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Comparison of Central and Individual Heating Systems Used for Heating Housings

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Abstract: Today, energy production based on fossil energy sources has become seriously questioned by societies due to both cost and environmental pollution. Fossil energy sources are mainly used for heating houses, which constitute a significant part of energy consumption. In this study, central heating systems, which are the most widely used methods to meet the heat energy needs of buildings and individual heating systems are examined and compared. In the study, the heat loss and energy need of a 5-story building consisting of 10 flats in Kars Center with a total heated area of 1080 m^2 were calculated using the TS 825 calculation method, accordingly, calculation of heater devices for both systems, determination of heating system elements, annual fuel consumption amount and cost calculation has been made. Natural gas was used as fuel in both systems to be compared for heating the building. According to the values obtained as a result of the study, it was seen that individual heating systems have higher costs than central heating systems in terms of both initial investment and heating cost. It has been determined that central heating systems are more advantageous in terms of initial investment cost, fuel consumption, and total cost. While the total cost was 441096 TL for the central heating system, it was 508825 TL for the individual heating system.

Konutların Isıtılmasında Kullanılan Merkezi ve Bireysel Isıtma Sistemlerinin Karşılaştırılması

Anahtar Kelimeler
Isıtma sistemleri,
Enerji tasarrufu,
Yakıt tüketimi,
Maliyet analizi

Öz: Fosil enerji kaynaklarına dayalı enerji üretimi günümüzde hem maliyet hem de oluşturduğu çevre kirliliği nedeni ile toplumlar tarafından ciddi anlamda sorgulanır hale gelmiştir. Enerji tüketiminin önemli bir bölümünü oluşturan konutların ısıtılması için ağırlıklı olarak fosil enerji kaynakları kullanılmaktadır. Bu çalışmada, binaların ısı enerji ihtiyacının karşılanmasında en yaygın kullanılan yöntemlerden olan merkezi ısıtma sistemleri ve bireysel ısıtma sistemleri incelenerek karşılaştırılmıştır. Çalışmada Kars Merkezde 10 daireden oluşan toplam 1080 m^2 ısıtılan alana sahip olan 5 katlı bir binanın ısı kaybı ve enerji ihtiyacı TS 825 hesap metodu kullanılarak hesaplanmış buna göre her iki sistem için ısıtıcı cihazların hesaplanması, ısıtma sistemi elemanlarının belirlenmesi, yıllık yakıt tüketiminin miktarı ve maliyet hesabı yapılmıştır. Binanın ısıtılması için karşılaştırılacak her iki sistemde de yakıt olarak doğalgaz kullanılmıştır. Çalışma sonucunda elde edilen değerlere göre bireysel ısıtma sistemleri hem ilk yatırım hem de ısıtma maliyeti açısından merkezi ısıtma sistemlerine göre daha yüksek maliyete sahip olduğu görüldü. İlk yatırım maliyeti yakıt tüketimi ve toplam maliyet açsından merkezi ısıtma sistemlerinin daha avantajlı olduğu belirlenmiştir. Toplam maliyet merkezi ısıtma sisteminde 441096 TL olurken, bireysel ısıtma sisteminde ise 508825 TL bulunmuştur.

1. INTRODUCTION

Energy is one of the most important needs of humanity and has had a great impact on the development of humanity from its existence to the present [1]. Energy costs are increasing daily due to international political crises, global economic crises, and wars. In addition, the use of fossil-based energy types is one of the most significant factors in environmental pollution and has led countries and states to search for the efficient use of fossil-based energy resources [2].

Due to the increase in energy use, there is a significant increase in the rate of carbon emissions in the atmosphere [3]. Emissions from the combustion of fossil fuels while creating a greenhouse effect in the atmosphere, natural balances are deteriorating and global disasters are increasing [4]. The majority of CO_2, which is more effective in the increase of global warming compared to other emissions, occurs in energy production [5]. For these reasons, renewable, non-fossil sourced energy generation such as wind, solar, and hydrogen becomes important [6].

