

TRANSLATION from the Romanian language

Energy Audit

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

Beneficiary:
Sibiu City Hall
Illegible signature, Official stamp

Drafted by:
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Illegible signature, Official stamp

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Energy Audit Report of the building

Gf+3F Student dormitory 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 Student dormitory building within the Technical Energy College located in Sibiu municipality, Electricienilor street number 1. Its height regime is ground floor and three 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 Highschool 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 a single section. The building was built in 1965 and erected in the following period.

The main access to the building is on the NE side parallel to Electricienilor Street between axes 4 and 5, axis A. Height regime: ground floor and 3 floors.

The student dormitory building is an independent building that does not adjoin other buildings. From the architectural point of view, the envelope is made up of:

- masonry walls with a thickness of 30 cm;
- PVC windows with double glazing;
- floor slab composed of screed and reinforced concrete slab
- floor above the 3rd floor made of narrow doors with gaps.
- floor above the basement made of monolithic concrete

The building's structural strength is made of load-bearing masonry walls provided on both directions of the structure.

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The dormitory is made of a single section having the form of a rectangle with dimensions in plan 54.3x15.10m. Except makes the access area that protrudes about 1.20 m outside the mentioned rectangle. The dormitory is a regular construction with walls that delimit the rooms with a width of 3.6 m between axes. In the long direction, the dormitory is provided with 15 modules of 3.6 m usually hosting one room. In the area of the sanitary group developed on the width of three modules and in the area of the main staircase developed on the width of two modules, a transverse wall lacks its rigidity and is replaced by a reinforced concrete frame. The building is divided into 3 openings 5.40+2 +5.40 m, representing 2 rooms and a median hall that is developed along the entire length of the construction. The building is equipped with two staircases.

The roof of the building is made in the form of a wooden frame with a ceramic tile in 4 layers.

The roof is built between the elevations +12.15 and +17.80 m, considering the elevation +0.00 m as the floor elevation on the ground floor. The floor elevation is located approximately 50 cm above the elevation of the landscaped land.

Through the design topic, the beneficiary requests the implementation of energy efficiency measures, repairs to damaged elements, the complete modernization of the exterior finishes, the replacement/repair of the heating system, the preparation of hot running water and the existing artificial lighting.

The works will lead to the improvement of the operating conditions, by:

- improving the internal air conditioning conditions;
- reducing energy consumption;
- reducing maintenance costs for heating, hot water, mechanical ventilation and lighting;
- rational use of the interior space in accordance with the regulations in force;
- increasing the hygrothermal comfort in the building;
- achieving the specific requirements of the space intended as an educational unit

1.2 Strength structure items

The architectural part comprises one building, with a regular rectangular shape with one side planned along Electricienilor Street and the second perpendicular to the street. The dimensions in plan are 54.30 m long and 15.10 m wide.

According to the technical expert report, the structural system is made of load-bearing masonry walls that work together with reinforced concrete frames in the laundry and staircase with reinforced concrete frames.

In terms of structural strength, the dormitory consists into masonry walls with a thickness of 25 cm on the inside and 30 cm for the perimeter walls. The floors are made of belts, beams and prefabricated Step slabs in the room area.

The perimeter closures are 30 cm thick and the interior ones are 25 cm and 12.5 cm. The additional frame has a resistance structure in the form of a wooden structure, over which there is a ceramic tile covering.

The technical condition of the building is appropriate with some local deficiencies (degraded exterior plaster, leaky carpentry, the sidewalks around the building are detached from the building and have a reverse slope, the basement with infiltrations, the basement is partially flooded). The frame of the building subsequent to the construction.

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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 strengths 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	1299.2
Floor over technical basement	767.0
Floor above the last floor	767.0
Floor -loggia	14.9
Exterior carpentry	416.2
Developed built area	3264.3

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	γ		
		[kg/m ³]	[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

2.1.3 Unidirectional thermal strengths 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:

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

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- 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	466.6	0.507	0.8	0.40	3.00
NW masonry exterior wall	162.8	0.507	0.86	0.44	3.00
SW masonry exterior wall	484.2	0.507	0.79	0.40	3.00
SE masonry exterior wall	185.6	0.507	0.91	0.46	3.00
Floor over technical basement	767.0	0.357	0.93	0.33	4.50
Floor over the last floor under the attic	767.0	0.623	0.94	0.59	5.00
Floor - loggia	14.92	0.323	0.9	0.29	5.00
PVC NE Exterior windows	162.9	0.43	1	0.43	0.83
Wooden NE exterior windows	13.5	0.21	1	0.21	0.83
Wooden NE exterior doors	19.5	0.20	1	0.20	0.77
PVC NW Exterior windows	15.8	0.43	1	0.43	0.83
Wooden NW exterior windows	16.6	0.20	1	0.20	0.77
PVC SW Exterior windows	178.3	0.43	1	0.43	0.83
PVC SE Exterior windows	9.6	0.43	1	0.43	0.83

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 strengths recommended for the renovation of existing non-residential buildings (according to page 2.9.b Mc001-2022). 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 a student dormitory with an operating schedule of 8 hours per day, 5 days per week, from Monday to Friday according to the table below:

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		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No. of days	Week	Month	
September	W28								28		672	
	W29	24	24	24	24	24						168
	W30	24	24	24	24	24						168
	W31	24	24	24	24	24						168
	W32	24	24	24	24	24						168
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No. of days	Week	Month	
October	W33								28		672	
	W34	24	24	24	24	24						168
	W35	24	24	24	24	24						168
	W36	24	24	24	24	24						168
	W37	24	24	24	24	24						168
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No. of days	Week	Month	
November	W38	24	24	24	24	24			30		720	
	W39	24	24	24	24	24						168
	W40	24	24	24	24	24						168
	W41	24	24	24	24	24						168
	W42	24	24	24	24	24						168
		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	No. of days	Week	Month	
December	W43	24	24	24	24	24			21		504	
	W44	24	24	24	24	24						168
	W45	24	24	24	24	24						168

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 MC001-2022, depending on the external and internal climatic parameters.

External climatic parameters

Conventional external calculation temperature

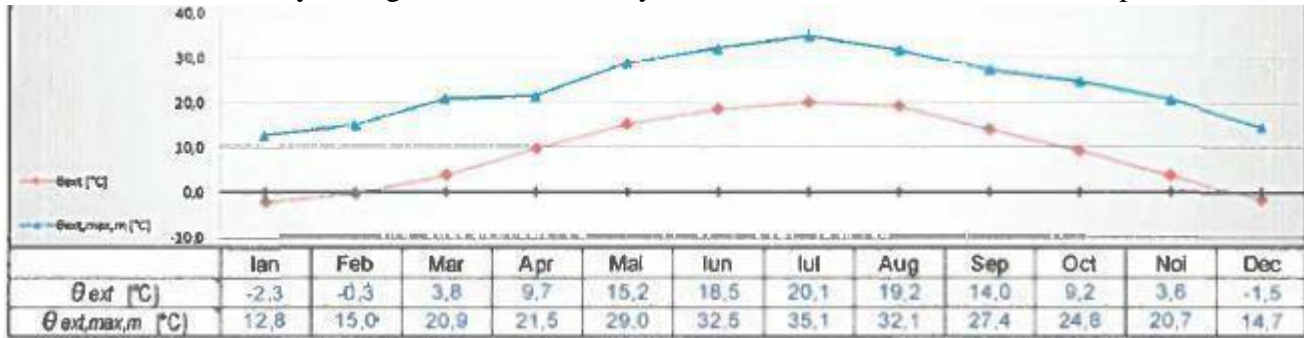
For winter, the conventional calculation temperature of the external air is considered depending on the climatic zone where the locality Sibiu is located (zone III), according to the MC001-2022 Methodology, Chapter 2.1.1, as follows:

$$\Theta_e = -18^\circ\text{C}$$

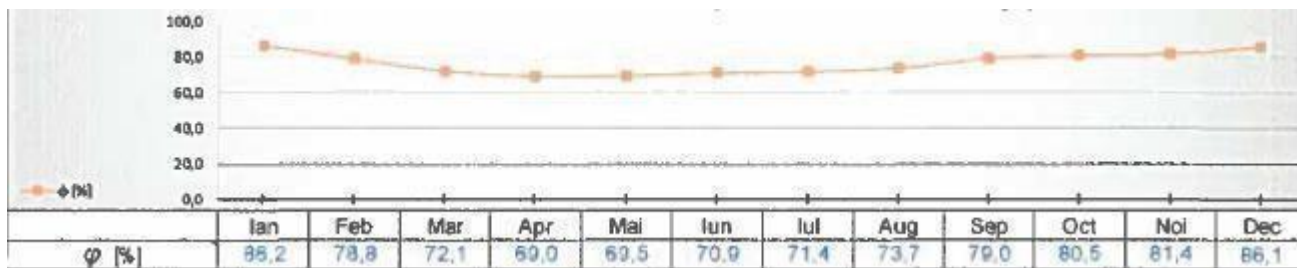
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CLIMATE DATA for Sibiu

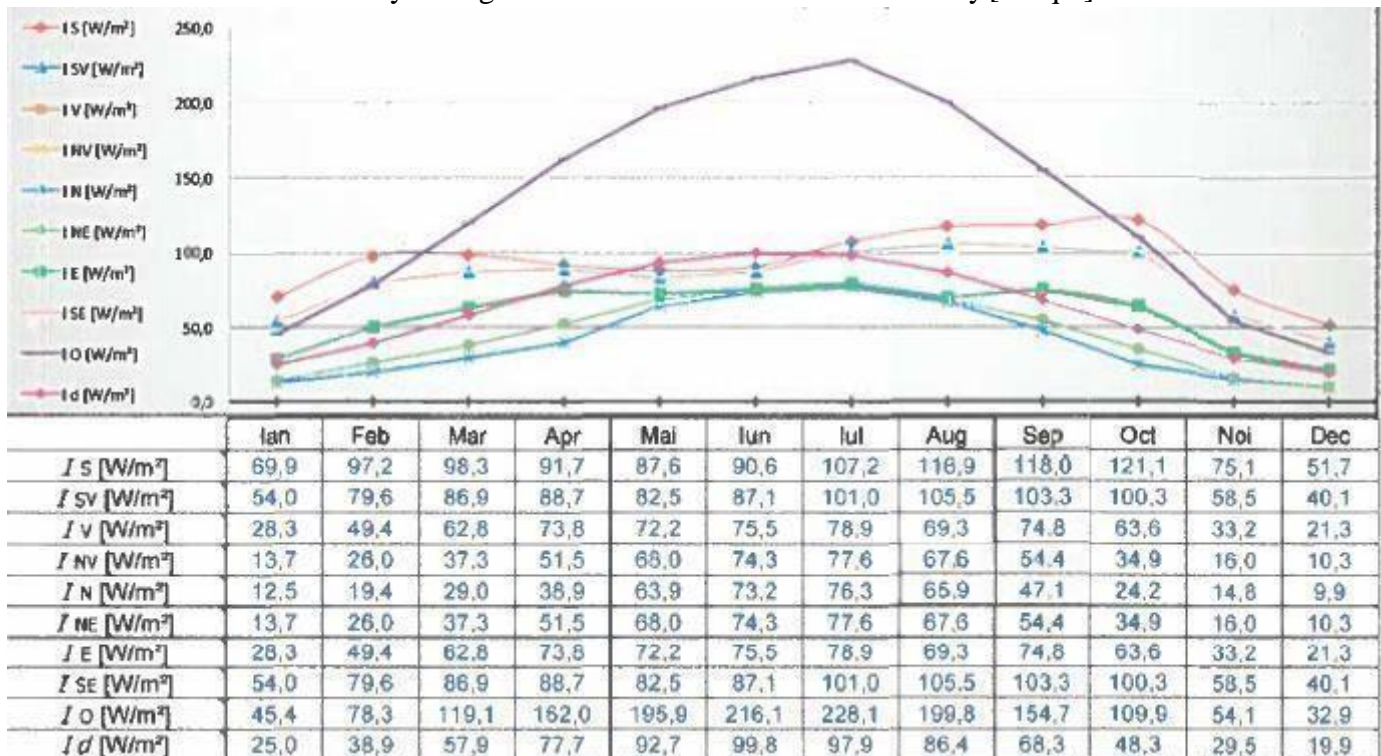
Monthly average values & monthly maximum values of the exterior temperature [°C]



