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Energy Efficiency Analysis for a Sport Complex

Bir Spor Kompleksi için Enerji Verimliliği Analizi

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Abstract

Today, people spend 87% of their time indoors and an additional 6% inside vehicles (on average). The buildings and construction sector are responsible for 36% of the global total energy consumption and 40% of the total direct and indirect CO_2 emissions. Therefore, with each passing day, the efforts to increase efficiency in building energy usage are gaining importance. In this study, an energy survey was conducted for a sports complex in Istanbul with a capacity of 1,306 spectators and annual energy consumption of 729.6 TOE (Tons of Oil Equivalent) and then, some measures to increase efficiency were presented. These measures were examined on the systems where energy consumption was intense, such as cooling, air conditioning, instalments and lighting. With the measures to be taken, it is predicted that annually 68.2 TOE of energy can be saved.

Keywords: Energy analysis, Carbon footprint, Sustainability, Sport complex, Environment.

Özet

Günümüzde insanlar zamanlarının %87'sini kapalı mekanlarda ve ek olarak %6'sını (ortalama olarak) araçların içinde geçirmektedir. Binalar ve inşaat sektörü, küresel toplam enerji tüketiminin %36'sından ve toplam doğrudan ve dolaylı CO_2 emisyonlarının %40'ından sorumludur. Bu nedenle bina enerji kullanımında verimliliği artırmaya yönelik çalışmalar her geçen gün önem kazanmaktadır. Bu çalışmada, İstanbul'da bulunan 1.306 seyirci kapasiteli ve yıllık 729.6 TEP enerji tüketimine sahip bir spor kompleksi için enerji etüdü yapılmış ve ardından verimliliği artırmaya yönelik bazı önlemler sunulmuştur. Bu önlemler soğutma, iklimlendirme, tesisat ve aydınlatma gibi enerji tüketiminin yoğun olduğu sistemler üzerinde incelenmiştir. Alınacak tedbirlerle yıllık 68,2 TEP (Ton Eşdeğer Petrol) enerji tasarrufu sağlanabileceği öngörülmektedir.

Anahtar Kelimeler: Enerji analizi, Karbon ayak izi, Sürdürülebilirlik, Spor kompleksi, Çevre.

1. Introduction

Energy efficiency is the reduction of energy consumption without changing the living standards and quality of service. In order to prevent the depletion of energy resources, energy must be saved in all areas possible. In buildings, energy conservation is legally regulated by the Building Energy Performance Regulations. According to these regulations, all buildings constructed as of the year 2011 fall into the "new buildings" category. After these regulations in order to use energy efficiently, efforts to improve energy performance have been made compulsory, in all new buildings. In addition, according to the "Energy Performance in Buildings Directive", all new buildings should be in nearly zero energy class.

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Studies about heating, cooling, ventilation, lighting, CO_2 emission and hot water issues are being carried out for buildings depending on climate conditions, architectural design and insulation standards.

Buildings consume approximately 40% of the total primary energy in the US and EU, 27.3% in China and 30% in Turkey [1]. The most important areas for the efforts to reduce energy consumption in buildings and to reduce carbon dioxide emissions are the “Public buildings”. Many studies are being carried out by the governments on saving energy in public buildings. Service buildings are normally 60% more energy-intensive than the residential buildings. Since most of the public buildings are old, the aim here is to retrofit these buildings [2]-[7]. However, there are some obstacles that need to be overcome before retrofitting the existing buildings [7]-[10]. To overcome these obstacles, governments' investments in energy policies are very important. One of the plans of the French government is to renovate 500,000 homes per year and to make them energy-efficient, and to cut the heat losses, power consumption, and carbon emissions. The government also plans to set aside some 4.8 billion Euros for renovating the public-sector buildings, including schools and hospitals, to make them energy-efficient. At the time of this study, the building sector accounts for 45% of energy consumption and 27% of greenhouse gas emissions, additionally, some 7 million homes are not adequately insulated [2]-[3]. The UK government has successfully reduced greenhouse gas emissions by providing a variety of incentive mechanisms to improve energy usage according to the national energy policy. The projection is to reduce greenhouse gas emissions by 80% from 1990 to 2050 [11]. Looking at China, the statistics show that the electrical energy consumption per square meter in large public buildings is 70 to 300 kWh, which is 10 to 20 times higher than that of the residential buildings. Therefore, the government has introduced some mandatory regulations aimed at increasing energy efficiency in public buildings. These regulations aim to save 50% energy especially in new public buildings [12]-[13].

