Energy Inspection

Energy Audit in Buildings of Resen

INTRODUCTION

The conduction of an energy efficiency study is compulsory for all new or radically renewed buildings, according to the Greek Law 3661/2008 "Measures for Buildings' Energy Consumption Reduction and other provisions" (Government Gazette A 89), with the exceptions of Article 11, as amended in accordance with Article 10 and 10A of the law 3851/2010. The Energy Efficiency Study is conducted based on the Buildings Energy Efficiency Regulation (KENAK) (Government Gazette B 407/9.4.2010) and the Technical Directives of the Technical Chamber of Greece, as formally drawn supportively to the Regulation and are valid updated. More specifically, the energy efficiency study is based on the following Technical Directives:

- 20701-1/2010: "Analytical National Specifications of the parameters for the calculation of the buildings' energy efficiency and the issuance of the energy efficiency certificate"
- 20701-2/2010: "Thermo physical properties of construction materials and buildings' thermal insulation efficiency testing",
- 20701-3/2010: "Greek cities' climate conditions".

The incorporation of passive solar systems beyond the direct gain, renewable energy systems (RES) installations and cogeneration or combined heat and power (CHP) systems will be covered in the next following phase with the issuance of the following Technical Directives which clearly define the parameters and the specifications of the relevant studies - installations:

- 20701-X/2010: "Bioclimatic design"
- 20701-X/2010: "RES installations in buildings",
- 20701-X/2010: "CHP installations in buildings".

According to the financial circular 1603/4.10.2010: "For the best possible implementation of the requirements of paragraph 1 of Article 8 "Building Design"", a systematic approach of the principles of the bioclimatic design of the building with sufficient technical documentation, on the basis of the available literature and until the issuance of the relevant technical Directive is required. In case that there are several restrictions (urban, technical, aesthetic, economic, etc.) which possibly preclude the implementation of the best solution as far as the energy efficiency is concerned, a Technical Report is compulsory submitted, which will adequately document the reasons for not implementing each of the cases of paragraph 1 of Article 8.

The objective of the energy efficiency study is the, as far as possible, minimization of the building's energy consumption for the building's proper operation through:

- the bioclimatic design of the building shell, exploiting the building's location relative to its surroundings, the available sunlight per side orientation, etc,
- the building's insulation efficiency through the appropriate thermal insulation enhancement on the opaque structural elements (walls), avoiding if possible the creation of thermal bridges, and through the selection of appropriate window frames i.e. combination of glass pane, and framework,
- the selection of appropriate high efficient electromechanical systems, to meet the needs of heating, cooling, air conditioning, lighting, and domestic hot water at the minimum possible consumption of (ανηγμένης) primary energy,
- the use of renewable energy sources (RES) technologies such as solar thermal systems, photovoltaic (PV) systems, geothermal heat pumps (ground, groundwater and surface water), etc. and,
- the application of automatic control devices for the operation of the electromechanical installations, to reduce their unnecessary usage (implementation of building management systems).

GENERAL BUILDING DESCRIPTION

In this section, an analytic description of the building under study is presented, concerning its location and its surroundings, its usage and the operating profile of its individual sections (areas).

GENERAL BUILDING DATA

Besides the common usage areas, the main entrance of the building as well as the stairway enclosure of all floors will be considered as heated spaces.
The office spaces belong to the heated zone 1 and the space of the stairway enclosure and the auxiliary rooms (WC-warehouses) belong to the heated zone 2. In the heated zone 1 the desired temperature is 22 degrees while in the heated zone 2 the desired temperature is 18 degrees. The temperature of the premises must not in any case drop below 16 degrees Celsius even during the hours of non-operation of the building.
The two basements with the warehouses, the parking areas and the boiler room will be considered as unheated spaces in the building.
The operating hours of the building will be differentiated according to its usages and will be obtained as defined in the technical Directive 20701-1/2010.

TOPOGRAHY OF THE BUILDING PLOT

The plot on which the building has been erected is rectangular in shape with its large axis in 30° angle deviation from the North - South axis. The corner plot is situated in a densely built urban environment, with multistoried buildings of more than four floors.
The building location will be conducive to the insulation, especially of the roof and the vertical sides from the first floor and above, except for its north side, while on the west side it is sunned from the third floor and above. The roof of the building has enough free space with the possibility of adequate insulation.

