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Research Article

Investigation of Methods to Increase Energy Efficiency in Old Buildings: A Case Study on a School Building Constructed in 2007

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ABSTRACT

In this study, the energy efficiency study of the school building whose construction was completed in 2007 was conducted. First of all, information about energy consumption and the amount of CO_2 emission released into the atmosphere was obtained by measuring the building elements, heating system, piping and lighting system. Afterward, some suggestions were made in the areas where energy consumption is high and inefficient, in line with efficiency-increasing methods, considering the relevant standards and regulations. Finally, with these proposed improvements, the energy savings of the building, the economic value of this savings and the reduction in carbon emission are calculated. As a result of the study, 65.04 kWh/m^2 energy and 0.012 tonCO_2/m^2 carbon emission savings per unit area, 334 379 kWh/year energy and 66.18 tonCO_2/year carbon emission savings, the investment cost of 319 653 TL as 65.2 TL/m2 per unit area., and 6.1 years payback period was calculated.

Keywords: *Old buildings, energy efficiency, energy saving, CO_2 emissions, environment*

Eski Binalarda Enerji Verimliliğini Artırma Yöntemlerinin Araştırılması: 2007'de İnşa Edilen Bir Okul Binası Üzerine Bir Vaka Çalışması

ÖZ

Bu çalışmada 2007 yılında inşaatı tamamlan okul binasının enerji verimliliği etüdü gerçekleştirilmiştir. İlk olarak, yapı elemanları, ısıtma sistemi, boru tesisatı, aydınlatma sistemi üzerinde ölçümler gerçekleştirilerek enerji tüketimi ve atmosfere bıraktığı CO_2 emisyon miktarı hakkında bilgilere ulaşılmıştır. Sonrasında binada enerji tüketiminin fazla ve verimsiz olduğu bölümlerde, ilgili standart ve yönetmelikler de göz önünde bulundurularak verimlilik artırıcı yöntemler doğrultusunda birtakım öneriler sunulmuştur. Önerilen bu iyileştirmeler ile binanın enerji tasarrufu, bu tasarrufun ekonomik değeri ve karbon emisyonundaki düşüş hesaplanmıştır. Çalışma sonucunda; birim alan başına 68.24 kWh/m^2 miktar enerji ve 0.0135 tonCO_2/m^2 miktar karbon emisyon tasarrufu ile 334 379 kWh/yıl miktar enerji ve 66.18 tonCO_2/yıl miktar karbon emisyon tasarrufu, birim alan başına 65,2 TL/m^2 olmak üzere 319 653 TL yatırım maliyeti ve 6,1 yıl geri ödeme süresi hesaplanmıştır.

Anahtar Kelimeler: *Eski binalar, enerji verimliliği, enerji tasarrufu, CO_2 emisyonları, çevre*

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I. INTRODUCTION

The effect of petroleum originated fuel prices on macroeconomy is a popular topic in the economy [1]. Today, fossil fuels such as oil and natural gas still dominate global energy consumption. Energy consumption in buildings accounts for approximately 40% of global energy consumption and contributes about 30% to global CO_2 emissions [2]. In addition, it is predicted that the energy consumption in buildings will increase by approximately 1.5-2.4% annually until 2040. Therefore, it is critical to reducing energy consumption and CO_2 emissions in buildings [3], [4]. Energy consumption rates have paved the way for many studies to improve energy efficiency in buildings worldwide. In particular, studies on materials used in the construction of buildings, the use of thermal insulation materials and reflective paints, energy optimization and life-cycle analysis, research of energy efficiency areas for the renovation of existing buildings, optimization of heating, ventilation and air conditioning (HVAC) systems and lighting system management were intensified in recent years [2], [5]. In this context, Turkey aims to reduce energy intensity (energy consumed per national income) up to 2023, by at least 20% compared to the last 12 years by the Energy Efficiency Statute in 2007. In 2017 Turkey Statistical Institute (TSI) announced 9.1 million buildings and 22 million households in Turkey [6]. Accordingly, it is possible to save a high amount of energy by increasing energy efficiency in buildings. For this purpose, many studies have been carried out on reducing energy consumption in buildings. For instance, in a faculty building, Kırbaş showed that 4646 fluorescent lamps at 18W power and 686 luminaires with 8W are replaced with 8W LED fluorescent, and 5.5W LED bulbs, 3 154 006 kWh energy will be saved [7]. Ertürk et al., evaluated the optimum insulation thickness, total cost, payback period and energy savings according to fuel type in case the outer shell of the building is insulated with EPS, XPS and rock wool. They stated that approximately a 79% reduction in flue gas emission with this insulation could be achieved. In addition, he noted that the emissions per person in a 100 m^2 uninsulated house are 3483 kg CO_2 and 7 kg SO_2, and in an insulated house, 826 kg CO_2 and 5 kg SO_2, respectively [8]. Gürel and Daşdemir calculated optimum insulation thicknesses and energy savings according to heating and cooling loads in their study in four cities located in different climatic zones. They also showed that energy savings vary between 32.91 TL / m^2 and 58.28 TL / m^2 depending on the city [9]. Daşdemir determined the optimum insulation thickness in Ardahan by using XPS insulation material and three different fuel types. In addition, he investigated the effect of air gaps left in-wall components on energy saving, CO_2 and SO_2 emissions. As a result, they observed that 4 cm of air space left in the building component provided 81% energy savings and also reduced flue gas emissions by 80% [10]. Haksevenler et al. investigated the carbon footprint arising from housing, business, public buildings and transportation in a pilot area. As a result of the research, the carbon footprint consists of 43% residences, 35% commercial and public buildings [11]. Lanzarote et al. Analyzed the effect of insulating the exteriors and roofs of 324 uninsulated houses built in the '60s in Alicante, Spain and adding a new window on the existing windows on energy efficiency and greenhouse gas emissions. After the facade improvements, a 14% decrease was observed in the cooling demand, while a 45% decrease was observed in the heating demand. It was found that with the improvement of window and roof insulation, there was a decrease of approximately 20% and 13% in the heating and cooling demand, respectively. In total, 52% energy savings were achieved, while a 47% reduction was achieved in CO_2 emissions by 322 tCO_2 / year [12]. However, when the researches are examined, it is seen that energy studies in buildings focus on one or several areas. There is no study in which all heating, air conditioning, thermal insulation, the electricity consumption of buildings are addressed.

II. MATERIALS AND METHOD

This study consists of determining the current state of energy management of a building, examining the building elements, heating system, lighting system, pipelines, presenting improvement suggestions and determining the amount of savings of a building was completed in 2007 in Karabük/TURKEY.

A. ENERGY MANAGEMENT

Energy management aims to utilize waste energy, increasing energy efficiency and minimizing energy losses. In addition, it ensures that energy consumption is minimized without hindering economic development and social welfare and without reducing quality and performance. In this context, the consumption values created according to the electricity and natural gas bills of the last three years for the building under investigation are listed in Table 1 regarding kWh and TEP.

