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Calculation of Annual Consumption of Lighting Energy for Five Different Cities and Building Types and a Control System Proposal

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Abstract: The buildings are at the beginning of the constructions where energy is consumed the most with a rate of 40%, when the total energy consumed is considered. For this reason, the "Energy Performance of Buildings Directive" has been established by the European Union to reduce energy consumption rates and CO_2 emissions in buildings and to establish a common methodology. Following this directive, EN 15193 "Energy Performance of Buildings - Energy requirements for lighting" has been published. According to EN 15193 standard, the amount of energy consumed annually is dependent on factors such as daylight, used control system, annual working hours, total installed lighting power. In this study, based on EN 15193 standard, it will be determined which control system is more efficient by calculating the amount of energy consumed per year for five different building types and five different cities and a comparison will be made according to buildings and cities and a proposal will be made.

Keywords: Lighting Energy Saving, Lighting Control Systems, Energy Efficiency in Buildings, Energy Requirements for Lighting, EN 15193

I. INTRODUCTION

Energy efficiency is important for a variety of reasons, such as the global warming that has arisen since today and the reduction of energy reserves. At the beginning of the structures where energy efficiency needs to be provided, buildings have high priority at all of them. When the energy consumption ratios of the buildings are considered in terms of sectoral distribution, it is at the beginning of constructions where energy is consumed most at a rate of 40%. This situation is seen through the graph in Figure 1.

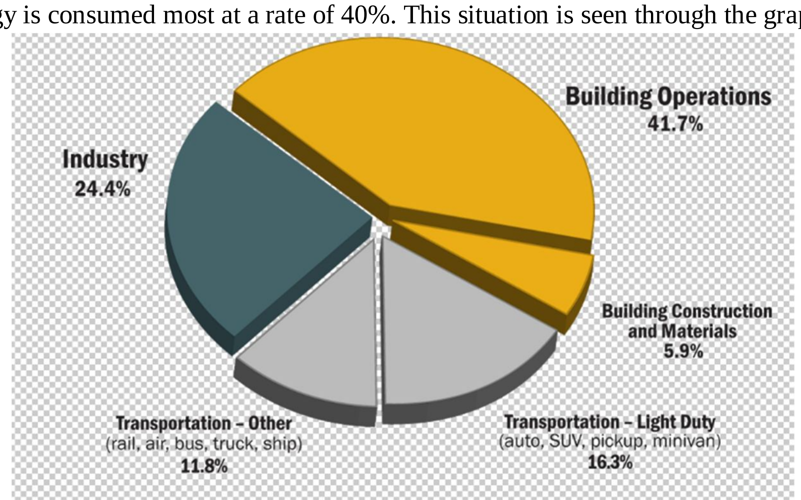

Fig.1 Energy consumption rate of buildings

The most consuming energy systems are HVAC systems when looking at the energy consumption rates of the systems in the building. The energy consumption rates of the HVAC systems in the buildings are 44%. Following these systems, the most consuming energy system is lighting systems. The energy consumption rates of the lighting systems in the buildings are 28%. For this reason, it is important that saving energy in the lighting of the buildings.

The buildings are divided into various types. They are generally divided into commercial buildings and residential buildings [1]. In this study, five different types of buildings will be examined: office, hospital, hotel, school and factory. The reason for the

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examination of five different types of buildings is to analyze the intensity case differently in each building type and make better analyze the energy efficiency of the artificial lighting control system depends on the intensity conditions. Energy efficiency will be examined in five different cities with five different buildings. The reason for the examination of five different cities is that the latitude of each city is different, and as a result, the effect of daylight changes. As a result of the difference in daylight effect, the effect on the energy efficiency of the artificial lighting control system due to the daylight effect will be better analyzed. The cities to be examined in this study are Antalya (36°), Adana (37°), İzmir (38°), Ankara (39°) and Istanbul (41°).

In this study, annual consumption of lighting energy for five different buildings and five different cities will be calculated using the data in the EN 15193 standard. According to this calculation, a comparison will be made between the buildings and the cities and a proposal will be made to decide which of the automation systems are efficient. To make the control system proposal will be calculated by the values of Lighting Energy Numeric Indicator (LENI) with these calculated values, it will be analyzed which control system should be used according to cities and building types.

There is the energy simulation (BEP-TR) of the Ministry of Environment and Urbanization regarding the control systems that should be used in the buildings. However, in this study, the theoretical and detailed proposals of the control systems that should be used in buildings in different cities are made.