In Turkey, while 30% of the energy is consumed by the buildings, especially with the regulations related to energy performance, it is known that up to 50% of the energy can be saved. There are many studies carried out by the European Union about energy efficiency at the buildings. There are many studies carried out by the European Union about energy efficiency in the buildings. According to this directive all the new buildings must be nearly zero-energy buildings (NZEB) starting from 31 December 2020 (As of 31 December 2018, all new public buildings already need to be NZEB). One of the regulations stipulated by the legislation in Turkey is the one that is about the Energy Performance of the Buildings. This regulation aims to develop methods to evaluate all energy usage in buildings, to classify them in terms of CO_2 emissions and the types of energy used, to assess minimum criteria for energy efficiency, to implement them to the existing buildings and to evaluate the usage possibilities of renewable energy sources for the buildings. The regulation also covers architectural, mechanical and electrical design and applications. Thus, it provides adjustments about the issues such as heating, cooling, lighting; renewable energy sources; building layouts; energy efficiency certificates; regular inspections of heating and ventilation systems and also training and certification of energy performance auditing personnel.

Figure 1. Overview of the facility

In this study, the sports complex building structure and mechanical systems were examined considering all the energy-consuming spots. In this context, faulty and inefficient usage and losses in the heating, cooling, ventilation, mechanical installation, electric motors, lighting systems, and possible energy savings were identified with measurements and examinations throughout the facility. Especially a public building has been chosen for the study. Energy efficiency studies in public buildings aim to reveal saving potentials in buildings and systems, to create suitable and feasible energy efficiency projects, to reduce CO_2 emissions to protect the environment and to contribute to the country's economy by reducing energy expenses.

2. Building Information

The sports complex started its operations in Istanbul in 2012. The complex established on an area of 57,081 m² consists of a tribune with a capacity of 280 spectators (in the pool area), an indoor (basketball) sports hall with a capacity of 1,306 spectators, fitness halls, a step-aerobics and pilates hall, a far east sports hall, a Turkish bath (2 units), a sauna (4 units), a solarium (2 units), a table tennis hall, a grass football field, a synthetic carpet field (2 units), administrative units, two cafeterias and a parking lot for 316 vehicles, 50 of which are indoors (Table 1). Electricity, natural gas, and diesel oil are used as energy sources in the facility. The facility land and site plans are shown below. The facility consists of a single building (Fig. 1). The building is divided into 3 blocks. Blocks are named Basket Area, Middle Section, and Pool Area. The facility consists of a ground floor plus four floors.

There are 5 entrances to the facility building. Doors are traditional open-close aluminum doors. There are no air curtains above the doors. There is an indoor parking garage at the facility. The garage door operates automatically. Facility exit doors are not automatic. The windows of the facility are aluminum joinery. Glasses are 4+4 laminated type and there is no film coating. There is only coloring on the glasses.

Table 1. Building Information

Construction Year	2010
Purpose of usage	: Sports Complex
Constructional area	: 57,081 m^2
Number of degree days for heating	: 1,537
Number of degree days for cooling	: 327
Insulation Status	: Exists
Location	: Istanbul

Annual Average Energy Consumption (TOE)

Year	Energy Consumption (TOE)
2017	729.6

3. Methodology

In the scope of the study, the highest energy-consuming spots in the plant were examined. These spots were:

- Heating systems (hot water, boiler, installation lines, etc.),
- Cooling system,
- HVAC/R system,
- Electric motors,
- Lighting.

Studies have been done on the elements that mostly affect energy consumption. Flue gas measurements were taken in order to calculate the combustion and boiler efficiency. Measurements have been taken with the thermal camera to detect loss/leakage points on all electricity and heating lines and building surfaces. For some panels and motors, measurements were taken with the energy analyzer. Speed and temperature measurements were taken at air handling units and compressor waste heat points. Using all these measurements, potential energy efficiency projects were studied and presented.

The flue gas measuring device (Testo 335) was used to obtain the necessary data for the general and combustion efficiency of the boilers in the plant. The compliance of the indoor air quality with the standards was examined with indoor air quality measurements. The heat losses in the installation and the condition of the surfaces of the boiler and cooling units were observed with the thermal imager (Testo 865, Accuracy ±2 °C) and the boiler surface temperatures needed to determine the overall efficiency were obtained with the contact thermometer. Heat losses on the heating and cooling lines, valves and pumps were also determined with the thermal camera, in addition, surface heat losses were observed with the thermal shots on the surfaces of the building.