Table 1. *Electricity and natural gas consumption values by years.*

Years	Consumption type	Quantity	Unit	TEP	Total *(%)*
2018	Electric	3 7812.6	*(kWh)*	3.26	7.9
	Natural Gas (Heating)	4 6182	*(Sm^3)*	38.1	92.1
	Total	41.36 *TEP*			
2017	Electric	43 427.9	*(kWh)*	3.7	10.6
	Natural Gas (Heating)	37 947	*(Sm^3)*	31.3	89.4
	Total	35 *TEP*			
2016	Electric	37 665.11	*(kWh)*	3.24	7.9
	Natural Gas (Heating)	45 812	*(Sm^3)*	37.8	92.1
	Total	41.04 *TEP*			

As seen in Table 1, most of the energy consumed in our current building, approximately 90%, is used in the heating system as natural gas.

B. STRUCTURAL ELEMENTS

The building subject to examination consists of 3 blocks in total. Block A is a single-story building with an 850 m^2 floor space and 9 m floor height to serve as a sports hall. There are dressing rooms, backstage volumes, and sinks. B and C blocks have a total floor area of 1 250 m^2 and B Block 19.7 m, C Block 10.2 m eave height. There is a boiler room, cafeteria and warehouses on the basement floor. The ground and upper floors consist of classrooms with an average area of 50 m^2, administrative units, music class, painting class, science laboratories, conference hall and washbasins. The building consists of approximately 4 900 m2 closed areas, and its total closed volume is about 16 065 m^3. The structure is reinforced concrete, and the total horizontal length of the beams in contact with the outside air in the x plane is 36.2 m. There is a 2 cm thick interior and exterior plaster on 20 cm brick on the outer wall. Approximately 18% of the 4 heat-losing facades of the B and C blocks, where the classrooms and administrative sections are taken as reference in the calculations, consisting of windows and doors, and 19% consists of reinforced concrete. Information on the building elements of the building is summarized in Table 2.

Table 2. *Area table results of building elements.*

Structural Element	School Building (B and C Block) *(m^2)*	Sports Hall (A Block) *(m^2)*
Brick wall	1507	824.4
Reinforced concrete wall	456.3	118.4
Soil contact flooring	275	850
Floor facing the unheated interior	975	-
Window	406.63	69.784
North	163.8	69.784
South	164.29	0
East	14.28	0
West	64.26	0
Door	17.25	0
Unused roof	1250	850

The roof of the sports hall was built with steel construction, and no heat insulation was applied. The sports hall is not included in the calculations since it is not operated continuously and is not air-conditioned depending on the central hot water boiler system. To determine the conformity of the building to TS 825 standards, the thermal conductivity coefficients of each building element were calculated using the SDL200 type indicator temperature meter calibrated by the Turkish Accreditation Agency (TÜRKAK). While T1 and T4 data from the four-probe outputs in the device give the external and internal temperatures, T2 and T3 data provide the structural element's external and internal surface temperatures. Probe connections during the measurement can be seen in Figure 1.

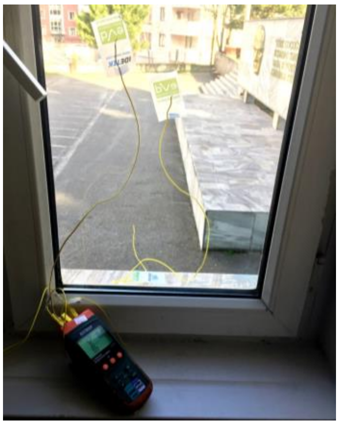


Figure 1. *Temperature measurements in windows.*

The total heat transfer coefficient U (W/m^2K) of a building component is shown in Equation 1. Here, R shows the thermal conductivity resistance of the building components, Ri shows the thermal conduction resistance of the inner surface and R_e the outer shell. In Equation 2, it is stated that the thermal permeability resistance R is found by summing the d_n (m) and λ_k (W/mK) parts of the individual thicknesses of each structural element to the thermal conductivity values [13].

$$\frac{1}{\mathrm{U}} = (R_i + R + R_e) \tag{1}$$

$$R = \left(\frac{\mathrm{d1}}{\lambda \mathrm{k1}} + \frac{\mathrm{d2}}{\lambda k2} + \cdots + \frac{\mathrm{d3}}{\lambda k3}\right) \tag{2}$$

The heat flux q̈ is calculated by Equation 3. Here T_i refers to indoor temperature, T_d refers to outdoor temperature [14].

$$\ddot{q} = U(T_i - T_d) \tag{3}$$

Since the heat transfer from the indoor air to the wall is equal to the heat transfer from the wall to the outdoor air, Equation 4 is used in the heat flux calculation. Equation 5 is obtained using Equations 1-4 to calculate the temperature difference between indoor and outdoor environments [14].

$$(\mathrm{T_i} - \mathrm{T_d}) = \ddot{\mathrm{q}}\left(\frac{1}{\mathrm{hi}} + \frac{\Delta \mathrm{x}}{\mathrm{k}} + \frac{1}{\mathrm{hd}}\right) \tag{5}$$

The heating system's heat energy to the indoor environment is expressed in Equation 6 monthly [13]. It is shown in Equation 7 that there is an annual heating energy requirement by summing up the monthly heating energy needs covering the heating period. Where *H* is the specific heat loss of the building (W / K), θ_i monthly average internal temperature (°C), θ_e monthly average external temperature (°C), η monthly average usage factor for earnings, $\Phi_{i,m}$, monthly average internal gains (W), $\Phi_{g,m}$, month means monthly average solar energy gains (W), and t denotes time (s) [15], [16].

$$Q_{ay} = [H\,(\theta_i - \theta_e) - \eta\,(\phi_{i,m} + \phi_{g,m})]\,.\,t \tag{6}$$

$Q_y = \sum Q_m$ (7)

The amount of carbon dioxide emission E ($tonCO_2$ / year) and fuel consumption FC (tj / year) is calculated with Equations 8 and 9. Here, EF CO_2 emission factor ($tonCO_2$ / tJ) means FA fuel amount (kg / year or m^3 / year) and LCV expresses low calorific value (kcal / kg or kJ / m^3) [17], [18].

$$E = FC \times EF \quad (8)$$

$$FC = FA \times LCV \quad (9)$$

C. HEATING SYSTEM

Two different systems provide heating in the building. In the teaching building where classrooms and administrative departments are located, the AKC3-500 type Alarko branded liquid/gas-fueled hot water boiler with a capacity of 500 000 kcal / h is operated continuously the months when it is needed to be heated. Hot water is provided by the circulation pumps in the boiler room. Thermal losses are reduced by insulating the central distribution system. However, since the valves in the installation do not have insulation jackets, heat losses occur. The boiler layout is given in Figure 2.

Figure 2. *Existing hot water boiler.*

Boiler feedwater is used directly from the network without softening and preheating. There are two circulation pumps, one of which is backup, to distribute the heated water in the boiler. The system is commissioned only in winter months when there is a need for heating. The catalog information of the boiler is given in Table 3.

Table 3. *Liquid/gas-fired hot water boiler technical features.*

Brand	**Alarko**
Type	AKC3-500
Capacity	500 000 Kcal/h
Capacity	582 kW
Operating pressure	3.0 bar
Operating temperature	90 ºC
Production year	2010
Category	B_{23}
Serial number	1732
Origin	TR

To determine the efficiency of the combustion in the boiler, MRU brand Optima 7 series flue gas analyzer and flue gas temperature probe were used. Flue gas measurements are shown in Figure 3.