II. MATERIALS AND METHODS

A. Formula of Total Energy used for Lighting

The formula for total energy used for lighting is defined as follows according to EN 15193 standard.

$$W_t = W_{L,t} + W_{P,t} \quad (kWh) \qquad (1)$$

W_t : Total energy used for lighting
$W_{L,t}$: Energy consumption used for illumination
$W_{P,t}$: Luminaire parasitic energy consumption [2]

The total amount of lighting energy consumed annually is calculated according to Equation (1). Equation (1) is found by summing the energy consumption used for illumination and luminaire parasitic energy consumption. Formula of the energy consumption used for illumination is as in Equation (2) [3].

$$W_{L,t} = \{(P_n \, x \, F_C) \, x \, [(t_D \, x \, F_O \, x \, F_D) + (t_N \, x \, F_O)]\} \, / \, 1000 \, (kWh) \qquad (2)$$

P_n: Total installed lighting power (W)
F_C: Constant illuminance factor
t_D: Daylight time usage (h)
F_O: Occupancy dependency factor
F_D: Daylight dependency factor
t_N: Usage outside of day hours (h) [2, 3]

As shown in equation (2), P_n represents the total installed lighting power [3]. This value is calculated based on such factors as the area of the region to be illuminated, the brightness level, and so on [3]. Fc is the constant illuminance factor. This value participates in the account when there is a dimming situation in the control system. This value will not be included in the calculation so that all control systems can be compared equally [4]. t_D is the period of daylight utilization, and t_N is the daylight-unavailable period. These values are found separately according to the location of the building and the area to be illuminated. F_O, occupancy dependency factor is a variable that depends on the number of people in the area to be illuminated and the type of control system. The F_D, daylight dependency factor is a value that varies according to the position of the region to be illuminated and the type of artificial lighting control. These values will be calculated separately in the following sections. The $W_{P,t}$ in Equation (1) can be used as a constant at 5 kWh / m^2 according to the EN 15193 standard. In this study, 5 kWh / m^2 will be used [2, 5].

B. Calculation of Total Installed Lighting Power

The total installed lighting power will be calculated separately for five different building types. The formulas used to perform this calculation are as follows [6].

$$h = H - hwp \qquad (3)$$

The value of *H* in Equation (3) represents the height of the space, *hwp* is the height of the working plane, and h is the height of the area to be illuminated [7].

$$k = \frac{a \times b}{h \times (a + b)} \qquad (4)$$

The value *a* in Equation (4) represents the width of the space, *b* the length of the space. *k* value represents the room index.

$$\varnothing_O = \frac{E \times a \times b}{\eta \times m} \qquad (5)$$

The $\varnothing_O$ value in Equation (5) represents the total light flux, *E* is the illuminance, η is the efficiency, and *m* is the maintenance factor.

$$N = \frac{\varnothing_O}{\varnothing_{lamp}} \qquad (6)$$

The value $\varnothing_{lamp}$ in Equation (6), the light flux of a lamp, the *N* value indicates the total number of luminaires to be used.
The values to be calculated according to these equations should be calculated for five different building types. According to the standards, the lighting level should be 300 lx for hospital, school and hotel, 500 lx for office and 750 lx for factory [8]. For all buildings, the area of the space will be 60 m^2 (a=6m, b=10m), the height of the area will be illuminated as 1.9m and the maintenance factor is 0.8. The LED lamp will be used as the lamp type. The light flow of the LED lamp is 4200 lm and the power is 40W [9]. According to these values, the total number of armatures is calculated as follows.

$$k = \frac{6 \times 10}{1.9 \times (6 + 10)} = 1.97 \qquad (7)$$

From the utilization factor table, $\eta = 0.578$ for $k = 1.97$. 300 lx brightness level used for hospital, school and hotel, a common calculation will be made for all of them.

$$\varnothing_O = \frac{300 \times 6 \times 10}{0.578 \times 0.8} = 38927\ lm \qquad (8)$$

As seen in Equation (8), the total light flux was found to be 38927 lm. This value is the total number of lamps to be used when divided by the light flux value of a lamp.

$$N = \frac{\varnothing_O}{\varnothing_{lamp}} = \frac{38927}{4200} = 9.27 \cong 10 \qquad (9)$$

If that value in Equation (9) is taken approximately, the number of lamps to be used for hotel, school and hospital is 10.
If above calculations are performs for the office and factory in the same way, the number of lamps to be used for the office is 16 and the number of lamps to be used for the factory is 24. Thus, the total installed lighting power is multiply among the power of a lamp and the total number of lamps to be used. According to this, the total installed power for hotel, school and hospital is 400 W, 640 W for office and 960 W for factory.

