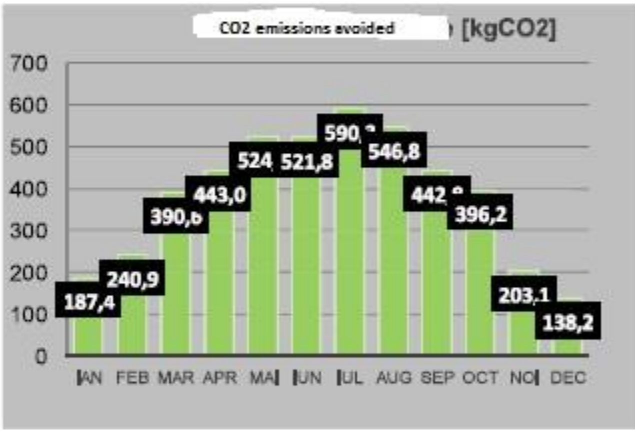
Energy loss expressed in percentages:

Dust: 0.01%	Age: 0.1%	Initial degradation: 0.1%	Availability: 1%	Inverter loss: 10%
Shadowing: 0.25%		Cables: 0.2%	Producer:0.15%	FV panels: 0.2%
Snow: 0.5%		Connections: 0.1%	Imperfections: 0.2%	Total energy loss: 2.81%

ENERGY PRODUCTION RESULTS

	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
$I_{T,Oriz}$ [W/m²]	45,4	78,3	119,1	162,0	195,9	216,1	228,1	199,8	154,7	109,9	54,1	32,9	1596,3
fcap	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
$I_{inclined}$ [W/m²]	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
$I_{i\ inclined}$ [W/m²]	62,0	99,2	134,1	166,6	189,1	203,7	218,4	201,7	170,4	139,7	73,6	45,6	1704,1
N_{zl}	31	28	31	30	31	30	31	31	30	31	30	31	365
$P_{max,1000}$ [W]	400,0	400,0	400,0	400,0	400,0	400,0	400,0	400,0	400,0	400,0	400,0	400,0	
A_{panel} [m²]	2,11	2,11	2,11	2,11	2,11	2,11	2,11	2,11	2,11	2,11	2,11	2,11	
A_{tot} [m²]	105,68	105,68	105,68	105,68	105,68	105,68	105,68	105,68	105,68	105,68	105,68	105,68	
ε_{PV}	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	
η_t	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	0,97	
η_{inv}	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	
$E_{inc,I}$ [kWh]	4871,351	7045,949	10543,468	12678,081	14869,096	15499,831	17168,060	15859,792	12968,433	10986,022	5599,882	3582,007	131671,97
$E_{I,I}$ [kWh]	700,385	900,413	1460,275	1656,007	1961,764	1950,523	2206,827	2044,159	1655,143	1481,272	759,331	516,500	17292,60
issionsI[kgCO₂]	187,4	240,9	390,6	443,0	524,8	521,8	590,3	546,8	442,8	396,2	203,1	138,2	4625,77
η_{intake}	22,1%	21,7%	21,3%	20,7%	20,3%	20,0%	19,8%	19,8%	20,3%	20,7%	21,5%	22,2%	





TOTAL ENERGY PRODUCED: 17292.601 [kWh/year]
TOTAL SPECIFIC ENERGY PRODUCED: 11.54 [kWh/sqm.year]
TOTAL CO2 EMISSIONS AVOIDED: 4625.771 [kgCO2/year]
TOTAL CO2 EMISSIONS AVOIDED OF THE AREA: 3.09 [kgCO2/sqm.year]

The total energy produced by photovoltaic panels over a year is obtained with the formula:

$$Etot. \text{ — } \sum E\ li \text{ — } 17292.60\ kWh/year$$

$$Especific \quad 11.54 \quad KWh/sqm.year$$

The CO2 emissions avoided by installing the photovoltaic panels are 4.6 tons/year or 3.09 kg/sqm/year.
In package 2 the gym hall ventilation is made by installing a heat-recovery ventilator with a recovery efficiency of min.72%.
Also, package 2 provides a heat air-water pump. The calculation considered conventionally a single heat pump that provides the heating and the hot running water preparation. The following table shows for package 2 the heat pump production for heating and hot running water preparation.

Month	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
$\theta_{gen,ext}$ [°C]	-2,3	-0,3	3,8	9,7	15,2	18,5	20,1	19,2	14,0	9,2	3,6	-1,5
No.of days	15	15	23	15	25	10	6	0	8	20	25	15
t_{ci} [h]	360	360	552	360	600	240	150	0	200	480	600	360
Q_{gen,dis,out_1} [kWh]	2324,8	2324,0	3561,6	3869,2	3867,2	3711,4	2318,6	0,0	3094,1	3095,5	3871,8	2324,5
θ_{gen,dis,out_1} [°C]	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0
Q_{gen,dis,out_2} [kWh]	13048,8	12869,4	18301,3	7460,5	6565,0	2326,1	0,0	0,0	5821,0	10323,3	18947,3	12818,6
θ_{gen,dis,out_2} [°C]	36,2	35,2	33,1	30,2	27,4	25,8	25,0	25,4	28,0	30,4	33,2	35,8
$\theta_{gen,in}$ [°C]	-2,3	-0,3	3,8	9,7	15,2	18,5	20,1	19,2	14,0	9,2	3,6	-1,5
$\theta_{gen,sto,out}$ [°C]	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0
$E_{H,gen,in}$ [kWh]	3124,2	2874,6	3748,0	2472,8	2499,2	1594,6	905,7	0,0	1330,3	2830,9	4107,1	3018,8
$Q_{H,gen,ls,rbl}$ [kWh]	78,1	71,9	93,7	61,8	62,5	39,9	22,6	0,0	33,3	70,8	102,7	75,5
$Q_{H,gen,ren,in}$ [kWh]	2238,6	2618,3	5082,9	3317,3	7933,0	2258,0	1412,9	0,0	1761,0	5361,4	5470,0	2396,0
$W_{H,gen,aux}$ [kWh]	156,2	143,7	187,4	123,6	125,0	79,7	45,3	0,0	66,5	141,5	205,4	150,9
$E_{H,gen,bu,in}$ [kWh]	3,0	3,0	3,0	3,0	62,5	3,0	22,6	0,0	3,0	3,0	3,0	3,0
$Q_{H,gen,out}$ [kWh]	2962,9	3100,0	5178,6	1862,1	6565,0	104,4	0,0	0,0	0,0	5029,0	5605,6	3017,8
$Q_{W,gen,out}$ [kWh]	2324,8	2324,0	3561,6	3869,2	3867,2	3711,4	2318,6	0,0	3091,3	3095,5	3871,8	2324,5
$Q_{H,gen,sto,out}$ [kWh]	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Final calculation – heat pump energy performance (PdC)

Total electricity consumed : 28506.215 [kWh/year]
Total consumption of the back-up source energy: 112.122 [kWh/year]
Total heat loss from auxiliary source: 712.655 [kWh/year]
Total energy supplied for heating: 33425.560 [kWh/year]
Total energy amount from renewable sources: 39849.600 [kWh/year]
Total energy supplied for hot running water: 34359.979 [kWh/year]
Total auxiliary energy: 1425.311 [kWh/year]
Energy supplied for storage: 0.000 [kWh/year]

Package 3 is a maximal package that includes all the solutions proposed above (solutions 1-3) for both the envelope elements and the building installations. The calculation for the heat pump was redone similar to the previous package. The following table shows only the final results for the heat pump. It can be seen that the heat pump will take over approximately 85% of the heating load, the rest continuing to operate on the heating plant.

The following table $E_{H,gen,in}$ shows the electricity consumed in each month from the heat pump.