Fossil-based energy is widely used in residential heating systems. Houses constitute a large share of 40% of total energy consumption worldwide [7]. There are many systems used for heating houses. While these systems are grouped, they are named according to the place where the heat energy is obtained, the fluid in which the power is carried, and the way the heat energy is given to the volume. Heating systems according to the place where the heat energy is obtained; individual and central heating systems, according to the fluid in which the power is carried;

- Hot water heating system
- Steam heating system
- Hot water heating system
- Heating system with hot air

According to the way the heat energy is given to the volume;

- Heating system with heater
- Underfloor heating system
- Panel heating system
- Radiant heating system
- Heating system design with hot air

Central and individual heating systems are the most preferred systems for heating houses. The most important considerations in determining the system to be applied for heating the buildings are the comfort in the living area, the cost of the system to be applied, the compatibility of the heating system with the volume to be heated, the storability and cost of the fuel type to be used.

While 34% of the energy consumed in Turkey is used for heating and a large part of this heat energy is spent in residences [8]. For this reason, in this study, central heating systems and individual heating systems used for heating houses were examined and compared in terms of initial investment cost, fuel consumption amount, and fuel costs. There are many studies in the literature on the comparison of central and individual heating systems, the efficiency of these systems used in heating the houses, heat sharing, and measurement in the systems, some studies are given below.

Cockroft et al. (2017) examined the potential energy savings in meeting the zone-controlled independent volume with a standard central heating system. In their study, they evaluated and analyzed the savings that could be achieved by taking into account the type, age, location, and number of people in the house. Annual simulations with dynamic models for thermal zones and airflow affecting the potential energy savings of zone-controlled and non-zone-controlled volumes were carried out. [9].

Meng et al. (2022) developed a model for heating control and comfortable energy saving of high-rise residential buildings with a central heating system. For the model, they analyzed the correlation between the temperature of the adjacent rooms and used it for the control of the heating elements in the boiler room, the optimization of the space temperature, and heat energy distribution. Compared to the central control method, they found that the energy consumption decreased by 14.28% and the efficiency of the heating elements in the boiler room increased. [10].

Yuruk et al. (2022) examined the cleaned installation of heating systems in houses in terms of efficient energy. In the study, they determined the energy loss caused by calcification and pollution in the heating systems with the measurements before and after the system cleaning. As a result of the study, they found a homogeneous temperature distribution and a decrease of 21.16% and 25% in natural gas consumption and harmful emissions, respectively, and an increase of 17.2% in convection heat transfer in the radiators in the lime and dirt-free system. [11]. Omar et al. (2015) developed and experimentally investigated a hemispherical porous metal matrix burner for boilers and combi boilers used as heating devices in central and individual heating systems. In the experimental study, the thermal and flow behavior of the burner in a combi unit used in heating systems were investigated. As a result of the improvements in the combustion processes in the device used in the heating systems in the study, they achieved a reduction in emission values by providing fuel and energy savings [12].

Tahir et al. (2022) evaluated a central energy system with an individual heating system using energy and exergy analysis. In this study, the energy and exergy analysis of individual heating systems in China according to the energy conservation laws of thermodynamics for an economically viable and carbon-free clean environment are examined. In the study, they proposed natural gas-fueled micro-combined heat-power, hydrogen-fueled micro-combined heat-power, and heat pump systems to meet different energy needs instead of fossil fuel boilers. [13].

Pavlovic et al. (2022) conducted a study to examine the situation of individual heating systems in Serbia. In the study, they found that the thermal insulation of the residences in Serbia was inadequate, and the heating systems were old and low-efficiency. In their studies, they emphasized that the effect of energy efficiency on climate change is important and this situation is significant for developing countries [14].

Zhang (2021) examined the measurement management system of individual heating in mass housing buildings with the central heating system. In the study, a pricing management system has been designed to ensure that the heating measurement is fair in the mass housing building and to solve the heat-sharing problem. He found that this measurement system is important in terms of energy optimization, energy saving, and emission values [15].

Cho et al. (2020) investigated the effect of hydraulic balancing of the heating system in buildings on energy saving and improving the thermal conditions of the volume. The methodology they developed consists of characterization, prediction, and scenario analysis for thermal comfort and energy savings through hydraulic balancing. They achieved energy saving between 2% and 14% by applying the study in Geneva, Switzerland [16]. Saba et al. (2017) experimentally investigated the heating cost distribution method for apartment buildings. In the study, they tried a new heat cost distribution method for apartments and compared this method with traditional heat cost distribution systems. Contrary to traditional methods, they have verified experimental study results by providing an estimation of the energy consumed without the need to measure the temperature of the heater radiators [17].