C. Calculation of t_D and t_N

Daylight time usage (t_D) represents the period during which daylight is utilized during working hours, and non-daylight time usage (t_N) represents the period during which daylight cannot be utilized. In this calculation, both the location of the city and the working hours of the building must be known. According to the location of the city, the sunrise and sunset times change during the day [10].
In this study, calculations will be demonstrated for five cities in Turkey. In addition, five different building types will be used in calculations. In order to calculate t_D and t_N values depend on building usage hours, day lengths must be calculated for the cities in Turkey. Day lengths are calculated as average values using the values of 15 days of the month for each month. Calculations need to take into account the conversion of the country clock and summer time applications. The method used to calculate t_D and t_N values is given below.
08:00 - 17:00 (January day times for Istanbul)
DT1 = 08:00, DT2 = 17:00
09:00 -18:00 (Working hours for all months)
WH1 = 09:00, WH2 = 18:00
if (WH1 $\geq$ DT1) $\rightarrow$ WH1 = t_{D1}, if (WH1 < DT1) $\rightarrow$ DT1 = t_{D1}
if (WH2 $\leq$ DT2) $\rightarrow$ WH2 = t_{D2}, if (WH2 > DT2) $\rightarrow$ DT2 = t_{D2}

With the help of the equations given above, Table 1 shows the values of t_D and t_N calculated for five different cities and five different building types. According to these calculated values, hospitals have the maximum working hours. Schools are most

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benefiting the type of building from daylight. The least utilized type of building is hotels. This is due to the time of day within working hours.

TABLE I
T_d And T_n Values Calculated For Five Different Buildings And Five Different Cities

Building Types	Calculated t_D and t_N values (h)									
	Adana		Ankara		Antalya		Istanbul		Izmir	
	t_D	t_N	t_D	t_N	t_D	t_N	t_D	t_N	t_D	t_N
Office / Factory	2192	106	2237	86	2259	64	2256	67	2272	51
Education Building	1792	16	1794	14	1812	5	1810	7	1824	2
Hospital	3179	3004	3181	3002	3192	2991	3134	3001	3172	3011
Hotel	953	2873	926	2899	907	2918	908	2917	886	2939

These calculated values will be used when calculating the total annual lighting energy consumed in the buildings.

D. Calculation of Daylight Dependency Factor (F_D)

It is a value that depends on the daylight dependency factor, the daylight supply factor (F_{DS}), and the value of daylight dependent artificial lighting control factor (F_{DC}) [11]. The F_D value is calculated according to the F_{DS} and F_{DC} values according to Equation (10).

$$F_D = 1 - (F_{DS} \times F_{DC}) \qquad (10)$$

For the F_{DS} value, the coefficients a and b and the latitude degree must be known. The coefficients a and b are specified in the EN 15193 standard according to the illuminance level and daylight effect of the area to be illuminated. The formula for calculating the F_{DS} value is given in Equation (11).

$$F_{D,S} = a_{fds} + (b_{fds} \times \gamma_{latitude}) \qquad (11)$$

a and b coefficients depends according to daylight effect and brightness level as shown in Table 2.

TABLE III
a_{fds},b_{fds} values calculated according to maintained illuminance and daylight penetration [2, 5]

Maintained Illuminance (lx)	Daylight penetration	a_{fds}	b_{fds}
300	Weak	1.2425	-0.0117
	Medium	1.3097	-0.0106
	Strong	1.2904	-0.0088
500	Weak	0.9432	-0.0094
	Medium	1.2425	-0.0117
	Strong	1.322	-0.011
750	Weak	0.6692	-0.0067
	Medium	1.0054	-0.0098
	Strong	1.2812	-0.0121

The F_{DS} values calculated according to the values in Table 2 and the latitude of five different cities are given in Table 3.