Month	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
$\theta_{gen,ext}$ [°C]	-2,3	-0,3	3,8	9,7	15,2	18,5	20,1	19,2	14,0	9,2	3,6	-1,5
No.of days	15	15	23	15	25	10	6	0	8	20	25	15
t_{ci} [h]	360	360	552	360	600	240	150	0	200	480	600	360
Q_{gen,dis,out_1} [kWh]	2327,7	2326,9	3565,6	3872,0	3868,5	3711,8	2318,8	0,0	3095,4	3097,8	3875,8	2327,4
θ_{gen,dis,out_1} [°C]	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0	60,0
Q_{gen,dis,out_2} [kWh]	4667,9	4142,2	4921,7	1891,5	1461,4	350,9	0,0	0,0	1309,7	2612,9	5652,8	4475,5
θ_{gen,dis,out_2} [°C]	36,2	35,2	33,1	30,2	27,4	25,8	25,0	25,4	28,0	30,4	33,2	35,8
$\theta_{gen,in}$ [°C]	-2,3	-0,3	3,8	9,7	15,2	18,5	20,1	19,2	14,0	9,2	3,6	-1,5
$\theta_{gen,sto,out}$ [°C]	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0
$E_{H,gen,in}$ [kWh]	2837,3	2469,8	2851,5	1985,2	1725,8	1500,8	905,8	0,0	1330,3	1719,1	3223,3	2686,2
$Q_{H,gen,ls,rbl}$ [kWh]	70,9	61,7	71,3	49,6	43,1	37,5	22,6	0,0	33,3	43,0	80,6	67,2
$Q_{H,gen,ren,in}$ [kWh]	2524,9	3022,5	5635,8	3778,2	3604,1	2351,7	1413,0	0,0	1761,0	3991,5	6305,4	2728,0
$W_{H,gen,aux}$ [kWh]	141,9	123,5	142,6	99,3	86,3	75,0	45,3	0,0	66,5	86,0	161,2	134,3
$E_{H,gen,bu,in}$ [kWh]	3,0	3,0	71,3	49,6	43,1	3,0	22,6	0,0	3,0	43,0	80,6	3,0
$Q_{H,gen,out}$ [kWh]	2966,5	3106,6	4921,7	1891,5	1461,4	106,2	0,0	0,0	0,0	2612,9	5652,8	3022,7
$Q_{W,gen,out}$ [kWh]	2327,7	2326,9	3565,6	3872,0	3868,5	3711,8	2318,8	0,0	3091,3	3097,8	3875,8	2327,4
$Q_{H,gen,sto,out}$ [kWh]	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Final calculation – heat pump energy performance (PdC)

Total electricity consumed : 23235.272 [kWh/year]
Total consumption of the back-up source energy: 325.269 [kWh/year]
Total heat loss from auxiliary source: 580.882 [kWh/year]
Total energy supplied for heating: 257742.371 [kWh/year]
Total energy amount from renewable sources: 37116.004 [kWh/year]
Total energy supplied for hot running water: 34383.551 [kWh/year]
Total auxiliary energy: 1161.764 [kWh/year]
Energy supplied for storage: 0.000 [kWh/year]

The determination of final energy consumption before and after refurbishment is carried out in accordance with MC00l-chapters 3 and 4 following the same steps detailed in the previous chapters.

The following table shows the annual consumption of thermal energy, electricity, primary energy and specific primary energy for heating, hot water consumption, ventilation, cooling, lighting followed by energy from renewable sources. The calculations were made for each package separately. The last column shows the consumption reductions of each indicator in the package compared to the unrefurbished building.

Packages		INC	ACC	VENT	R	LIGHTING	Energy from renewable sources	TOTAL	Decrease compared to CNR (%)
CNR	Thermal energy [MWh/year]	154.019	37.848	0	0	0	0	191.867	
	Electricity [MWh/year]	1.09	0.41	23.372	0	15.079	19.975	39.951	
	Primary energy [MWh/year]	182.296	45.306	58.431	0	37.697	19.975	324.36	
	Special primary energy [MWh/year]	122.1	30.24	39	0	25.16	13.33	216.5	
P1	Thermal energy [MWh/year]	85.382	37.862	0	0	0	0	123.244	35.8
	Electricity [MWh/year]	0.944	0.41	23.372	0	15.079	19.903	39.805	0.4
	Primary energy [MWh/year]	102.258	45.324	58.431	0	37.967	19.903	243.71	24.9
	Special primary energy [MWh/year]	68.25	30.25	39	0	25.16	13.28	162.66	24.9
P2	Thermal energy [MWh/year]	100.743	34.363	0	0	0	0	135.106	29.6
	Electricity [MWh/year]	29.737	15.562	6787	0	7318	38.314	59.404	-48.7
	Primary energy [MWh/year]	144.072	29.969	13.09	0	14.114	38.314	201.245	38.0
	Special primary energy [MWh/year]	96.16	20	8.74	0	9.42	25.57	134.32	38.0
P3	Thermal energy [MWh/year]	28.003	34.388	0	0	0	0	62.391	67.5
	Electricity [MWh/year]	15.047	14.471	6787	0	7318	30.366	43.623	-9.2
	Primary energy [MWh/year]	32.782	26.641	12.559	0	13.541	30.366	85.523	73.6
	Special primary energy [MWh/year]	21.88	17.78	8.38	0	9.04	20.27	57.08	73.6

According to the calculation methodology, the maximum allowable values of the total primary energy consumption for the major refurbishment of the current building is 82.7 kWh/m2, year and the CO2 emissions are 13.1 kg/m2.year. It is observed that the works that make the scope of this work (the works in package 3) cause a significant reduction in consumption as a result of the interventions in the envelope but also due to the introduction of renewable energy production sources.

5. **Analysis of the economic efficiency of interventions works**

The second activity carried out during this stage consists into the analysis of the energy effects of applying each solution presented above.

This analysis involved the reassessment of the basic energy indicators of the building in each new option. Mainly, it concerns the annual energy consumption of the building, the primary energy consumption and the CO emissions resulting from applying each measure, and the extent to which this is reduced compared to the current situation.

Observing the energy effects of the various solutions, two solution packages were created, obtained by coupling the solutions presented previously. In calculating the investment cost, only the cost of investments that have a direct influence on the energy efficiency of the building was taken into account.

5.1. Economic calculation premises

The following were assumed and calculated respectively:

- The amounts necessary to carry out the investment works are considered to be at the disposal of the investment beneficiary, who does not have to resort to bank loans;
- Economic calculations are carried out in EUR;
- The specific cost of unsubsidized thermal energy is 94 EUR/ MWh;
- The specific cost of electricity is 212 EUR/ MWh;

In this regard, the annual final energy consumption [MWh/year], onsite renewable energy consumption (photovoltaic panels, heat pump), total final energy consumption with payment, non-renewable and renewable primary energy consumption and equivalent CO2 emissions [ton CO2/year] are taken into account. These values were determined for each solution package.

CNR - UNREFURBISHED BUILDIING

Solution/ Package Class	Final energy consumption acc.to Mc001					REG onsite energy consumption (PTS,PV CE, mH		Total final energy cons. with payment		Primary energy consumption acc.to Mc001			CO2 equivalent emissions acc.to Mc001
	Heating	HRW	Ventilation	Cooling	Lighting	Electric	Thermal	Electric	Thermal	NREG	REG	Total	
	MWh/year					MWh/year		MWh/year		MWh/year			[tCO_2e/ yr
CNR	155,1	38,3	23,4	0,0	15,1	0,0	0,0	40,0	191,9	304,4	20,0	324,4	56,0
Clasa	C	D	E	-	C							C	C

CR - REFURBISHED BUILDIING

Solution/ Package Class	Final energy consumption acc.to Mc001					REG onsite energy cons (PTS,PV, CE, mH)		Total final energy cons. with payment		Primary energy consumption acc.to Mc001			CO2 equiv emissions acc.to Mc001	RER
	Heating	HRW	Ventilation	Cooling	Lighting	Electric	Thermal	Electric	Thermal	NREG	REG	Total		
	MWh/year					MWh/year		MWh/year		MWh/year			[tCO_2e/ yr	[%]
P1	86,3	38,3	23,4	0,0	15,1	0,0	0,0	39,8	123,2	223,8	19,9	243,7	39,8	8,17
Class	B	D	E	-	C							C	C	
P2	130,5	49,9	6,8	0,0	7,3	17,3	67,8	42,1	67,3	162,9	38,3	201,2	27,8	39,44
Class	C	C	B	-	A							C	B	
P3	43,1	48,9	6,8	0,0	7,3	17,3	60,1	26,3	2,3	55,2	30,4	85,5	8,2	62,13
Class	A+	B	B	-	A							A	A+	

In the following table, for each package, the final energy savings, the variation in energy consumption from renewable sources, the total final energy savings charged, the primary energy savings and the CO2 emission reductions compared to the unrefurbished building were calculated.