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



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



Interior climate parameters

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

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Calculation of heat loss coefficients H_{tr} and H_{ve}

Calculation of the building's heat loss coefficient through ventilation, H_{ve}

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

- ρ_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, H_{tr}

$$H_{tr\,final} = H_d + H_g + H_{iu} + H_a$$

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

H_g - 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 $\left[\frac{W}{K}\right]$

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1		ZTC1.1		$\theta_{int,inc}$ [°C]	$\theta_{int,rec}$ [°C]	$A_{use,z}$ [m ²]	q [W/m ² h]	Thermal inertia class	Average
				20,0		3974,8	6828,0	6828,0	165000
								Concl/Ause,z [(h·m ² ·K)]	

Code	A _{e,l} category		A _{e,l} [m ²]	Orientation	r [-]	R' [m ² ·K/W]	U' [W/m ² ·K]	Type of adjacent space	Adjacent area code	H _g [W/K]	H _d [W/K]	H _{iu} [W/K]	H _{ve} [W/K]
	Nr.	[m ²]											
1	PE1		466,8	NE		0,40	2,47	Ext.					
2	PE1		162,8	NV		0,44	2,29	Ext.			1154,28		
3	PE1		484,2	SV		0,40	2,48	Ext.			372,48		
4	PE1		185,6	SE		0,46	2,17	Ext.			1202,31		
5	PL	atic	767,0	ORIZ		0,59	1,70	ZT	ZTU1			1304,50	
6	PH	basement wall	767,0	ORIZ		0,34	2,92	ZT				2242,78	
7	FE-PVC		162,9	NE		0,43	2,33	Ext.			378,84		
9	FE-wood		13,5	NE		0,21	4,79	Ext.			64,72		
10	UE-wood		19,5	NE		0,20	5,08	Ext.			98,99		
11	FE-PVC		15,8	NV		0,43	2,33	Ext.			36,84		
12	UE-wood		16,6	NV		0,20	5,08	Ext.			84,07		
13	FE-PVC		178,3	SV		0,43	2,33	Ext.			414,58		
14	FE-PVC		9,6	SE		0,43	2,33	Ext.			22,33		
15	PH	loggia	14,9	ORIZ		0,29	3,43	Ext.			51,19		2253,24
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													
										0,00	4283,83	3947,28	2253,24

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]	α wf [W/mK]	γ g [W/mK]	P c [W/mK]	\bar{O} (m)	α	β	r	θ_{int} [C]	θ_{int} [K]	θ_e [C]	θ_e [K]
144.19	0.30	1.38	0.3	1.26E+0.6	2.20	0	0	1	20.2	0.4	9.1	11.4

	Jan	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	
$\theta_{int,inc}$ [°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
$\theta_{int,rec}$ [°C]													COOLING
$\theta_{int,adj}$ [°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 _{is} [W/K]													Max
H _d [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]	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 _u [W/K]	2596,55	2596,55	2596,55	2596,55	2596,55	2596,55	2596,55	2596,55	2596,55	2596,55	2596,55	2596,55	2596,5
H _v [W/K]	6880,18	6880,18	6880,18	6880,18	6880,18	6880,18	6880,18	6880,18	6880,18	6880,18	6880,18	6880,18	6880,2

HEATING		COOLING		HEATING		COOLING		HEATING		COOLING	
Decreased day	Decreased night	Decreased day	Decreased night	Decreased day	Decreased night	Decreased day	Decreased night	Decreased day	Decreased night	Decreased day	Decreased night
$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$	$\Delta I_{H,red,y}$
$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$	$\eta_{red,y}$
$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$	$f_{H,red,y}$
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

$\Delta t_{c,red,wind}$	$\eta_{H,red}$	LOW
$\eta_{red,y}$	$(\Delta X t)_{exp}$	$\sigma_{H,0}$ 1
$f_{C,red,wind}$	φV_{comf2}	$\tau_{H,0}$ 15
$b_{C,red,wind}$	$f_{DHUC,0}$	
$\theta_{C,red,wind}$		H_{finel} [W/K] 9133,42

Energy Audit Report of the building:

Student dormitory building within the Technical Energy College from Electricienilor street, no. 1, Sibiu
Internal intakes

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

1		ZTC1.1														
Type	Thermal power		Operating period												No. of hours /day (hrs)	
	Predefined Nr	User [W]	Jan [zile]	Feb [zile]	Mar [zile]	Apr [zile]	Mai [zile]	Iun [zile]	Iul [zile]	Aug [zile]	Sep [zile]	Oct [zile]	Noi [zile]	Dec [zile]		
1	180	17600	21	21	31	21	31	30	21	0	28	28	30	21	24	
2	400	10000	21	21	31	21	31	30	21	0	28	28	30	21	24	
3	11	398	21	21	31	21	31	30	21	0	28	28	30	21	24	
4	80	5600	21	21	31	21	31	30	21	0	28	28	30	21	24	
5	5	250	21	21	31	21	31	30	21	0	28	28	30	21	24	
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
Total putere și ore de funcționare		33846	0	504,0	504,0	744,0	504,0	744,0	720,0	504,0	0,0	672,0	672,0	720,0	504,0	6792,0

	Interior heat intakes												TOTAL	
	Jan [kWh]	Feb [kWh]	Mar [kWh]	Apr [kWh]	Mai [kWh]	Iun [kWh]	Iul [kWh]	Aug [kWh]	Sep [kWh]	Oct [kWh]	Noi [kWh]	Dec [kWh]	Source type [kWh]	Anual [kWh]
1	8870,40	8870,40	13094,40	8870,40	13094,40	12672,00	8870,40		11827,20	11827,20	12672,00	8870,40	119539,20	
2	5040,00	5040,00	7440,00	5040,00	7440,00	7200,00	5040,00		6720,00	6720,00	7200,00	5040,00	67920,00	
3	199,58	199,58	294,62	199,58	294,62	285,12	199,58		266,11	266,11	285,12	199,58	2689,63	
4	2822,40	2822,40	4166,40	2822,40	4166,40	4032,00	2822,40		3763,20	3763,20	4032,00	2822,40	38035,20	
5	126,00	126,00	186,00	126,00	186,00	180,00	126,00		168,00	168,00	180,00	126,00	1696,00	
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
														229882,03
17058,38 17058,38 25181,42 17058,38 25181,42 24369,12 17058,38 0,00 22744,51 22744,51 24369,12 17058,38														

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

Energy Audit Report of the building:
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Code	Type	A _{gl} [m ²]	U _{gl} [W/m ² K]	Orientation	Inclination angle		g _{ext} [-]	g _{ext,w} [-]	g _{ext,w} [-]	F _{ext,w} [-]	F _{ext,w} [-]	F _{ext,w} [-]
					introduced	[°]						
1	PE1 DULL	496,55	2,47	NE		90	0,60				0,50	0,90
2	PE1 DULL	162,90	2,29	NV		90	0,60				0,50	0,90
3	PE1 DULL	484,19	2,48	SV		90	0,60				0,50	0,90
4	PE1 DULL	185,90	2,17	SE		90	0,60				0,50	0,90
5	FL pod INTERIOR	767,00	1,70	ORIZ								
6	Pl - sol GROUND	672,65	1,98	ORIZ		0						
7	Placaj labale INTERIOR	94,34	3,01	ORIZ								
8	FE-PVC TRANSPARENT	162,50	2,33	NE		90		0,60	0,54	0,21	0,50	0,90
9	FE-lamin TRANSPARENT	13,50	4,79	NE		90		0,85	0,77	0,23	0,50	0,90
10	UE-lamin TRANSPARENT	19,50	5,06	NE		90		0,85	0,77	0,16	0,50	0,90
11	FE-PVC TRANSPARENT	15,84	2,33	NV		90		0,60	0,54	0,21	0,50	0,90
12	UE-lamin TRANSPARENT	16,56	5,06	NV		90		0,85	0,77	0,16	0,50	0,90
13	FE-PVC TRANSPARENT	178,27	2,33	SV		90		0,60	0,54	0,21	0,50	0,90
14	FE-PVC TRANSPARENT	9,60	2,33	SE		90		0,60	0,54	0,21	0,50	0,90
15	Pl-bgle DULL	14,92	3,43	ORIZ	0	0	0,60				0,50	0,90

Dec. (D)	Monthly solar intake by elements												Total	
	Jan	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec		
1	20,81	27,53	49,51	66,53	83,32	163,81	537,49	396,81	0,00	465,55	90,48	41,94	26,81	
2	6,65	8,68	15,98	26,81	26,89	52,86	173,44	126,11	0,00	139,87	29,20	13,54	6,65	
3	594,95	781,15	1105,08	1368,86	1048,29	1448,19	1203,21	671,34	0,00	1470,57	995,87	1118,17	544,95	
4	198,08	285,19	370,42	504,78	358,72	465,74	463,31	325,59	0,00	492,94	635,90	374,81	198,08	
5														
6														
7														
8	32,41	43,11	81,81	173,25	182,04	315,84	1001,90	732,48	0,00	884,68	143,41	71,92	32,41	
9	3,74	4,67	9,43	19,07	18,68	36,42	115,52	84,45	0,00	78,94	16,86	8,29	3,74	
10	5,84	7,77	14,74	31,21	29,19	56,90	180,51	131,87	0,00	123,25	26,38	12,96	5,84	
11	3,15	4,18	7,95	16,85	15,76	30,71	97,42	71,22	0,00	66,57	14,24	6,89	3,15	
12	4,98	6,60	12,52	26,51	24,79	48,32	153,29	112,07	0,00	104,75	22,40	11,00	4,98	
13	666,53	1301,58	1918,58	3091,84	2137,93	2935,39	2356,43	1812,74	0,00	2688,36	3223,36	2014,31	866,53	
14	32,06	70,09	103,32	166,50	115,12	158,07	528,99	103,00	0,00	140,43	173,58	108,47	52,06	
15	29,19	40,46	66,17	125,53	110,23	209,29	231,89	199,82	0,00	170,49	128,35	82,00	29,19	
16														
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
	1906,1	2571,5	3755,5	5779,6	4127,0	5942,3	6580,3	5131,6	0,0	6477,3	6400,6	3845,3	1906,1	52517,8

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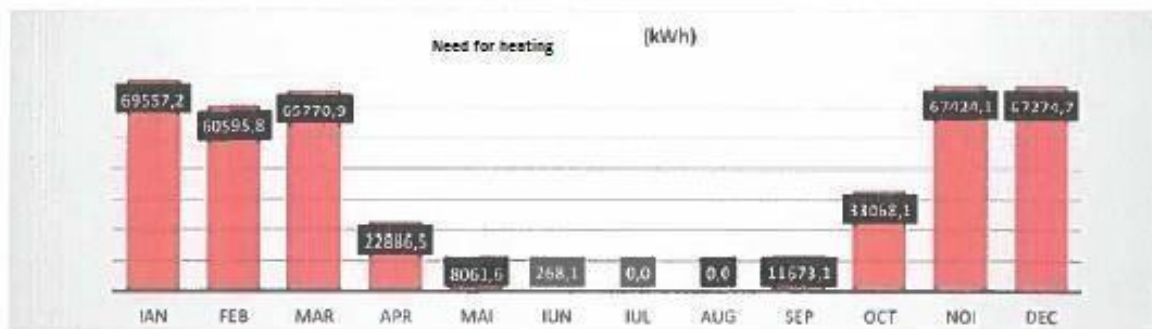
The heat lost as a result of thermal radiation to the sky is:

$$Q_{\text{sky,eli}} = 41544.8 \text{ KWh/year}$$

Need for heating

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

Need for heating [kWh]													
ZTC code	Jan	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
ZTC1.1	69557,2	60595,8	65770,9	22886,5	8061,6	268,1	0,0	0,0	11673,1	33068,1	67424,1	67274,7	406580,1
ZONE	Jan	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
ZT1	69557,2	60595,8	65770,9	22886,5	8061,6	268,1	0,0	0,0	11673,1	33068,1	67424,1	67274,7	406580,1
Total ZT	69557,2	60595,8	65770,9	22886,5	8061,6	268,1	0,0	0,0	11673,1	33068,1	67424,1	67274,7	406580,1



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.

