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Araştırma Makalesi / Research Article

# Heating System Modernisation and Carbon Emission Comparison; Vocational School Example

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## Abstract

Since Türkiye is a country with an increasing population and a growing economy, its need for energy is also increasing. To ensure the continuity of sustainable development by eliminating problems such as deterioration of ecological balance, destruction of the environment, increase in unbalanced urbanization, increasing urbanization rate, strengthening of the service and industrial sectors, decrease in resources, increase in prices, deterioration in budget and current account balance and foreign dependency resulting from this increase, energy saving, and energy efficiency have become mandatory in Türkiye and around the world. This research is the development research of the heating system in our Sarayönü Vocational School. Due to the current system cost, maintenance, and repair expenses, there has been a need for a more environmentally friendly and feasible heating system. In addition, the current system's negative impact on personnel needs and sustainable business management negatively affects heating efficiency. Finally, the current system causes disruptions during education due to some environmental problems (fuel oil smell, emission discharge, aesthetic pollution, etc.). In addition to all these negativities, a new heating system was installed with an environmentally friendly and sustainable approach. With the data and figures obtained, CO2 Emission (Ton/year) was reduced by 35% with the help of the natural gas heating system.

**Keywords:** Carbon Emission, Energy efficiency, Heating system conversion, Cascade System.

# Isıtma Sistemi Modernizasyonu ve Karbon Emisyonu Karşılaştırması; Meslek Yüksekokulu Örneği

## Öz

Türkiye artan nüfusa ve büyüyen ekonomiye sahip bir ülke olduğundan enerji ihtiyacı da artmaktadır. Ekolojik dengenin bozulması, çevrenin tahribi, dengesiz kentleşmenin artması, kentleşme oranının artması, hizmet ve sanayi sektörlerinin güçlenmesi, kaynakların azalması, fiyatların artması, bütçe ve cari dengede bozulma ve bu artıştan kaynaklanan dışa bağımlılık gibi sorunları ortadan kaldırarak sürdürülebilir kalkınmanın sürekliliğini sağlamak için enerji tasarrufu ve enerji verimliliği Türkiye'de ve dünyada zorunlu hale gelmiştir. Bu araştırma Sarayönü Meslek Yüksekokulumuzdaki ısıtma sisteminin geliştirme araştırmasıdır. Mevcut sistem maliyeti, bakım ve onarım giderleri nedeniyle daha çevre dostu ve uygulanabilir bir ısıtma sistemine ihtiyaç duyulmuştur. Ayrıca mevcut sistemin personel ihtiyaçları ve sürdürülebilir işletme yönetimi üzerindeki olumsuz etkisi ısıtma verimliliğini olumsuz etkilemektedir. Ayrıca, mevcut sistem bazı çevresel sorunlar (mazot kokusu, emisyon deşarjı, estetik kirlilik vb.) nedeniyle eğitim öğretim döneminde aksaklıklara neden olmaktadır. Tüm bu olumsuzluklara ek olarak çevre dostu ve sürdürülebilir bir yaklaşımla yeni bir ısıtma sistemi kurulmuştur. Elde edilen veriler ve hesaplamalar ışığında, doğalgazlı ısıtma sisteminin katkısıyla $CO_2$ Emisyonu (Ton/yıl) %35 oranında azaltılmıştır.

**Anahtar Kelimeler:** Karbon emisyon, Enerji verimliliği, Isıtma sistem dönüşümü, Kaskad sistem.

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## 1. Introduction

Energy efficiency contributes to energy security, sustainable energy supply, employment, reduction in foreign dependence on energy and greenhouse gas emissions, in short, sustainable development, sustainable energy, and sustainable environment (Sevım, 2012). For this reason, energy efficiency has become an important part of energy policies in recent years. Therefore, energy efficiency, which has the potential to be Turkey's most important source of energy, is also at the center of strategies and targets (Durmuşoğlu, 2015). The increasing need for energy day by day has brought the concept of energy efficiency to an important level. Energy efficiency is a study that covers all stages of the life cycle, from energy production to waste (Çağlar, 2021; Yücel & Ekmekçiler, 2008). For this reason, activities carried out to do more work with the energy produced are gaining value. Strategies are being developed to keep waste heat, waste gas, and other losses to a minimum level (Yavuz, 2010). When energy-saving potentials are examined on a sectoral basis, it is seen that the largest share belongs to buildings. By identifying energy efficiency focuses in buildings, energy consumption can be reduced and losses can be kept to a minimum (Sağbaş & Başbuğ, 2018). It is possible to save 25-30% as a result of controlling HVAC (Heating Ventilating and Air Conditioning) and lighting in buildings (Genli, 2005; Gündüz, 2015). A common energy consumption unit, TOE (Tonne of Oil Equivalent), has been created to enable comparison of the energy consumption values of buildings, facilities, and industrial enterprises using different types of energy. It is known as TOE (ton oil equivalent) in English (Kiyilmaz, 2019).