Table III
F_{ds} values calculated according to maintained illuminance and daylight penetration

City	Latitude γ	Daylight Supply Factor F_{DS} ranges								
		300 lx			500 lx			750 lx		
	[°]	weak	medium	strong	weak	medium	strong	weak	medium	strong
Antalya	36	0.82	0.93	0.97	0.60	0.82	0.93	0.43	0.65	0.85
Adana	37	0.81	0.92	0.96	0.59	0.81	0.91	0.42	0.64	0.83
Izmir	38	0.79	0.91	0.96	0.58	0.79	0.90	0.41	0.63	0.82
Ankara	39	0.78	0.89	0.94	0.57	0.78	0.89	0.40	0.62	0.81
Istanbul	41	0.76	0.87	0.93	0.56	0.76	0.87	0.39	0.60	0.78

The highest F_{DS} value according to the values in Table 3 belongs to Antalya city. This is due to the decrease in daylight effect as the latitude increases. The F_{DS} value increases when daylight effect increases, and the F_{DS} value decreases when brightness level increases.

Another factor for calculating the F_D value is the F_{DC} value. The F_{DC} value is given in Table 4 according to the type of control system used and the daylight effect.

Table IV
F_{dc} values varying with control system and daylight effect [2, 5]

Control of Artificial Lighting System	F_{DC} as function of daylight penetration		
	Weak	Medium	Strong
Manual	0.2	0.3	0.4
Automatic, daylight dependent	0.75	0.77	0.85

According to the values in Table 4, when the control system is automatic, the F_{DC} value is larger than if the control system is manual. Table 5 shows the F_D values calculated based on daylight intensity and brightness level for five cities when the artificial lighting control system is manual.

Table V
Variable f_d values according to maintained illuminance, daylight penetration, latitude and manual artificial lighting control

City	Latitude γ	$F_D = 1 - (F_{DS} * F_{DC})$ Manual Control								
		300 lx			500 lx			750 lx		
	[°]	weak	medium	strong	weak	medium	strong	weak	medium	strong
Antalya	36	0.835	0.721	0.610	0.879	0.753	0.620	0.910	0.804	0.85
Adana	37	0.838	0.724	0.614	0.880	0.757	0.634	0.915	0.807	0.660
Izmir	38	0.840	0.727	0.617	0.882	0.760	0.638	0.917	0.810	0.671
Ankara	39	0.842	0.731	0.621	0.884	0.764	0.640	0.918	0.813	0.676
Istanbul	41	0.847	0,737	0.628	0.888	0.771	0.651	0.921	0.818	0.685

Table 6 shows the F_D values calculated based on daylight intensity and brightness level for five cities when the artificial lighting control system is automatic.

TableVI
Variable f_d values according to maintained illuminance, daylight penetration, latitude and automatic artificial lighting control

City	Latitude γ	$F_D = 1 - (F_{DS} * F_{DC})$								
		Automatic Control								
		300 lx			500 lx			750 lx		
	[°]	weak	medium	strong	weak	medium	strong	weak	medium	strong
Antalya	36	0.384	0.285	0.172	0.546	0.367	0.212	0.679	0.497	0.281
Adana	37	0.392	0.293	0.179	0.553	0.376	0.222	0.684	0.505	0.291
Izmir	38	0.401	0.301	0.187	0.560	0.385	0.231	0.689	0.512	0.301
Ankara	39	0.410	0.309	0.194	0.567	0.394	0.240	0.694	0.520	0.312
Istanbul	41	0.427	0.326	0.209	0.581	0.412	0.259	0.704	0.535	0.332

According to the values in Table 5 and Table 6, daylight dependency factor increases as latitude grade increases. That is, as latitude increases, the effect of daylight decreases. When the daylight effect increases, the F_D value decreases, the F_D value increases depends brightness level increases. These calculated F_D values will be used when calculating the amount of energy consumed annually [12].

E. Calculation of the Occupancy Dependency Factor (F_O)

The occupancy dependency factor varies depends on the number of people in zone and the control system used [13]. The value of F_O depends on the absence factor (F_A) and occupancy-dependent lighting control system factor (F_{OC}). The method of calculating the F_O value varies depending on the value of the absence factor [3, 13]. This is seen in Equations (12), (13) and (14).

$$F_O = [7 - (10\, x\, F_{OC})]x\,(F_A - 1)(0.9 \leq F_A \leq 1) \quad (12)$$
$$F_O = 1 - [(1 - F_{OC})\, x\, F_A\, /\, 0.2]\,(0 \leq F_A < 0.2) \quad (13)$$
$$F_O = F_{OC} + 0.2 - F_A\ (0.2 \leq F_A < 0.9) \quad (14)$$

The F_{OC} value used depends on the type of control system and the F_A value changes according to the occupancy status. In the EN 15193 standard, F_A absence factor is given as 0.2 for office, factory and hospital, 0.25 for school and 0.6 for hotel [2, 5]. As the occupancy status decreases, the F_A absence factor increases. The F_O value calculated according to F_{OC} and F_A values are in Table 7.