With the help of the energy analyzer (HIOKI 3196), the presence of possible instabilities in the general electricity consumption with and without lighting was determined. In addition, electrical measurements were taken in cooling groups, mechanical installation, motors, equipment (fans, pumps, etc.) and compressors. For the flow measurements of the Air Handling Units and Rooftop units, the Handheld TUF-2000H (± 1%) portable ultrasonic flow meter was used. Testo 470 (± 0.02%) optical-mechanical speed meter was used for speed measurements. Testo 815 (±1.0 Db) sound meter was used for sound level measurements. Testo 435-1 (± 0.2 °C) was used as the lux meter. Testo U temperature probe was used for measurement of wall U values and for air vents and air handling units, an anemometer was used.

4. Results

4.1. Energy Consumption and Costs

Electricity and natural gas are used as the main energy types in the facility and a small amount of fuel oil is consumed in the diesel generator. Electricity consumptions of the facility for 2017 are shown in Table 2.

Table 2. Monthly electricity consumption for 2017

	Purchased		Purchased (Euro)
Months	**kWh**	**TOE**	
January	353,343	30.4	30,852.69
February	263,069	22.6	22,970.35
March	267,154	23.0	23,326.94
April	226,872	19.5	19,809.88
May	232,348	20.0	20,287.72
June	361,207	31.1	31,539.52
July	380,022	32.7	33,182.33
August	436,397	37.5	38,104.79
September	307,414	26.4.	26,842.51
October	248,555	21.4	21,702.99
November	234,663	20.2	20,490.11
December	268,824	23.1	23,472.75
TOTAL	**3,579,869**	**307.9**	**312,582.58**

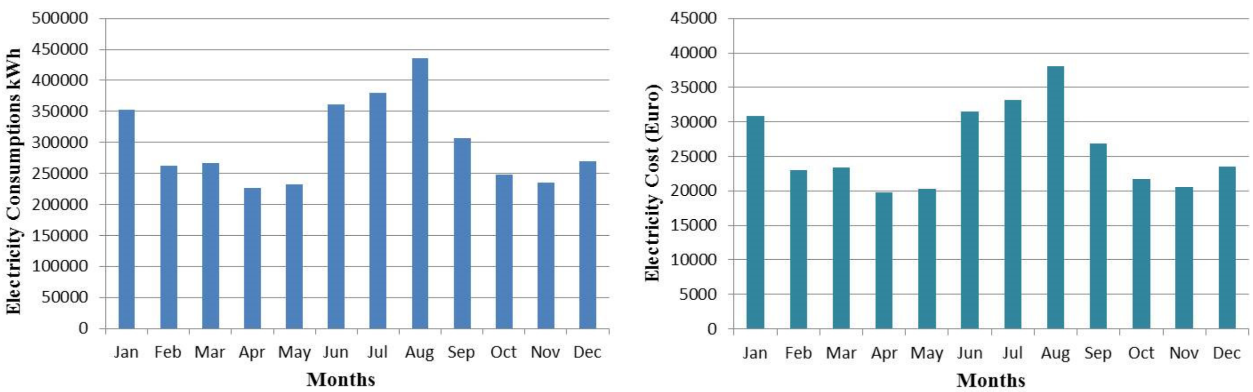

Figure 2. Electricity consumption in 2017 in kWh and the costs in Euros

As can be seen from Fig. 2, when the electricity consumption amounts are examined, the consumption increases in summer months and decreases in the transitional spring period. This arises from the operation of chiller groups due to the need for cooling in the summer period. The highest electricity consumption was in August with 436,397 kWh, whereas the lowest was in April with 226,872 kWh.

The facility consumes natural gas as fuel in the boilers in order to meet the heating and domestic hot water need in winter and in summer for heating the domestic hot water and pool water. When we examine the annual natural gas consumption graph (Fig. 3, Table 3), in parallel with the demand for heating, we observe that the consumption reaches the highest values in winter, decreases in spring and reaches the lowest levels in summer. Since there is no need for heating in summer, it can be said that the summer consumption of natural gas is due to water heating only. It can be seen that the highest natural gas consumption of 59,332 m^3 is in January and the lowest natural gas consumption of 12,500 m^3 takes place in August.