Meeting the need arising from the increasing energy demand from non-renewable resources that are harmful to the environment but produce significant amounts of energy may cause problems that will restrict the living spaces of all living things. The energy produced by renewable energies without disrupting the ecosystem cycle is included in clean, renewable, and reliable energy sources. Electrical energy is not the only energy we use to meet our needs. Fossil fuels are used to a large extent in transportation, heating, and some industrial products. However, with the developments in recent years, the widespread use of electric vehicles in transportation continues rapidly. In addition to passenger vehicles, electric trucks, and buses have started to be used in recent years. Twenty percent of the energy consumed worldwide is from renewable sources. As of 2016, 35% of electricity production in our country is obtained from renewable sources. Hydroelectric power plants (HEPP) come to the fore among renewable energy sources in our country. However, the desired level has not been reached in wind and solar energy (Uçar, 2016).

A resource is anything we take from the living or non-living environment to meet our needs and wants. In terms of energy production, resources are divided into two parts. These are Non-renewable resources and Renewable resources. Figure 1 shows resource, energy use, environmental impact, and sustainability conversion. Non-renewable resources are coal, oil, natural gas, etc. These are resources that are constantly consumed by people, that constantly harm the environment as they are consumed, and that decrease over time. Environmental pollution caused by its consumption leads to climate changes, resulting in floods, melting of polar glaciers, and increased temperatures. As a result, a situation contrary to sustainable development is developing, with living life under threat. Non-renewable energy resources are inversely proportional to sustainable development and directly proportional to environmental pollution. The predominant use of fossil energy resources is an indication that the responsibility towards the environment, living creatures, and future generations is not fulfilled. Now, with a reverse approach, it is mandatory to use renewable energy sources. Energy resource use and a clean environment must be considered together. Renewable energy sources are geothermal, solar, wind, hydraulic, etc. The energy generated as a result of their consumption either leaves no waste or very little waste. In addition, obtaining energy from the wastes produced by people (burnt oil, garbage, used paper, glass, etc.) and reducing waste while obtaining energy constitute sustainable development. As a result, the creation of a clean world is inevitable (Aydın, 2016; Selici et al., 2005).

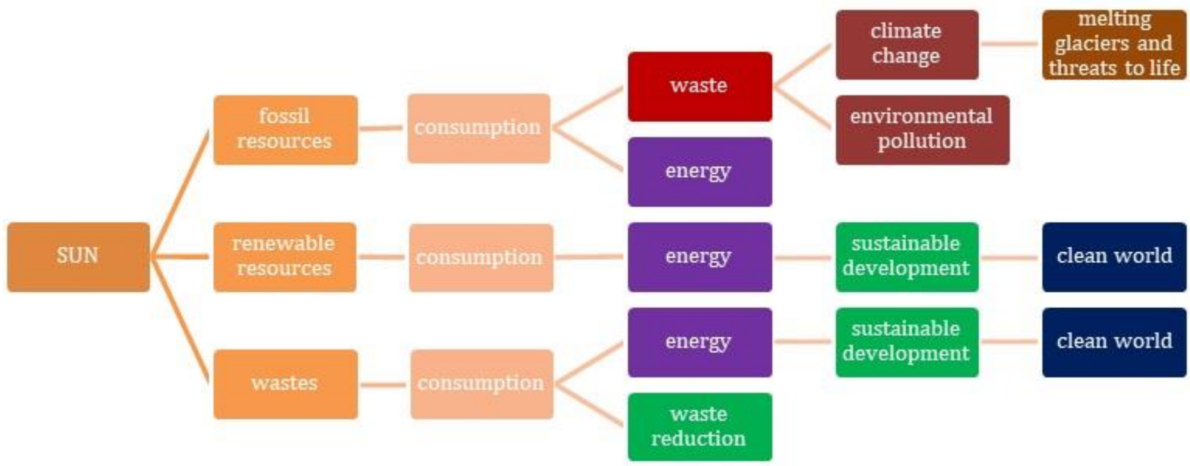


**Figure 1**. Energy resources use, environmental impact, and sustainability transformation (Selici et al., 2005)

To better understand sustainable development, it will be useful to consider it from several perspectives.