Energy Audit Report of the building:

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1		ZTC1.1		$H_{\text{ext,red}}$ 0,90 [W/K]		Humidification																	
Luna	Ore	$Q_{\text{Htr,cont}}$	$Q_{\text{Htr,cont}}$	$Q_{\text{Htr,cont}}$	T_H	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$Q_{\text{Htr,red}}$	$\gamma_{\text{Htr,cont}}$	γ_{Htr}	β_{Htr}	η_{Htr}	$Q_{\text{Htr,red}}$	f_{Htr}	f_{Htr}	$Q_{\text{Htr,red}}$
[-]	[h]	[kWh]	[kWh]	[kWh]	[h]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[-]	[-]	[-]	[-]	[kWh]	[-]	[-]	[kWh]
Dec	504	58307	24416	82723	15,4	1906	3894	-1188	17991	15903	58307	24416	82723	0,19	0,19	2,03	0,97	62775	1,00	0,17	0,0		
Jan	504	60138	25325	85659	15,4	2571	3080	-509	17091	16582	60335	25325	85659	0,19	0,19	2,03	0,97	69557	1,00	0,17	0,0		
Feb	504	54700	23053	77753	15,4	3755	2964	771	17068	17859	54700	23053	77753	0,23	0,23	2,03	0,96	60956	1,00	0,15	0,0		
Mar	744	64049	27158	91207	15,4	5700	3855	1985	25214	27068	64049	27158	91207	0,30	0,30	2,03	0,94	66771	1,00	0,16	0,0		
Apr	504	27223	11697	36920	15,4	4127	2825	1362	17090	18392	27223	11697	36920	0,47	0,47	2,03	0,87	22887	1,00	0,06	0,0		
Ma	744	17519	8047	25566	15,4	5942	4456	1466	25214	26700	17519	8047	25566	1,04	1,04	2,03	0,66	3062	1,00	0,02	0,0		
Jun	720	3540	2433	6373	15,4	6581	4516	1965	24401	26366	3540	2433	6373	4,13	4,14	2,03	0,23	268	0,00	0,00	0,0		
Jul	504	0	0	0	15,4	5132	3266	1865	17091	18956	0	0	0	0,00	0,00	2,03	0,00	0	0,00	0,00	0,0		
Aug	0	0	0	0	0,0	0	0	0	32	32	0	0	0	0,00	0,00	1,00	0,00	0	0,00	0,00	0,0		
Sep	672	20617	9085	29702	15,4	6478	4529	1938	22776	24714	20617	9085	29702	0,83	0,83	2,03	0,73	11673	0,95	0,03	0,0		
Oct	672	38445	16353	54798	15,4	6401	4502	1898	22777	24675	38445	16353	54798	0,45	0,45	2,03	0,88	33098	1,00	0,08	0,0		
Nov	720	63561	26606	90168	15,4	3845	4287	-442	24401	23959	63561	26606	90168	0,27	0,27	2,03	0,95	67424	1,00	0,17	0,0		
Dec	504	58307	24416	82723	15,4	1906	3894	-1188	17091	15903	58307	24416	82723	0,19	0,19	2,03	0,97	62775	1,00	0,17	0,0		
		406893	982889			32518	41545	10673	230284	241237	406893	174174	582889					406893			0		

Night decrease				Day decrease				Weekend decrease				Final	
$d\theta_{\text{Htr,red}}$	$\Delta t_{\text{Htr,red}}$	$d\theta_{\text{Htr,red}}$	$\Delta t_{\text{Htr,red}}$	$d\theta_{\text{Htr,red}}$	$\Delta t_{\text{Htr,red}}$	$d\theta_{\text{Htr,red}}$	$\Delta t_{\text{Htr,red}}$	$d\theta_{\text{Htr,red}}$	$\Delta t_{\text{Htr,red}}$	$d\theta_{\text{Htr,red}}$	$\Delta t_{\text{Htr,red}}$	$\theta_{\text{Htr,red}}$	$\theta_{\text{Htr,red}}$
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[°C]
0,19	0,00	0,07	1,90	1,00	0,00	1,00	0,00	0,07	1,00	1,00	0,00	1,00	20,00
0,19	0,00	0,10	1,90	1,00	0,00	1,00	0,00	0,10	1,00	1,00	0,00	1,00	20,00
0,23	0,00	0,21	1,90	1,00	0,00	1,00	0,00	0,21	1,00	1,00	0,00	1,00	20,00
0,30	0,00	0,30	1,90	1,00	0,00	1,00	0,00	0,30	1,00	1,00	0,00	1,00	20,00
0,47	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
1,00	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
1,00	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
1,00	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
0,00	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
0,83	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
0,45	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
0,27	0,00	0,00	1,90	1,00	0,00	1,00	0,00	0,00	1,00	1,00	0,00	1,00	20,00
0,19	0,00	0,07	1,90	1,00	0,00	1,00	0,00	0,07	1,00	1,00	0,00	1,00	20,00

$\Theta_{\text{h(tr,ve;sol,int,-)}}$ -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.



The graph above shows:

Θ_e = monthly average external temperature, in Celsius degrees

Energy Audit Report of the building:

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

Θ_{emz} - 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: 86098.957 kWh/year

Specific heating emission energy consumption: 28.00 kWh/sqm.year

Total floor reference area: 3074.78 sqm

Equipments electric consumption

	Jan	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
ZT1	10137.3	9761.3	13194.8	7221.5	5458.4	580.9	0.0	0.0	6322.9	9661.0	13361.5	10189.4	86098.957
TOTAL	10137.3	9761.3	13194.8	7221.5	5458.4	580.9	0.0	0.0	6322.9	9661.0	13361.5	10189.4	86098.957

ZT1	0,000
TOTAL	0,000

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

	Jan	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec
QH;dis;in [kWh]	80405,197	70998,609	79973,323	30783,349	14449,987	877,283	0,000	0,000	18217,168	43866,064	81782,040	78151,178
QW;dis;in [kWh]	6803,429	5886,819	10129,958	5884,891	10121,961	9793,203	5671,842	88,837	6901,410	9154,710	8803,331	8893,049
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]	87298,626	77885,428	90103,291	37668,239	24571,948	10670,467	8671,842	88,837	26718,517	53050,774	81585,371	89044,228

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

Totalspecific 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:

$$q_{inc} = 208,5 \left[\frac{kWh}{yr. sqm} \right]$$

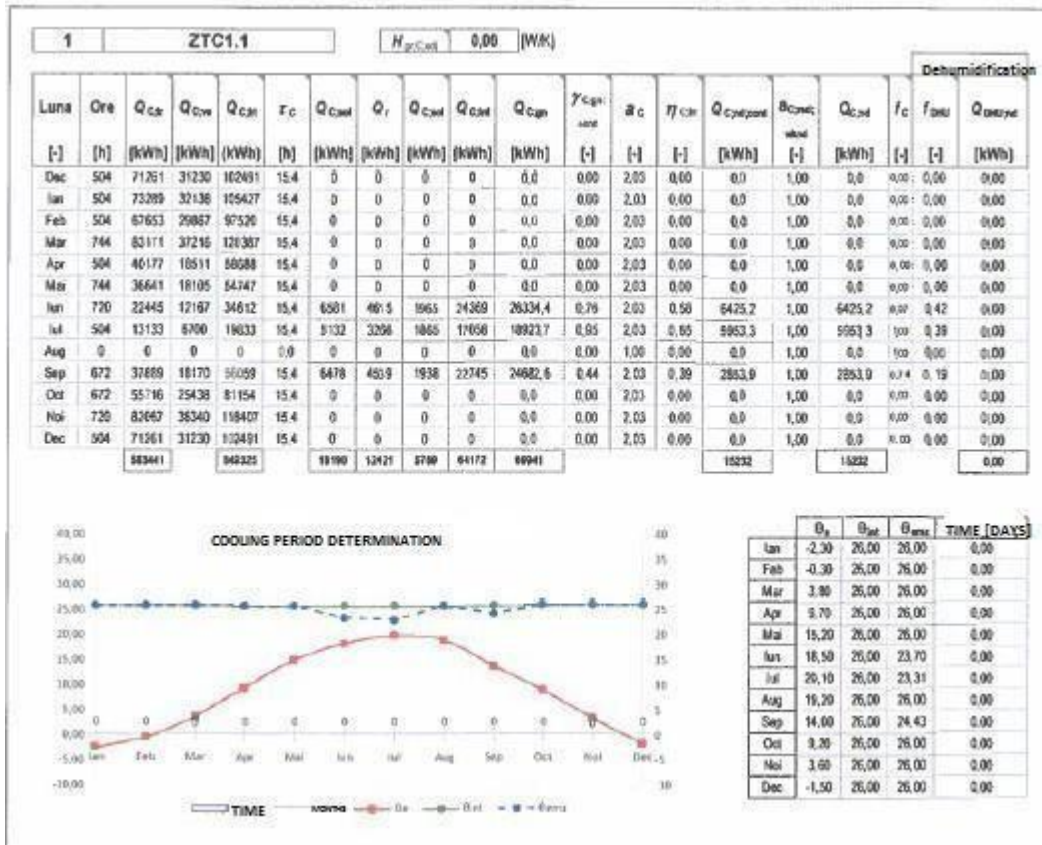
The building, from a heating point of view, falls into class D, with a specific annual primary energy consumption of 208.5 kWh/sqm per year.

Energy Audit Report of the building:

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

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.



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

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

CALCULATION OF THE NUMBER OF OVERHEATING HOURS

Area with the highest overheating risk is: ZT C1.1.

Reference floor area: 3074.78 sqm

Reference interior volume: 8609.328 m³

Area infiltrations ratio: 0.53 vol/h

Ground thermal transfer coefficient calculated in stationary mode: 0.0 W/K

Thermal transfer coefficient through transmission: 6880.2 W/K

Specific thermal capacity: 45.8 Wh/m³K

Internal intakes: 33846.0 W

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17058.4	17058.4	25181.4	17058.4	25181.4	24369.1	17058.4	0.0	22744.5	22744.5	24369.1	17058.4

Solar intakes: 8.8 KWh/day

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sbp	Oct	Nov	Dec
2571.5	3755.5	5779.6	4127.0	5942.5	5580.5	5131.6	0.0	6477.5	6400.6	3845.3	1906.1

Does the mechanical ventilation system exist? No

Fresh air flow provided by the ventilation system from the building: m³/h
0,00 vol/h

Ventilation system yield: 1 %

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) : 486 hours

Percentage of total yearly number of hours: 5.54%

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

Energy source for preparing the hot running water: 780 kW

Energy Audit Report of the building:

Student dormitory building within the Technical Energy College from Electricienilor street, no. 1, Sibiu
 07 – Buildings for accomodating students, pupils, elders

a. with sanitary items in common sanitary groups (for one occupant per day)

V _{day}	Days											
l/day	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5544,0	21	21	31	21	31	30	21	0	26	28	30	21

Consumption corresponding to water loss –

- increase coefficients f1, f2 f1-sites supplied in local system systems equipped with single command batteries
- f average number of daily consumption units 160.00 Number of occupants: 160 people
- V w, f, day– specific need for one consumer 30,00 unit/day
- V w, day– necessary hot consumption water volume 4800,00 l/day

V w,l,s day– volume corresponding to water loss 744.00 l/day

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HRW consumption - no recirculation	504	504	744	504	744	720	504	0	624	672	720	504
Recirculation pump operating hours	374	504	744	504	744	720	504	0	624	672	720	504
Qw, nd monthly [kWh/month]	6701,1	6701,1	9892,1	6701,1	9892,1	9573,0	6701,1	0,0	8296,6	8934,8	9573,0	6701,1

Qw,nd, annual, ZT1 89666,757 [kWh/yr] Qw,nd, annual, spec., ZT1 29,16 [kWh/m², yr]

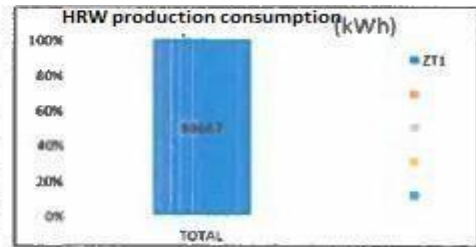
Total HRW energy supply –SUMMARY

Total need for energy for hot water consumption – 89666.757 [kwh/year]