BUILDING ARCHITECT DESIGN JUSTIFICATION

According to Article 8 of KENAK, the building must be designed, taking into consideration the following:

- The sitting of the building and its orientation in the plot,
- The internal sitting of spaces due to the building's operation,
- The appropriate sitting of the openings for adequate insulation, natural lighting and natural cooling, as well as their sun shading,
- The incorporation of at least one passive solar system, one of which may be the system of direct gain,
- The configuration of the surrounding landscape for the improvement of the microclimate.

<u>Failure to implement the above requires adequate justification, according to KENAK.</u>

Moreover, according to Article 11 of KENAK, the contents of the energy efficiency study, which are also taken into consideration for the energy planning, are the following:

- Geometrical characteristics of the building and the openings (floor plan, volume, surface, orientation, shading coefficients, etc.),
- Justification of the sitting and the orientation of the building for the maximum exploitation of the local climatic conditions (sunlight exploitation), through insulation charts taking into consideration the surrounding buildings impact,
- Justification of the selection and the sitting of the plantation and other items for the improvement of the microclimate,
- Justification of the design and sitting of the openings per orientation depending on the requirements of insulation, lighting and ventilation (percentage, type and surface of transparent surfaces per orientation),
- Sitting of the room operations depending on the usage and the requirements for comfort and indoor environmental quality (thermal, natural ventilation and lighting),
- Description of the passive solar systems' operation for the winter and summer periods: calculation of the passive solar systems' surface of direct and indirect gain (vertical / inclined / horizontal surface), for the systems with a maximum deviation of 30° from the south, as well as of the percentage of this surface on

the corresponding total surface of the side,

- Description of the building's sun-shading systems per orientation: dimensions and construction materials, type (steady / mobile, horizontal / vertical, compact / perforated) and display of the resulting shading percentage for
    - 21st of December (winter solstice: shortest day duration and lower sun position)
    - 21st of June (summer solstice: longest day duration and higher sun position)
- General description of the natural lighting (sunlight) exploitation techniques,
- Design illustration with construction details of the insulating layer, the passive systems and the sun-shading systems in the architectural plans of the building (floor plans, views/sides, incisions/cuts/sections).

BUILDING SITING ON THE PLOT

The building has been erected within the densely populated urban web without effectively allowing the best utilization of the basic principles of the bioclimatic architecture. Nevertheless, the placement of the building on the plot has been done in such a way so as to allow at least the partial exploitation of the basic climate parameters.

The sitting of the building on the plot has been done so that, at its northern side, a minimum number of openings to be placed.

OPENINGS SUN-SHADING

No medium has been selected as a means of sun-shading of the openings. In conjunction with the mobile sun-shading, which, however, is not taken into consideration in the calculations of the building's energy consumption, they are considered to offer adequate shading.

NATURAL LIGHTING

In all the main areas, openings that offer adequate lighting have been placed. Especially in the areas with great depth, there is special provision and large openings have been placed.

NATURAL COOLING

Openings on the east and west sides have been placed ensuring cross ventilation for the maximum possible exploitation of the natural cooling. Effort will also be made so as to place openings, which will provide adequate natural cooling, in all the areas.

STRUCTURAL ELEMENTS AND BUILDING THERMAL INSULATION EFFICIENCY TESTING

According to KENAK, all the structural elements of a new or radically renewed building must fulfill the thermal insulation constraints of Table 4.1.:

Table 4.1.: Maximum permissible values of the thermal transmittance coefficient of different structural elements per climate zone.

Structural element	Symbol	Maximum permissible thermal transmittance coefficient [W/(m²·K)]					Building in study
		Zone A	Zone B	Zone C	Zone D	Zone E	
External horizontal or inclined surface in contact with surrounding	U_R	0,50	0,45	0,40	0,35	0.30	0.95
External walls in contact with	U_T	0,60	0,50	0,45	0,40	0.35	0.95
Surfaces in contact with surrounding air (open parking floors)	U_{FA}	0,50	0,45	0,40	0,35	0.30	0.95
External walls in contact with non-	U_{TU}	1,50	1,00	0,80	0,70	0.60	--
External walls in contact with ground	U_{TB}	1,50	1,00	0,80	0,70	0.60	--
Floors in contact with closed non-	U_{FU}	1,20	0,90	0,75	0,70	0.65	--
Floors in contact with ground	U_{FB}	1,20	0,90	0,75	0,70	0.65	--
Windows frames	U_W	3,20	3,00	2,80	2,60	2.40	4.5
Glass buildings facades fixed or partially openable	U_{GF}	2,20	2,00	1,80	1,80	1.80	--

Zone E is the proposed for FYROM

Simultaneously, the value of the average thermal transmittance coefficient of the building under study must not exceed the limits of Table 4.2.:

Table 4.2.: Maximum permissible values of the average thermal transmittance coefficient of a building per climate zone as a function of the ratio of the building's surrounding surface to its volume.