Figure 3. *Flue gas analysis probe connection point.*

While measuring flue gas, it is necessary to wait for the boiler to come to stable operation at total capacity. When the flue gas temperature probe is placed at the sampling point, the effects of disrupting the waste gas flow are avoided. Care has been taken to keep the probe within the radius of the chimney on the straight line to get accurate measurements. To record the values such as gas temperature, air temperature, CO_2 amount in the analyzer, the measurement results on the analyzer screen were expected to reach a fixed value.

Equations 13-15 were used for the calculation of heat loss on the boiler surface. Here Q is the heat loss (W / m), U_c convection heat transfer coefficient (W / m^2K), Ur radiation heat transfer coefficient (W / m2K), Ts surface temperature (K), Ta ambient temperature (K), d1 pipe the outer diameter (m), A is the surface area (m^2), B is the multiplication factor. The multiplication factor for vertical surfaces is 1.45 [19].

$$Q = (U_C + U_r)xAx(T_S - T_a) \quad (13)$$

$$U_C = Bx(T_S - T_a)^{0,25} \quad (14)$$

$$U_r = 5{,}67xEx[(T_S/100)^4 - (T_S/100)^4]/(T_S - T_a) \quad (15)$$

Equations 16 and 17 are used to calculate the heat loss after insulation on the flat surface used on the boiler surface. Here Ts is the surface temperature (K), Ta is the ambient temperature (K), Ri is the thermal resistance of the insulation material (m^2K / W), Rs is the thermal resistance of the surface (m^2K / W) [19].

$$Q = Ax(T_S - T_a)/\sum \mathrm{R} \quad (16)$$

$$\sum R = R_i + R_S \quad (17)$$

D. PIPELINE SYSTEM

There is only plumbing and heating installation in the building. The boiler hot water return regime operates at 90/70°C. Insulation was applied to the distribution line in the boiler room. However, there is no insulation in the auxiliary equipment in the system. Therefore, 60 cm high cast radiators are used in the spaces. For efficiency calculations, the boiler outlet, hot water distribution line, hot water collection line and radiators were imaged with Fluke brand Ti 10 type M101013 serial numbered thermal imager. Since one of the pumps is out of order, it was disassembled from the system, and its place was left empty.

Equation 18-20 is used in the calculation of heat losses in uninsulated pipe systems. Here Q is the heat loss (W / m), U_c convection heat transfer coefficient (W / m^2K), U_r radiation heat transfer coefficient (W / m^2K), T_s surface temperature (K), T_a ambient temperature (K), d1 pipe the outer diameter (m), E refers to the emissivity coefficient [19].

$$Q = (U_C + U_r) x \pi x d_1 x (T_S - T_a) \tag{18}$$

$$U_C = 1{,}15x[(T_S - T_a)/d_1]^{0.25} \tag{19}$$

$$U_r = 5{,}67x10^{-8} x E x \left(T_S{}^2 + T_a{}^2\right) x (T_S + T_a) \tag{20}$$

The equation used in calculating heat loss in insulated pipe systems is given in Equation 21. Here, d2 refers to the outer diameter (m) after insulation, λ refers to the thermal conductivity of the insulation material (W / mK), U_{so} refers to the surface heat transfer coefficient (W / m^2K) depending on the air velocity [19].

$$Q = \frac{\pi\ x\ (T_S - T_a)}{\frac{ln\,(d_2/d_1)}{2\ x\ \lambda} + \frac{1}{U_{SO}\ x\ d_2}} \tag{21}$$

D. LIGHTING SYSTEM

Most of the armature used in the lighting system in the building are fluorescent lamps (Figure 5). There are no photocell lamps in places such as WC that are not used continuously. There is no automation system for lighting in the building. In addition, there is a compensation panel in the building. The number of armatures in the system and their information are given in Table 4.

Table 4. *Armature information of the lighting system*

Armature type	Armature number	Number of lamps in the armature	Total number of lamps
2*40 *W* fluorescent	215	2	430
1*40 *W* fluorescent	142	1	142
C 60 *W*	36	1	144
L 100 *W*	16	1	16
3*40 *W* fluorescent	18	3	54

Lighting intensity in classrooms and corridors was measured with Extech SDL400 light intensity measurement and recording device. The data in the measurement locations were obtained by scanning the device at the height of approximately 90 cm from the ground, as shown in Figure 4.

Since there are reflections in the interior installations, the efficiency method is used when calculating the lighting. When calculating the room illumination efficiency, the room index was calculated by Equation 22. Here, a is the width of the room (m), b is the length of the room (m), and H is the distance (m) between the light source and the working plane [20].

$$k = \frac{axb}{Hx(a+b)} \tag{22}$$

Figure 4. *Measurement of light intensity.*

Faulty applications regarding the positions of the lighting armatures used in the school were observed. The lighting armatures of the first floor are installed on the beams, and the other lighting armatures are placed between the beams. As a result, incorrect positioning is shown in Figure 5b.

(a) ***(b)***

Figure 5. *Location of lighting armatures:* ***(a)*** *1st-floor corridor,* ***(b)*** *Ground floor corridor.*

III. RESULTS AND DISCUSSIONS

A. CONSTRUCTION ELEMENTS

More than one data was taken from each structural element during the measurement, and the arithmetic mean of these temperature data in the calculations is given in Table 5. In Figure 5, one of the values read by the temperature meter with the display while connected to the structural elements is shown.

(a) ***(b)*** ***(c)***

Figure 6. *Temperature measurement:* ***(a)*** *brick wall,* ***(b)*** *reinforced concrete Wall,* ***(c)*** *window*

Table 5. *Temperature measurement values of building components used in calculations.*

Temperature *(ºC)*	**Outdoor Air**	**External Wall**	**Internal Wall**	**Indoor Air**
Brick wall	3.7	5.3	17.2	21.1
Reinforced Concrete Wall	3.8	7.0	15.6	21.1
Window	4.0	8.3	16.1	21.4

The Aerated Concrete Manufacturers Association of Turkey TS825 Thermal Insulation Calculator V 5.0 program was employed to calculate the heat conduction coefficient of other structural elements in the building. The data used in the program are given in Table 6. Using Equations 1 and 2, the program calculated the thermal permeability coefficients of the ground-contact floor, the floor facing the unheated indoor environment and the roofed ceiling as 1.595 W / m^2K, 1.849 W / m^2K, 0.61 W / m^2K, respectively.

Table 6. *Material list of building elements.*

	Building Element Thickness	**Thermal Conductivity Calculation Value**	**Thermal Conductivity Resistance**
	(m)	*(W/mK)*	*(m^2K/W)*
Flooring (Earth Contact)			
Cement mortar screed	0.05	1.4	0.04
Reinforced-Normal concrete	0.5	2.5	0.2
Unreinforced - Normal concrete	0.2	1.65	0.12
Sand, sand-gravel	0.2	2.0	0.1
Flooring (Adjacent to the Non-Heated Indoor Environment)			
Artificial Gems	0.008	1.3	0.01
Cement mortar screed	0.05	1.4	0.04
Reinforced-Normal concrete	0.25	2.5	0.1
Plaster	0.03	0.51	0.06
Ceiling (With Roof)			
Plaster	0.03	0.51	0.06
Reinforced-Normal concrete	0.25	2.5	0.1
Cement mortar screed	0.03	1.4	0.02
Insulation Material	0.05	0.04	1.25

The annual heating energy need of the building was found to be 571 811 kWh when the monthly heating energies were calculated using Equation 6 in the calculation methodology given in the heat insulation rules standard (TS 825) in buildings. Since this value calculated in the existing building is more than the energy requirement limited to 307 163 kWh / year, it has been determined that the thermal insulation values of the building do not comply with the TS 825 standards. Likewise, when the heat demand identity document is issued, it cannot be included in the efficient building class in the energy efficiency index.