Specific need for energy for hot water consumption – 29.15 [kwh/sqm.year]

Total reference area of the floor: 3074.76 sqm

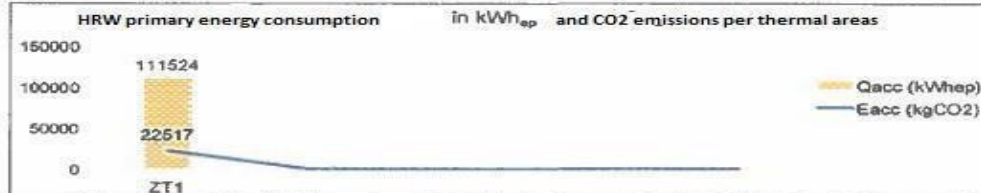
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ZT1	6701,1	6701,1	9892,1	6701,1	9892,1	9573,0	6701,1	0,0	8296,6	8934,8	9573,0	6701,1
TOTAL	6701,1	6701,1	9892,1	6701,1	9892,1	9573,0	6701,1	0,0	8296,6	8934,8	9573,0	6701,1



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

#	AREA	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 _{sp}]	[kWh _{sp}]	[kWh _{sp}]	[kgCO ₂]
1	ZT1	89666,757	1325,805	1030,888	3198,471	95221,920	45,888	111409,647	114,720	111524,367	22517,024
TOTAL		89666,757	1325,805	1030,888	3198,471	95221,920	45,888	111409,647	114,720	111524,367	22517,024

#	AREA	Qw,max
um	[-]	[kW]
1	ZT1	1,994
TOTAL		1,994



Qw,r, total 111524,367 [kWh/yr] Qw,r, spec 36,27 [kWh/m², yr]

CO2 emissions: 22517,024 [kgCO₂/yr] Specific CO2 emissions 7,32 [kgCO₂/m², yr]

Energy Audit Report of the building:

Student dormitory building within the Technical Energy College from Electricienilor street, no. 1, Sibiu
The building, in terms of the preparation of hot running water, falls into class B, having
a specific annual primary energy consumption of 36.27 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 Mc001-2022, 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 39 kWh/sqm/year in case of buildings destined for education.

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: 02 – residential buildings ZT area destination: b - dormitory

power estimated: yes

Floor reference area: 3074.76 sqm

Length, L: 307.48 [m]

Width, W: 10.00 [m]

Height, h_m : 2.80 [m]

Room index, K: 3.459 [-]

Lighting source distribution, UFF: 10%

Type of flow: direct

Power density per flow: 0.0215 [W/x]

Power density: 7.68 W/sqm

Estimated lighting power: 23617.01 W

Correction factor, F_{mf} : 1.14 [-]

Absence factor, F_a : 0.4 [-]

Power decrease factor, F_{CA} : 1.00 [-]

Source efficiency factor, F_L : 1.56 [-]

Lighting power known: 4400,0 [W]

Lighting level, E_m : 200 [lx]

Maintainance factor, F_M : 0,7 [-]

Lighting area percentage: 100% [%]

Lighting charging batteries: No

Stand-by for lighting control: No

Type of lighting source: fluorescent compact 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, F_c : 1 [-]

control II dependency factor, F_{oc} : 1 [-]

occupation dependency factor, F_c : 0.8 [-]

Natural light dependency factor

Type of natural light control: Manual

Constantly controlled system: No

Natural light dependency factor, F_d : 0.496 [-]

Thermal area results – ZT1

Safety lighting charging power, P_{em} : 0.0 W

power lighting controls- P_{pc} : 0.0 W

- Usage hours/day: 1820

- Usage hours/night: 1680

- Total usage hours: 3500

- Total electricity lighting annual consumption: 48782.660 [kWh/year]

- LENI (Preliminary) indicator: 15.87 [kWh/sqm.year]

W_{total} : 121956.850 [kWh/year]

CO2 emissions: 13649.362 [kgCO2/year]

Energy consumption for lighting

LENI: 39.65 [kWh/sqm.year]

Specific CO2 emissions: 4.24 [kgCO2/sqm.year]

Energy Audit Report of the building:
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The building, from lighting point of view, falls into class C, with a specific annual primary energy consumption of 39.66 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]	543.338	95.222	0.000	0.000	0.000	0.000	638.560
Final electricity consumption [MWh/year]	2.149	0.446	0.000	0.000	48.783	25.489	50.978
Primary energy consumption [MWh/year]	641.078	111.524	0.000	0.000	121.957	25.489	874.559
Specific energy consumption [kWh/sqm.year]	208.5	36.27	0	0	39.66	8.29	284.43
ENERGY EFFICIENCY CLASS	D	B	-	-	E	-	D

The primary energy consumed to ensure comfort in the building is determined, 284.43 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 53.5 kg/sqm. year.

The RER indicator is determined with the relationship

$$RER = \frac{E_{p,regen}}{E_{in}} \cdot 100 = 2.91\%$$

3. Drafting of the energy performance certificate

The building's energy performance certificate is drafted according to Mc001-2022. The actual building falls into energy efficiency class D.

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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 (123.1 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 (19.9 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]		CO ₂ emissions [kgCO ₂ /sqm.year]
Heating	123.1	19.9
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 000130/550311 Valid 10 years until 13.05.2025 Cruciat Radu-Iuliu Energy auditor
if no major changes appear Certificate SSA/02258 grade I

DATA REGARDING THE BUILDING/BUILDING BLOCK CERTIFIED NZEB NO

Building category: student dormitory building Year of building/major refurbishment: 1965-1970

Building address: Sibiu, Electricienilor street no.1, Sibiu county Floor reference area: 3074.78 sqm

GPS coordinates (lat x long): 45.78345x 24.16875 Built/developed area: 832.1/3328.4 sqm

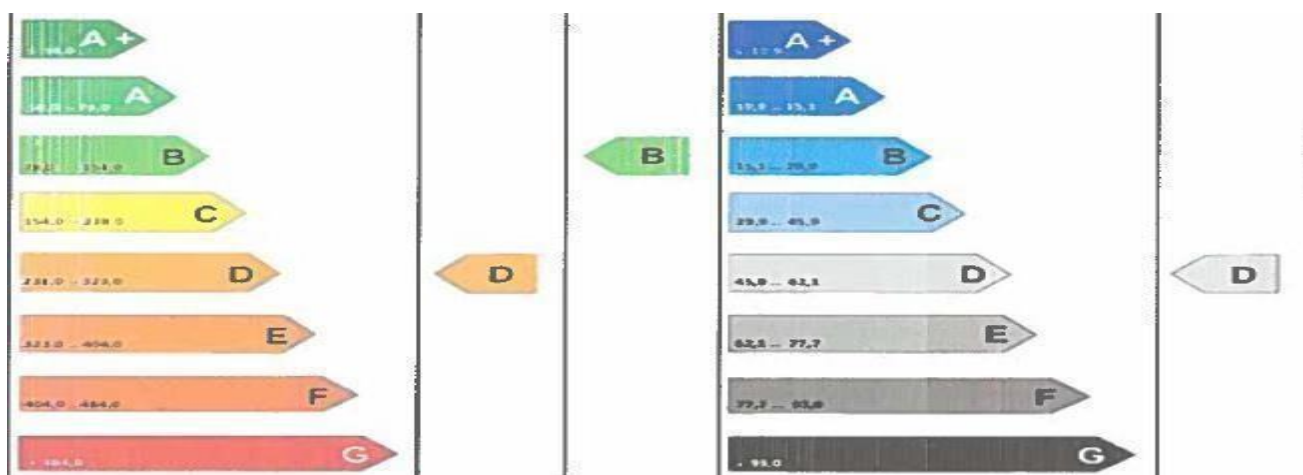
Height regime: Gf+3F Reference interior volume: 9893.97 m³

CPE drafting purpose: Information Calculation programme used: ENER+ version 04/2024

ENERGY PERFORMANCE TRUE BUILDING REFERENCE BUILDING CO2 EMISSIONS LEVEL

kWh/sqm.year – total primary energy kgCo2/sqm.year

High energy performance Low pollution level



Total annual specific energy consumption (kWh/sqm.year)	Final	207.7	16.6	CO2 equivalent emissions level (kgCo2/sqm.year)	53.5
	primary	284.4	123.1		

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	8.3	8.3

Type of system true building	Energy class/Annual specific consumption of primary energy per utility [kWh/sqm.yr]															
	A+	A	B	C	D	E	F	G	A+	A	B	C	D	E	F	G
Heating	≤ 30	30	42	42	54	54	150	218.5	217	271	271	325	325	325	325	325
Hot running water	≤ 21	21	29	29	37	37	65	73	73	91	91	109	109	109	109	109
Cooling ***	≤ 13	13	18	18	23	23	28	33	33	40	40	49	49	49	49	49
Mechanical ventilation	≤ 4	4	5	5	6	6	7	8	8	10	10	12	12	12	12	12
Lighting	≤ 5	5	7	7	9	9	11	13	13	16	16	19	19	19	19	19

*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 = 486h (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 Mc001-2022 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, floor above the last floor and floor above the technical channel.

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

Energy Audit Report of the building:

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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 $\gamma < 0.038$ W/mK.

Thermal insulation of the floor above the technical channel with polystyrene or mineral wool thick of 10 cm. We recommend that the thermal insulation used to have a thermal conductivity of $\gamma < 0.038$ 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 $R_{min} = 0.83$ sqm K/ W (or a transfer coefficient lower than $U = 1.2$ W/sqm K) and respectively $R_{min} = 0.77$ 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 current thermal plant. It will serve for overtaking the eventual consumption peaks, the building heating following to be made mainly by using heat pumps.

3.2. A air-water heat pump will be installed. The boiler will be used to take over the consumption peaks during the winter and will be adjusted as to prioritize as much as possible the use of heat pumps. The calculation took into account one heat pump with COP4. We recommend to change the thermal agent distribution network and we also recommend to replace the used static bodies with new ones.

3.3. A system of 50 photovoltaic panels (20 kWh) will be arranged on the roof structure, on SW and/or SE directions that will produce electricity for the lighting system, for the heat pumps, and for preparing the hot running water. The photovoltaic panels will be connected to the national network in order to benefit from a compensation according to the regulations in force.

3.4. Ventilation will be made in an organized manner. From technical point of view, implementing a ventilation system is expensive and involves substantial changes of the strength structure.

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

Energy Audit Report of the building:

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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.
- Sanitary groups will be introduced in the rooms.

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	466.6	3.17	3.00	YES
NW exterior masonry wall	162.8	3.40	3.00	YES
SW exterior masonry wall	484.2	3.18	3.00	YES
SE exterior masonry wall	185.6	3.79	3.00	YES
Floor over the last floor below the attic	767.0	5.13	5.00	YES
Floor over the technical channel	767.0	2.50	2.50	YES
NE exterior windows	176.4	0.830	0.83	YES
NE exterior doors	19.5	0.770	0.77	YES
NW exterior windows	15.8	0.830	0.83	YES
NW exterior doors	16.6	0.770	0.77	YES
SW exterior windows	178.3	0.830	0.83	YES
SW exterior doors	9.6	0.830	0.83	YES

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One finds that all the envelope items have their thermal strengths corrected and observe the values requested by the calculation methodology.