REFURBISHED BUILDING VS UNREFURBISHED BUILDING															
Solution/ Package	Final energy saving acc.to Mc001					REG onsite energy consumption variation		Total final energy saving priced		Primary energy saving				CO2 equiv. emissions reduction	
	Heating	HRW	ventilation	Cooling	Lighting	Electric	Thermal	Electric	Thermal	NREG	REG	Total			
	MWh/year					MWh/year		MWh/year		MWh/year			[%]	[tCO2/an]	[%]
P1	68,8	0,0	0,0	0,0	0,0	0,0	0,0	0,1	68,6	80,6	0,1	80,7	24,9	16,3	29,0
P2	24,6	-11,7	16,6	0,0	7,8	17,3	67,8	-2,2	124,5	141,5	-18,3	123,1	38,0	28,2	50,4
P3	112,1	-10,6	16,6	0,0	7,8	17,3	60,1	13,6	189,6	249,2	-10,4	238,8	73,6	47,9	85,4

5.2. Economic efficiency indicators used in the economic analysis of the solutions:

The third activity undertaken within this team consists into the economic analysis of the implementation of the proposed individual solutions and the proposed solution packages. This analysis involves the evaluation of:

• the investment costs of the refurbishment options,
• the life span of the refurbishment options,
• the energy savings due to implementing the refurbishment options.

Taking into account the specific cost of thermal energy, the following is determined:

• the investment recovery period for each refurbishment option;
• the percentage reduction in energy consumption;

For a better understanding of the terms presented in this chapter, we will present the definitions in accordance with the Mc00l methodology.

• Energy modernization measure - Intervention on the construction and its related systems, with the aim of reducing the building's energy consumption.
• Lifetime of the modernization solution - The estimated life time for the modernization solution analyzed, for which the considered parameters remain unchanged from the initial stage, at the time of implementing the respective solution.
• Investment payback period - The duration of the investment recovery through the savings achieved as a result of the reduction in energy consumption due to applying the energy refurbishment/modernization measures.
• Net present value - The projection at time “0” of all the costs involved in the application of a measure/solution for the energy modernization of the building, depending on the depreciation rate of the currency considered - in the form of the average annual depreciation and the average annual rate of increase in the energy cost.

Global updated cost CG - Sum of the updated initial investment costs, annual operating costs and replacement costs as well as disposal costs if necessary, over a fixed calculation period (20 years for commercial buildings, 50 years for residential buildings, 30 years for other building categories)

• Operating cost COrun - The operating cost that includes the maintenance cost, the operational cost and the energy cost for the time step considered.

• COma Maintenance costs - The cost of measures related to the conservation and restoration of the desired quality for the building, construction element or system. This includes the annual costs for inspection, cleaning, interventions, repairs as part of preventive maintenance, the cost of consumable materials.

• COen Energy costs - The cost of energy, including fixed items and tariffs and taxes applicable at national level.

• CORpl - Replacement cost of the component or system Replacement investment for a component of the building, based on the estimated economic life cycle during the calculation period.

* COC02 Greenhouse gas emissions cost - Monetary value of the environmental damage due to general CO2 emissions from energy use in buildings (20/35/50 Eur/t CO2 from 2020/2025/2030). CO2 emissions reflect the effects of all greenhouse gases weighted according to their global warming potential, expressed in kilograms of CO2 equivalent over a period of 100 years.

• RATdev Price change rate - Changes in the prices of energy, products, building systems, services, labour, maintenance and other costs over time. This rate may differ from the inflation rate.

The economic analysis of energy modernization measures for the current buildings leads to the choice of economically efficient measures, through the prism of economic indicators, among which the fundamental indicator is the updated global cost (CG).

The effective implementation of an energy modernization project also involves the analysis of the possible financing of the project, from the point of view of the possible financing scheme to be applied and from the point of view of the affordability of the project beneficiary.

The Updated Global Cost (CG) is given by the relationship:

$$CG = CO_{init} + \sum [\sum^{rc} \left(CO_{a(i)}(j) * \left(1 + RAT_{xx(i)}(j)\right) + CO_{CO2(i)}(j) + CO_{fin(TLS)}(j) - Val_{ft}t(j)\right]$$

where:

CG total investment cost in year “0” [Euro];

CO_{init} initial investment cost;

CO a(i) (j) the annual cost of renovation component or measure j for year i;

RATxx(i) price change rate for year I of renovation component or measure j

COCO2 (j)- cost of CO2 emissions for measure j in year i

$CO_{fin.}$(TLS)(j)- final cost for decommissioning and disposal in the last year of the TLS life cycle of component j or of the building (related to the first year T0);

Val $_{fct}$(j)— residual value of component j in year TC at the end of the calculation period (related to the first year T0);

$$\Delta VNA_{(m)} = C_{(m)} - \sum \Delta C_{E_k} \cdot X_k$$

VNA related to additional investment due to the applying the energy modernization projects and energy savings resulting from applying the aforementioned projects:

where:

$C_{(m)}$ - the investment cost related to the energy modernization project, at the level of year “0”, [Euro];

ΔC_E- reduction in annual operating costs following the implementation of energy modernization projects at the level of the reference year, [Euro/year]:

$$\Delta C_{E_k} = c_k \cdot \Delta E_k$$

where:

ΔE_K - represents the estimated annual energy saving k, obtained by implementing an energy modernization measure, [kWh/year],

ck - represents the current cost of the energy unit k, [Euro / kWh]

The following table shows the total investment cost and the other parameters of the economic calculation for the unrefurbished building (CRN) and for the refurbished building, respectively for each package (CR-P), the total investment cost and the other parameters of the economic calculation.

Dimension	MU	CNR	CR-P1	CR-P2	CR•P3
Floor reference area	sqm	1498.22			
Investment initial total cost	[EUR VAT included)	0.0	305565.0	137564.0	443129.0
Investment specific cost	EUR.sqm VAT included	0,0	204.0 91.8 295.8		0.0
Maintainance annual cost	EUR VAT included/year	6432.0	2864.0 3142.0		3880.0
Average annual rate maintenance cost	%	6.0			
Annual operating costs	EUR VAT included/year	0.0	0.0	0.0	0.0
Average annual rate operating costs	(%)	3.0			
Annual final thermal energy consumption	MWh/year	191.9	123.2	67.3	2.3
Thermal energy unit cost	EUR VAT incl./MWh	94.0	94.0	94.0	94.0
Annual thermal energy cost	EUR VAT included/year	18035.4	11584.9	6328.1	212.9
Annual average thermal energy increase rate	%	5.0			
Annual final electricity consumption	MWh/year	40.0	39.8	42,1	26,3
Electricity unit cost	EUR VAT incl./MWh	212.0	212.0	212.0	212.0
Annual electricity cost	EUR VAT included/year	8469.6	8438.7	8927.7	5582.0
Annual average electricity increase rate	%	5.0			
Periodic replacement costs	EUR VAT included/year	28645.0	286545.0	45650,0	59977.3
Annual average replacement costs increase rate	%	5.0			
Decommissioning costs	EUR VAT included)	0.0	0.0	0.0	0.0
CO2 equivalent emissions/year	tCO2e/year	56.0	39.8	27.8	8.2
Specific CO2 cost	EUR/ tCO2e	20.0			
Annual CO2 equivalent emissions costs [2025]	EUR VAT included/year	1120.6	795.6	555.8	163.4
Package life cycle	years		30	20	20
Calculation period/Global cost calculation period	years		30		
Residual value	EUR VAT included	0.0	0.0	24950.5	32781.3
Costs update rate{interest rate)	%	3.0			

The condition for an investment in the energy modernization solution to be efficient is the following:

CG < 0

In this economic analysis of the refurbishment options, the following assumptions and values were taken into account:

- the beneficiary bears the cost without bank credit;
- economic calculations are made in euros;
- annual rate of increase in maintenance costs 6%
- annual rate of increase in the cost of heat and electricity 5%;
- annual rate of increase in replacement costs 5%;
- annual rate of depreciation of the currency (Euro) 3%;
- in each package it is considered that the thermal and electrical systems including photovoltaic and solar panels are replaced after 20 years
- the calculation of the investment cost does not include the interior finishes of the building, the repair of the cold water supply system and the sewage system, the organization of construction site, design services, other related expenses (management, consultancy, etc.) or costs for the building to comply with other national requirements (ISU, DSP, etc.)