Table VII
Occupancy dependency factor (f_o) values varying according to f_a and f_{oc} values [2, 5]

Scenario of control system	F_{OC}	F_O		
		F_A= 0.2	F_A= 0.25	F_A= 0.6
Manual on / off	1	1	0.95	0.6
Auto on / dimmed	0.95	0.95	0.9	0.55
Auto on / off	0.9	0.9	0.85	0.5
Manual on / dimmed	0.9	0.9	0.85	0.5
Manual on / Auto off	0.8	0.8	0.75	0.4

According to the values in Table 7, the F_O value decreases when the absence factor value increases, and when the F_{OC} value increases, the F_O value increases. These calculated F_O values will be used when calculating the total amount of lighting energy consumed per year.

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III. RESULTS AND DISCUSSION

A. Calculation of the Annual Total Energy Consumed for Five Cities and Five Building Types

In this section, annual lighting values for five cities and five building types will be analyzed. These calculations should be made using the total energy formula used for lighting that defined in EN 15193. While calculating the total amount of energy used for lighting, the energy consumption used for illumination and the values for luminaire parasitic energy consumption should be known. The luminaire parasitic energy consumption value should be taken as 5 kWh / m^2 according to EN 15193 standard [2, 5]. The formulas to be used for this calculation are in Equations (1) and (2).

If the daylight effect is low for the city of Adana according to the above formulas, the total amount of lighting energy consumed per year according to building types and control system type is calculated as in Table 8. In these calculations, the luminaire parasitic energy consumption is used as 300 kWh for a 60 m^2 area and added to the energy consumption value used for illumination [3]. The energy consumption used value for illumination is calculated for five cities, five building types and five different control scenarios based on the F_O, F_D, t_D, t_N and P_n values calculated in the previous sections.

Table VIII

Total energy values used for ılluminatıon calculated for adana cıty

City	Control of Artificial Lighting System	Building Type	Scenario of control system (kWh)				
			Manual on/off	Auto on/dimmed	Auto on/off	Manual on/dimmed	Manual on/Auto off
Adana	Manual	Factory	2328.02	2226.62	2125.22	2125.22	1922.42
		Hospital	2567.35	2453.98	2340.62	2340.62	2113.88
		Hotel	1181.03	1107.61	1034.19	1034.19	887.35
		Office	1603.17	1538.01	1472.85	1472.85	1342.54
		School	876.62	846.27	815.93	815.93	755.23
	Automatic	Factory	1840.49	1763.46	1686.44	1686.44	1532.39
		Hospital	2001.06	1916.01	1830.96	1830.96	1660.85
		Hotel	1079.24	1014.30	949.36	949.36	819.49
		Office	1143.83	1101.64	1059.45	1059.45	975.07
		School	573.41	559.02	544.63	544.63	515.85

When the control of artificial lighting system is automatic by the values in Table 8, more savings are achieved than in manual situation. The most saving type of building is school. The situation where the control system scenario is manual on / auto off is the most efficient situation.

Table IX

Total energy values used for illumination calculated for ankara city

City	Control of Artificial Lighting System	Building Type	Scenario of control system (kWh)				
			Manual on/off	Auto on/dimmed	Auto on/off	Manual on/dimmed	Manual on/Auto off
Ankara	Manual	Factory	2355.43	2252.66	2149.89	2149.89	1944.34
		Hospital	2573.21	2459.55	2345.89	2345.89	2118.57
		Hotel	1183.10	1109.51	1035.92	1035.92	888.73
		Office	1621.97	1555.87	1489.78	1489.78	1357.58
		School	879.70	849.19	818.68	818.68	757.66
	Automatic	Factory	1873.57	1794.89	1716.21	1716.21	1558.86
		Hospital	2023.03	1936.88	1850.73	1850.73	1678.42
		Hotel	1087.01	1021.42	955.84	955.84	824.67
		Office	1167.88	1124.48	1081.09	1081.09	994.30
		School	584.97	569.97	554.97	554.97	524.97

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Table 9 shows the total lighting energy values calculated for the city of Ankara. The amount of energy consumed in Ankara is higher than Adana city. The reason for this is that Ankara is at 39° latitude and Adana at 37° latitude, so Adana is more benefits from daylight [14]. Table 10 shows annual energy consumption values for Antalya city.