Package 2 is a package consisting of the implementation of package 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:

H 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

H_i inclined - solar radiation on an inclined surface;

E_{ji} 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: 36%

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%

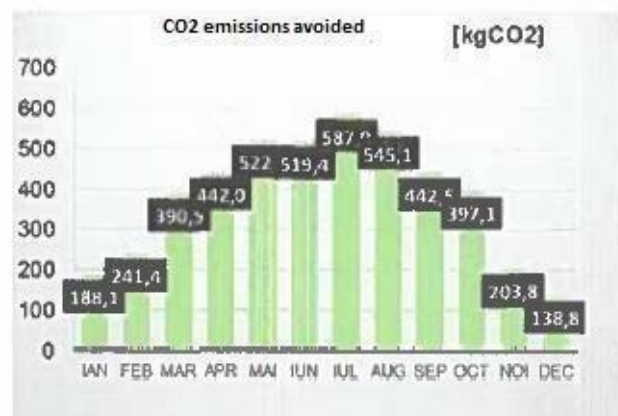
Connections: 0.1%

Imperfections: 0.2%

Total energy loss: 2.81%

ENERGY PRODUCTION RESULTS

	Jan	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Sep	Oct	Noi	Dec	Total
$I_{T,Onz}$ [W/m ²]	45,4	76,3	119,1	162,0	195,9	216,1	228,1	199,8	154,7	109,9	54,1	32,9	1596,3
f_{cap}	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_{inclat} [W/m ²]	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_{inclat} [W/m ²]	62,2	99,5	134,1	166,2	188,3	202,8	217,4	201,1	170,4	140,1	73,9	45,8	1701,7
N_d	31	28	31	30	31	30	31	31	30	31	30	31	385
$P_{max,1000}$ [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_{panou} [m ²]	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} [m ²]	105,88	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_i	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} [kWh]	4893,420	7063,918	10543,245	12648,988	14807,381	15426,836	17092,949	15810,458	12962,357	11013,293	5621,978	3599,092	131483,91
E_p [kWh]	703,255	902,367	1459,942	1652,184	1953,914	1941,789	2197,637	2037,927	1654,118	1484,403	761,999	518,749	17268,30
E_{emis} [kgCO ₂]	188,1	241,4	390,5	442,0	522,7	519,4	587,9	545,1	442,5	397,1	203,8	138,8	4619,27
η_{intake}	22,1%	21,7%	21,3%	20,7%	20,3%	20,0%	19,8%	19,8%	20,3%	20,7%	21,5%	22,1%	



TOTAL ENERGY PRODUCED: 17268.305 [kWh/year]
 TOTAL SPECIFIC ENERGY PRODUCED: 5.62 [kWh/sqm.year]
 TOTAL CO2 EMISSIONS AVOIDED: 4519.271 [kgCO₂/year]
 TOTAL CO2 EMISSIONS AVOIDED OF THE AREA: 1.50 [kgCO₂/sqm.year]

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

$$E_{tot} = \sum E_{li} = 17268.305 \text{ kWh/year}$$

$$E_{specific} = 5.62 \text{ KWh/sqm.year}$$

The CO₂ emissions avoided by installing the photovoltaic panels are 4.6 tons/year or 1.5 kg/sqm/year. 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.

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

Month	Jan	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	21	21	31	21	31	30	21	0	26	28	30	21
t_{el} [h]	504	504	744	504	744	720	504	0	624	672	720	504
$Q_{gen,ds,out,1}$ [kWh]	86318,7	76510,5	86880,1	34188,4	17109,7	1170,4	0,0	0,0	21192,1	48592,8	88506,0	83897,3
$\theta_{gen,ds,out,1}$ [°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
$Q_{gen,ds,out,2}$ [kWh]	6805,7	6804,8	10042,3	6800,0	10034,1	9708,3	6790,7	0,0	8416,5	9067,0	9718,5	6805,3
$\theta_{gen,ds,out,2}$ [°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
$\theta_{gen,in}$ [°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]	4679,2	4256,8	5224,8	3042,7	4705,7	2804,9	1752,2	0,0	3586,7	4081,6	5102,7	4500,4
$Q_{H,gen,sto}$ [kWh]	117,0	198,4	130,6	76,1	117,8	70,1	43,8	0,0	89,7	192,0	127,8	112,5
$Q_{H,gen,ren,in}$ [kWh]	8747,5	7422,8	12780,2	10084,4	15171,3	8073,8	5038,5	0,0	13505,3	13332,5	12285,3	7027,3
$W_{H,gen,aux}$ [kWh]	234,0	212,8	281,2	152,1	235,2	140,2	87,8	0,0	178,3	294,1	255,1	225,0
$E_{H,gen,bu,in}$ [kWh]	3,0	3,0	3,0	3,0	3,0	70,1	43,8	0,0	3,0	3,0	3,0	3,0
$Q_{H,gen,out}$ [kWh]	11312,7	11576,0	17877,2	13084,1	18995,1	1170,4	0,0	0,0	17005,4	17315,0	17263,4	11418,3
$Q_{W,gen,out}$ [kWh]	0,0	0,0	0,0	0,0	2785,3	9708,3	6790,7	0,0	0,0	0,0	0,0	0,0
$Q_{H,gen,sto,out}$ [kWh]	87,7	82,0	87,7	84,9	87,7	84,9	83,0	88,8	84,9	87,7	84,9	87,7

Final calculation – heat pump energy performance (PdC)

- Total electricity consumed : 43735.323 [kWh/year]
- Total consumption of the back-up source energy: 140.927 [kWh/year]
- Total heat loss from auxiliary source: 1093.383 [kWh/year]
- Total energy supplied for heating: 134997.560 [kWh/year]
- Total energy amount from renewable sources: 111479.939 [kWh/year]
- Total energy supplied for hot running water: 19264.348 [kWh/year]
- Total auxiliary energy: 2186.765 [kWh/year]
- Energy supplied for storage: 1031.842 [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.

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Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	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	21	21	31	21	31	30	21	0	26	28	30	21
t_{ei} [h]	504	504	744	504	744	720	504	0	624	672	720	504
$Q_{gen,dis,out,1}$ [kWh]	86318,7	76510,5	86880,1	34188,4	17109,7	1170,4	0,0	0,0	21192,1	48592,8	88506,0	83897,3
$\theta_{gen,dis,out,1}$ [°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
$Q_{gen,dis,out,2}$ [kWh]	6805,7	6804,8	10042,3	6800,0	10034,3	9708,3	6790,7	0,0	8416,5	9067,0	9718,5	6805,3
$\theta_{gen,dis,out,2}$ [°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
$\theta_{gen,in}$ [°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]	4679,2	4258,6	5224,6	3042,7	4703,7	2804,6	1752,2	0,0	3586,7	4081,6	5102,7	4500,4
$Q_{H,gen,sto,bl}$ [kWh]	117,0	106,4	130,6	76,1	117,6	70,1	43,8	0,0	89,7	102,0	127,6	112,5
$Q_{H,gen,ren,in}$ [kWh]	6747,5	7422,8	12780,2	10094,4	15171,3	8073,8	5038,5	0,0	13505,3	13332,5	12285,3	7027,3
$W_{H,gen,aux}$ [kWh]	234,0	212,8	261,2	152,1	235,2	140,2	87,6	0,0	179,3	204,1	255,1	225,0
$E_{H,gen,bu,in}$ [kWh]	3,0	3,0	3,0	3,0	3,0	70,1	43,8	0,0	3,0	3,0	3,0	3,0
$Q_{H,gen,out}$ [kWh]	11312,7	11576,0	17877,2	13084,1	16995,1	1170,4	0,0	0,0	17005,4	17315,0	17263,4	11416,3
$Q_{W,gen,out}$ [kWh]	0,0	0,0	0,0	0,0	2765,3	9708,3	6790,7	0,0	0,0	0,0	0,0	0,0
$Q_{H,gen,sto,out}$ [kWh]	87,7	82,0	87,7	84,9	87,7	84,9	83,0	88,8	84,9	87,7	84,9	87,7

Final calculation – heat pump energy performance (PdC)

- Total electricity consumed : 43735.323 [kWh/year]
- Total consumption of the back-up source energy: 140.927 [kWh/year]
- Total heat loss from auxiliary source: 1093.383 [kWh/year]
- Total energy supplied for heating: 134997.580 [kWh/year]
- Total energy amount from renewable sources: 111479.039 [kWh/year]
- Total energy supplied for hot running water: 19264.348 [kWh/year]
- Total auxiliary energy: 2186.766 [kWh/year]
- Energy supplied for storage: 1031.842 [kWh/year]

The determination of final energy consumption before and after refurbishment is carried out in accordance with MC001-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.

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Packages		INC	ACC	VENT	R	LIGHTING	Energy from renewable sources	TOTAL	Decrease compared to CNR (%)
CNR	Thermal energy [MWh/year]	543.338	95.222	0	0	0	0	638.560	
	Electricity [MWh/year]	2.149	0.046	0	0	48.783	25.489	50.932	
	Primary energy [MWh/year]	641.078	111.524	0	0	121.957	25.489	874.559	
	Special primary energy [MWh/year]	208.5	36.27	0	0	39.66	8.29	284	
P1	Thermal energy [MWh/year]	61.865	98.956	0	0	0	0	160.821	74.8
	Electricity [MWh/year]	1.309	0.095	0	0	48.783	25.093	50.092	1.6
	Primary energy [MWh/year]	75.656	116.016	0	0	121.597	25.093	313.629	64.1
	Special primary energy [MWh/year]	24.61	37.73	0	0	39.66	8.16	102	64.1
P2	Thermal energy [MWh/year]	580.452	94.477	0	0	0	0	674.929	-5.7
	Electricity [MWh/year]	42.087	6.055	0	0	20.917	43.111	69.059	-35.6
	Primary energy [MWh/year]	610.491	99.639	0	0	44.446	43.111	754.576	13.7
	Special primary energy [MWh/year]	198.55	32.41	0	0	14.46	14.02	245	13.7
P3	Thermal energy [MWh/year]	82.409	94.695	0	0	0	0	177.104	72.3
	Electricity [MWh/year]	24.028	20.392	0	0	20.917	41.149	65.337	-28.3
	Primary energy [MWh/year]	68.994	84.883	0	0	44	41.149	197.877	77.4
	Special primary energy [MWh/year]	22.44	27.61	0	0	14.31	13.38	64	77.4

According to the calculation methodology, the maximum allowable values of the total primary energy consumption for the major refurbishment of the current building is 123.9 kWh/m², year and the CO₂ emissions are 19.9 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

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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 BUILDING													
PACKAGE/ SOLUTION CLASS	Final energy consumption acc.to Mc001					Energy consumption REG onsite (PTS, PV, CE, mH)		Total final energy consumption with payment		Primary energy consumption according to Mc001			CO2 equivalent emissions according to Mc001
	Heating	RHW	Ventilation	Cooling	Lighting	Electric	Thermal	Electric	Thermal	NREG	REG	Total	
	[MWh/yr]					[MWh/yr]		[MWh/yr]		[MWh/yr]			
CNR	545,5	95,3	0,0	0,0	48,8	0,0	0,0	51,0	638,6	849,1	25,5	874,6	164,6
Class	D	B	-	-	E							D	D

CR - Refurbished building														
Solution/ Package Class	Final energy consumption acc.to Mc001					Energy consumption REG onsite (PTS, PV, CE, mH)		Total final energy consumption with payment		Primary energy consumption acc.to Mc001			CO2 equivalent emissions acc.to Mc001	RER
	Heating	RHW	Ventilation	Cooling	Lighting	Electric	Thermal	Electric	Thermal	NREG	REG	Total		
	[MWh/yr]					[MWh/yr]		[MWh/yr]		[MWh/yr]				
P1	63,2	99,1	0,0	0,0	48,8	0,0	0,0	50,2	160,8	288,5	25,1	313,6	51,4	8,00
Class	A+	B	-	-	E							B	B	
P2	622,5	100,5	0,0	0,0	20,9	17,3	155,3	51,8	519,6	711,5	43,1	754,6	137,3	21,81
Class	D	B	-	-	C							D	C	
P3	106,4	115,1	0,0	0,0	20,9	17,3	125,1	48,1	52,0	156,7	41,1	197,9	25,7	51,47
Class	A+	A	-	-	C							A	A+	

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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 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 equivalent emission decrease		
	Heating	RHW	Ventilation	Cooling	Lighting	Electric	Thermal	Electric	Thermal	NREG	REG	Total	[kCO ₂ e/yr]	[%]	
	[MWh/yr]					[MWh/yr]		[MWh/yr]		[MWh/yr]			[%]		
P1	482,3	-3,8	0,0	0,0	0,0	0,0	0,0	0,8	477,7	580,5	0,4	580,9	64,1	113,1	68,7
P2	-77,1	-5,3	0,0	0,0	27,9	17,3	155,3	-0,8	118,9	137,8	-17,8	120,0	13,7	27,3	16,6
P3	439,1	-19,8	0,0	0,0	27,9	17,3	125,1	2,9	588,6	692,3	-15,7	678,7	77,4	138,8	84,4

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 Mc001 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.