The following table shows the energy costs consumed for the unrefurbished building and for each package

Dimension	**UM**	**CNR**	**CR-PI**	**CR-P2**	**CR-P3**
Annual final thermal energy consumption	[MWh/year]	191.866	123.244	67.32	2.265
Thermal energy unit cost	[Eur VAT included/MWh	94			
Annual thermal energy cost	EUR VAT included/year	18035.404	11584.936	6328.08	212.91
Annual final electricity consumption	[MWh/year]	39.951	**39.805**	42.112	26.33
Electricity unit cost	Eur VAT included/MWh	212			
Electricity annual cost	EUR VAT included/year	8469.612	8438.66	8927.744	5581.96

The following tables show the savings calculation for the packages considered compared to the unrefurbished building, taking into account the maintenance costs, electricity and thermal energy, CO_2, replacement costs and residual value.

CNR – UNREFURBISHED BUILDING

0		1	2	3	4	5	6	7	8	9
YEAR		Annual maintenance cost CNR	Annual operating cost CNR	Thermal energy updated cost CNR	Electricity updated cost CNR	Replace ment periodic cost CNR	Residual value replacement cost CNR	Decommis sioning costs CNR	Annual costs CO2 equivalent emissions CNR	Updated operating costs CNR
2025	0	6432,0	0,0	18035,4	8469,6	28645,0	0,0	0,0	1120,6	34057,6
2026	1	6619,3	0,0	18385,6	8634,1	0,0	0,0	0,0	1961,1	35600,1
2027	2	6812,1	0,0	18742,6	8801,7	0,0	0,0	0,0	1961,1	36317,5
2028	3	7010,5	0,0	19106,5	8972,6	0,0	0,0	0,0	1961,1	37050,8
2029	4	7214,7	0,0	19477,5	9146,9	0,0	0,0	0,0	1961,1	37800,2
2030	5	7424,9	0,0	19855,7	9324,5	0,0	0,0	0,0	1961,1	38566,1
2031	6	7641,1	0,0	20241,3	9505,5	0,0	0,0	0,0	2801,5	40189,5
2032	7	7863,7	0,0	20634,3	9690,1	0,0	0,0	0,0	2801,5	40989,6
2033	8	8092,7	0,0	21035,0	9878,3	0,0	0,0	0,0	2801,5	41807,5
2034	9	8328,4	0,0	21443,4	10070,1	0,0	0,0	0,0	2801,5	42643,4
2035	10	8571,0	0,0	21859,8	10265,6	0,0	0,0	0,0	2801,5	43497,9
2036	11	8820,7	0,0	22284,3	10464,9	0,0	0,0	0,0	2801,5	44371,4
2037	12	9077,6	0,0	22717,0	10668,1	0,0	0,0	0,0	2801,5	45264,2
2038	13	9342,0	0,0	23158,1	10875,3	0,0	0,0	0,0	2801,5	46176,8
2039	14	9614,1	0,0	23607,8	11086,5	0,0	0,0	0,0	2801,5	47109,8
2040	15	9894,1	0,0	24066,2	11301,7	0,0	0,0	0,0	2801,5	48063,5
2041	16	10182,3	0,0	24533,5	11521,2	0,0	0,0	0,0	2801,5	49038,4
2042	17	10478,8	0,0	25009,9	11744,9	0,0	0,0	0,0	2801,5	50035,1
2043	18	10784,0	0,0	25495,5	11972,9	0,0	0,0	0,0	2801,5	51054,0
2044	19	11098,1	0,0	25990,5	12205,4	0,0	0,0	0,0	2801,5	52095,6
2045	20	11421,4	0,0	26495,2	12442,4	0,0	0,0	0,0	2801,5	53160,5
2046	21	11754,0	0,0	27009,7	12684,0	0,0	0,0	0,0	2801,5	54249,3
2047	22	12096,4	0,0	27534,1	12930,3	0,0	0,0	0,0	2801,5	55362,4
2048	23	12448,7	0,0	28068,8	13181,4	0,0	0,0	0,0	2801,5	56500,4
2049	24	12811,3	0,0	28613,8	13437,3	0,0	0,0	0,0	2801,5	57664,0
2050	25	13184,5	0,0	29169,4	13698,3	0,0	0,0	0,0	2801,5	58853,6
2051	26	13568,5	0,0	29735,8	13964,2	0,0	0,0	0,0	2801,5	60070,0
2052	27	13963,7	0,0	30313,2	14235,4	0,0	0,0	0,0	2801,5	61313,8
2053	28	14370,4	0,0	30901,8	14511,8	0,0	0,0	0,0	2801,5	62585,5
2054	29	14788,9	0,0	31501,8	14793,6	0,0	0,0	0,0	2801,5	63885,9
2055	30	15219,7	0,0	32113,5	15080,8	0,0	0,0	0,0	2801,5	65215,6

CR - P3 (REFURBISHED BUILDING - PACKAGE 3)

0		1	2	3	4	5	6	7	8	9	10	11
YEAR		Annual maintenance cost CNR	Annual operating cost CNR	Thermal energy updated cost CNR	Electricity updated cost CNR	Replace ment periodic cost CNR	Residual value replacement cost CNR	Decommis sioning costs CNR	Annual costs CO2 equivalent emissions CNR	Annual mainten ance cost CNR	CASH FLOW	VNA
2025	0	3880,0	0,0	212,9	5582,0	59977,3	32781,3	0,0	163,4	9838		443129
2026	1	3993,0	0,0	217,0	5690,3	0,0	0,0	0,0	286,0	10186	-25414	417715
2027	2	4109,3	0,0	221,3	5800,8	0,0	0,0	0,0	286,0	10417	-25900	391815
2028	3	4229,0	0,0	225,6	5913,5	0,0	0,0	0,0	286,0	10654	-26397	365418
2029	4	4352,2	0,0	229,9	6028,3	0,0	0,0	0,0	286,0	10896	-26904	338515
2030	5	4478,9	0,0	234,4	6145,4	0,0	0,0	0,0	286,0	11145	-27421	311093
2031	6	4609,4	0,0	239,0	6264,7	0,0	0,0	0,0	408,5	11522	-28668	282425
2032	7	4743,6	0,0	243,6	6386,3	0,0	0,0	0,0	408,5	11782	-29208	253218
2033	8	4881,8	0,0	248,3	6510,3	0,0	0,0	0,0	408,5	12049	-29759	223459
2034	9	5024,0	0,0	253,1	6636,7	0,0	0,0	0,0	408,5	12322	-30321	193138
2035	10	5170,3	0,0	258,1	6765,6	0,0	0,0	0,0	408,5	12603	-30895	162243
2036	11	5320,9	0,0	2631	6897,0	0,0	0,0	0,0	408,5	12889	-31482	130761
2037	12	5475,9	0,0	268,2	7030,9	0,0	0,0	0,0	408,5	13183	-32081	98680
2038	13	5635,4	0,0	273,4	7167,4	0,0	0,0	0,0	408,5	13485	-32692	65988
2039	14	5799,5	0,0	278,7	7306,6	0,0	0,0	0,0	408,5	13793	-33316	32671
2040	15	5968,4	0,0	2841	7448,5	0,0	0,0	0,0	408,5	14110	-33954	-1283
2041	16	6142,3	0,0	289,6	75931	0,0	0,0	0,0	408,5	14434	-34605	-35888
2042	17	6321,2	0,0	295,2	7740,6	0,0	0,0	0,0	408,5	14765	-35270	-71157
2043	18	6505,3	0,0	301,0	7890,9	0,0	0,0	0,0	408,5	15106	-35948	-107105
2044	19	6694,8	0,0	306,8	80441	0,0	0,0	0,0	408,5	15454	-36641	-143747
2045	20	6889,8	0,0	312,8	8200,3	0,0	0,0	0,0	408,5	15811	-37349	-181096
2046	21	7090,4	0,0	318,9	8359,5	89821,5	0,0	0,0	408,5	105999	51749	-129347
2047	22	7297,0	0,0	325,0	8521,8	0,0	0,0	0,0	408,5	16552	-38810	-168157
2048	23	7509,5	0,0	331,4	8687,3	0,0	0,0	0,0	408,5	16937	-39564	-207720
2049	24	7728,2	0,0	337,8	8856,0	0,0	0,0	0,0	408,5	17330	-40333	-248054
2050	25	7953,3	0,0	344,3	9027,9	0,0	0,0	0,0	408,5	17734	-41120	-289173
2051	26	8185,0	0,0	351,0	9203,2	0,0	0,0	0,0	408,5	18148	-41922	-331096
2052	27	8423,4	0,0	357,9	9381,9	0,0	0,0	0,0	408,5	18572	-42742	-373838
2053	28	8668,7	0,0	364,8	95641	0,0	0,0	0,0	408,5	19006	-43579	-417417
2054	29	8921,2	0,0	371,9	9749,8	0,0	0,0	0,0	408,5	19451	-44434	-461852
2055	30	9181,0	0,0	3791	99391	0,0	-32781,3	0,0	408,5	-12874	-78089	-539941

The calculation was redone for each package, resulting into the following recovery times for each of the packages::

Renovation measures package	Decreased duration of „investment recovery”	Global cost [Eur VAT included] **(20** years)	Package hierarchy **f(CG)**
CNR	-	1476532.1	-
CR-P1	22	1321087.1	III
CR-P2	9	997448.8	II
CR-P3	15	936591.5	I

C. Conclusions

Following the energy and economic analyses presented in the calculation notes and the interpretation of the results obtained, the following conclusions were reached.