Table X
Total energy values used for ıllumınatıon calculated for antalya cıty

City	Control of Artificial Lighting System	Building Type	Scenario of control system (kWh)				
			Manual on/off	Auto on/dimmed	Auto on/off	Manual on/dimmed	Manual on/Auto off
Antalya	Manual	Factory	2344.99	2242.74	2140.49	2140.49	1935.99
		Hospital	2563.52	2450.35	2337.17	2337.17	2110.82
		Hotel	1182.30	1108.77	1035.25	1035.25	888.20
		Office	1612.20	1546.59	1480.98	1480.98	1349.76
		School	877.15	846.77	816.40	816.40	755.64
	Automatic	Factory	1834.43	1757.70	1680.98	1680.98	1527.54
		Hospital	1986.70	1902.37	1818.03	1818.03	1649.36
		Hotel	1084.01	1018.67	953.34	953.34	822.67
		Office	1131.22	1089.65	1048.09	1048.09	964.97
		School	566.19	552.18	538.17	538.17	510.15

According to the values in Table 10, the buildings with the most energy consumption are hospitals. The reason for this is that the working hours in the hospital and the occupancy rate are higher than other building types. Consumption of minimum illumination energy is also in Antalya city because of daylight effect.

Table XI
Total energy values used for ıllumınatıon calculated for ıstanbul cıty

City	Control of Artificial Lighting System	Building Type	Scenario of control system (kWh)				
			Manual on/off	Auto on/dimmed	Auto on/off	Manual on/dimmed	Manual on/Auto off
Istanbul	Manual	Factory	2359.74	2256.75	2153.77	2153.77	1947.79
		Hospital	2562.90	2449.75	2336.61	2336.61	2110.32
		Hotel	1184.79	1111.06	1037.32	1037.32	889.86
		Office	1625.99	1559.69	1493.39	1493.39	1360.79
		School	885.32	854.51	823.71	823.71	762.09
	Automatic	Factory	1889.73	1810.25	1730.76	1730.76	1571.78
		Hospital	2036.87	1950.03	1863.18	1863.18	1689.50
		Hotel	1093.34	1027.23	961.11	961.11	828.89
		Office	1182.95	1138.80	1094.66	1094.66	1006.36
		School	596.83	581.21	565.58	565.58	534.34

Table 11 shows the annual consumed lighting energy values calculated for Istanbul city. According to these values, the most consuming control scenario is the control system for the manual on / off scenario. Moreover, because Istanbul city has the highest latitude, it is the city with the most consumption of lighting energy. Table 12 shows the annual consumed lighting energy values calculated for Izmir city.

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Table XII
Total energy values used for ıllumınatıon calculated for ızmır cıty

City	Control of Artificial Lighting System	Building Type	Scenario of control system (kWh)				
			Manual on/off	Auto on/dimmed	Auto on/off	Manual on/dimmed	Manual on/Auto off
Izmir	Manual	Factory	2349.77	2247.28	2144.79	2144.79	1939.81
		Hospital	2570.81	2457.27	2343.73	2343.73	2116.65
		Hotel	1184.12	1110.45	1036.77	1036.77	889.41
		Office	1616.66	1550.82	1484.99	1484.99	1353.32
		School	882.94	852.26	821.58	821.58	760.22
	Automatic	Factory	1852.34	1774.72	1697.10	1697.10	1541.87
		Hospital	2014.05	1928.34	1842.64	1842.64	1671.24
		Hotel	1090.84	1024.94	959.03	959.03	827.23
		Office	1147.94	1105.54	1063.15	1063.15	978.35
		School	578.72	564.05	549.38	549.38	520.04

A general comparison of the values given in the tables above was made in the graphs of Figure 2 and Figure 3. The graphic in Figure 2 is for the case where the artificial lighting control system is manual, whereas the graphic in Figure 3 is for the case where the artificial lighting control system is automatic.