Ratio A/V $[m^{-1}]$	**Maximum permissible values of the average thermal transmittance coefficient U_m $[W/(m^2\cdot K)]$**			
	Zone A	**Zone B**	**Zone C**	**Zone D**
≤ 0,2	1,26	1,14	1,05	0,96
0,3	1,20	1,09	1,00	0,92
0,4	1,15	1,03	0,95	0,87
0,5	1,09	0,98	0,90	0,83
0,6	1,03	0,93	0,86	0,78
0,7	0,98	0,88	0,81	0,73
0,8	0,92	0,83	0,76	0,69
0,9	0,86	0,78	0,71	0,64
≥ 1,0	0,81	0,73	0,66	0,60

The thermal insulation efficiency testing is done in two stages:

1. The thermal transmittance coefficient U of all the structural elements is calculated and its compliance to the limits of the requirements of Table 4.1. is verified.
2. The average thermal transmittance coefficient of the building U_m is calculated and its compliance to the limits of Table 4.2. is verified.

1) <u>Structural element thermal insulation testing</u>

The calculation of both the thermal transmittance coefficient U of the structural elements and the average thermal transmittance coefficient U_m of the building is based on the technical Directive 20701-2/2010.

According to the technical Directive 20701-2/2010, the general formula for calculating the thermal transmittance coefficient of the opaque structural elements (walls) is:

$$U = \frac{1}{R_i + \sum_{j=1}^{n} \frac{d_j}{\lambda_j} + R_\delta + R_a} \qquad [4.1]$$

where,

d_j the thickness of the homogeneous and isotropic layer structural material j,

λ_j the thermal conductivity coefficient of the homogeneous and isotropic material j,

R_i and R_a the thermal transition resistances on either side of the structural element and

R_δ the thermal resistance of enclosed air gap

Respectively, the thermal transmittance coefficient U_w of transparent structural elements is calculated as:

$$U_W = \frac{A_f \cdot U_f + A_g \cdot U_g + l_g \cdot \Psi_g}{A_f + A_g} \quad [4.2]$$

where,

U_f the thermal transmittance coefficient of the window's framework,

U_g the thermal transmittance coefficient of the window's glass pane,

A_f the surface area of the window's framework,

A_g the surface area of the window's glass pane,

L_g the length of the thermal bridge of the window's glass pane, and

Ψ_g the linear thermal transmittance coefficient of the window's glass pane.

In any case, the following relation for both the transparent and opaque structural elements must hold:

$$U \leq U_{\delta.\sigma,max} \quad [4.3]$$

where,

U the thermal transmittance/permeability coefficient of structural element as calculated according to the relations [4.1.] or [4.2.] and

$U_{\delta.\sigma,max}$ the maximum permissible value for the structural element [Table 4.1.].

2) <u>Building thermal insulation testing</u>

Provided that each structural element fulfills the requirements of Table 4.1., it is also required that the building as a whole has a minimum degree of thermal protection. The calculation of the average thermal transmittance/permeability coefficient of the building is given by the formula:

$$U_m = \frac{\sum_{j=1}^{n} A_j \cdot U_j \cdot b + \sum_{i=1}^{v} l_i \cdot \Psi_i \cdot b}{\sum_{j=1}^{n} A_j} \qquad [4.4]$$

where,

A_j the surface area of structural element j,

U_j the thermal transmittance coefficient of structural element j,

Ψ_i the linear thermal transmittance coefficient of thermal bridge i,

li the length of thermal bridge I, and

b reduction factor

In any case, the following must hold:

$$U_m \leq U_{m,max} \qquad [4.5]$$

where,

$U_{m,max}$ is the maximum permissible thermal transmittance coefficient of the building and is provided in Table 4.1.