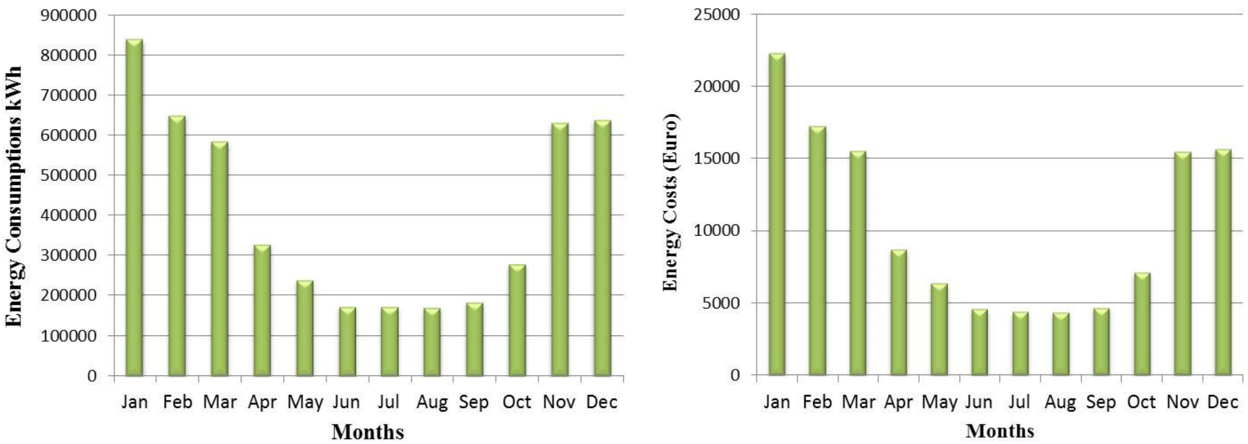

Figure 3. 2017 natural gas consumption in m^3 and Euros

Table 3. Monthly natural gas consumption for 2017

Months	Purchased		Purchased
	kWh	TOE	Euro
January	840,587	72.3	22,299.7
February	650,164	55.9	17,245.50
March	584,019	50.2	15,505.39
April	328,611	28.3	8,720.05
May	239091	20.6	6,348.20
June	172,797	14.9	4,594.01
July	172,520	14.8	4,396.40
August	169,803	14.6	4,326.94
September	183,387	15.8	4,673.35
October	278,409	23.9	7,094.61
November	631,152	54.3	15,455.39
December	638,852	54.9	15,644.01
TOTAL	**4,889,391**	**420.5**	**126,303.55**

Tons of Oil Equivalent (TOE) is an energy unit to express all energy resources under the same unit and it corresponds to 10 million kCal of energy. The conversion coefficients of all energy resources to the TOE unit were determined with the "Regulation on Improving Efficiency in the Use of Energy and Energy Resources" dated 25 October 2008. For this reason, while comparing electricity, natural gas, and diesel consumptions, they were converted to TOEs for calculations. In Fig. 4, electricity and natural gas consumed by months are compared in terms of TOE. The highest consumption was in January with 103 TOE. The lowest consumption was in May with 41 TEP. Diesel data has been achieved only annually, so it is not included in the chart.

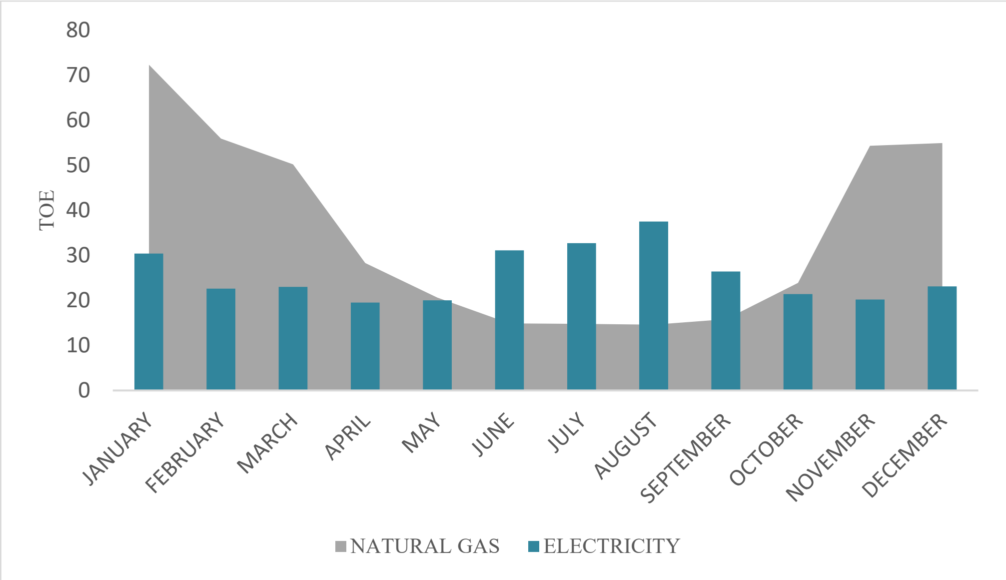

Figure 4. Energy consumption for 2017 (TOE)

If we examine the annual consumption in total (Table 4), electrical energy constitutes 42.2% of the total TOE consumption and 71% of the annual paid money, whereas natural gas energy constitutes 57.6% of the total TOE consumption and 28.7% of the annual paid money. Diesel energy constitutes 0.2% of total TOE consumption and 0.4% of the annual paid money. The plant consumed a total of 729.6 TOE of energy annually.