a- What is meant by economic development is the production of goods and services that will meet the unlimited demands of people by creating an advanced economic system and ensuring the increase of welfare and happiness in society.

b- What is meant by social development is to increase social welfare by ensuring improvements in issues such as education, health, culture, urbanization, and infrastructure.

c- What is meant by environmental development is the establishment of an environmentally sustainable system that is not classified as an economic resource, but includes the protection of atmospheric balance, biodiversity, and other ecosystem functions.

There is a need to make energy use more efficient, not only because of the scarcity of resources and the rise in prices of fossil energy fuels but also to protect the environment and climate. Additionally, energy use has great significance in the economic process. Because almost every production activity is associated with energy consumption.

With this work;

-More efficient and effective use of our resources,

-Considering that we previously needed TOE for more energy and these needs were imported, to prevent the current account deficit for our country,

-As it is a higher education institution, it ensures that the widespread and appropriate use of greener technologies is explained to our young people who come for educational activities,

-Preventing fuel oil flows and leaks that cause environmental pollution,

-To use the volume occupied by the old system for useful purposes,

-Preventing the heavy oil derivative odor that occurs during filling and transfer to the school storage tank,

-More flexible and precise comfortable heating thanks to the automation system,

-More effective and efficient use of state resources,

-Ensuring the performance of a fully automatic system with less personnel employment,

-In terms of environmental pollution, emission discharge is reduced to natural gas emissions, which is a more acceptable energy source,

-Ensuring the promotion of cleaner and greener technologies in terms of application and sustainability,

-There are many social, and environmental effects that we have difficulty in counting. Most importantly, this work has made it possible to leave a cleaner environment to our young people, who are the guarantee of our future.

According to the studies carried out by the General Directorate of Electrical Power Resources Survey and Development Administration (EİE), an energy-saving potential of 30% in the building sector, 20% in the industrial sector, and 15% in the transportation sector, with a total monetary value of approximately 7.5 billion TL, has been determined. It is roughly explained that the potential is at a level that can build four Keban Dams (Yücel & Ekmekçiler, 2008).

In this context, the "Low Carbon Emission and Automatic Controlled Heating System" study has many benefits and advantages. However, its main purpose is to provide our institution with a heating system that uses a more environmentally friendly energy source with low operating costs, automation, and high thermal efficiency. The scope of the project implementation is to implement more efficient energy use in the education building of Selçuk University, Sarayönü Vocational High School. The objectives of this study are;

- Observing the trend-related decrease in the energy production method currently used in our school and the corresponding energy consumption,
- Determining a more environmentally friendly and sustainable energy use method,
- Achieving more energy efficiency with less labor,
- Having a more flexible and precise working system thanks to the automation system,
- Reducing carbon emissions,
- Having existing infrastructure and using primary energy sources,
- Planning the system with lower operating and installation costs,
- In addition to many other direct and indirect goals, such as implementing an exemplary project that will reduce fuel costs by using public equity resources more profitably, this project serves as a guide in terms of demonstrating its applicability to many public institutions.

## 2. Materials and Methods

### 2.1. Contribution/Compatibility Of The Heating System To Its Strategic Goals

Since the place of project implementation is the Higher Education Institution, the education and research studies must be carried out in a more efficient and cleaner environment. In addition, it is essential to use public resources more efficiently. In light of this information, the newly established system ensured that the energy budget previously transferred to the institution was transferred to education and research activities. The half-cylindrical boiler and smoke pipes used in heating the educational building can be seen in Figure 1. and Figure 2.

**Figure 2.** Old Heating System Images

As seen in Table 1, in natural gas-fueled systems with high lower calorific value and high $H_2O$ ratio, the ratio of convective heat transfer to radiative heat transfer from the surface increases. This increases the efficiency of boiler systems with the same heating surface.