In case that $U_m > U_{m,max}$, the designer/engineer is obliged to follow one of the three following options or a combination thereof, and to perform the calculations from the beginning:

- To improve the thermal protection of the opaque structural elements (walls),
- To improve the thermal protection of the transparent structural elements (windows),
- To reduce the creation of thermal bridges in the building envelope, modifying the design of the structural elements in which they are due.

According to the technical Directive 20701-2/2010 "Thermophysical properties of building materials and buildings thermal insulation efficiency testing" for the calculation of the thermal bridges, the designer/engineer has two options:

1. to follow the simplified method using Table 15 of the technical Directive 20701-2/2010
2. to make the calculations analytically using Tables 15a up to 15λ of the technical Directive 20701-2/2010.

The reduction factor b is calculated using the relation 2.21 of the technical Directive 20701-2/2010. Alternatively, and for simplicity purposes, it can be considered equal to 0.5.

In the present study, the simplified method of calculation of the thermal bridges is followed and the reduction factor b is considered equal to 0.5.

Table 2.1. *Building area usage and surface.*

	Surface in m^2			
	Residence	Stores area	Common usage areas,	Boiler room
Floor	3200		944	

Measurements of the thermal insulation efficiency of the building materials

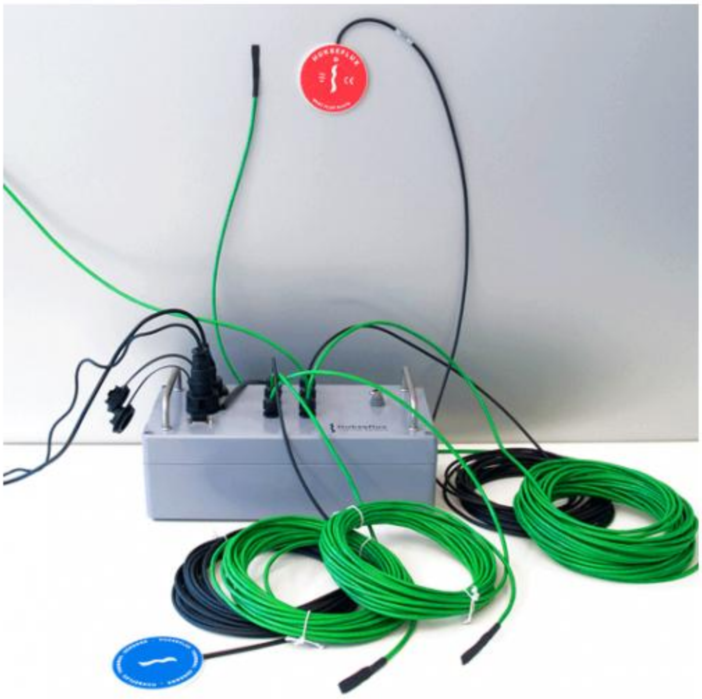
Measurement of the "λ" coefficient of the opaque and transparent materials

The measurements were performed using a heat flux meter, which is presented in the photo below, both at the western and the eastern sides of the building.

The duration of the measurement was 72 hours - one measurement was carried out on the opaque structural element (wall), while the second one concerned the transparent structural element (window).

The heat transfer coefficient U of the opaque building materials resulted equal to 0.78 W/m^2K as far as the eastern walls were concerned, while this value increased to 0.95 W/m^2K regarding the western walls since the permanent shading from the tall trees does not allow the sun to remove the moisture that accumulates on the walls during the winter.

Building materials' thermal resistance meter



The TRSYS01 is a tool for measuring and analyzing the thermal resistance of building materials with the measurement made in existing buildings. It can be used for measurements in accordance with ISO 9869 and ASTM C1155 / C1046.

www.hukseflux.com

HEAT LOSS MEASUREMENTS USING THE THERMOGRAPHIC CAMERA MEASUREMENT METHODOLOGY STAGES

Measurement planning. The measurement planning concerns the contact with the responsible engineer for the determination of the date of the measurement, the determination of the measuring points, i.e. for which transmission pipelines of hot liquid or steam, thermo grams for determining their insulation will be carried out as well as any existing stoves or boilers. Moreover, all the relevant data is gathered. This data is: the number of stoves or boilers, the calcinations or combustion temperature respectively, the thickness of the insulation and the insulation material. Also, as far as the transmission pipelines of hot liquid or steam are concerned, the diameter of the pipelines, the thickness of the insulation and the insulation material, the overall meters of the pipelines as well as the temperature of the liquid or steam.