Table 4. Comparison of Annual Energy Consumption and Costs (2017)

Energy Type	Consumption			Cost		Unit Cost
	Quantity	**TOE**	**Total %**	**EURO**	**Total%**	**EURO / TOE**
Electricity	3,579,869 kWh	307.9	42.2	312,582.58	71	1,014.03
Natural Gas	4,889,391 kWh	420.5	57.6	126,303.59	28.7	300.36
Fuel	14,914 kWh	1.3	0.2	1,678.44	0.4	1,291.10
TOTAL	8,484,174 kWh	729.6	100	440,204.61	100	

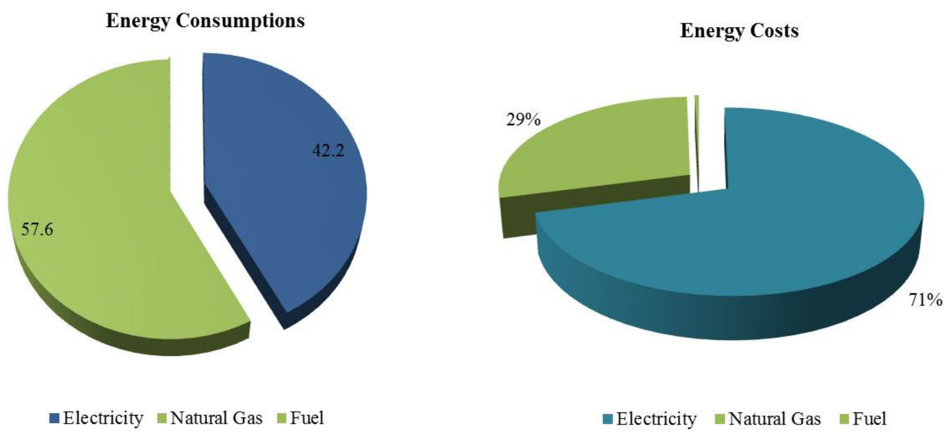

Figure 5. Percentages of energy consumption and costs for 2017

Throughout the facility, diesel energy is spent only on generators. The annual consumption of diesel varies due to the intermittent supply of electricity in the region (Fig. 5).

4.2 Consumption Analyses

Under this topic, the number of degree days for heating (HDD) and cooling (CDD) in Istanbul and the energy consumption of the building are correlated with the degree days of energy consumption of the facility. The degree day statistics were used to correlate the plant's energy consumption with the climatic conditions during the year in the region where the facility is located. Table 5 clearly shows how energy consumption changes according to climate conditions. A degree day is a unit for measuring how much of a 24-hour period is hot and how much is cold. Heating Degree Days (HDD) value describes the intensity of the cold weather that, the outdoor and room temperatures at a given time (day, month, year) are taken, while Cooling Degree Days (CDD) value describes the intensity of the hot weather that, the outdoor temperature at a given time (day, month, year) is taken. The threshold value for the HDD is 15 °C and the HDD value is zero when the ambient temperature is above this value. The threshold value for CDD is 22 °C. The HDD and CDD values in Table 5 are the sum of the daily results on a monthly basis. In short, the HDD and CDD indicate the need for heating and cooling according to the season.

Table 5. Monthly energy consumption and degree-day values for cooling and heating

Months	Electricity (kWh)	Natural Gas (kWh)	Total Consumption (kWh)	HDD	CDD	Number of People Using the Facility
January	353,343	840,587	1,193,930	374	.	5,701
February	263,069	650,164	913,233	232	.	5,873
March	267,154	584,019	851,173	229	.	7,302
April	226,872	328,611	555,483	55	2	7,473
May	232,348	239,091	471,439	15	64	6,603
June	361,207	172,797	534,004	.	107	3,597
July	380,022	172,520	552,541	.	117	2,134
August	436,397	169,803	606,200	.	37	3,623
September	307,414	183,387	490,801	.	.	3,822
October	248,555	278,409	526,963	57	.	5,139
November	234,663	631,152	865,815	172	.	5,010
December	268,824	638,852	907,676	403	.	5,294
TOTAL	3,579,869	4,889,391	8,469,260	1,537	327	61,571