**Table 1.** Lower Calorific Values of Energy Resources and Conversion Coefficient to Oil Equivalent TOE rates refer to official document No. 3505/BCT-KHCN, 19/04/2011. Energy conversion rates were calculated using the IPCC conversion value of 1 TOE = 41,870 MJ.

| Unit | Type | Lower calorific value kcal | TOE/unit | MJ/unit | $CO_2$ emission ton $CO_2$/unit |
|---|---|---|---|---|---|
| **kWh** | Electricity | 880.000 | 0.1543 | - | 0.9130 |
| **Ton** | Coal | 6.100.000 | 0.7-0.75 | 29309 - 31402.5 | 2.77-2.97 |
| **Ton** | DO | 10.200.000 | 1.02 | 42707.4 | 3.165 |
| **Ton** | FO | 9.860.000 | 0.99 | 41451.3 | 3.208 |
| **Ton** | LPG | 10.900.000 | 1.09 | 45638.3 | 2.880 |
| **1000m$^3$** | NG | 8.250.000 | 0.9 | 37683.0 | 2.114 |
| **Ton** | Gasoline | 10.400.000 | 1.05 | 43963.5 | 3.047 |
| **Ton** | Jet Fuel | 10.150.000 | 1.05 | 43963.5 | 3.143 |
| **Ton** | Wood | 3.000.000 | - | 16200 | - |

**Figure 3.** Old Heating System Boiler and Burner Collector Images

### 2.2. Techniques and Methods Used in Heating Efficiency

Unlike classical systems, the newly installed heating system has a structure that provides heat capacity modulation in line with seasonal changes. Due to this feature, the cascade heating system provides optimum fuel consumption during seasonal transitions. In addition, thanks to a cascade automation panel with a weekly program, automatic temperature adjustments can be made day and night. Full automation is achieved thanks to the external weather compensation device that can make acute automatic temperature adjustments in response to the variability of external weather conditions.

### 2.3. Risks in the Heating System and Precautions Taken

Project components consist of TSE and CE-certified modules that comply with the relevant standards. All parts were assembled by complying with occupational health and worker safety measures. Before the system was put into operation, it was inspected by an independent organization authorized by Energy Market Regulatory Authority (EMRA), and its compliance with security tests was determined and activated. In addition, since the energy fuel type used is natural gas, gas safety systems were activated to prevent leaks and leaks. The differences between the installed system and its transformation are shown in Figure 4. and Table 2.


**Figure 4.** Sarayönü Vocational School and Approximate Resource Usage Amounts

**Table 2.** Revised system and New System TOE Calculation

| **Previously Heating System TOE Value** | **New Heating System TOE value** |
|---|---|
| 25,140 x 9600 = 241,344,000KCal = 241,344,000/10,000,000 **=24.134 TOE** | 17640 X 8250 = 145,530,000KCal = 145,530,000 / 10,000,000 **= 14.553 TOE** |

*Table 1 was used for lower calorific values.

## 3. System Implementation and Design

### 3.1. Activity and Implementation Plan of The Project

As a result of the technical study and heat loss calculations of the building, the Cascade System design shown below was realized. The system assembly was carried out as indicated in Figure 6 and Figure 7.