Terhan and Abak (2023) studied the optimization of insulation thickness in buildings using energy and exergy methods. For the study, they searched for optimum insulation thickness for exterior walls by taking the actual consumption values and dimensions of buildings in a campus in Turkey as a reference. They considered energy consumption, fuel Life Cycle Assessment, and payback periods to determine the optimum insulation thickness. They found the optimum insulation thickness as 2.3–10.0 cm for the outer wall according to different climatic regions. They determined that the fuel consumption of the insulated building decreased by 46.63%-53.46% compared to the uninsulated situation [18].

1.1. Central Heating Systems

Central heating systems are a system applied to meet the heating needs of buildings and living spaces. The heat energy produced by a common heating device is transferred to all volumes by one or more columns and heated to the radiators. As shown in Figure 1, these systems have types of multi-column central heating systems and single-column central heating systems according to the way they are applied.

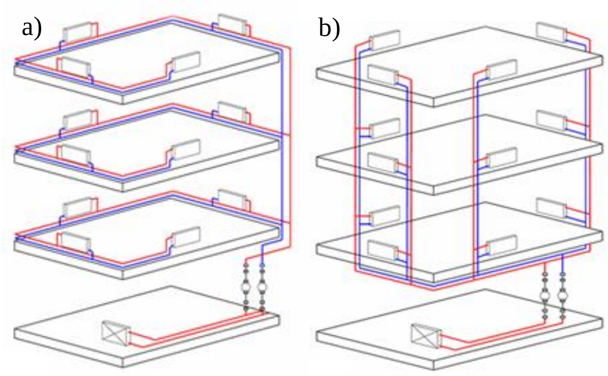

Figure 1. a) single column central heating system, b) multi-column central heating system [19]

According to the distribution type of water, which is the heat transfer fluid of central heating systems;

- Bottom-distribution-bottom-collection
- Top-distribution-bottom-collection
- Top-distribution-top-collection

It is examined in groups. Figure 2 shows the diagram of the central system with the bottom distribution-bottom collection and top distribution-bottom collection.

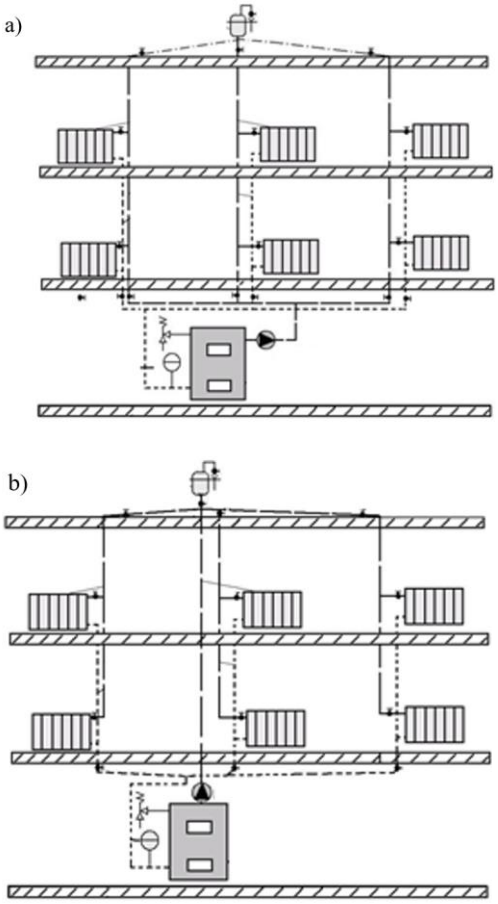

Figure 2. a) Bottom distribution-bottom collection, b) top distribution-bottom collection heating system [20]

1.2. Individual Heating Systems

Individual or individual heating systems are the type of heating system in which the heat energy of independent volumes is met separately. In Figure 3, floor heating and combi boiler used in individual heating systems are shown. Individual heating systems are systems used for energy requirements below 40 kW [21]. These systems are the most used systems because of the easy measurability of the energy consumed in the houses.