Knowledge of the sum of heating or cooling day temperatures is important to know the energy requirement for heating or cooling the buildings. If the outside temperature is above 15 °C, heating is unnecessary. The cost of heating is directly proportional to the annual HDD. The annual fuel cost divided by the HDD within one-year yields the heating price for HDD. The HDD is also used to compare the toughness of multiple winters. The HDD is also a parameter used in the construction industry to calculate insulation, heating and cooling costs during the construction of new buildings. Considering this, when we examine Table 5, we observe that HDD and natural gas consumption generally go parallel with each other. Since the facility needs hot water in summer months when the HDD is zero, the amount of natural gas consumed is considerably reduced. Based on these data, we can say that the plant is generally being heated correctly. Similarly, electricity consumption increases with the increasing demand for cooling in the summer months. The reason for this increase is the energy consumption of the cooling groups in the summer months. It is seen that generally total consumption tendency is compatible with HDD in winter months when natural gas is dominant and with CDD in summer when electricity is dominant. Fuel consumption rate and monthly HDD rates overlap in facilities where fuel is used for heating purposes only. Likewise, in the case of cooling, CDD value and electricity consumption must match. However, apart from HDD and CDD values, one of the parameters to be considered for evaluating consumption is the number of people using the facility. Consumption analysis is an analysis method that shows the change of energy spent on heating and cooling depending on the weather conditions and the number of visitors and allows them to be examined together. With this analysis, it is very important to keep track of how much energy is consumed as a result of which conditions in which months and to reveal the relationships between each other. The main results that can be deducted from the analysis are the decreases and increases in consumption as a result of the efficiency change of the system, the changes in the amount of energy spent as a result of climate change on a yearly basis, the character of thermal leaks in the system and the adequacy of the existing system for the spaces in need of air conditioning. In addition, the need for heating and cooling in order to provide comfort for the visitors coming to the facility may vary. Although there is no need for cooling, the increase in electricity consumption in January is due to the increase in the number of people using the facility. It can be commented that the change in the total energy consumption of the facility is determined by the demand for heating-cooling and the need for domestic hot water depending on the number of people.

The graph in which the total amount of energy consumption and the cost per person arriving at the facility evaluated by months are given in Fig. 6. As total consumption data, consumption and cost of electricity and natural gas used in the facility were taken. While the highest energy consumption occurred per capita was in July with 258.9 kWh, the lowest electricity consumption per capita was in May with 71.4 kWh.

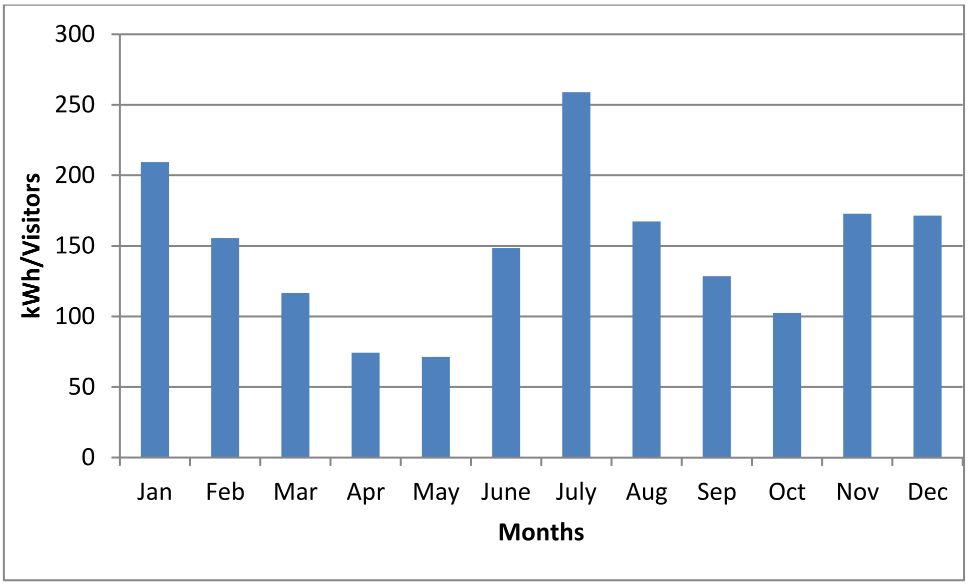

Figure 6. Energy consumption per visitor per month

The energy consumption values of the facility for the last 3 years are given in detail together with CO_2 emission coefficients in Table 6.

Table 6. Energy Consumption and CO_2 Emission Coefficients for the Last Three Years

Year	Electricity Cons. (kWh)	Natural Gas Cons. (kWh)	Fuel Cons. (kWh)	Total Cons. (kWh)	CO_2 Emission Coefficient (kg CO_2/kWh)		
					Electricity	Natural Gas	Fuel
2015	3,685,666	4,463,824	27,689	8,177,179	0.626	0.234	0.32
2016	3,571,085	5,425,049	6,192	9,002,326	0.626	0.234	0.32
2017	3,579,869	4,889,391	14,914	8,484,174	0.626	0.234	0.32

The energy types and annual consumption in the facility being known, the annual total CO_2 emission of the facility was calculated by using the emission coefficients provided by the “Energy Performance in Buildings” regulation.