Moreover, when it comes to imprinting the thermal behavior of a building envelope (walls, windows, etc.), their construction material (concrete, bricks, insulation, coating, type of window frames, usage of single or double glass panes) and generally their technical characteristics are recorded.

Visiting the site of measurement. When visiting the measurement sites, the possibility of thermo graphing the pipelines and the surfaces of the boilers and stoves is checked, i.e. if there is adequate space for the operator of the thermo graphic camera to get close to the surfaces and the pipelines to be measured. For the thermography of the building envelope, a cold and cloudy day is selected in order to avoid the heating of the walls due to the incident solar radiation.

The procedure is done in accordance with the standard ELOT 1364 "Thermal insulation – detection of uniformities in building envelopes – infrared rays' method".

Measurement preparation. As mentioned, the thermo grams are generated with the thermo graphic camera. The thermo graphic camera detects the infrared radiation from the surface that is thermographed and measures the surface temperature. Before the thermography, the boilers and the stoves must operate at their ordinary operating temperatures so that the measurements are as representative as possible. The thermo graphic camera must operate for about 5 minutes before the thermography in order to be automatically calibrated. For the thermography of the building envelope, the internal temperature must be much larger than the external temperature so that it is possible to identify the heat losses from the building envelope as well as the points where the existing insulation is degraded. Measurement of surface temperature using infrared radiation. Each body at a temperature above 0^oC emits infrared radiation. Between an object's temperature and the amount of energy that it radiates, a stable relation exists. It is therefore possible to achieve the accurate measurement of the object's temperature by measuring the amount of radiation. The infrared radiation is a form of electromagnetic energy – other forms are the visible light, the ultraviolet radiation, the gamma rays and the microwaves.

When the temperature of the object to be thermographed rises, two important things happen. Firstly, the amount of the energy radiated from the surface of the object increases excessively fast and secondly, the concentration of the energy is greater in the short wavelengths. The knowledge of this result allows us to establish precise rules of application. For example, a detection instrument of infrared radiation, which is sensitive only to short wavelengths, is used for the measurements of high-temperature surfaces. For measurements of low-temperature surfaces, the detection instrument of infrared radiation must be sensitive to longer wavelengths since the greatest amount of the radiant energy is concentrated in this area.

The purpose of the optical system is to collect and focus the incoming infrared radiation from the sensor with the minimal possible transmission loss. The infrared radiation, after passing the optical system is focused on the sensitive area of the sensor. The sensor converts the infrared radiation into an electrical signal that requires to be amplified and modulated/transformed/converted into a final temperature indication/reading.

Emissivity ability. The characteristics of the materials, especially with respect to the ability of the materials to absorb, transmit or reflect infrared radiation, lead to the emissivity ability of the materials.

The emissivity ability of the materials, which are to be thermographed, used in the construction of the buildings is:

plaster: 0,910

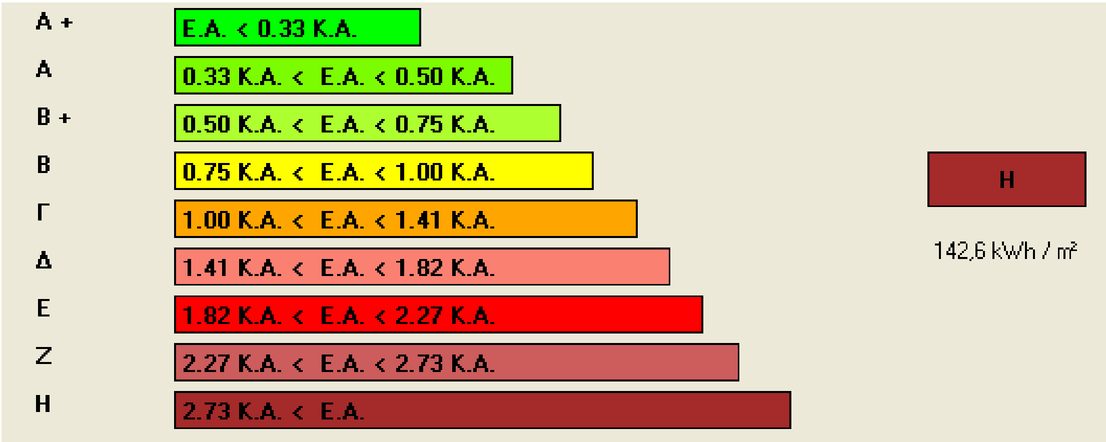
bricks: 0,930

glass: 0,940

marble: 0,930

colours: 0.920 to 0.960

After a complete study of the building the results and the energy classification of the building is



The optimum building must have 33,6 kWh/m2

A zero emission building is placed in classification category A+.