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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 CO_{run} - The operating cost that includes the maintenance cost, the operational cost and the energy cost for the time step considered.

- CO_{ma} 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.

- CO_{en} Energy costs - The cost of energy, including fixed items and tariffs and taxes applicable at national level.

- CO_{rpl} - 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.

- * CO_{CO2} 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.

- RAT_{dev} 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:

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

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;

RAT_{xx(i)} price change rate for year I of renovation component or measure j

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 $CO_2(j)$ - 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],

c_k - 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 therefurbished building, respectivelyfor 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	3074.76			
Investment initial total cost	[EUR VAT included)	0,0	402948.0	144347.0	547295.0
Investment specific cost	EUR.sqm VAT included	0.0	131.1	46.9	178.0
Maintainance annual cost	EUR VAT included/year	5972.0	3251.0	3765.0	4362.0
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	638.6	160.8	519.6	52.0
Thermal energy unit cost	EUR VAT incl./MWh	94.0	94.0	94.0	94.0
Annual thermal energy cost	EUR VAT included/year	60024.6	15117.2	48845.7	4888.3
Annualaverage thermal energy increase rate	%	5,0			
Annual final electricity consumption	MWh/year	51.0	50.2	51.8	48.1
Electricity unit cost	EUR VAT incl./MWh	212,0	212,0	212,0	212,0
Annual electricity cost	EUR VAT included/year	10807.1	10639.6	10979.5	10190.5
Annual average electricity increase rate	%	5,0			
Periodic replacement costs	EUR VAT included/year	32466.0	32466.0	56564.7	56564.7
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	164.6	51.4	137.3	25.7
Specific CO2 cost	EUR/ tCO2e	20.0			
Annual CO2 equivalent emissions costs [2025]	EUR VAT included/year	3291.0	1028.6	2745.4	514.6
Package life cycle	years	-	30	20	20
Calculation period/Global cost calculation period	years	30			
Residual value	EUR VAT included	0, 0	0,0	30916.1	30916.1
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]	638.56	160.821	519.635	52.003
Thermal energy unit cost	[Eur VAT included/MWh]	94			
Annual thermal energy cost	EUR VAT included/year	60024.64	15117.174	48845.69	4888.282
Annual final electricity consumption	[MWh/year]	50.977	50.187	51.79	48.069
Electricity unit cost	Eur VAT included/MWh	212			
Electricity annual cost	EUR VAT included/year	10807.124	10639.644	10979.48	10190.628

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, CO₂, replacement costs and residual value.

CNR – UNREFURBISHED BUILDING

0	1	2	3	4	5	6	7	8	9
YEAR	Annual maintenance cost CNR	Annual Updated thermal operating cost CNR	Updated energy cost CNR	Updated electricity cost CNR	Periodic replacement costs CNR	Residual value replacement costs CNR	Decommissioning costs CNR	Annual CO2 equivalent emissions costs CNR	Updated operating costs CNR

2025	0	5972,0	0,0	60024,6	10807,1	32466,0	0,0	0,0	3291,0	80094,8
2026	1	6145,9	0,0	61190,2	11017,0	0,0	0,0	0,0	5759,3	84112,3
2027	2	6324,9	0,0	62378,3	11230,9	0,0	0,0	0,0	5759,3	85693,4
2028	3	6509,2	0,0	63589,6	11449,0	0,0	0,0	0,0	5759,3	87306,9
2029	4	6698,8	0,0	64824,3	11671,3	0,0	0,0	0,0	5759,3	88953,6
2030	5	6893,9	0,0	66083,0	11897,9	0,0	0,0	0,0	5759,3	90634,1
2031	6	7094,7	0,0	67366,2	12128,9	0,0	0,0	0,0	8227,5	94817,3
2032	7	7301,3	0,0	68674,3	12364,4	0,0	0,0	0,0	8227,5	96567,5
2033	8	7514,0	0,0	70007,8	12604,5	0,0	0,0	0,0	8227,5	98353,7
2034	9	7732,8	0,0	71367,1	12849,3	0,0	0,0	0,0	8227,5	100176,7
2035	10	7958,0	0,0	72752,9	13098,8	0,0	0,0	0,0	8227,5	102037,2
2036	11	8189,8	0,0	74165,6	13353,1	0,0	0,0	0,0	8227,5	103936,0
2037	12	8428,4	0,0	75605,7	13612,4	0,0	0,0	0,0	8227,5	105874,0
2038	13	8673,9	0,0	77073,8	13876,7	0,0	0,0	0,0	8227,5	107851,8
2039	14	8926,5	0,0	78570,3	14146,2	0,0	0,0	0,0	8227,5	109870,5
2040	15	9186,5	0,0	80096,0	14420,9	0,0	0,0	0,0	8227,5	111930,8
2041	16	9454,1	0,0	81651,2	14700,9	0,0	0,0	0,0	8227,5	114033,7
2042	17	9729,4	0,0	83236,7	14986,3	0,0	0,0	0,0	8227,5	116179,9
2043	18	10012,8	0,0	84852,9	15277,3	0,0	0,0	0,0	8227,5	118370,6
2044	19	10304,4	0,0	86500,6	15574,0	0,0	0,0	0,0	8227,5	120606,5
2045	20	10604,6	0,0	88180,2	15876,4	0,0	0,0	0,0	8227,5	122888,6
2046	21	10913,4	0,0	89892,4	16184,7	0,0	0,0	0,0	8227,5	125218,0
2047	22	11231,3	0,0	91637,9	16498,9	0,0	0,0	0,0	8227,5	127595,6
2048	23	11558,4	0,0	93417,3	16819,3	0,0	0,0	0,0	8227,5	130022,5
2049	24	11895,1	0,0	95231,2	17145,9	0,0	0,0	0,0	8227,5	132499,7
2050	25	12241,5	0,0	97080,4	17478,8	0,0	0,0	0,0	8227,5	135028,2
2051	26	12598,1	0,0	98965,4	17818,2	0,0	0,0	0,0	8227,5	137609,2
2052	27	12965,0	0,0	100887,1	18164,2	0,0	0,0	0,0	8227,5	140243,8
2053	28	13342,6	0,0	102846,1	18516,9	0,0	0,0	0,0	8227,5	142933,1
2054	29	13731,3	0,0	104843,1	18876,4	0,0	0,0	0,0	8227,5	145678,3
2055	30	14131,2	0,0	106878,9	19243,0	0,0	0,0	0,0	8227,5	148480,5

CNR – REFURBISHED BUILDING (PACKAGE 3)

0	1	2	3	4	5	6	7	8	9	10	11
YEAR	Annual maintenance cost CNR	Annual operating cost CR	Updated thermal energy cost CR	Updated electricity cost CNR	Periodic replacement costs CNR	Residual value replacement costs CNR	Decommissioning costs CNR	Annual CO2 equivalent emissions costs CNR	Updated operating costs CNR	CASH FLOW	VNA

2025	0	4362,0	0,0	4888,3	10190,6	56564,7	30916,1	0,0	514,6	19956	-	547295
2026	1	4489,0	0,0	4983,2	10388,5	0,0	0,0	0,0	900,6	20761	-63351	483944
2027	2	4619,8	0,0	5080,0	10590,2	0,0	0,0	0,0	900,6	21191	-64503	419441
2028	3	4754,4	0,0	5178,6	10795,9	0,0	0,0	0,0	900,6	21629	-65678	353764
2029	4	4892,8	0,0	5279,2	11005,5	0,0	0,0	0,0	900,6	22078	-66876	286888
2030	5	5035,3	0,0	5381,7	11219,2	0,0	0,0	0,0	900,6	22537	-68097	218791
2031	6	5182,0	0,0	5486,2	11437,0	0,0	0,0	0,0	1286,5	23392	-71426	147365
2032	7	5332,9	0,0	5592,7	11659,1	0,0	0,0	0,0	1286,5	23871	-72696	74669
2033	8	5488,3	0,0	5701,3	11885,5	0,0	0,0	0,0	1286,5	24362	-73992	677
2034	9	5648,1	0,0	5812,0	12116,3	0,0	0,0	0,0	1286,5	24863	-75314	-74637
2035	10	5812,6	0,0	5924,8	12351,6	0,0	0,0	0,0	1286,5	25376	-76662	-151299
2036	11	5981,9	0,0	6039,9	12591,4	0,0	0,0	0,0	1286,5	25900	-78036	-229335
2037	12	6156,2	0,0	6157,2	12835,9	0,0	0,0	0,0	1286,5	26436	-79438	-308774
2038	13	6335,5	0,0	6276,7	13085,1	0,0	0,0	0,0	1286,5	26984	-80868	-389642
2039	14	6520,0	0,0	6398,6	13339,2	0,0	0,0	0,0	1286,5	27544	-82326	-471968
2040	15	6709,9	0,0	6522,8	13598,2	0,0	0,0	0,0	1286,5	28117	-83813	-555781
2041	16	6905,3	0,0	6649,5	13862,3	0,0	0,0	0,0	1286,5	28704	-85330	-641111
2042	17	7106,4	0,0	6778,6	14131,4	0,0	0,0	0,0	1286,5	29303	-86877	-727988
2043	18	7313,4	0,0	6910,2	14405,8	0,0	0,0	0,0	1286,5	29916	-88455	-816443
2044	19	7526,4	0,0	7044,4	14685,6	0,0	0,0	0,0	1286,5	30543	-90064	-906506
2045	20	7745,7	0,0	7181,2	14970,7	0,0	0,0	0,0	1286,5	31184	-91705	-998211
2046	21	7971,3	0,0	7320,7	15261,4	84710,8	0,0	0,0	1286,5	116551	-8667	-1006878
2047	22	8203,4	0,0	7462,8	15557,7	0,0	0,0	0,0	1286,5	32510	-95085	-1101963
2048	23	8442,4	0,0	7607,7	15859,8	0,0	0,0	0,0	1286,5	33196	-96826	-1198790
2049	24	8688,3	0,0	7755,4	16167,8	0,0	0,0	0,0	1286,5	33898	-98602	-1297391
2050	25	8941,3	0,0	7906,0	16481,7	0,0	0,0	0,0	1286,5	34616	-100413	-1397804
2051	26	9201,7	0,0	8059,5	16801,8	0,0	0,0	0,0	1286,5	35350	-102260	-1500064
2052	27	9469,8	0,0	8216,0	17128,0	0,0	0,0	0,0	1286,5	36100	-104143	-1604207
2053	28	9745,6	0,0	8375,6	17460,6	0,0	0,0	0,0	1286,5	36868	-106065	-1710272
2054	29	10029,4	0,0	8538,2	17799,6	0,0	0,0	0,0	1286,5	37654	-108025	-1818296
2055	30	10321,5	0,0	8704,0	18145,3	0,0	-30916,1	0,0	1286,5	7541	-140939	-1959236

Energy Audit Report of the building:

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

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	-	3425004.3	-
CR-P1	8	1688704.3	II
CR-P2	10	3027174.6	III
CR-P3	18	1466268.6	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 Highschool building of the Technical Energy College located within the premises 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 D (overall) with a specific primary energy consumption of 284.4 kWh/m²/year, compared to the reference building which is classified into energy class B with a specific primary energy consumption of 123.1 kWh/m²/year. Regarding the level of equivalent CO₂ emissions, the current building falls into class D with 54.3 kgCO₂/m²/year, compared to the reference building which is classified into class B with 19.9 kgCO₂/m²/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 $\gamma < 0.038$ W/mK

- Thermal insulation of the floor above the ground floor with sheep wool-based insulation material with a thickness of 25 cm and a minimum thermal strength of $\gamma < 0.038$ 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 minimum thermal resistance of $\gamma < 0.038$ W/mK, over which a wooden floor will be built

• Solution 2.

- Replacing the exterior windows with efficient carpentry which thermal strength is at least $R_{min} = 0.83$ m² K / W.

- Replacing the exterior doors with efficient carpentry which thermal strength is at least $R_{min} = 0.77$ m² K / W.