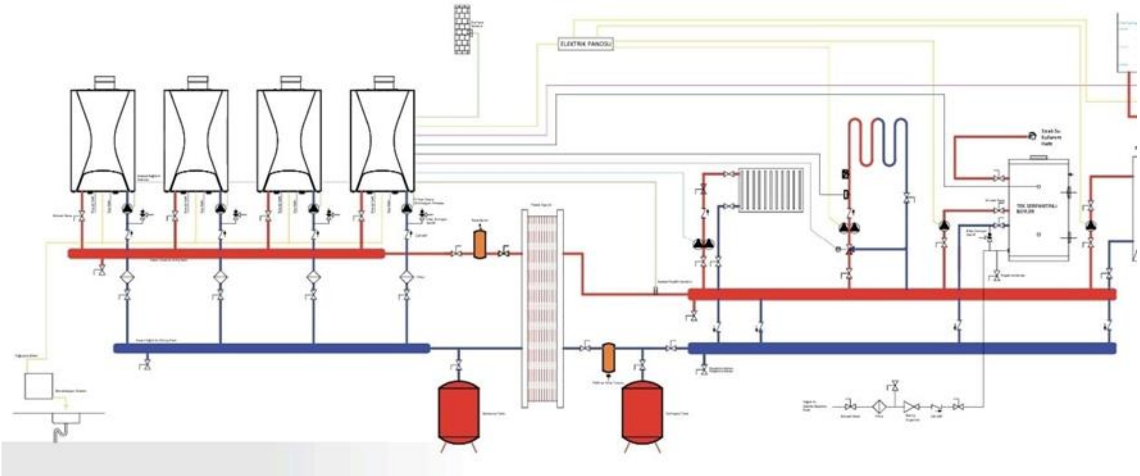

**Figure 5.** New Heating System Project Image

**Figure 6.** Installation of cascade heating system

**Figure 7.** Cascade heating system pomps and balance tank installation

### 3.2. Sustainability of the Heating System

Before the project system investment, the monthly winter season approximate consumption was calculated as 24,134 TOE. After the investment, it was calculated as approximately 14,553 TOE per month in the winter season. Thanks to the new cascade natural gas system built after the investment cost, almost 40% TOE energy consumption unit gain was achieved. This calculation shows us that approximately 9,581 tons of oil equivalent (TOE) was gained.

The low cost of using the newly installed heating system amortizes the initial investment cost within 2 years.

### 3.3. Measurable effects of the Heating System on operating performance

During the education and research carried out in line with the mission of our institution, the old system was not able to provide a homogeneous heat distribution, negatively affecting the performance of staff and students. With the commissioning of the new system subject to the project, homogeneous thermal comfort has been achieved. In addition, optimum heat capacity is provided thanks to the system automation and thermostatic valves in the heaters. Figure 8.

**Figure 8.** Thermostatic Valve Application

Thermostatic valves are used in central heating systems and other heating systems such as combi boilers, floor heaters, etc. It is used to ensure room temperature comfort in systems. It allows you to determine the room comfort temperature from the sTOE settings on the thermostatic valve. Adjusting the temperature coming to the radiators in heating systems according to the room temperature need provides comfort and economy in heating by saving approximately 15%.

### 3.4. Carbon Emission Reduction

Combustion is defined as the rapid chemical combination of combustible C and H in the fuel with oxygen in the air. Carbon dioxide ($CO_2$) from flue gas emissions and carbon monoxide (CO) formed as a result of poor combustion are gases that negatively affect the environment and human health. Therefore, it is very important to use energy effectively and efficiently in heating buildings.

$CO_2$ emissions resulting from the combustion of fuels were used as the basic parameter in this study (Doğan & Yılankırkan, 2015).

Carbon dioxide is the largest greenhouse gas produced by human activities. The biggest factor in the release of $CO_2$ emissions is the oxidation of carbon during the burning of fossil fuels. At the same time, burning fossil fuels accounts for 70-90% of the $CO_2$ emissions resulting from human activities (Kimble et al., 2007).

Tonne of Oil Equivalent (TOE) is an energy unit that defines the amount of energy released by burning 1 ton of crude oil. 1 TOE is approximately equal to 10 million kcal (kilocalories), 42 GJ (gigajoule), or 11628 kWh (kilowatt-hour). TOE conversion coefficients of all energy resources were determined under the "Regulation on Increasing Efficiency in the Use of Energy Resources and Energy" dated October 25, 2008 (Yılmaz et al., 2024). Terajoule (TJ) is equal to one trillion (1012) joules. Approximately 63 TJ of energy was released by an atomic bomb exploding in Hiroshima (Mendoza et al., 2015). Lower calorific values of fuels are given in Table 3. 85% of the waste gases released as a result of the burning of fuels used in heating installations are $CO_2$, and 15% are emissions such as sulfur dioxide ($SO_2$), carbon monoxide (CO), particulate matter ($PM_{10}$ and $PM_{2.5}$), nitrogen oxide compounds ($NO_x$). However, since the percentage rates of emission values other than $CO_2$ are small, $CO_2$ emissions are taken into account as a general approach in the calculations. In the Regulation on Energy Performance in Buildings published in the Official Gazette No. 27075 on December 5, 2008, the annual $CO_2$ emissions of buildings are limited, and conversion coefficients (FSEG) are given to determine the amount of $CO_2$ released as a result of final energy consumption, depending on the energy source (fuel type) used. Depending on the net energy consumption of the building and the type of fuel used, the annual $CO_2$ emission amount is calculated from equation (1) according to the annual heating energy need (Arslan, 2015; Gazete, 2008; Gökçen et al.)