1. The energy audit was carried out for the Workshops building of the Technical Energy College located in the municipality of Sibiu. It was carried out taking into account the in-depth thermal refurbishment works expected by the beneficiary.

2. The building envelope in the current situation does not comply with the minimum strengths provided by the regulations in force.

3. Based on the calculations of specific consumption and the penalties granted in the energy rating, the certified building is classified into energy class C (overall) with a specific primary energy consumption of 216.0 kWh/m2/year, compared to the reference building which is classified into energy class B with a specific primary energy consumption of 82.70 kWh/m2/year. Regarding the level of equivalent CO2 emissions, the current building falls into class C with 37.4 kgCO2/rn^2/year, compared to the reference building which is classified into class B with 13.10 kgCO2/rn2/year-

4. The following solutions, developed in detail in chapter 4.1, are proposed for the building investigated:

• Solution 1.
- Thermal insulation of the exterior walls with a layer of expanded polystyrene or mineral wool with a thickness of 15 cm and a thermal conductivity γ<0.038 W/mK
- Thermal insulation of the floor above the last floor with sheep wool-based insulation material with a thickness of 25 cm and a minimum thermal strength of γ<0.038 W/mK, over which a wooden floor will be built.
- Thermal insulation of the floor over the technical channel with a layer of expanded polystyrene or mineral wool with a thickness of 10 cm and a thermal conductivity of γ<0.038 W/mK

• Solution 2.
- Replacing the exterior windows with efficient carpentry which thermal strength is at least Rmin = 0.83 m2 K / W.
- Replacing the exterior doors with efficient carpentry which thermal strength is at least Rmin = 0.77 m2 K/ W.

• Solution 3. Modifying the building's installations as follows:

o Introducing a new heat production system composed of heat pumps and condensing gas boilers that will serve three building units (high school, workshop and Highschool building). Gas-fired central heating will take over any peaks in consumption.

o A photovoltaic panel system with a capacity of 20 kWh will be installed on the workshops roof on the SE or SW orientations

o A heat recovery fan system with an average thermal transfer efficiency of 72% will be installed.

o The lighting fixtures and lighting sources will be replaced with LEDs. Presence sensors will be used for circulation spaces.

The energy and economic analyses presented in the calculation notes in this document highlight the qualities of the different refurbishment packages. Thus:

1. The P1 package is a package that includes solutions S1-S2 and is recovered in 22 years. The package of measures leads to an increase in the thermal strengths of the opaque envelope up to the minimum strenghts requested by the codes in force. In terms of primary energy consumption and CO_2 emissions, the package does not fall within the minimum values provided by the methodology. With this package of measures, the annual primary energy saving is 24.9% (from 324.36 MWh/year to 243.71 MWh/year) and CO_2 emissions are reduced by 29% (from 56 tons/year to 39.8 tons/year).
2. Package P2 is a package that includes solution S3 and is recovered in 9 years. The package of measures leads to increased efficiency of systems and the use of renewable energy sources. This package does not fall within the minimum values provided by the methodology in terms of primary energy consumption and CO_2 emissions. With this package of measures, the annual primary energy saving is 38% (from 324.36 MWh/year to 201.245 MWh/year) and CO_2 emissions are reduced by 50.4% (from 56 tons/year to 27.8 tons/year)
3. Package P3 is a maximum package in terms of investment that includes solutions S1-S3 and is recovered in 15 years. The package of measures leads to an increase in both the thermal strength of the envelope to the minimum strenghts requested by the codes in force and a reduction in consumption within the minimum values provided by the methodology. With this package of measures, the annual primary energy saving is 73.6% (from 324.36 MWh/year to 85.523 MWh/year) and CO_2 emissions are reduced by 85.4% (from 56 tons/year to 8.2 tons/year).

The results obtained following the application of the package of measures are presented in tabular form below.

Energy Audit Report of the building:
Workshops building within the Technical Energy College from Electricienilor street, no. 1, Sibiu

Fulfillment indicator for package P3	Indicator value before renovation	Indicator value after renovation	Reduction (%)
Total final thermal energy consumption (MWh/year)	**191.867**	62.391	67.5
Total final electricity consumption (MWh/year)	39.951	43.623	**-9.2**
Total primary energy consumption (MWh/year)	**324.36**	85.523	73.6
Total specific primary energy consumption (kWh/m2year)	216.5	**57.08**	73.6
Energy class	C	A	
Amount of CO_2 equivalent emissions (kg CO_2/m2,year)	37.4	5.5	85.3
Environmental class	C	A+	
Final thermal payment energy[MWh/year)	191.9	2.3	98.8
Final electricity payment [MWh/year]	40	26.3	34.3

4. Applying the package of measures proposed is economically feasible, amortizing the investment value over a period of 15 years. The value is lower than the shelf life of the package, which is estimated at 20 years, and causes significant energy reductions. The longer recovery period is conditioned by the high intervention costs of the envelope. However, considering the significant CO_2 decreases 85%, the package 3 is recommended.

5. The results of the building's energy audit represent the calculation basis for the feasibility study that establishes the appropriate refurbishment option for the beneficiary of the building under analysis. Once the refurbishment option has been identified, it will proceed to its design and then to the execution of the refurbishment works according to the refurbishment project.

6. Based on the technical and economic analyses carried out, it is recommended to implement the P3 package, as it represents the efficient and compliant solution with the regulations in force. Following the application of thermal refurbishment measures, the building becomes energy efficient, falling into energy performance class A+.

The financial evaluation included in the energy audit cannot be used as documentation to substantiate the request for financing or crediting the proposed works, however, based on the energy audit, it is easy to proceed to the preparation of the feasibility study, for the approval of the economic indicators of the investment.

Energy auditor for buildings	Drafted by
eng. Cruciat Radu	Energy auditor for buildings
	eng. Pricopie Andrei Gheorghe
Illegible signature, Official stamp	Illegible signature, Official stamp

D. Recommendations for the owners

- Informing the responsible technical staff about the expected energy savings;
- Correct understanding of how the building and its installations should operate at a general and detailed level
- Designating a representative to monitor the execution of the thermal rehabilitation works;
- Establishing an energy saving policy in operation;
- Analyzing energy bills and energy supply contracts and modifying them if necessary. It is recommended to choose suppliers that produce energy from renewable sources.
- Hiring an energy manager;
- Adapting and adjusting the heating plants of the spaces to the reduced heat requirement as a result of the execution of the intervention works;
- Washing the heating installation, including the radiators, at regular intervals of 3 years;
- Correct thermo-hydraulic balancing of the heating elements;
- Checking and changing batteries that are not perfectly sealed;
- Replacing classic light bulbs with energy-efficient ones;
- Maintaining proper ventilation of occupied spaces. The ventilation system with heat recovery will be maintained in working order;
- Periodic inspections of the own central heating systems and their adjustment according to the manufacturers' instructions will be respected. Gas detectors will be installed by the owners.

E. Bibliography

The preparation of the energy audit report of the building was carried out in accordance with the provisions of the new Methodology Mc 001/2022, regarding the calculation of energy consumption of buildings.