MEASURES TO IMPROVE ENERGY EFFICIENCY

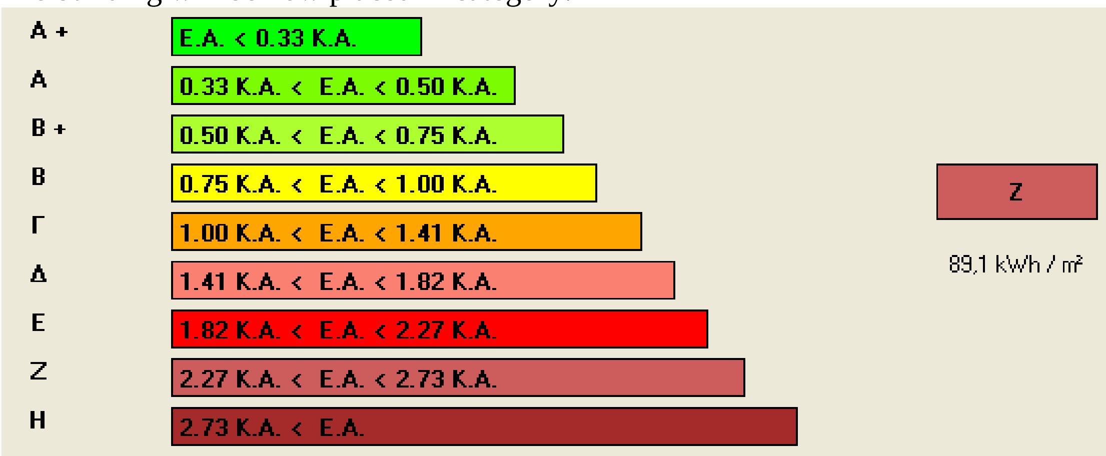
After reviewing the analyzed heat losses and energy requirements of the building the following measures to improve the energy efficiency of the analyzed building were proposed.

First case scenario: Smart Solution Study-

Replace the window frames with synthetic ones and with U=1.3 W/m2K
Glass panel: four season glass fulfilled with argon.

$$\boldsymbol{I}\,.\,\mathbf{2}\ [MKD] = 3.044.250{,}00\ [MKD]$$

The building will be now placed in category:



The optimum building must have 33,6 kWh/m2

By replacing the windows we not only gain from the new improved U of the building but also from the air penetration into the building , as an example we can see that with wooden window frames and with simple glass plane we have a penetration of 5.6m3/h per square meter of glass plane.
If we have a synthetic window frame with four season glass we have a 6m3/h per square meter of glass plane.

The investments to replace the glass in the plastic window framing according to the specifications of the joinery are for the complete works – removal of the existent framework, procurement and installation of the new windows complete with patchwork of the damaged parts of the wall as well as placing supporting boards on both the interior and exterior under the windows. .

Simple period of return of investment

$$EPV2 = \frac{I\,2}{N} = \frac{3.044.250{,}00}{250000{,}0} = \mathbf{12years}$$

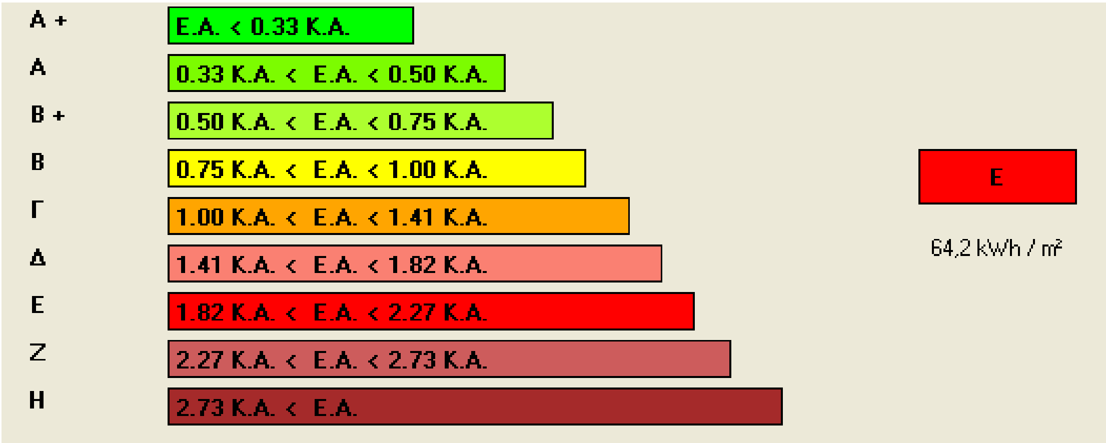
$I2$ $[МКД]$ – Financial investments
$N2$ $[МКД]$ – Monetary gain from the realized measure