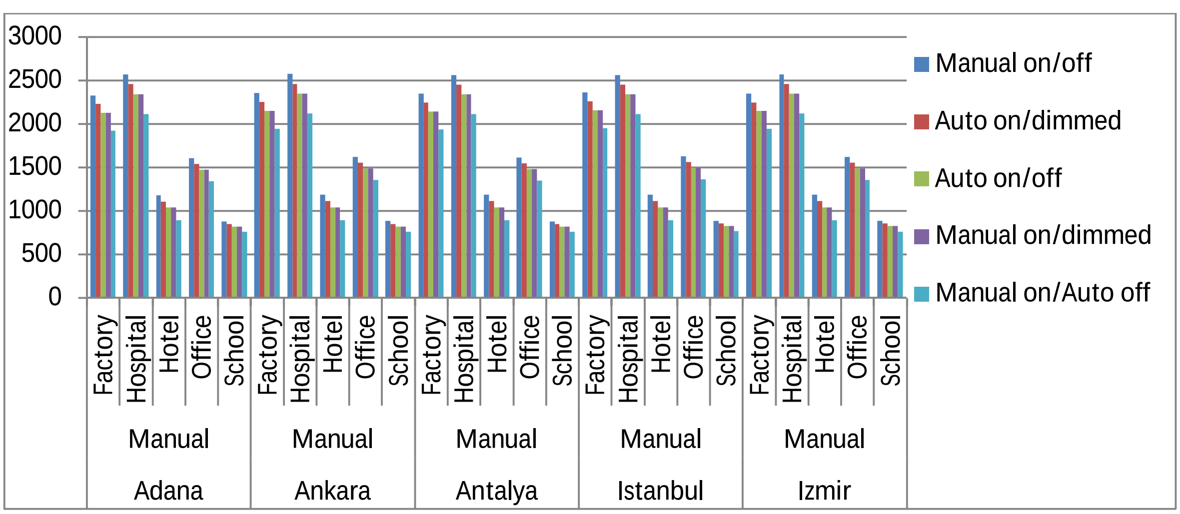

Fig.2 The total amount of lighting energy consumed for the artificial lighting control system is manual

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According to the graph in Figure 2, the lighting energy is building type hospital where the energy is consumed most. The type of building where lighting energy is least consumed is school. The reason for this arises from the working hours and the occupancy factor as mentioned in the previous sections.According to the graph in Figure 3, the control system which consumes most of the lighting energy is the control system for the manual on / off scenario. The city where lighting energy is consumed most is Istanbul.

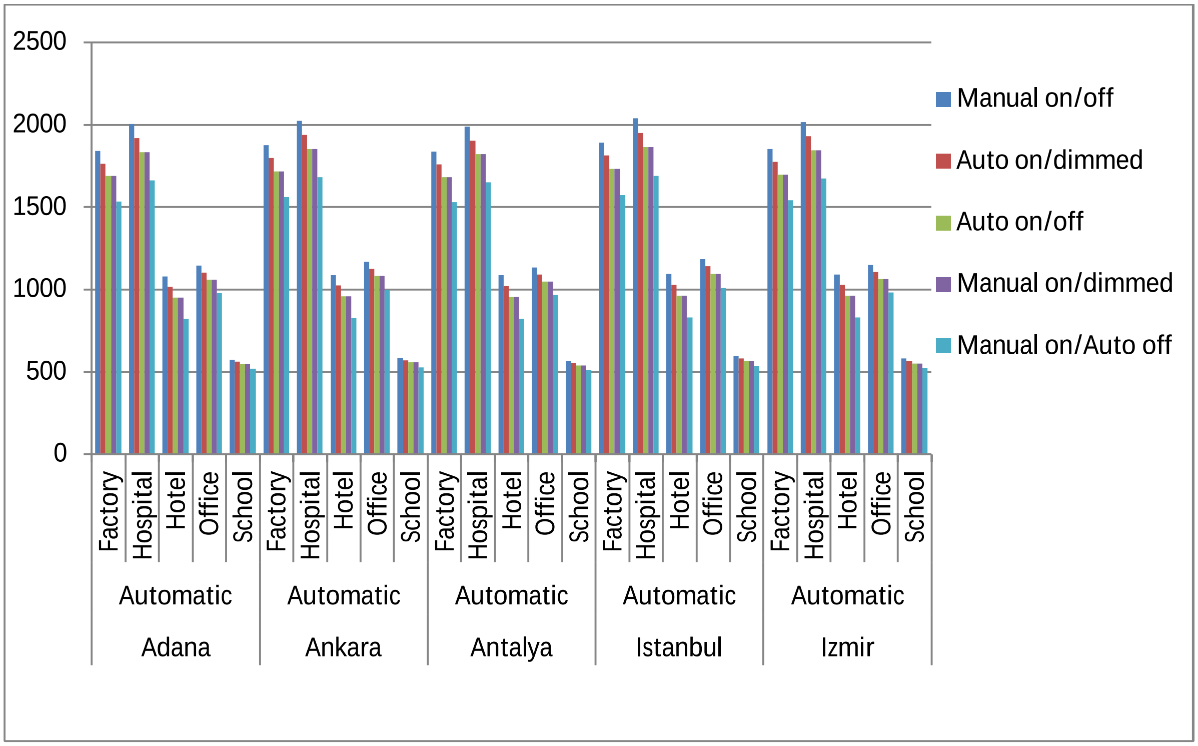

Fig.3 The total amount of lighting energy consumed for the artificial lighting control system is manual

After calculating the total amount of lighting energy consumed annually, calculated the value of Lighting Energy Numeric Indicator (LENI) for Istanbul city is as in Table 13 [15]. These values are the result of dividing the total consumed lighting energy into the area of the zone to be illuminated.