Using Equation 9, annual fuel consumption was found to be 1.86 Tj. Here, the lower calorific value of natural gas was taken as 8250 kcal / m^3 and the CO_2 emission factor as 56.1 [21], [22]. Benefiting from Equation 8, the annual CO_2 emission amount was found to be 104.14 tons.

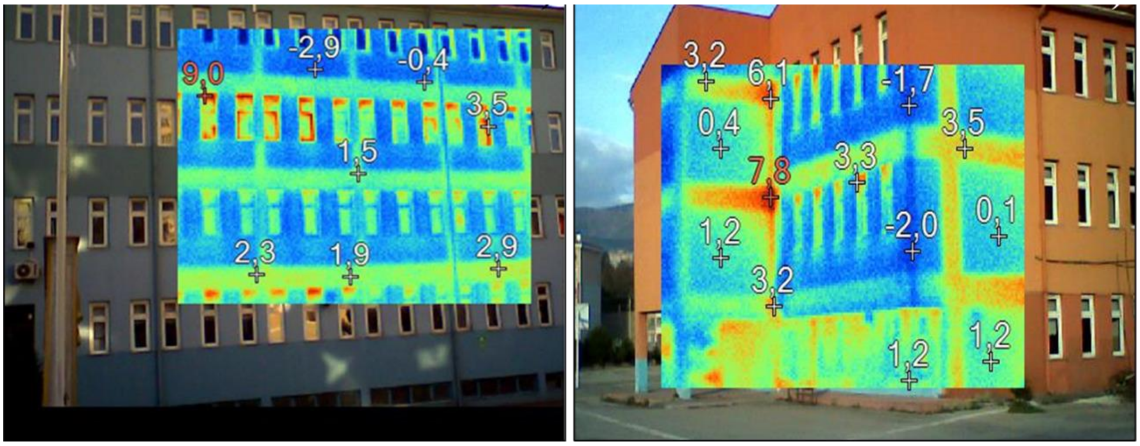
After the thermal imaging performed in the studied building, heat losses from the building surface and bridges are visualized in Figure 7. It is also understood from the surface temperature that the heat loss occurs on the column and beam surfaces, which are made of reinforced concrete and serve as the bearing system of the building, is higher. It is seen in Figure 7b that the temperature value read in columns and beams where convection is intense is higher than other structural elements. The high heat transfer in these areas is the high heat transfer coefficient of the iron reinforcement and concrete in the reinforced concrete regions.

To reduce the annual energy need, which is calculated as 571 811 kWh, it is necessary to improve the insulation on the heat-losing surfaces to the limited energy need. Suppose it is assumed that the heat loss in the uninsulated wall is 100%. In that case, heat loss occurs at 40-60% levels with average heat insulation application and 15-35% when insulation is applied with sufficient status and quality craft [23]. With the correct thermal insulation, energy efficiency increases by 50%, and energy savings are achieved at high rates [24]. Therefore, considering the thermal insulation thickness and craft quality, priority should be given to the building elements with the highest heat loss.

Heat losses in building elements are listed according to Table 7. Although the building element with the highest heat transfer coefficient value is the reinforced concrete wall, the heat loss occurs more in the brick wall and ceiling structural components due to the width of the surface area. Therefore, insulation application should be started from brick and reinforced concrete walls with external air contact. Then, it is predicted that it is more appropriate to perform insulation works on the roof and floors facing the unheated interior.

Table 7. *Distribution of thermal losses and overall heat transfer coefficients according to structural elements.*

Building element	**Surface Area** *(m^2)*	**U** *(W/m^2K)*	**Heat loss** *(W/K)*
Brick wall with external air contact	1507	1.827	2753.29
Roofed ceiling	1250	2.562	2562.00
External weather contact reinforced concrete wall	456.30	2.614	1192.77
Window	406.63	2.500	1016.58
Adjacent base with unheated interior	975.00	1.849	901.39
Ball contact sole	275.00	1.595	219.31
Door	17.25	3.500	60.38



(a) ***(b)***

Figure 7. *Thermal camera measurements:* ***(a)*** *front facade, classrooms block,* ***(b)*** *rear facade, administrative block.*

Leak-proofing should be provided with suitable materials that prevent air passage in buildings, surfaces where heat loss occurs, ventilation gaps, shafts, including joints [24]. The heat loss from inside to outside through infiltration is seen at the window corners in Figure 7a, as the volumes left for windows and doors on the wall do not fully coincide with the window frames. These heat leaks increase energy consumption and decrease energy efficiency.

B. HEATING SYSTEM

The values obtained in the flue gas analysis are listed in Table 8.

Table 8. *Flue gas analysis results.*

Date: 29.03.2019 Time: 08:55:47 Fuel Type: Natural gas	Gas temperature	158.7 *°C*
	Air temperature	17.6 *°C*
	CO_2	10.3*%*
	Loses	6.3*%*
	O_2	3.2*%*
	Pressure	-0.44 *hPa*
	CO	4 *ppm*
	Air ratio	1.18
	Efficiency	93.7*%*
	Excess air	18*%*

In natural gas and LPG fuel boilers, the chimney outlet temperature should be in the range of 130-150 ° C [25]. As a result of the measurements made, the boiler efficiency was found to be 93.7%. Therefore, the operating efficiency of the boiler has been found suitable. It is stated in the catalog information of the Alarko ACK3-500 type hot water boiler that it is produced with body insulation. As can be understood from Figure 8, it has been observed that the temperature is around 95 ° C on the surface where the burner fires and the surfaces where the chimney outlet is located, so it is predicted that the heat loss is high.

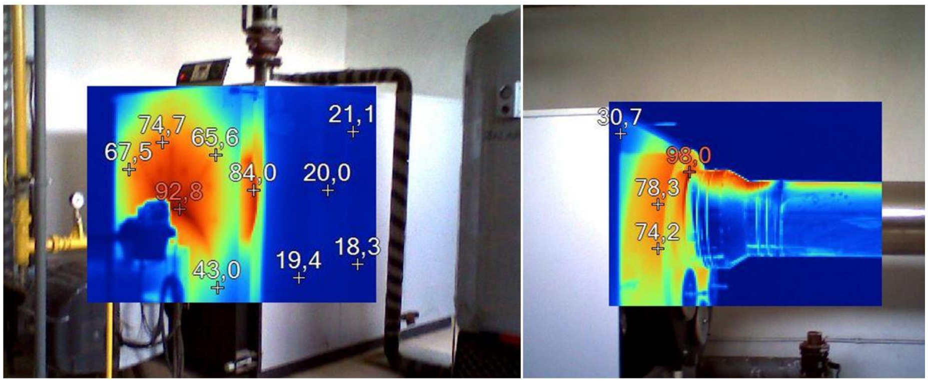


Figure 8. *Hot water boiler temperature distribution.*

The external temperature values are taken from the thermal camera measurements while calculating the heat losses on the front and back surfaces where the boiler insulation is insufficient. An outer surface temperature was obtained by taking the arithmetic average of the temperature values taken from 8 points. While determining the surface area of the boiler walls, catalog data were used. Heat losses occurring at the front and rear walls of the uninsulated boiler were found by using Equation 13-15. In the calculation, the areas of the surfaces are 1.985 m^2. The indoor temperature is 15 ° C. The front wall surface temperature is 71.4 ° C, and the rear wall surface temperature is 77.8 ° C. A total of 1294 W loss is realized, 577.20 W on the front surface of the boiler and 716.76 W on the rear surface. When the system's operating time is 4320 hours, 5 589.9 kWh / year heat loss occurs from surfaces and equipment, and thus, 1.02 tons of CO_2 is released into the atmosphere annually.