From this change only we gain up to 35% less petrol energy

Second case scenario:

Place external isolation of 10cm width with λ=0.035W/mK the U of the wall will be now be equal to 0.32W/m2K (total surface of walls is 2175 m2)

The building will be now placed in:



The optimum building must have 33,6 kWh/m2

The thickness of the insulation - δ for the elements of the cover is calculated using the following formula:

$$\delta = \frac{(U_p - U_m) \cdot \lambda_{iz}}{U_p \cdot U_m} \quad (m)$$

U_p – Heat transference coefficient for the existing state (W/m^2K)- 0.82
U_m – Heat transference coefficient for the new existing state following measurement (W/m^2K)-0.35
λ_{iz} – Conduction coefficient for insulation $(W/m\ K)$-0.04

The calculated thickness of the insulation is: 0.065м- we acknowledge 8см

The investments amount to

$$\boldsymbol{I}.\mathbf{1}[MKD] = \mathrm{A}_{zid} \cdot c_{iz} = 2175.0\mathrm{x}1200{,}0 = 2.675.250{,}00[MKD]$$

$A\ (m^2)$ –Surface area of the barrier elements -2175,0m2
$C(MKD/m^2)$ – Specific price of the works (procurement and installation of Styrofoam, complete with finishing works on the wall on the inside) 1.200,00mkd

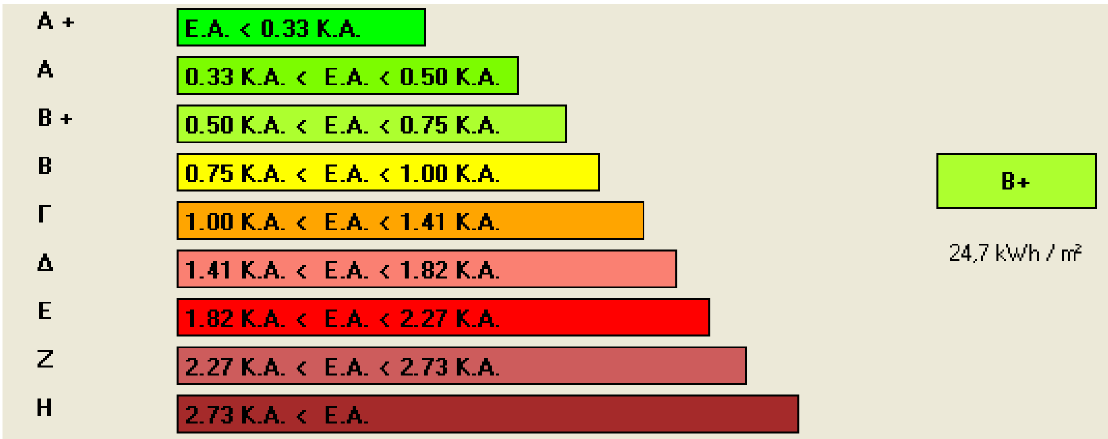
Simple period of return of investment

$$EPV1 = \frac{I\,1}{N} = \frac{2.675.250{,}00}{125.000{,}00} = \mathbf{22}\boldsymbol{years}.$$