Other related documents are:

- Normative regarding the thermotechnical calculation of building construction elements. Indicative: C107/2005, approved by the Order of Transport, Construction and Tourism no. 2055/29.11.2005, as amended and completed;
- Normative for the design, execution and operation of central heating installations, indicative 113-2015, approved by Order of the Minister of Regional Development and Public Administration no. 845/12.10.2015
- Normative for the design, execution and operation of ventilation and air conditioning installations, indicative 15-2010, approved by Order of the Minister of Regional Development and Tourism no. 1.659/22.06.2011
- Normative for the design and execution of sanitary installations, indicative I9-2015, approved by Order of the Minister of Regional Development and Public Administration no. 818/06.10.2015

- Regulations for the design, execution and operation of electrical installations related to buildings, reference I7-2011, approved by Order of the Minister of Regional Development and Tourism no. 2,741/01.10.2011
- Framework solutions for the thermo-hygro-energetic rehabilitation of the envelope of existing residential buildings, reference SC 007-2013, approved by Order of the Minister of Regional Development and Public Administration no. 2,280/05.07.2013.
- Guide for the design and execution of thermal rehabilitation works of apartment buildings, reference GP 123-2013, approved by Order of the Minister of Regional Development and Public Administration no. 2,211/26.06.2013, as amended and completed.
- Law no. 372/2005 on the energy performance of buildings, republished,
- Law no. 10/1995 on quality in construction, republished, as amended and completed
- Law no. 50/1991 on the authorization of construction works, republished, as amended and completed

F. ENERGY ANALYSIS SHEET

A. GENERAL DATA

Building layout plan

Building: Workshops building
Address: Electricienilor street no.1, Sibiu county
Owner: Sibiu City Hall
Building category:
educational establishment (nurseries, kindergardens, schools, highschools, universities)
Climate area where the building is located: III
Wind area where the building is located: IV
Wind exposure level: sheltered
Height regime of the building: groundfloor
Construction year: 1970
Construction structure: double strength structure made of reinforced concrete frames and load-bearing masonry
Documents related to the construction and its systems:
architecture survey for each type of representative level
construction representative sections
Building technical basement condition: flooded/floodable basement (water discharge may be due to the exterior sewerage)

B. Features of the living/heated space
Built area (sqm): 741.29
Built unfolded area (sqm): 1571.63

Reference area of the heated space floor (sqm): 1498.22
Reference volume of the heated space (m^3): 6442.35
Reference area of the cooled space floor (sqm), as appropriate: -
Free average height of one level (m): 4.30
Occupation level of the heated space [no.of operating hrs of the heating system]: 10h/210 days
Ratio between the area of the closed balconies facade and the total area of the facade provided with balconies/loggia: -
Average depth of the groundwater (m): -
Average basement height towards the systematized land share: -
Building basement floor perimeter: 40.6 m

C. BUILDING CONSTRUCTIVE STRUCTURE IDENTIFICATION

Dull exterior walls

Exterior wall – masonry

No. crt.	Material	γ [W/mK]	δ [m]	a	R [m^2K/W]
1	Lime mortar plaster	0.87	0.02	1.1	0.021
2	Solid brick masonry	0.8	0.24	1.15	0.261
3	Cement mortar plaster	0.93	0.03	1.1	0.029
4.	Polystirene	0.044	0.1	1.6	0.070
δi=8 δe=24			R0	=	0.478

Exterior walls condition: dampness
Finishings condition: partially fallen plaster
Type and colour of the finishing materials:
- type: plaster
- colour: grey

Dividing joints for building sections: Not applicable
Walls to annex areas (staircase, dumpsters): Not applicable
Ground slab:

No.crt	Material	k [W/mK]	δ [m]	a	R [m^2 K/W]
1	Sandstone and quartzite	2.03	0.01	1.03	0.005
2	Plain concrete	1.16	0.05	1.03	0.042
3	Reinforced concrete slab	1.62	0.1	1.05	0.059
4	Gravel fill	0.7	0.1	1	0.143
5	Top soil	1.16	0.15	1	0.129
δi = 6 δe= 12			R0	=	0.545

Total area of the ground slab [sqm]: 638.7

Terrace/Roof
Type of terrace/roof: truss type roof
Terrace/roof condition: dry
Last repair of the terrace/roof: more than 5 years ago
Finishings materials: corrugated sheet

No. Crt.	Material	λ [W/mK]	6 [m]	a	R [m²K/W]
1	Ceramic tile	1800	0.01	1.05	0.012
2	Roof boarding	0.17	0.025	1.1	0.134
			R0	=	0,313

δi=8
δe=24
Total roof area [sqm]: 830

Floor under the attic:

No. Crt.	Material	λ [W/mK]	δ [m]	a	R [m²K/W]
1	Reinforced concrete slab	1.62	0.14	1.1	0.079
2	Cement mortar plaster	0.87	0.02	1.03	0.022
3	Ash and slag	0.290	0. 1	1.1	0.313
			R	=	0.623

δi=8
δe=12

Total area of the floor under the attic [sqm]: 679.2
Total area of the floor under the attic [sqm]: 14.9

Exterior windows/doors

Carpentry condition: good

EW/ED	Description	Area [sqm]	Type of carpentry	Sealing grade	Shutter (i / e)
EW	Windows R=0.43	438.7	PVC carpentry insulated glass	With outdated sealing that is no longer flexible	No
EW	Windows R=0.15	17.2	Metal carpentry	No sealing	No
ED	Doors R=0.41	32.4	PVC carpentry insulated glass	With outdated sealing that is no longer flexible	No
EW	Glass brick R=0.17	**23.5**	Glas brick carpentry	-	No

Other construction elements: Not applicable

Mobile construction elements from joint spaces: Not applicable

D. INTERIOR HEATING SYSTEM

Does the heating system exist: Yes

Need for calculation heating [W]: 46799

Energy source for heating the spaces: own source, gas fuel

Type of heating source: heating with static bodies

Data regarding the interior heating system with static bodies:

Type of thermal heating: lower

Connection to the centralized heating source: single connection

Thermal energy meter: does not exist

Thermal and hydraulic adjustment items: on the distribution network, on the static bodies

The static bodies are not equipped with adjustment fittings or at least half of the current adjustment fittings are not operating

Distribution network located in unheated spaces: - length:67.6 m; - nominal diameter: 88.9 m; thermal insulation: yes

Interior heating system condition in terms of deposits: the static bodies have been dismantled and washed/cleaned fully more than three years ago

Separation and drainage fittings of the heating pipes: The heating pipes are provided with separation and drainage fittings, operational

Heating system vessels/ventilation fittings: There are manual ventilation valves

Are there heat cost allocators installed on the heating systems? No

Type of heating body/Type of heating system	Number of heating bodies [pcs.]Number of static bodies[pcs.]		
	In the living area	In the common area	Total
steel	70		

Heating source – own thermal system

Nominal power: 2x160kW

Are there ISCIR documents: YES

Regulation/automation system and regulation equipments: NO

Are there invoices for the last 5 years that can be examined: YES

E. DATA REGARDING THE HOT RUNNING WATER

Is there a system for preparing the hot running water: Yes
Energy source for preparing the hot water of the spaces: Own source – gas thermal system
Cool water/hot water consumption points:
basins: 4
washers: 1
bidets: 0
urinals: 2
showers: 0
bath: 0
WC : 5
dishwasher: 0
washing machine: 0
Fittings condition: there are small liquid losses
Connection to the centralized heating system: single connection
Recirculation pipe: does not exist
Debit metres of the consumption points: do not exist
ADDITIONAL INFORMATION
Are there any invoices for hot running water for the last 5 years that can be examined: NO
Cool water temperature in the area: 10°C

F. DATA REGARDING THE VENTILATION/ AIR CONDITIONING SYSTEM

Data regarding the air conditioning system
Is there a ventilation and air conditioning system: NO

Data regarding the ventilation system
Type of ventilation: natural

G. DATA REGARDING THE LIGHTING SYSTEM
Type of lighting fixtures: fluorescent
Lighting system control: no automatic detection of the users' presence
Lighting fixtures condition: good
Electrical conductors condition: good