C. PIPELINE

The pipes in the main distribution line starting from the boiler outlet are insulated in the heating installation. It is shown in Figure 9 that polyethylene material is preferred as insulation material in pipes, and the application thickness is 1 cm.

Figure 9. *Insulation material and application thickness used in the heating system pipeline.*

In Figure 10, it is seen that the circulation pump is about 70 ° C while the distribution and collection installation is at approximately 30 ° C. At the same time, it is seen that the valves in the distribution collector are not insulated, and the temperature is about 60 ° C.

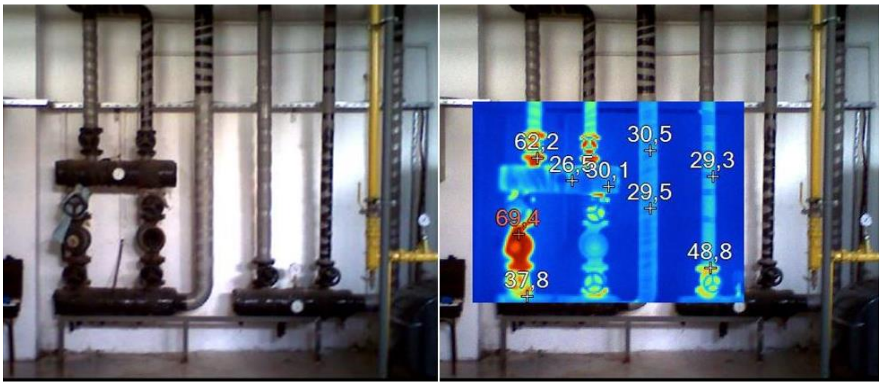


Figure 10. *Thermal images of the heating installation in operating conditions.*

Figure 11 shows the images of the valves at the boiler outlet and connection points. Since the valves are not insulated, it has been observed that the temperature values are around 65 ° C. Considering that the indoor temperature is 15 ° C, high heat losses are predicted.

Figure 11. *Thermal images of uninsulated valves.*

There are 5 DN 100, 6 DN80 diameter gate valves and 1 DN 65 strainer in the installation, which does not have insulation and cause excessive heat loss. The equivalent lengths of various fittings and other devices in terms of straight lines are provided in Table 9.

Table 9. *Equivalent pipe lengths of fittings and valves.*

Equivalent pipe lengths of fittings and valves *(m)*							
Fittings and valves	50	65	80	100	150	200	250
90° standard threaded elbow	1.5	1.9	2.4	3.0	4.3	5.7	7.4
90° welded elbow (r/d =1.5)	0.69	0.88	1.1	1.4	2.0	2.6	3.4
45° elbow	0.76	1.0	1.3	1.6	2.3	3.1	3.9
Te (90 ° turn in flow)	2.9	3.8	4.8	6.1	8.6	11.0	14.0
Gate valve	0.38	0.51	0.63	0.81	1.1	1.5	2.0
Alarm or check valve (swing type)	2.4	3.2	3.9	5.1	7.2	9.4	12.0
Alarm or check valve (mushroom type)	12.0	19.0	19.7	25.0	35.0	47.0	62.0
The butterfly valve	2.2	2.9	3.6	4.6	6.4	8.6	9.9
Globe valve	16	21	26	34	48	64	84

The total heat lost from uninsulated installation equipment is 2447.43 W. When the system's operating time is 4320 hours, 10572.91 kWh / year heat loss occurs from uninsulated equipment. With this heat loss, 1.92 tons of CO_2 is released into the atmosphere annually.

Installation insulations that seem insignificant in buildings are essential savings resources. Regardless of whether the purpose of the fluid in the installation is heating or cooling, insulating it to prevent heat transfer without being affected by external environment conditions provides energy savings and contributes to the environment's protection. Insulation of the installation equipment without insulation at appropriate thickness will prevent heat loss to a great extent.

D. ELECTRICAL SYSTEM

As a result of the lux measurements made in the ground floor and first-floor corridor, it was determined that the average illuminance level was around 55 lx and 115 lx, respectively. The most important reason for the low level of illumination on the ground floor compared to the first floor is that the luminaires in the ground floor corridor (Figure 5b) narrow the angle of light due to the beams running along the corridor, which are 50 cm high and cross the corridor.

Current luminaires, working periods and annual consumption are listed in Table 14 according to floors. Fluorescent lamps of 1 * 40 W are used in the corridors, 2 * 40 W in classrooms and 3 * 40 W in optional classes. There are 6 armatures in a classroom. The working times of the luminaires have been evaluated based on the direction of the classes, between classes, entry and exit times and seasons. As shown in Table 10, the annual energy used by the building for lighting is 32 179.2 kwh. Therefore, lighting has an essential share in the electricity consumption of the building. CO_2 emission is calculated by multiplying the estimated annual consumption amount by the emission factor of 0.472 kgCO_2 / kWh [26]. Thus, the CO_2 emission resulting from the building's lighting system is 15 188 tons of CO_2 / year.

Table 10. *Building lighting usage and consumption information.*

	Armature Type	**Armature number**	**Number of lamps in the luminaire**	**Total lamp number**	**Operating time** *(hour/year)*	**Annual energy consumption** *(kWh/year)*
Basement	2*40 W fluorescent	42	2	84	360	1 209.6
	1*40 W fluorescent	10	1	10	360	144
	C 60 W	4	1	4	1440	345.6
	L 100 W	16	1	16	0	0
Ground floor	1*40 W fluorescent	40	1	40	600	960
	2*40 W fluorescent	24	2	48	1440	2764.8
	3*40 W fluorescent	18	3	54	1440	3110.4
	C 60 W	8	1	8	270	129.6
1st floor	1*40 W fluorescent	20	1	20	540	432
	2*40 W fluorescent	79	2	158	1440	9100.8
	C 60 W	8	1	8	270	129.6
2nd floor	1*40 W fluorescent	16	1	16	540	345.6
	2*40 W fluorescent	56	2	112	1440	6451.2
	C 60 W	8	1	8	270	129.6
3rd floor	1*40 W fluorescent	16	1	16	540	345.6
	2*40 W fluorescent	56	2	112	1440	6451.2
	C 60 W	8	1	8	270	129.6
	Total					32 179.2

IV. RECOMMENDATIONS

A. CONSTRUCTION ELEMENTS

As a result of the calculations, the annual heating energy need for the building was calculated as 571 811 kWh. This value is approximately 1.8 times greater than the energy need, which is limited to 307.163 kWh.