**Table 3.** Lower calorific value, boiler efficiency, and College Average Consumption Amount of some fuels

| Fuel Type | Fuel Lower Calorific Value [18] | Fuel Lower Calorific Value Fuel Lower Calorific Value [19] | Approximate Boiler Efficiency, % | Seasonal Average Consumption, 6 months |
|---|---|---|---|---|
| **Natural gas** | 34535 kJ/m$^3$ | 34526.2 kJ/m$^3$ | 0.85-0.92 | 17640 m$^3$ |
| **Lignite coal** | 23020 kJ /kg | 19451.8 kJ/kg | 0.70-0.85 | - |
| **Fueloil** | 41860 kJ /kg | 40594.5 kJ/kg | 0.75-0.90 | 25140 kg |

$$EMy = 0{,}278\ 10{-}3ByHuDK \quad (1)$$

EMy in this equation is the annual $CO_2$ emission amount (kg); DK refers to the $CO_2$ emission conversion coefficient according to fuel type.

The DK ($CO_2$) conversion coefficients of the fuel types used in the study and included in the Energy Performance Regulation in Buildings are given in Table 4.

**Table 4.** DK ($CO_2$) conversion coefficients of fuel types

| Fuel Type | DK ($CO_2$) conversion coefficient (kg eq.$CO_2$/kWh) |
|---|---|
| **Coal** | 0.433 |
| **NG** | 0.234 |
| **Fueloil** | 0.330 |
| **Gasoline** | 0.320 |

The amount of $CO_2$ emissions varies depending on the amount of carbon (C) in the type of oil-based energy consumed. The fixed carbon (C) rate in natural gas is known to be approximately 75%. As a result of burning 1 Sm3 of natural gas, 2.75 kg of $CO_2$ is formed. Similarly, 1 kWh of electricity consumption produces approximately 0.55 kg of $CO_2$. As a result, the amount of $CO_2$ formed in a business is calculated in kg as the sum of the $CO_2$ amounts formed from all energy sources consumed. The amount of $CO_2$ per product is obtained by dividing the total $CO_2$ amount by the product (ton) value ($CO_2$/kg product) (Özbudak, 2011; Rüşen, 2019). With the data and figures obtained, $CO_2$ Emission (Ton/year) was reduced by 35% with the help of the natural gas heating system.

**Table 5.** Fuel Consumption in our Vocational School by Years

| Year | Fuel Type | Average Monthly Consumption Amount | Fuel Unit Price | Approximate Total Amount, ₺/Month |
|---|---|---|---|---|
| **2021**<br>**2022** | Fuel-oil No:4 | 4190 kg/month | 5,19 TL/kg | 21.590,40 |
| **2021**<br>**2022** | Natural Gas | 2940 $m^3$/month | 3,62 TL/$m^3$ | 10.642,80 |

## 4. Conclusion

During the education and research carried out in line with the mission of our institution, the old system was not able to provide a homogeneous heat distribution, negatively affecting the performance of staff and students. With the commissioning of the new system subject to the project, homogeneous thermal comfort has been achieved. In addition, optimum heat capacity is provided thanks to system automation and thermostatic valves in the heaters. The project is expected to contribute to the country's economy by reducing the current account deficit. It can be considered as a sTOE towards more efficient and effective use of public equity resources. Within the scope of the project, over 49% savings in fuel bills were achieved, as seen in Table 5. While Fueloil 4 (kalyak) was used before the investment within the scope of the project, the energy source used in one winter season was calculated as 24,134 TOE. Thanks to the new cascade natural gas system built after the investment cost, almost 40% TOE energy consumption unit gain was achieved. After the project system investment, it was calculated as approximately 14,553 TOE per month in the winter season. This calculation shows us that approximately 9.5814 tons of oil equivalent (TOE) profit was achieved and this cost was prevented from being paid from public resources. With the data and figures obtained, CO2 Emission (ton/year) was reduced by 35% with the help of the natural gas heating system.

### Authors' Contributions

All authors contributed equally to the study.

### Statement of Conflicts of Interest

There is no conflict of interest between the authors.

### Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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