Illegible signatures, Official stamps

G. Photo Annex

Photo 1 – Main entrance

Photo 2 – Main entrance

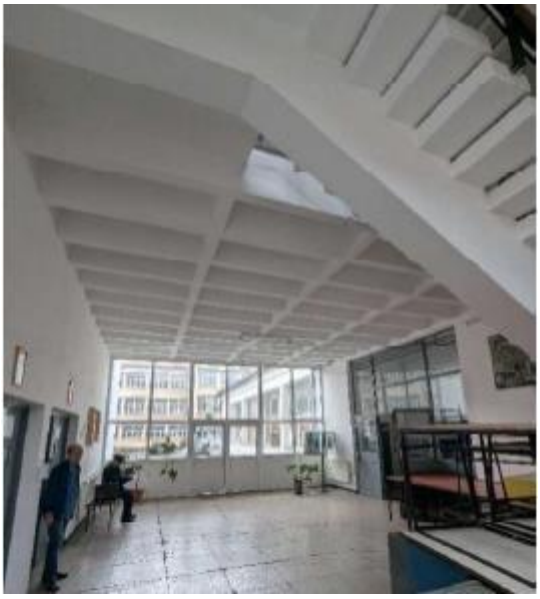


Photo 3 – Hallway and staircase

Photo 4 – Classroom

Photo 5 & 6 – Photos made in the workshops classroom

Photo 7 – Photo of the thermal plant, one can observe the two boilers providing heating and hot running water preparation

Photo 8 – Garage access

Photo 9 – Rear entrance

Photo 10 – The exterior walls show dampness

Photo 11 – The current thermal insulation is in a very advanced degradation condition

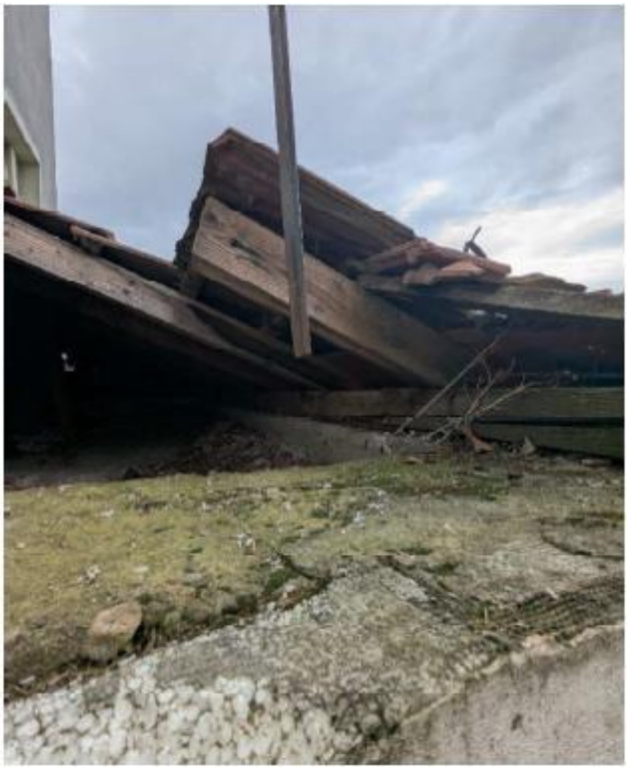


Photo 12 & 13 – The wooden truss over the groundfloor shows degradations, not being waterproof against rain

H. Other annexes

- Copy of Energy Auditor's badge
- Construction Survey
- Energy Certificate for the current building
- Energy Certificate Annexes

MINISTRY OF REGIONAL DEVELOPMENT, PUBLIC ADMINISTRATION AND EUROPEAN FUNDS

Mr. PRICOPIE GH. GHEORGHE-ANDREI
Personal identification number: 1850607460121
Job: Engineer
CERTIFIED
ENERGY AUDITOR FOR BUILDINGS
Professional degree: I
Specialization: CONSTRUCTIONS AND INSTALLATIONS
Date of issue: 08.02.2017

General manager
Illegible signature, Official stamp

Holder's signature - Illegible signature
This badge is valid only accompanied by the attestation certificate of the energy auditor for buildings
Series SSA number 02249

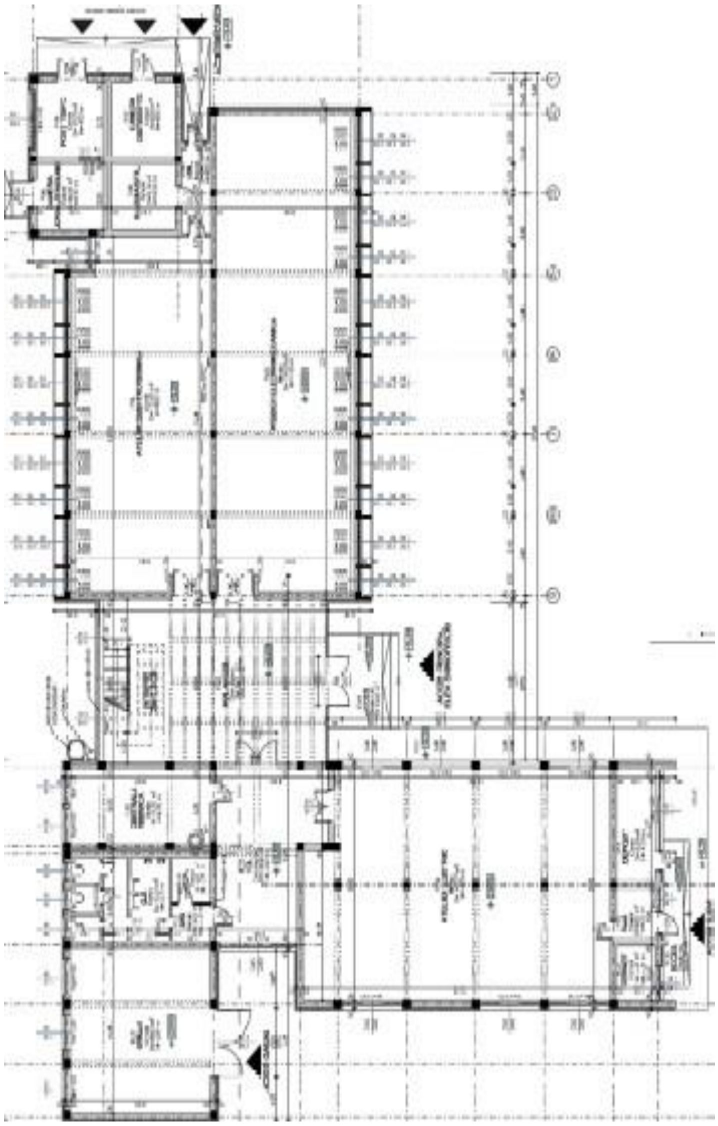
This badge will be endorsed by the issuing entity from 5 to 5 years from the date of issue
Valid until: 08.02.2022
Validity extension until: 08.02.2027

Mr. CRUCIAT I.RADU-IULIU
Personal identification number: 1850707324784
Job: Engineer
CERTIFIED
ENERGY AUDITOR FOR BUILDINGS
Professional degree: I
Specialization: CONSTRUCTIONS AND INSTALLATIONS
Date of issue: 08.02.2017

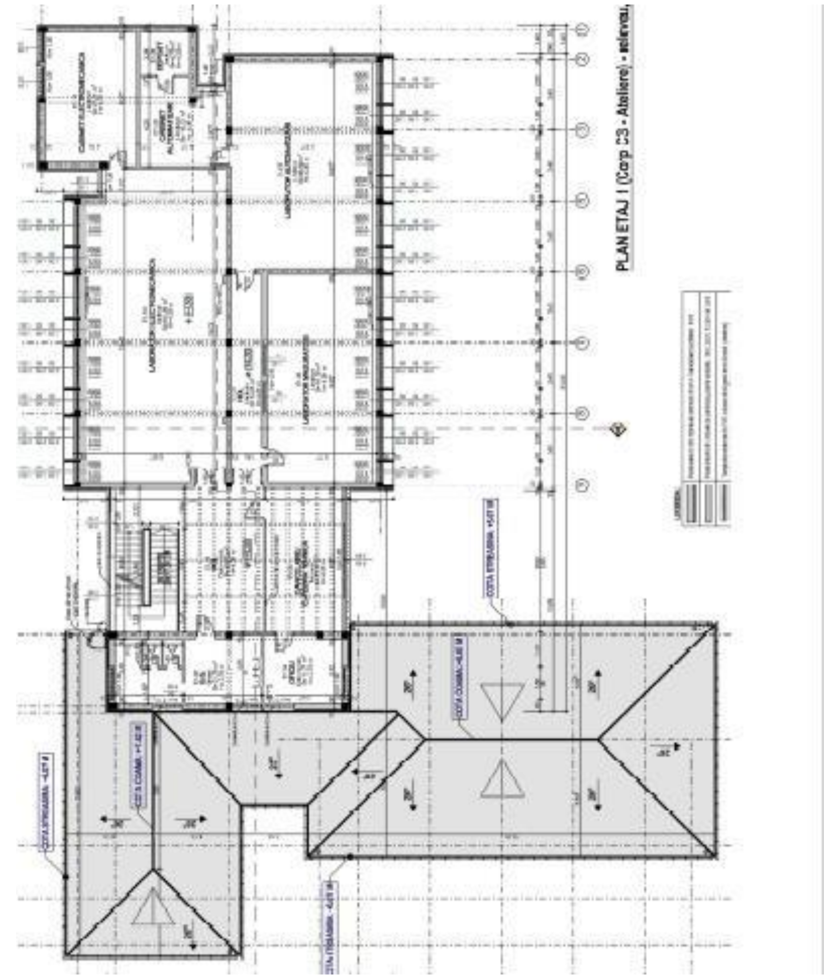
General manager
Illegible signature, Official stamp