It is essential to insulate the reinforced concrete and brick walls with external air contact, where the heat loss occurs the most. They are the building elements that are also primarily effective in increasing the heating energy need. In addition to these building elements, the suggestion of renewal of the roof insulation, which has been deformed and lost its insulation feature, and the application of insulation for the floor facing the unheated interior environment was evaluated. Insulation thicknesses are selected in accordance with the climatic conditions of Karabük province to comply with the TS 825 standard.

The theoretical analysis of covering the specified building elements with insulation materials in accordance with standards has been made. Technical features of the materials to be used in insulation are given in Table 11.

Table 11. *Technical characteristics of insulation materials.*

Construction element	**Material**	**Thickness** *(cm)*	**Density** *(kg/m³)*	**Heat conductivity** *(W/mK)*
Brick wall	Rock wool	6	250	0.035
	Plaster	1	900	0.35
Reinforced concrete wall	Rock wool	6	250	0.035
	Plaster	1	900	0.35
Roofed ceiling	Rock wool	12	250	0.035
Base facing the unheated interior	EPS	6	25	0.030
Earth contact base	EPS	5	25	0.030
	Handle	3	2 000	1.6

In line with the information given in Table 11, the U thermal permeability coefficient values were found in the insulated state of the building elements by using Equations 1 and 2. The thermal permeability coefficient value of the outer air contact brick wall is 0.437 (W / m^2K), the thermal permeability coefficient value of the outer air contact reinforced concrete wall is 0.471 (W / m^2K), the roofed ceiling thermal permeability coefficient value is 0.262 (W / m^2K), the soil contact floor thermal The permeability coefficient value was calculated as 0.432 (W / m^2K) and the thermal permeability coefficient value of the floor facing the unheated indoor environment as 0.394 (W / m^2K). When the data is entered into TS825 Thermal Insulation Calculation Program V 5.0, the annual heating energy need of the building is calculated as 268 250 kWh and the allowed annual heating energy as 307 163 kWh. When the recommended insulation improvements are made, since the calculated heat requirement for the building is lower than the limited energy requirement (Q <Q '), the thermal insulation project for this building has been determined in accordance with the TS 825 standard. By using Equation 8, the CO_2 emission realized in the improved building with insulation in accordance with the recommendations, and the annual CO_2 emission amount was found to be 48.85 tons.

In the proposed insulation improvements, an average cost of 243 660 TL was deducted according to the offers received from the market. Considering that the school building is 4900 m^2, the cost per m^2 is calculated as 49.72 TL/m^2. The building elements, insulation material, application thickness and surface area, unit price and total prices are given in Table 12. Shipping, auxiliary products (plaster, paint, adhesive, etc.) and labor prices are included in the unit prices shown.

Table 12. *Insulation application cost list (in2019).*

Construction element	**Insulation material**	**Thickness** *(cm)*	**Surface area** *(m²)*	**Unit cost** *(TL/m²)*	**Total cost** *(TL)*
Brick wall	Rock wool	6	1507	65	97 955
Reinforced concrete wall	Rock wool	6	457	65	29 705
Roofed ceiling	Rock wool	12	1250	50	62 500
Earth contact base	EPS	5	275	35	9 625
Base facing the unheated interior	EPS	6	975	45	43 875
		Total			243 660

The consumption cost of 1 kWh natural gas is 0.105 TL + VAT. It is shown in Table 13 that the payback period of the proposed insulation application is 6.4 years. Labor costs are the main factor in the high calculated period.

Table 13. *Facade ınsulation cost analysis (in2019).*

Facade Insulation Cost Analysis	Cost	Unit
Current state energy consumption	571 811	*kWh/year*
Improved state energy consumption	268 250	*kWh/year*
The amount of energy saved	303 561	*kWh/year*
The amount of savings (including VAT)	37 705	*TL*
Investment cost	243 660	*TL*
Payback Period	6.4	*Year*

B. HEATING SYSTEM

The boiler efficiency in the heating system was determined to be 93.7% after measurements. Considering the insulation of the front surface of the boiler where the insulation is insufficient and the back surface where there is no insulation, the heat losses that will occur with the rock wool insulation material with a thermal conductivity value of 0.035 W / mK are calculated using Equation 16 and shown in Table 14.

Table 14. *The state of insulation of the boiler (in2019).*

Insulation thickness	**Heat loss after insulation**	**Difference**	**Annual fuel cost**	**Unit investment cost**	**Annual Economical Input**	**Investment cost**	**Annual Saving**
(cm)	*(kWh)*	*(kWh)*	*(TL/year)*	*(TL)*	*(TL/year)*	*(TL/year)*	*(TL/year)*
3	1127.62	4462.29	118.697	25	469.72	4.96353	464.753
4	857.53	4732.37	90.2668	29.4	498.15	5.83711	492.31
5	691.824	4898.08	72.824	36.1	515.59	7.16733	508.423
6	579.788	5010.12	61.0306	40.9	527.38	8.12033	519.263
7	498.981	5090.92	52.5246	52.9	535.89	10.5028	525.387
8	437.944	5151.96	46.0996	65.4	542.31	12.9846	529.33
9	390.211	5199.69	41.0751	70.65	547.34	14.0269	533.312
10	351.861	5238.04	37.0382	75.9	551.38	15.0693	536.307
11	320.375	5269.53	33.7238	81.15	554.69	16.1116	538.579
12	294.061	5295.84	30.9539	95.65	557.46	18.9904	538.47
13	271.741	5318.16	28.6045	100.9	559.81	20.0328	539.777
14	252.571	5337.33	26.5865	105.3	561.83	20.9064	540.921
15	235.927	5353.98	24.8345	112	563.58	22.2366	541.343
16	**221.341**	**5368.56**	**23.2992**	**116.8**	**565.11**	**23.1896**	**541.925**
17	208.453	5381.45	21.9426	128.8	566.47	25.5721	540.899
18	196.984	5392.92	20.7353	141.3	567.68	28.0538	539.625
19	186.711	5403.19	19.6539	146.55	568.76	29.0962	539.664
20	177.457	5412.45	18.6798	151.8	569.73	30.1385	539.596

When the fuel cost, investment cost and total costs are evaluated according to the data obtained from Table 14, it is shown in Figure 12 that the optimum insulation thickness for the boiler is 16 cm.