a) b)

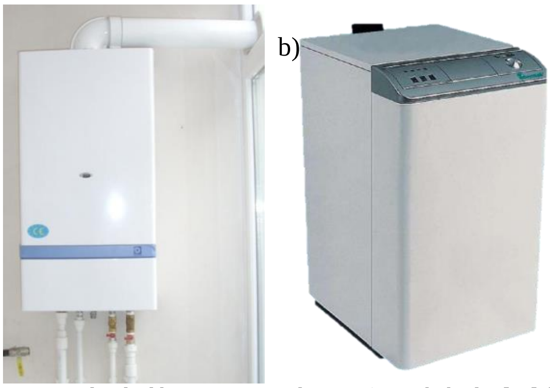

Figure 3. Individual heating system devices a) Combi boiler [22], b) Floor heating [23]

Today, combi boilers are preferred instead of floor heating systems in individual heating systems. Combi boilers are classified as chimney combi boilers, hermetic combi boilers, semi-hermetic combi boilers, and condensing combi boilers. It is possible to save 17% on the fuel cost of the household by using a device that works with condensation technology as the heating device in houses that are heated individually or with a combi boiler [24].

The advantages of combi boilers are that they can be used independently in houses, their emission values are low, they can meet both hot water and heating needs with the same device, and they are environmentally friendly. Combi boilers work in wide modulation ranges and prevent the stop-start problem that causes an increase in efficiency and a decrease in emissions. It can be adjusted by the electronic system of the combi boiler by determining the instantaneous energy needed and accordingly the air-fuel ratio. As a result of combustion with an optimum air-fuel ratio, high combustion efficiency, and low emission values can be obtained.

2. MATERIAL AND METHOD

In this study, the heat loss calculations of a building with a total heated area of 1080 m^2 were calculated by considering the temperature values of Kars province. The flats in the building are of standard type and consist of a living room, bedroom, living room, kitchen, children's room, and bathroom. The floor plan of the building is given in Figure 4.

Figure 4. Floor plan of the building

2.1. Features of the Building and the System to be Applied

The building examined in this study is located in the center of Kars and consists of 5 floors and 10 apartments, including the basement, ground, first and second floors. The floor height of each floor is 3m and the total height of the building excluding the basement is 10m. Condition and property information about the building is given in Table 1.

In the insulation of the building, extruded polyurethane foam (XPS) was used as 5 cm on the outer walls and 3 cm on the outside, between floors, and between independent sections. Considering Kars climatic conditions, -27 °C for Kars Center, windy zone, 3rd Climate Zone (TS 825) The building is a free-standing, reinforced concrete building in a windy zone.

Table 1. State property information of the building

City in which it is located	Kars, Center
TS825 zone of the building	Region 4
Outside temperature value	-27 °C
Building condition	Discrete order
Window type	Double glazed plastic joinery
Building height	12m
Floor height	3m
Number of floors	5 (basement + 4 floors)

The building is insulated from the outside and the insulation material is 7cm extruded polystyrene foam (XPS). The outer walls are made of vertically perforated bricks in accordance with TS EN 771-1 with a thickness of 15 cm. The outer and inner surfaces are plaster made using 2 cm thick plaster. The cross-section of the outer walls of the building is shown in Figure 5. The heat transmission coefficients of the building components selected according to TS 825 are shown in Table 2.

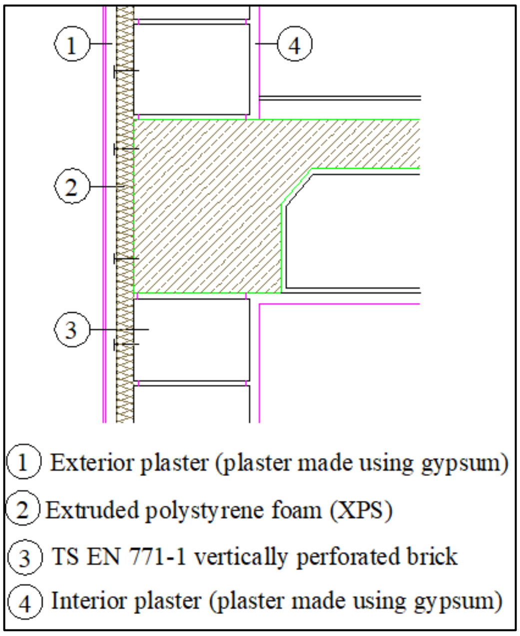

Figure 5. Cross section of the exterior walls of the building [25]