Holder's signature - Illegible signature
This badge is valid only accompanied by the attestation certificate of the energy auditor for buildings
Series SSA number 02208

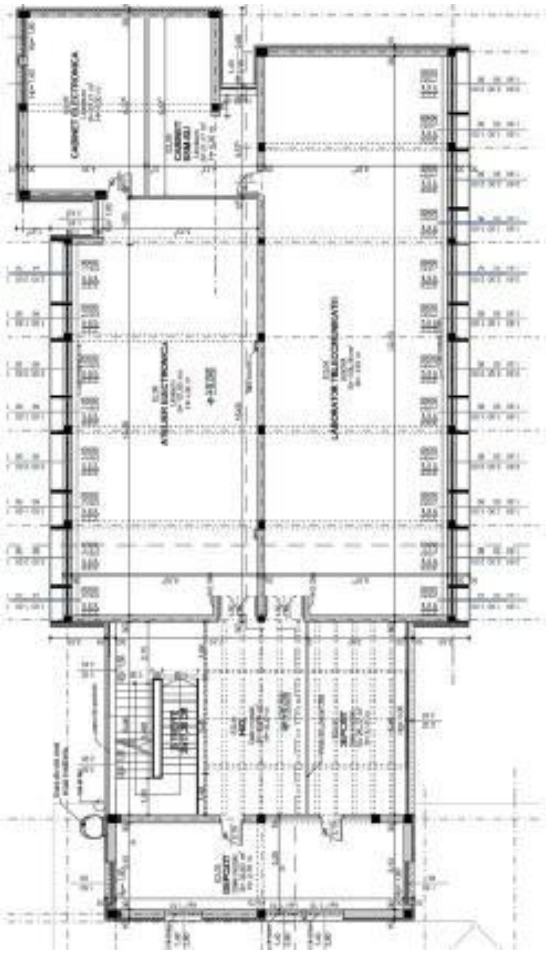
This badge will be endorsed by the issuing entity from 5 to 5 years from the date of issue
Valid until: 08.02.2022
Validity extension until: 08.02.2027



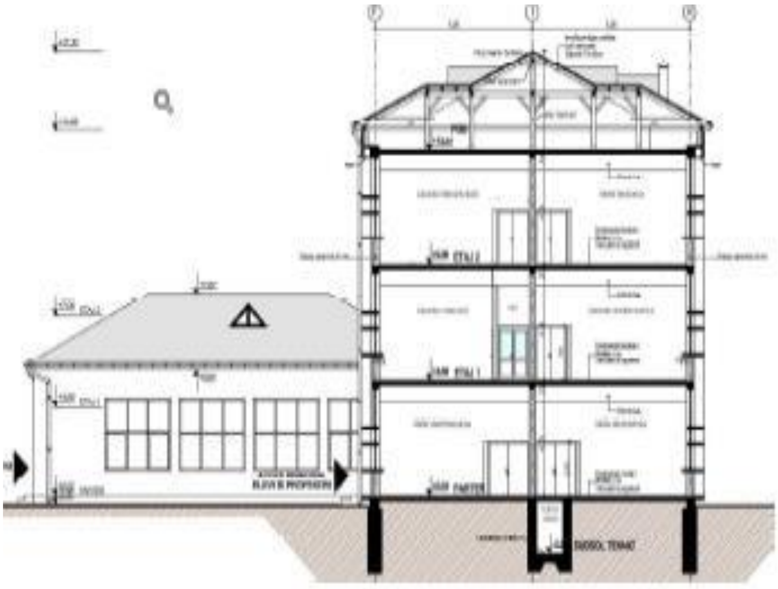
Groundfloor survey



1st floor survey



2nd floor survey



Section

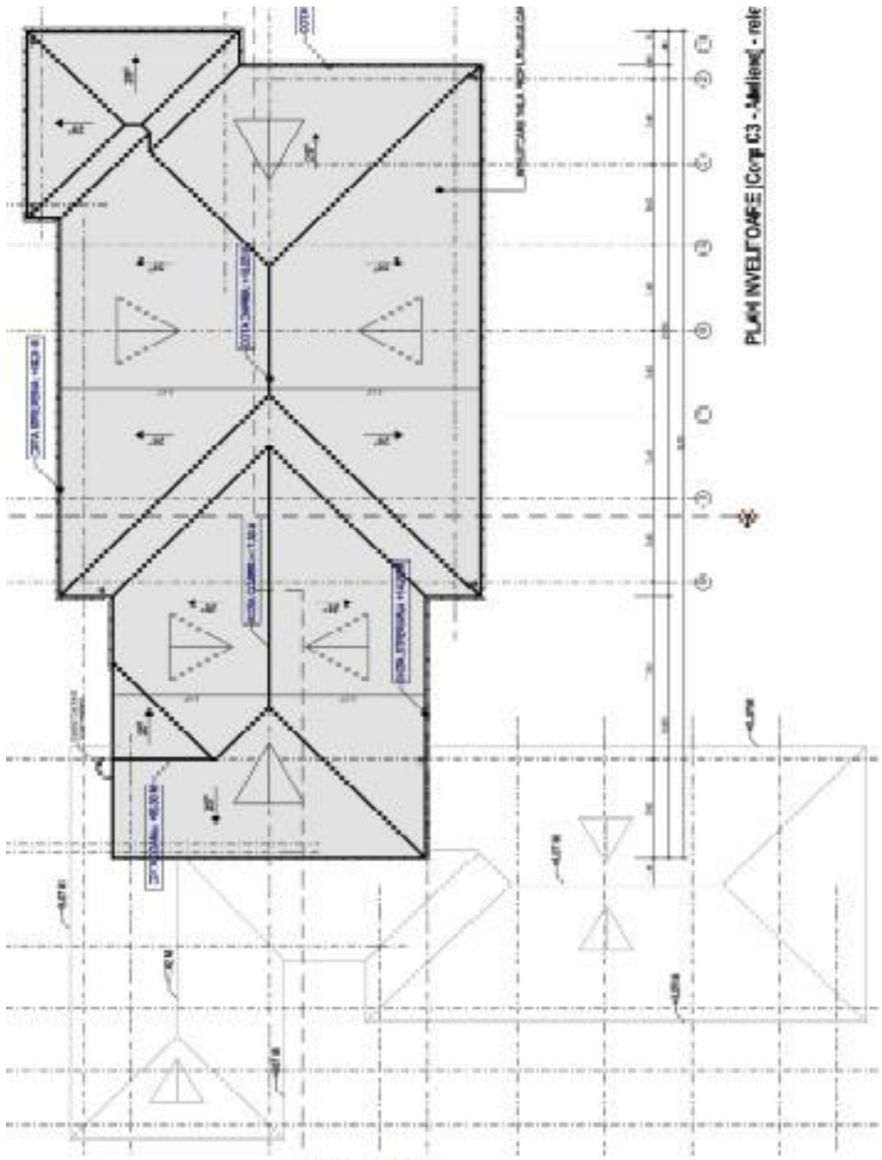
Truss survey

Main entrance

Rear entrance

Left side entrance

Right side entrance



Covering plan