Table XIII

Lıghtıng energy numerıc ındıcator values calculated for ıstanbul

City	Control of Artificial Lighting System	Building Type	Lighting Energy Numeric Indicator (LENI) (kWh/m^2) Scenario of control system: Manual on/off	Auto on/dimmed	Auto on/off	Manual on/dimmed	Manual on/Auto off
Istanbul	Manual	Factory	39.32	37.6	35.88	35.88	32.45
		Hospital	42.7	40.82	38.93	38.93	35.16
		Hotel	19.73	18.52	17.28	17.28	14.82
		Office	27.08	25.98	24.88	24.88	22.66
		School	14.75	14.23	13.72	13.72	12.7
	Automatic	Factory	31.48	30.16	28.83	28.83	26.18
		Hospital	33.93	32.5	31.05	31.05	28.15
		Hotel	18.22	17.12	16.02	16.02	13.8
		Office	19.7	18.96	18.23	18.23	16.76
		School	9.93	9.68	9.42	9.42	8.9

In this section, the control system proposal has been made in the conclusion section with the help of the total consumed annual illumination energy and the Lighting Energy Numeric Indicator values.

IV. CONCLUSIONS

In the conclusion, in Table 13, the values of Lighting Energy Numerical Indicator calculated for Istanbul city and five different building types and the energy class types in Table 14 should be used to propose the control systems to be used in the buildings and the energy classes of building types will be found.

Table XIV
Energy classes determined according to leni values

Energy classes	LENI values
A^+	0-14
A	15-24
B	25-49
C	50-69
D	70-89
E	90-119
F	120-159
G	160-…

According to the values in Table 13, for the type of factory and hospital buildings in Istanbul, the energy class is B class in the case where the artificial lighting control system based on daylight effect is manual, and the artificial lighting control system based on the intensity state is manual on / off [16, 17]. In the case of the factory and hospital building type, the artificial lighting control system based on the daylight effect is automatic, the artificial lighting control system based on the intensity condition is the manual on/auto off, that is, the energy class remains as the B class even when the control system is the best [18]. As a result, there is no need to upgrade the control system for the factory and hospital building type in Istanbul.

the case of the hotel building located in Istanbul, the artificial lighting control system is based on the daylight effect is manual, whereas the artificial lighting control system based on the intensity state is manual on / off, the energy level of the hotel building is in the energy class A [16, 17]. If it is desired to increase the energy class A^+ of this hotel building, an artificial lighting control system based on the intensity condition needs to be developed. If the artificial lighting control system based on the intensity condition is raised to manual on / off state, the energy class of the building is A^+. The energy class of the building remains the same if artificial lighting control system based on the daylight effect is developed. The reason is that the intensity condition has more effect on the efficiency than the daylight effect. Because of this, it is necessary to develop artificial lighting control system for the hotel building in Istanbul only depends on the intensity condition.

In the case of office building in Istanbul city, the artificial lighting control system based on daylight effect is manual, the artificial lighting control system based on intensity state is manual on / off, the energy class of the building is in class B [16, 17]. If the artificial lighting control system based on the daylight effect is raised to the automatic control system, the energy class of the building is A class [18]. In the same way, if the artificial lighting control system depends on intensity condition is raised to the manual on / auto off state; it is classified into energy class A class. However, when artificial lighting control system based on daylight effect is upgraded, more energy saving is achieved. The reason for this is that daylight effect is more effective in the office building compared to intensity condition. Therefore, for the office building in Istanbul, artificial lighting control system based on daylight effect should be upgraded.

Even if control system is at the lowest level in the school building in Istanbul, there is no need to make any improvements in the control system of this building type because the energy class of the building is A^+.

In this study, the amounts of annual lighting energy consumed in five different cities and five different building types were calculated. With these calculated values, LENI values are found for buildings in Istanbul city. With the help of these values, the energy class of the buildings was found and a control system proposal was made.

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