Table 7. CO_2 emissions for the Last Three Years

Year	Elektricity CO_2 Emission (Ton)	Natural Gas CO_2 Emission (Ton)	Fuel CO_2 Emission (Ton)	Total Emission (Ton)
2015	2,307	1,045	8.86	3,361
2016	2,235	1,269	1.98	3,507
2017	2,241	1,144	4.77	3,390

The total CO_2 emissions for the last three years can be seen in Table 7. When the table is examined; CO_2 emission in 2015 is 3,361 tons. By 2016, CO_2 emissions increased by 146 tons compared to the previous year and reached 3,507 tons. In 2017, CO_2 emissions decreased by 117 tons and became 3,390 tons. It is seen that the emissions remained approximately the same for three years. All improvements to be made in the facility for energy efficiency or energy saving would reduce CO_2 emissions.

5. Discussions

The main systems consuming energy in the sports complex are; Heating System, Air Conditioning and Ventilation System, Cooling System, Electric System and Lighting System. In this study, the potential energy gains through improvements to be made in these systems were examined.

5.1. Heating System Improvements

Oxygen-O2 levels in flue gas were measured to be slightly above the ideal levels. Boiler efficiency can be increased by adjusting these settings considering the boiler and burner capacity.

In boiler chimneys, flue gas velocity measurements were made to determine the flue draft. Since there is no automatic flue gas flap in the boiler chimneys of the facility, it was observed that the flue draft continued while the boilers stopped and the heated air inside the boiler was lost. In order to prevent the heat contained in the boiler from being thrown into the atmosphere by natural transport and flue draft at the pauses of the boilers, a power-operated flue gas clapper should be installed in the boiler chimneys. During the inspections and thermal camera measurements made in the facility, it was observed that some mechanical installation elements in the heating group were not insulated, and some insulations had been deformed. Deformed pipelines and insulation jackets should be modified. Heat losses occur due to the uninsulated boiler back covers as well. These losses should be eliminated with the insulation to be applied to the back covers. Potential savings as a result of all these improvements are shown in Table 8.

Table 8. Predicted savings in the heating system after modifications.

Case Studies	Energy Type	Amount of Savings			The Amount of CO_2 Reduction	Investment Cost	Amortization Period
		Quantity (kWh/year)	TOE/ Year	Euro/ Year	Ton/Year	Euro	Year
Adjustment of air-fuel rate and burner flame length	Natural Gas	97,788	8.4	2,518	22.9	---	---
Flue gas flap implication	Natural Gas	146,682	12.6	3,777	34.3	6,811	1.80
Insulation of some mech. installation elements in the heating system	Natural Gas	23,534	2.0	606	5.5	6,179	0.91
Insulating boiler back covers	Natural Gas	9,467	0.8	244	2.2	5,845	2.15

5.2. HVAC System Improvements

CO_2 measurements taken in the facility sports hall showed an average of 500 ppm during the day and did not exceed 700 ppm. In terms of energy efficiency, it would be appropriate to use CO_2 controlled proper ventilation systems in the air handling units.

In some air handling units, the belts were found to be broken or worn and the filters were dirty. Belts and pulleys should regularly be checked, and damaged parts should be reconditioned. The filters must be renewed or cleaned for hygiene and energy efficiency reasons. Potential savings as a result of all these improvements are shown in Table 9.

Table 9. Savings with improvements to be made in air handling units

Case Studies	Energy Type	Amount of Savings			The Amount of CO_2 Reduction	Investment Cost	Amortization Period
		Quantity (kWh/year)	TOE/ Year	Euro/Year	Ton/Year	Euro	Year
Implication of a CO_2 Controlled ventilation system	Electricity	35,799	3.1	3,130	22.4	116,900	3.35
Air handling unit cleaning and maintenance	Electricity	31,500	2.7	2,754	19.7	---	---
Air handling unit belt-pulley improvements	Electricity	25,920	2.2	2,266	16.2	8,350	0.33

5.3. Refrigeration System Improvements

During the measurements and observations carried out with the chillers, it was seen that periodic maintenance should be carried out in a more regular and detailed manner.

The chillers are located in the garden under the exposure of the sun. Adhesion of the dust in the environment on the coil surfaces negatively affects the operation of the devices and reduces the cooling efficiency. Condenser surfaces are also deformed due to hail. By covering the device with a net or tarpaulin, foreign materials can be prevented from entering the serpentines. In addition, due to the constant exposure of the groups to sunlight during summer, the condenser can not be able to expel the heat in an efficient way, resulting in a decrease in efficiency. Sun blinds should be placed in the areas where the chillers are located, so as to obtain maximum efficiency. Potential savings as a result of all these improvements are listed in Table 10.