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

• 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 18 kWh will be installed on the high school's roof on the SE or SW orientations

o A heat recovery fan system with an average thermal transfer efficiency of 75% 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 8 years. The package of measures leads to an increase in the thermal strengths of the opaque envelope up to the minimum strengths requested by the codes in force. In terms of primary energy consumption and CO₂ 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 64.1% (from 874.559 MWh/year to 313.629 MWh/year) and CO₂ emissions are reduced by 68.7% (from 164.6 tons/year to 51.4 tons/year).

2. Package P2 is a package that includes solution S3 and is recovered in 10 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 CO₂ emissions. With this package of measures, the annual primary energy saving is 13.7% (from 874.559 MWh/year to 754.576 MWh/year) and CO₂ emissions are reduced by 16.6% (from 164.6 tons/year to 137.3 tons/year)

3. Package P3 is a maximum package in terms of investment that includes solutions S1-S3 and is recovered in 9 years. The package of measures leads to an increase in both the thermal strength of the envelope to the minimum strengths 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 77.4% (from 874.559 MWh/year to 197.877 MWh/year) and CO₂ emissions are reduced by 84.4% (from 164.6 tons/year to 25.7 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:

Student dormitory 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)	638.56	177.104	72
Total final electricity consumption (MWh/year)	50.978	65.337	-28.17
Total primary energy consumption (MWh/year)	874.559	197.877	77.37
Total specific primary energy consumption (kWh/m ² year)	284.43	64.36	77.37
Energy class	D	A+	
Amount of CO ₂ equivalent emissions (kg CO ₂ /m ² ,year)	53.5	8.4	84.4
Environmental class	D	A+	
Final thermal payment energy [MWh/year]	638.6	52	91.86
Final electricity payment [MWh/year]	51	48.1	5.69

4. Applying the package of measures proposed is economically feasible, amortizing the investment value over a period of 9 years. The value is lower than the shelf life of the package, which is estimated at 20 years, and causes significant energy reductions.

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

eng. Cruciat Radu

Illegible signature, Official stamp

Drafted by

Energy auditor for buildings

eng. Pricopie Andrei Gheorghe

Illegible signature, Official stamp

Energy Audit Report of the building:

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

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
-

Energy Audit Report of the building:

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

- 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: Student dormitory building

Address: Electricienilor street no.1, Sibiu county

Owner: Sibiu City Hall

Building category:

educational establishment (nurseries, kindergardens, schools, highschoools, 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: 1965-1970

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): 832.10

Built unfolded area (sqm): 3328.4

Reference area of the heated space floor (sqm): 3074.76

Reference volume of the heated space (m³): 9693.97

Reference area of the cooled space floor (sqm), as appropriate: -

Free average height of one level (m): 2.8

Occupation level of the heated space [no. of operating hrs of the heating system]: 24h/281 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: 2 m

Building basement floor perimeter: 112.10 m

C. BUILDING CONSTRUCTIVE STRUCTURE IDENTIFICATION

Dull exterior walls

Exterior wall – masonry

No. crt.	Material	γ [W/mK]	δ [m]	a	R [m ² K/W]
1	Lime mortar plaster	0.87	0.02	1.1	0.021
2	Solid brick masonry	0.8	0.25	1.15	0.290
3	Cement mortar plaster	0.93	0.03	1.1	0.029
$\delta_i=8$ $\delta_e=24$			R0	=	0.507

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

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

$\delta_i = 6$
 $\delta_e = 12$

R0	=	0.545
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Total area of the ground slab [sqm]: 767

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]	δ [m]	a	R [m ² K/W]	
1	Corrugated sheet	0.8	0.01	1.05	0.012	
2	Roof boarding	0.17	0.025	1.1	0.134	
				R0	=	0,313

$\delta_i = 8$

$\delta_e = 24$

Total roof area [sqm]: 1053.4

Floor under the attic:

No. Crt.	Material	λ [W/mK]	δ [m]	a	R [m ² K/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

Total area of the floor under the attic [sqm]: 767.0

Floor over the basement

No. Crt.	Material	λ [W/mK]	δ [m]	a	R [m ² K/W]
1	Reinforced concrete slab	1.62	0.1	1.05	0.059
2	Cement mortar plaster	1.16	0.05	1.03	0.042
3	Ash and slag	2.03	0.01	1.03	0.005

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

$\delta_i=8$ $\delta_e=12$	R	=	0.357
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Total area of the floor over the basement [sqm]: 767.0

Loggia floor:

No. Crt.	Material	λ [W/mK]	δ [m]	a	R [m ² K/W]
1	Limestone	2.09	0.01	1.03	0.005
2.	Simple concrete	1.16	0.05	1.03	0.042
3	Reinforced concrete slab	1.62	0.15	1.05	0.059
4	Cement mortar	0.93	0.0	1.03	0.021
$\delta_i=8$ $\delta_e=24$					R = 0.357

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	366.6	PVC carpentry insulated glass	With outdated sealing that is no longer flexible	No
EW	Windows R=0.21	13.5	PVC carpentry insulated glass	With outdated sealing that is no longer flexible	No
ED	Doors R=0.20	36.10	PVC carpentry insulated glass	With outdated sealing that is no longer flexible	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]: 406580

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 columns, 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: 444.6 m; - nominal diameter: 88.9 mm; 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

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

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	150		150

Heating source – own thermal system

Nominal power: 2x390kW

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: 50

washers: 4

bidets: 0

urinals: 12

showers: 24

bath: 0

WC : 21

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

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

Hot water distribution network located in unheated spaces:

Length : 94 m

Thermal insulation: yes

There is an insulation, but it is wet

Average number of persons throughout one year (for the period when one knows the consumptions invoiced): 160

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 signature, Official stamp

G. Photo Annex



Photo 1 – Main entrance, one can see the main access in the building



Photo 2 – Left side entrance



Photo 3 – Rear entrance

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

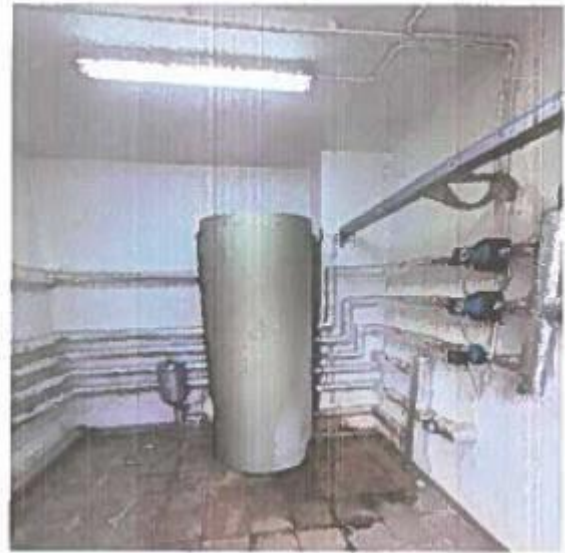


Photo 4. Photo of the thermal plant, one can see the two boilers providing heat and the boiler for storing the hot running water



Photo 5 – Heating system room



Photo 6 – Lighting fixture

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



Photo 7 – Kitchen



Photo 8 – Manager office



Photo 9 – Student dormitory room



Photo 10 – Balcony

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

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	General manager
Personal identification number: 1850607460121	Illegible signature, Official stamp
Job: Engineer	
CERTIFIED	
ENERGY AUDITOR FOR BUILDINGS	Holder's signature - Illegible signature
Professional degree: I	This badge is valid only accompanied by the attestation
Specialization: CONSTRUCTIONS AND INSTALLATIONS	certificate of the energy auditor for buildings
Date of issue: 08.02.2017	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	General manager
Personal identification number: 1850707324784	Illegible signature, Official stamp
Job: Engineer	
CERTIFIED	
ENERGY AUDITOR FOR BUILDINGS	Holder's signature - Illegible signature
Professional degree: I	This badge is valid only accompanied by the attestation
Specialization: CONSTRUCTIONS AND INSTALLATIONS	certificate of the energy auditor for buildings
Date of issue: 08.02.2017	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

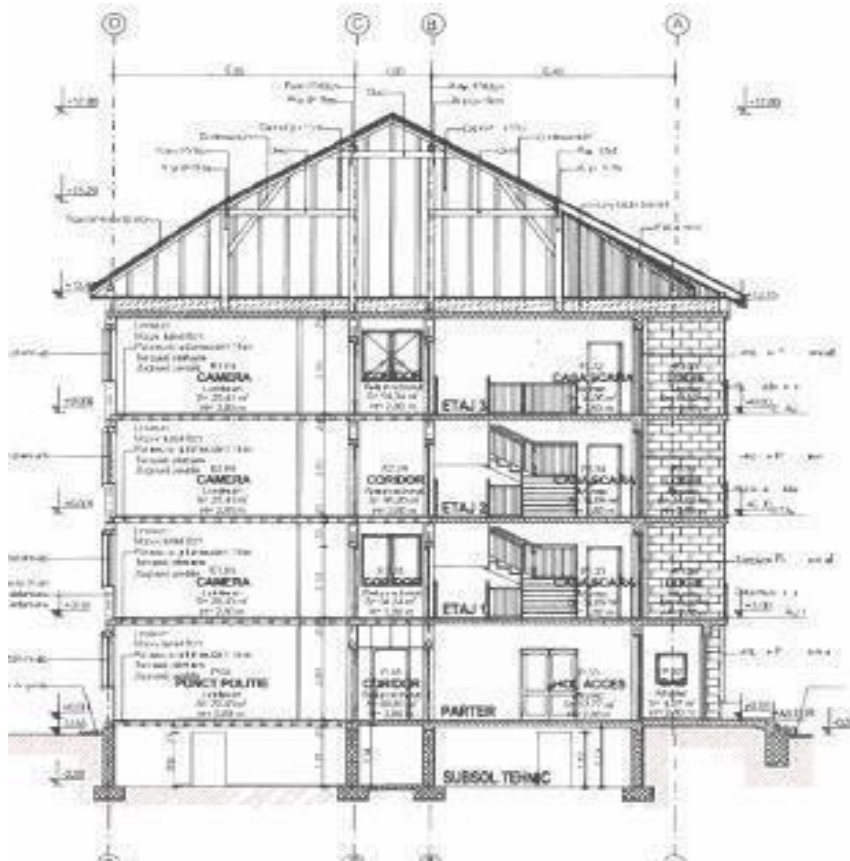


Energy Audit Report of the building:
Student dormitory building within the Technical Energy College from Electricienilor street, no. 1, Sibiu

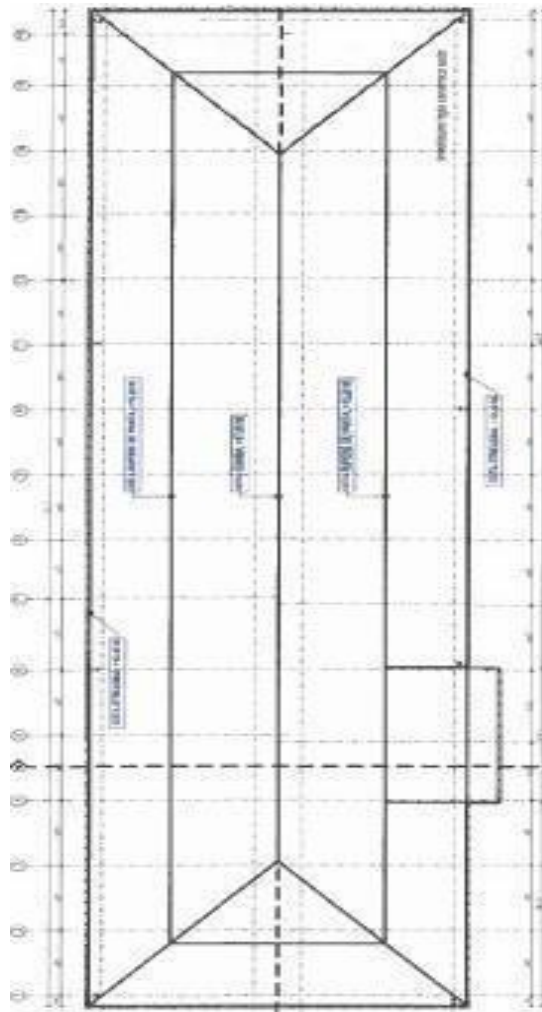


Current floor survey

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



Transversal section



Roof truss survey

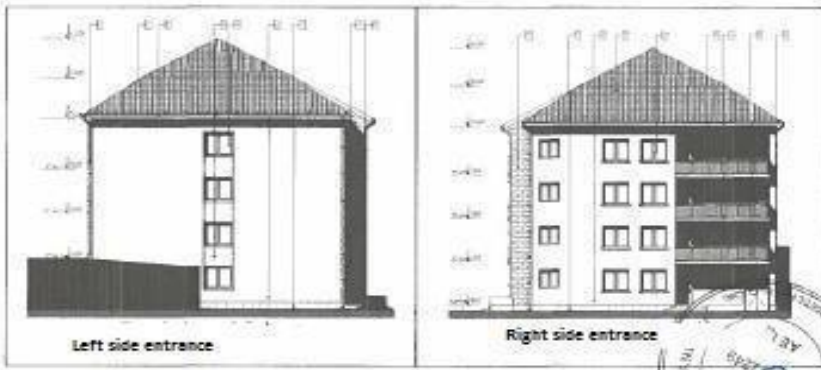
Energy Audit Report of the building:
Student dormitory building within the Technical Energy College from Electricienilor street, no. 1, Sibiu