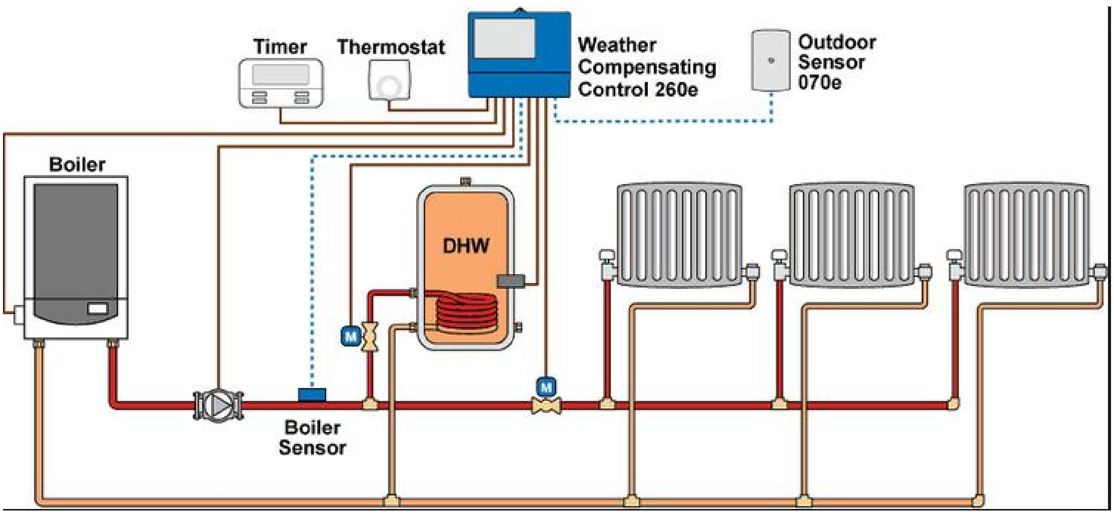
$I1\ [MKD]$ – Financial investments
$N1\ [MKD]$ – Monetary gains from the realized measure

Third case scenario:
Setting the boiler into a new operational place (smaller than the one of 2000 Mcal/h, like 700 Mcal/h) and install a compensation system in the heating boiler.

The building will be now placed in:



The compensation system is presented below:



Third case scenario:
Setting the boiler into a new operational place (smaller than the one of 2000 Mcal/h, like 700 Mcal/h) and install a compensation system in the heating boiler.

Investments amount to

$$\boldsymbol{I}.5[MKD] = C = 1.250.000,0[MKD]$$

$C(MKD) -$ Procurement and installation of a boiler with the required installation with armaflex insulation 9мм, complete with joining material

Simple period of return of investment

$$EPV5 = \frac{I\,5}{N} = \frac{1.250.000,00}{255.000,00} = \mathbf{5\ years}$$

$I.5\ [MKD] -$ Financial investments
$N.5\ [MKD] -$ Monetary gain from the realized measure

When the outdoor temperature is lower than -15°C the flow temperature must be lower than 80°C. As an example if the outer temperature is 5°C and we need to be heated in the room than the boilers temperature must be equal to 60°C which means that the boiler is saving 25% of petrol energy.

CALCULATION OF THE INVESTMENTS

Assessing the results of the application of the planned measures is in accordance with the investments, the energy savings, the period of return of the investment and reducing CO2 emissions. The table below has each proposed measures displayed in detail including the investments and their periods of return.

M. nr	**Title and description**	**Energy/water savings (kWh/год, m^3,t)**	**Monetary savings (mkd/year)**	**Required investments (mkd)**	**Investment return period (years)**	**Reductions in CO2 emissions (CO2/year)**
1	Replacement of windows	5.000,0t	255.000,00	3.044.250,00	12	/
2	Insulation – wall	2.500,0t	125.000,00	2.675.250,00	22	/
3	Replacement of boiler	5.000,0t	255.000,00	1.250.000,00	5	/

PROPOSITION PLAN TO CONDUCT THE MEASURES FOR IMPROVING ENERGY EFFICIENCY

The measures to improve energy efficiency can be divided into measures that are to be realized in one phase or in stages and are regarding the savings of final energy required to heat the building.

Plan to conduct the measures for improving energy efficiency				
Nr.	**Description of the activity**	**Planned start of the implementation measures**	**Planned finish of the implementation measures**	**Notes**
1	Replacement of joinery	15.08.2014	15.10.2014	
2	Installation of insulation on the building's exterior – walls, roof and floor	15.06.2015	20.08.2015	
3	Insulation of the heating pipes in the basement and boiler room	15.06.2014	10.08.2015	

The measures to further improve the energy class of the building should treat investments into renewable energy sources, but considering that the building operates in a single shift, (five days a week, 50 weeks a year or 2000 hours/year), i.e. 1000hours/year in the heating season, such investments are not profitable and are not recommended.

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