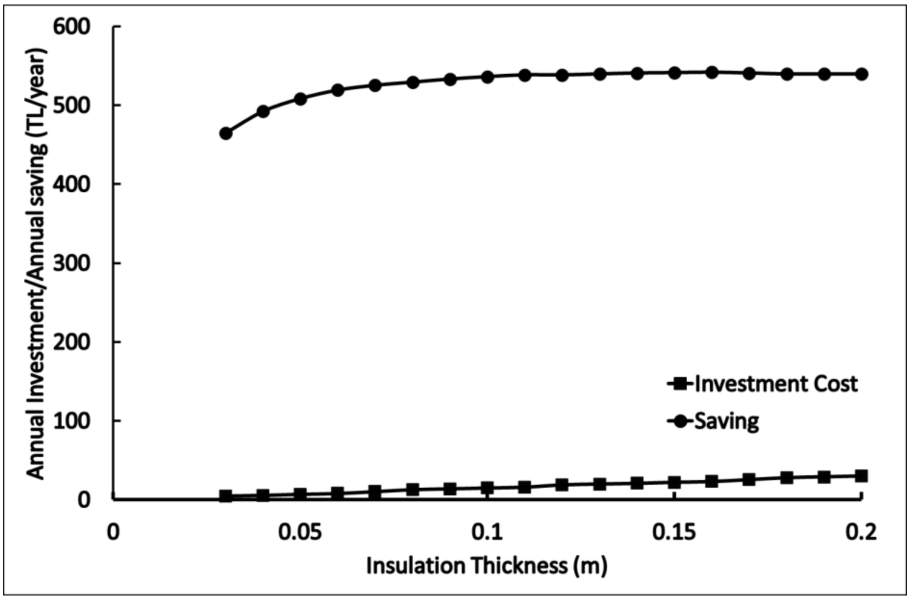


Figure 12. *Optimum thickness in boiler insulation.*

The heat loss from the existing boiler surfaces was found to be 1294 W. In the case of insulation, the heat loss is calculated as 51.24 W. In annual terms, before the insulation was made, only the heat loss on the front and rear surfaces of the boiler was calculated as 5590 kWh. After the insulation is made, the heat loss from the surfaces has been reduced to 221.3 kWh, and the amount of CO_2 emitted to the atmosphere to 0.04. The front surface and the back surface of the boiler do not have sufficient insulation; in Table 15, if the system is insulated with 16 cm thick rock wool with a thermal conductivity coefficient of 0.035 W / mK, the system pays off in 0.4 years.

Table 15. *Boiler Surface Insulation Cost Analysis.*

Boiler Surface Insulation Cost Analysis	**Cost**	**Unit**
Current state energy consumption	5.590	*(kWh/year)*
Improved state energy consumption	221.3	*(kWh/year)*
The amount of energy saved	4732.37	*(kWh/year)*
Saving	565.1	*(TL)*
Investment cost	231.9	*(TL)*
Payback Period	0.4	*(Year)*

C. PIPELINE

It was observed that the leading distribution and collection line in the heating system pipes were insulated, while the valves were not insulated. Therefore, images are given in Figures 10 and 11 by making necessary thermal shots.

Heat losses from uninsulated valves in the installation are 2447.43 W. To minimize the heat losses from the valves, the recommended thermal insulation thicknesses according to the pipe diameters are taken from the values given in Table 16.

Table 16. *Recommended minimum insulation thickness according to nominal pipe diameters.*

DN	**Recommended thickness** *(mm)*
20	20
22	30
35	30
40	Up to nominal diameter
100	Up to nominal diameter
>100	100

The insulation cost of 12 valves has been evaluated with the valve jackets available in the market. The recommended insulation thicknesses for the valves of DN 65 and DN 80 in the installation are the same as their nominal diameters. Valve jackets available in the market are commonly available in two thicknesses as 5 cm and 10 cm, while jackets in other thicknesses are produced as unique designs. The thermal conductivity coefficients of the 5 cm and 10 cm thick valve jacket are 0.044 W / mK and 0.021 W / mK.

Using Table 17 and Table 18, investment costs and annual fuel savings were examined for two insulation thicknesses. As the valve diameter increases, the unit price increases between three and six times. If a 10 cm thick valve jacket is preferred, the investment cost increases to 11 310 TL for 12 valves, while the annual savings increase to 180 TL. In the case of 10 cm insulation to the existing installation valves, the savings achieved is much less than the investment cost. Therefore, it is recommended to apply a 5 cm valve jacket to the valves in the system.

Table 17. *5 cm valve jackets cost analysis.*

Diameter	**Number of valve** (-)	**Heat loss before insulation** (W)	**Heat loss after insulation** (W)	**Unit cost** (TL)	**Total heat loss after insulation** (W)	**Heat loss after insulation** (kWh)	**Annual feul cost** (TL/year)	**Annual Economic Input** (TL/year)	**Annaul investment cost** (TL/year)	**Payback period** (Year)
DN 100	5	2175.3	100.589	335	502.947	2172.73	228.710	760.516	167.5	2.2
DN 80	2	63.2	13.529	300	27.059	116.897	12.305	16.438	60	36.5
DN 80	4	173.2	8.065	300	32.262	139.375	14.671	64.109	120	18.7
DN 65	1	35.6	10.781	275	10.781	46.577	4.902	11.290	27.5	24.3

Table 18. *10 cm valve jackets cost analysis.*

Diameter	**Number of the valve** (-)	**Heat loss before insulation** (W)	**Heat loss after insulation** (W)	**Unit cost** (TL)	**Total heat loss after insulation** (W)	**Heat loss after insulation** (kWh)	**Annual fuel cost** (TL/year)	**Annual Economic Input** (TL/year)	**Annual investment cost** (TL/year)	**Payback period** (Year)
DN 100	5	2175.3	29.9	1575	149.5	645.9	67.992	921.2	7875	8.5
DN 80	2	63.2	6.4	940	12.9	55.8	5.881	22.8	1880	82.2
DN 80	4	173.2	2.4	940	9.8	42.6	4.484	74.2	3760	50.6
DN 65	1	35.6	5.1	855	5.1	22.2	2.343	13.8	1545	111.5

The current heat loss of the valves was found to be 2 447 W. Therefore, the heat loss only from the valves before insulation is calculated as 10 573 kWh in annual terms. In the case of only 5 pieces DN100 insulation, the heat loss is calculated as 573 W, and the heat loss from the other 7 uninsulated valves is 272 W. After the insulation, the heat loss from the valves was reduced to 3348 kWh, and the amount of CO_2 released into the atmosphere was reduced to 0.61 tons.

Unit prices of 12 uninsulated valves of different diameters in the system are given in W and kWh heat losses. Investment costs and savings are calculated and listed in Tables 17 and 18.

D. ELECTRICITY

In the measurements, it was seen that although the window areas in the classrooms are suitable for natural lighting, the classrooms do not have sufficient illumination level due to the regional climatic conditions. Lighting is used intensely during the winter season and in the first lessons in the morning. Natural lighting is not sufficient in the corridors.

The minimum illuminance required in educational buildings is 300 lux in general education areas, 500 lux in libraries and laboratories, 150 lux in corridors and similar regions. In the measurements, the in-class illumination levels were measured between 100 lux and 150 lux, and in the corridors, between 20 lux and 150 lux.

While choosing the luminaire, the selection was made by paying attention to the required lighting intensity, luminous flux and number. Each classroom in the building has an area of approximately 49 m2. There are 9 classrooms, 2 WCs and 1 corridor on the 2nd and 3rd floors. On the ground and first floors, there are classrooms, painting and music class, administrative offices. In Table 19, the data used in the lighting calculation of the classroom, WC and corridor and the calculated luminaire information are given. Equation 22 was used to calculate the K room index.