Main entrance



Rear entrance



Left side entrance

Right side entrance

RECOMMENDATIONS FOR INCREASING THE ENERGY PERFORMANCE

ANNEX 1 to the Energy Performance Certificate no. 000130/ 550311

for the BUILDING/BUILDING BLOCK/APARTMENT from Siblu, str. Electricienilor no. 1, Sibiu County

1. Solutions recommended for the envelope of the building/building block/apartment

Increasing the thermal strength of the external walls above the minimum value provided by the technical regulations in force, by external thermal insulation

Increasing the thermal strength of the roof (floor under the attic), if any, above the minimum value provided by the technical regulations in force, by external thermal insulation

Replacing the current exterior joinery with energy-efficient joinery.

Assembling on the exterior carpentry or on the exterior walls of the hygroadjustable ventilation grids in order to avoid the increase in the interior moisture and providing the quality of the interior air

Installing devices to shade the facades or protect against solar radiation during the winter.

2. Solutions recommended for installations related to the building/building block/apartment.

Replacing the used pipes for the heating agent and possibly insulating them (same for the columns).

Replacing the used pipes for hot water distribution for heating and possibly insulating them (same for the columns).

Installation of thermostatic valves on the heating elements

Installation of automatic balancing valves at the base of the heating/cooling columns

Ensuring the quality of the indoor air through organized natural ventilation, mechanical ventilation or hybrid ventilation

Use of sanitary fittings with reduced total hot water consumption (use of economic diffusers at the consumption points)

Replacement of seals and repair of defective hot water fittings, installed on sanitary objects.

Provision of a minimum automation/regulation system if it does not exist, for heating/cooling/ventilation

Adjustment/cleaning of the equipment in the heating/air conditioning system, if it exists, and the equipment operates inefficiently

Installation of lighting fixtures with economical sources instead of the existing, inefficient ones

Installation of presence sensors for automatic activation of the lighting system

Use of renewable energy sources to increase the environmental performance of buildings

Use of thermal energy recovery equipment (air-to-air heat exchangers, water heaters, etc.)

Periodic cleaning of the chimneys and flues for the exhaust of combustion gases, if applicable

3. Related measures (corresponding to the energy calculation stages) for increasing the energy performance of the certified building:

A - General organizational measures

Informing building users (owners/tenants) about the advantages of energy savings and pollution reduction

Encouraging occupants/administrators to use the building and its facilities correctly, being motivated to reduce the energy consumption

Choosing the correct way how the building should operate both as a whole and at the level of individual blocks

Designating a representative to monitor the execution of thermal rehabilitation works in case of building refurbishment

Permanent recording of energy consumption, including analysis of energy bills

periodic review of energy supply contracts and their amendment, if necessary

providing energy consultancy services from specialized companies (which also ensure the proper maintenance of the building facilities)

B - Local measures to reduce the energy consumption

dismantling and washing of heat emitting equipment (heaters, fan-convectors, etc.)

removing objects that prevent the heat from the radiators from reaching the room

introducing a reflective surface between the radiator and the expansion wall that reflects the heat back into the room

thermo-hydraulic balancing of the heating units

replacing sanitary fixtures

hydraulic balancing of the hot running water distribution network

air balancing of air distribution networks

correction of the settings of the automatic operating parameters of the equipment

Estimated total costs (excluding VAT) of the measures proposed to increase the energy performance ≥ 100.000 EUR:

Estimated total energy savings: $\geq 60\%$

Estimated investment recovery duration: ≥ 10 years

List of the steps that need to be taken to implement the energy-saving and environmental performance improvement measures:

Envelope renovation

Carpentry replacement

Thermal insulation of the attic floor and of the floor over the thermal channel

Use of energy from renewable sources

Installations modernization, implementation of ventilation with heat recovery

Information on financial incentives or other funding opportunities:

European Funds

Government Funds

Own Funds

TECHNICAL INFORMATION REGARDING THE CERTIFIED BUILDING

ANNEX 2 to the Energy Performance Certificate no. 000130/ 550311

for the BUILDING/BUILDING BLOCK/APARTMENT from Siblu, str. Electricienilor no. 1, Sibiu County

A.DATA REGARDING THE CERTIFIED BUILDING

Type of building: existing

Construction year: 1965-1970

Building category: residential building - student dormitory

Climate zone where the building is located: III

Wind energy area where the building is located: IV

Height regime of the building: groundfloor, 3 floors

Constructive structure of the building:

- structural masonry walls

- reinforced concrete frames

Number and type of apartments/building blocks/thermal areas and floor reference areas:

Type of apart/block/area destination		Reference area of an apart/block/thermal area ZTC or ZTU [sqm]		Number of similar apartments/blocks/thermal area		Total reference area/type [sqm]	
C1	C2	C1	C2	C1	C2	C1	C2
ZTC.1.1		3074.76		1		3074.76	
ZTU1		767		1		767	
ZTU2		767		1		767	
TOTAL				3		4608.76	
<p>Total reference area of the floor of the building or building block: 3074.76 sqm Reference interior volume V, of the building/building block: 9693.97 m³</p>							

o Geometric and thermal characteristics of the envelope:

Type of construction element		Thermal strength corrected calculated [m ² K/W]		Thermal strength corrected standard [m ² K/W]		Area I [m ²]		
		C1	C2	C1	C2	C1	C2	
R1.	PE1	0,4				488,8		
R2.	PE1	0,44				162,8		
R3.	PE1	0,4				484,2		
R4.	PE1	0,48				185,8		
R5.	PL attic	0,59		5		787		
R6.	PH over the basement	0,34		2,9		787		
R7.	FE-PVC	0,43		0,77		366,8		
R8.	FE-I wood	0,21		0,77		13,5		
R9.	UE-I wood	0,2		0,77		38,1		
R10.	PH - wood	0,29		5		14,0		
Total envelope area						S _E [m ²]		3264,2

Building form factor S_g/V: 0.34 m⁻¹

Details of the annual specific consumption of primary energy [kWh/m² years, respectively of annual specific equivalent CO₂ emissions [kgCo₂/m².year]

Type of installation system	Real building			Reference building	
	Specific consumption Primary/linear energy	CO ₂ equivalent annual specific emissions	Energy performance class	Primary energy specific consumption	CO ₂ equivalent annual specific emissions
Heating	174.4/208.5	42.0	D		
Hot running water	31.0/36.3	7.3	B		
Cooling					
Mechanical ventilation					
Lighting	15.9/39.7	4.2	E		
TOTAL/CLASS	224.3/284.5	53.5	D	123.1	19.9

Standard number of persons inside the building/building block: 160.00 people

B. DATA REGARDING THE INTERIOR HEATING SYSTEM

Existence of the heating system: yes, functional

Current energysource for heating the spaces: own source (individual system, natural gas fuel)

Type of heating system: heating with static bodies power plant

Type of static body	Number of static bodies (pcs)			nominal thermal power [kW] for the heating flow/return temperature/interior temperature of ... Celsius degrees
	Area	In the living/work space	In the common spaces	
steel	ZTC1.1	80	70	600[kW] 55/45 20[°C]
TOTAL		80	70	600

- Type of thermal agent distribution: lower
- Calculation heat requirement (necessary thermal energy): 347.07 kW
- Energy necessary for humidification: 0.00 kW
- Total thermal power installed for heating: 780/kW (thermal/electric)
- Connection to the centralized heating source: standard diameter – 0 mm
available pressure: 0 mmCA
- Heating meter: does not exist
- Costs allocator: does not exist
- Thermal and hydraulic adjustment elements:
at connection/heating source level at columns level
at static bodies level

Total length of the distribution network located in unheated spaces: 0.00 m

Unheated space denomination	Section diameter (mm) / Section length (m)								
ZTU1- attic ZTU2 –technical channel									

Total standard flow of the heating agent: 52978.00 l/h

Occupation level of the heated space (operating schedule of the heating facility)

Area	Work day	Weekend day		
Hours	24	24		
Interior temperature (°C)	20	20		

C. DATA REGARDING THE HOT RUNNING WATER SYSTEM

Does the hot running water system exist? Yes, it is operating

Energy source for preparing hot running water: own source (individual thermal system with natural gas fuel)

Type of equipments for preparing the hot running water: boiler with accumulation (number/volume) 1/2000 l

Number of sanitary items per types:

Washbasin	50	Bathtub	0
Washers	4	WC	21
Bidets	0	Dishwasher	0
Urinals	12	Washing machine	0
Shower	24		

Total number of hot running water consumption points: 78

Thermal power necessary for preparing the hot running water: 0 kW

Maximum thermal power installed for preparing the hot running water: 780 kW

Connection to the heating centralized system:

- nominal diameter: 0 mm

- necessary pressure: 0 mmCA

The hot running water recirculation pipe: does not exist

The general hot running water meter: does not exist

Debit metres of the consumption points: do not exist

D. INFORMATION REGARDING THE COOLING/AIR CONDITIONING SYSTEM

Does the cooling/air conditioning system exist: no – ignore the energy consumption for cooling/air conditioning

Time of one year when the interior temperature exceeds the free comfort temperature during the summer: 486 hrs

Reference volume of the air-conditioned area: 8609 m³

Average nominal value of the EER performance coefficient of the cooling source: 0.00

The coldness necessary for cooling (refrigeration capacity): 0.00 kW

The coldness necessary for dehumidification (latent power): 0.00 kW

Total refrigeration power installed in the building: 0.00 Kw

E. INFORMATION REGARDING THE MECHANICAL VENTILATION SYSTEM

Does the mechanical ventilation system exist: No, ignore the electricity for residential buildings, respectively a virtual consumption of electricity is requested for non-residential buildings (acc.to Mc001 provisions, chapter 5.3)

Minimum fresh air flow for ventilation according to the legal rules, under standard terms/ensured by the mechanical ventilation system from the building: 0 m³/h

Is there a heat recoverer? No

F. INFORMATION REGARDING THE LIGHTING SYSTEM

Does the lighting system exist: Yes, it is functional

Type of control/adjustment system of the lighting system: no adjustment (on/off)

Type of lighting system: fluorescent

Electrical network condition/ lighting conductors network condition: Used

Total electricity necessary for the lighting system, corresponding to the normal use of the spaces/insuring the normal lighting level: 10.00 kW

Total installed electricity of the lighting system: 10.00 kW

G. INFORMATION REGARDING THE ENERGY RENEWABLE SOURCES

Solar thermal panel system: does not exist

Photovoltaic panels systems: does not exist

Heat pump: does not exist

Biomass usage system: does not exist

Wind farm: does not exist

Thermal energy exported: 0.00 kWh/year (produced on-site)

Electricity exported: 0.00 kWh/year (produced on-site)

Thermal energy exported from renewable sources: 0.00 kWh/year (produced on-site)

Electricity exported from renewable sources: 0.00 kWh/year (produced on-site)

Primary energy indicator EP_p : 284.4 kWh ($m^2.a$)

RER_p indicator: 2.91%

CO2 emissions indicator: 53.5 kgCO2 ($m^2.a$)

Drafted by,

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H.SITE PHOTOS