Table 10. Potential savings through improvements in chillers

Case Studies	Energy Type	Amount of Savings			The Amount of CO_2 Reduction	Investment Cost	Amortization Period
		Quantity (kWh/year)	TOE/ Year	Euro/Year	Ton/ Year	Euro	Year
Maintenance and cleaning of chillers	Electricity	10,800	0.9	944	6.8	---	---
Cooling group wire mesh netting	Electricity	5,400	0.5	472	3.4	135	0.29
Installing a canopy to the cooling group	Electricity	27,550	2.4	2,408	17.2	3,443	1.43
Solar window film implication	Electricity	36,250	3.1	3,169	22.7	7,485	2.36

5.4. Energy Monitoring System Improvements

Managing energy starts with monitoring it. It becomes very difficult to manage the energy we cannot monitor. The energy in the facility is currently monitored only through invoices. An energy monitoring system must be installed at the facility. With the installation of the energy monitoring system, different systems consuming electricity, natural gas and water can be monitored daily, hourly or even every minute.

According to the measurements made in the circulation pump engines belonging to the chiller, some pump groups continued to operate during the hours when the facility was closed. Unnecessarily consumed electricity should be prevented by making sure that these detected groups stop when the facility is closed. Potential savings as a result of all these improvements are shown in Table 11.

Table 11. Potential improvements and savings due to energy monitoring

Case Studies	Energy Type	Amount of Savings			The Amount of CO_2 Reduction	Investment Cost	Amortization Period
		Quantity (kWh/year)	TOE/ Year	Euro/Year	Ton/Year	Euro	Year
Energy monitoring system installation	Electricity	71,597	6.2	6,259	44.8	4,491	0.72

5.5. Purchased Electric Energy Recommendations

Based on the consumption data of the facility and the energy consumption characteristics, the facility can meet its heat requirements by generating its own electricity with the establishment of a cogeneration system, which is a combined energy system where electricity and heat are produced together. Thus, when the cogeneration system operates between 08:00 and 20:00 when the facility's energy consumption is the most intense, a total of 1,817,700 kWh of electricity can be produced annually. In order to produce such an amount of electricity, 4,327,857 kWh natural gas will be consumed. The facility will save 49.2% in total on electricity consumption from the grid. Potential savings as a result of all these improvements are shown in Table 12.

Table 12. Potential improvements and savings due to the changes in purchased electric energy

Case Studies	Energy Type	Amount of Savings			The Amount of CO_2 Reduction	Investment Cost	Amortization Period
		Quantity (kWh/year)	TOE/ Year	Euro/ Year	Ton/Year	Euro	Year
Establishment of the cogeneration system	Electricity	–	–	87,536	–	349,072	3.99

5.6. Lighting System Recommendations

When the lighting system is examined, it is seen that mostly fluorescent and recessed luminaires are preferred throughout the facility. Replacing luminaires used in facility lighting with low energy consumption LED luminaires will save money. As a result of all these improvements, potential savings are shown in Table 13.

Table 13. Potential savings with improvements in lighting

Case Studies	Energy Type	Amount of Savings			The Amount of CO_2 Reduction	Investment Cost	Amortization Period
		Quantity (kWh/year)	TOE/ Year	Euro/Year	Ton/ Year	Euro	Year
Indoor lighting LED conversion	Electricity	192,720	16.6	16,848	165.4	57,284	3.40
Outdoor lighting LED conversion	Electricity	77,400	6.7	6,767	48.5	6,662	1.12

6. Conclusion

As a result of technological developments, the energy consumption of buildings has increased today. In particular, the use of air conditioning systems contributes to this with the increase in the comfort standards of people. Research has shown that the main areas of energy consumption in buildings are heating, ventilation, air conditioning and lighting.

Therefore, studies to reduce energy consumption in buildings are very important. In this study, energy analyzes were made for a sample public building. Improvements were made in terms of energy consumption and evaluated.

The results of the study and the summary tables and the predicted energy savings are given in Table 14. According to this, with the realization of the project, a saving of 68.2 TEP/year is envisaged. Financial savings of 139,698 Euro/year are foreseen with the realization of the project. As a result of these applications, 432 tons less CO_2 will be released to the environment.

Table 14. Summary of proposed energy-saving projects

Energy Type	**Amount of Savings**		
	Quantity	**TOE/Year**	**Euros / Year**
Natural Gas	277,471 kWh	23.8	7,145
Electricity	960,016 kWh	44.4	132,553
Total	1,237,486 kWh	68.2	139,698

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