Table 19. *Lighting calculation parameters.*

Parameter	**Classroom**	**Corridor**	**WC**
Width *(m)*	7	3.7	3
Length *(m)*	7	47	6,5
Area *(m^2)*	49	173.9	19.5
Height *(m)*	2.9	2.9	2.9
Working Surface *(m)*	2.05	2.05	2.05
Room Index *(k)*	1.71	1.67	1
Actual Illumination Intensity *(lux)*	300	150	150
Fixture Type	2 x 19 W	1 x 19 W	1 x 20 W
Luminous Flux *(lumen)*	3550	3550	1900
Room Lighting Efficiency *(%)*	47	46	36
Number of Lights	9	16	4

Since the boiler room and storage in the basement are not used frequently, the armature has not been changed for these volumes. Therefore, in case the fixtures are renewed, 9 luminaires are sufficient for the classrooms. However, since the armatures are positioned in 2 pieces, the calculation was made to have 10 luminaires per classroom. Accordingly, the table of building lighting information given in Table 19 was updated and improved lighting information was shown in Table 20.

Table 20. *Recommended LED luminaire information.*

Location	**Armature**	**Unit power** *(W)*	**Armature number**	**Number of lamps in the armature**	**Total number**	**Operating time** *(Hour/year)*	**Annual energy consumption** *(kWh/year)*
Basement	2*40 W Fluorescent	40	42	2	84	360	1209.6
	1*40 W Fluorescent	40	10	1	10	360	144
	C 60 W	60	4	1	4	1440	345.6
	L 100 W	100	16	1	16	0	0
Ground floor	T8 LED Tupe	19	40	1	40	600	296.4
	T8 LED Tube	19	24	2	48	1440	1094.4
	T8 LED Tube	19	18	3	54	1440	1477.44
	LED Downlight	20	8	1	8	270	43.2
First floor	T8 LED Tube	19	20	1	20	540	184.68
	T8 LED Tube	19	79	2	158	1440	3556.8
	LED Downlight	20	8	1	8	270	43.2
Second floor	T8 LED Tube	19	16	1	16	540	164.16
	T8 LED Tube	19	56	2	112	1440	2571.84
	LED Downlight	20	8	1	8	270	43.2
Third floor	T8 LED Tube	19	16	1	16	540	164.16
	T8 LED Tupe	19	56	2	112	1 440	2571.84
	LED Downlight	20	8	1	8	270	43.2
Total							13 953.72

Currently, 86 % of electricity consumption is caused by lighting with 32 179 kWh. It is seen in Table 21 that it is possible to update to 13 953.72 kWh by using more efficient fixtures with the proposed improvement. With this calculated value, 3.72 kWh / m^2 energy saving is achieved for each unit area. When the annual consumption value is multiplied by the emission factor of 0.472 kgCO_2 / kWh, the yearly CO_2 emission amount resulting from the energy consumed in the improved status lighting is calculated as 6.58 tons / year. In the current situation, the energy consumption of the building due to lighting was calculated as 32 179.2 kWh / year. With these savings of 18 225.48 kWh, approximately 8.6 tons of CO_2 / year and 0.0018 tons of CO_2 / m^2 carbon emission is saved. Considering that the cost of 1 kWh electricity consumption is 0.7148 TL, the energy savings calculated from lighting will save 13028 TL per year for the building.

In case the existing fixtures are replaced with TP15-180-65T-3 type, 19.0 W power and 3550 lumens luminous flux T8 led tubes; A total of 488 T9 led tube luminaires are needed for 76 corridors and canteens, and 412 for use in classrooms and elective course classrooms. 32 recessed LED Downlights with 9502-120 type, 20 W power, 1900 lumens luminous flux is needed to build WC areas. Considering the unit prices, 19 W LED Tube luminaire 21.50 $ / piece, 20 W Downlight 20.0 $ / piece bid was received. While calculating a cost of 12.81 TL/m^2 per unit area, the total investment cost is 62 784.48

TL. ($ 1.00 = 5.64 TL April 2019) It is shown in Table 21 that the payback period is 4.82 years by dividing the investment cost by the savings cost.

Table 21. *Replacement cost analysis of lighting fixtures.*

Replacement cost	Cost	Unit
Current state	32 179.20	*kWh / year*
Improved Condition	13 953.72	*kWh / year*
Energy-saving	18 225.48	*kWh / year*
Energy Saving Cost	13 027.57	*TL / year*
Investment Cost	62 784.48	*TL*
Payback Period	4.82	*year*

Suppose a total of 520 luminaires in the usage areas such as classrooms, corridors, canteens and WCs in the building are replaced with efficient LED luminaires. In that case, the new system will pay for itself in 4.82 years and save the building in the following years. It limited the payback period of efficiency-enhancing projects supported by the Ministry of Energy and Natural Resources to a maximum of 5 years. Taking these 5 years as reference, the calculated payback period of 4.82 years is within the appropriate range for the investment.

V. CONCLUSIONS

Due to climate change and the increase of greenhouse gases in the atmosphere, international action plans on energy efficiency are prepared. Specific regulations limit energy consumption in new buildings. Energy managers or energy management units work in the building and industrial sectors with high consumption. In this study, an education building designed and completed before 2007 has been examined regarding energy efficiency. Total annual energy consumption is 50 TEP, including 46 TEP natural gas and 4 TEP electricity. Within the scope of this study, by considering the departments with high energy consumption, efficiency-enhancing studies have been achieved while saving energy and reducing the CO_2 greenhouse gas emission released into the atmosphere without sacrificing comfort conditions. The results achieved in the study are listed below:

1. When the heating system with the highest consumption was examined, the annual heating energy need of the building was found to be 571 811 kWh. In the measurements made, it was seen that the thermal conductivity values of the building structure elements were above the TS 825 standards. Therefore, when the heat-losing surfaces of the building are insulated, the annual heating energy need is calculated as 268 250 kWh and 54.75 kWh/m^2 per unit area.

2. With this calculated 268 250 kWh energy savings, it has been calculated that 37 705 TL will be saved annually. Considering the average investment cost of 243 660 TL due to the requests for insulation, it is estimated that the system's payback period is 6.4 years.

3. With the insulation made on the building elements facing the unheated environment, 53% of energy was saved and a reduction of 55.28 tons of CO_2 / year and 0.011 tons of CO_2 / m^2 from greenhouse gases emitted into the atmosphere.

4. Valves and non-insulated areas that cause efficiency reduction in the heating installation are insulated with appropriate thicknesses, saving 12 593. 43 kWh / year of energy.

6. A reduction from 2,3 tons of CO_2 / year greenhouse gas emissions was achieved with the valve and heating installation insulation.

8. As a result of replacing the lighting fixtures with economic ones, a 13 028 TL electricity bill was reduced per year. It has been calculated that the luminaires to be used in the system will pay for themselves in 5,6 years.

9. With this electricity saving of 18 225 kWh, 8.6 tons of CO_2 carbon emission was saved annually.

10. This school building, which has 29 classrooms with an average usage area of 50 m^2 each, has been made according to the standards, saving 334 397 kWh / year from consumption.

11. Simultaneously, a reduction of 66.18 tons of CO_2 / year in other words 0.0135 tons of CO_2 /m^2, was achieved in greenhouse gas emissions from the building.

Educational buildings built before 2007 and did not improve renovations are buildings with high potential for increased efficiency. Considering that by saving energy, the rate of external dependency on energy will be reduced, it is predicted that these simple measures will contribute to the national economy.

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