Table 2. Heat conduction of materials used in the exterior wall

Material	**Thickness (m)**	**Heat Conduction coefficient (W/mK)**	**Density (kg/m^3)**
Interior plaster (plaster made using gypsum)	0.02	0.51	1200
TS EN 771-1 vertically perforated brick	0.15	0.5	1200
Extruded polystyrene foam (XPS)	0.07	0.03	25
Exterior plaster (plaster made using gypsum)	0.02	0.51	1200

Both the central heating system and the individual heating system have been applied as a system in the building. For the central heating system, a 90/70 °C hot water pump heating system with bottom distribution has been applied. The individual heating system, on the other hand, is provided by the energy produced by the combi boiler independently in each flat. Natural gas was used as fuel for both heating systems.

2.2. Calculation of Energy Need

TS 825 calculation method was used to calculate the heating load. The heat loss calculations are calculated by taking into account the heat losses on the walls, windows, doors, roof, and floor of the rooms of each flat, with the equations given in Equation 1 - 4 below, which consists of long calculation steps [26] It is shown in Table 3.

$$Q = q_i + q_s \quad (1)$$

$$q_i = q_o(1 + \%Z_D + \%Z_H) \quad (2)$$

$$q_o = kA\Delta T \quad (3)$$

$$q_s = \sum (al)RH\Delta TZ_e \quad (4)$$

Here, Q is the total heat loss, q_i is the incremental heat loss, and q_s is the air leakage heat loss.

In Equation 2, q_s non-increasing heat loss (W), Z_D combined increase coefficient (%), Z_H direction increase coefficient (%).

In Equation 3 k heat transfer coefficient of building components (W/m^2 °C),

A is the surface area of the building component (m^2) and ΔT is the indoor and outdoor temperature difference (°C). In Equation 4, l leakage gap perimeter (m), R the room feature (0.9), H is the layout status of the structure (Wh/m^3 °C) and Z shows the corner increment coefficient. Annual fuel consumption in heating systems is calculated using Equation 5 [27].

$$B_y = \frac{Q_{yıl}}{H_u * \eta_k} \quad (5)$$

Here By is the annual fuel consumption amount (m^3), *Qy* annual heating energy requirement (kcal), *Hu* is the lower heating value of the fuel (kcal m^{-3}), *ηk* is the boiler efficiency (%).

Annual fuel consumption cost is calculated using Equation 6 [28].

$$M_y = B_y . C_{yak} \quad (6)$$

Here, *My* shows the annual fuel cost (TL), By the amount of fuel consumed (m^3) and the *Cyak* fuel unit price (TL/m^3).

3. FINDINGS AND DISCUSSION

In addition to different heating methods, different heat sources are widely used for heating houses [29]. These are the central heating system and individual heating systems. In this study, these two types of heating, which are widely used in our country, were compared. For the study, considering Kars climatic conditions, heat loss calculation, heating energy need, calculation of heating devices, determination of heating system elements, calculation of annual fuel consumption, and cost calculation were made according to TS 825.

The heat losses of the building examined in the study, calculated according to the floors and flats of the building by Equations 1 - 4, are shown in Table 3.

Table 3. Heat loss of apartments

Floor	Home No	Calculated Heat Loss (W)	Selected Radiator Thermal Power (W)
Ground floor	Home 1	12643	12853
	Home 2	12483	12621
1st floor	Home 3	15710	16101
	Home 4	15779	16333
2nd floor	Home 5	15675	16217
	Home 6	15642	16333
3th floor	Home 7	15875	16333
	Home 8	15750	15985
Loft	Home 9	4663	4849
	Home 10	7112	7633

In order to meet the total energy requirement calculated according to the building's heat loss in Table 3, central and individual systems and system elements are examined separately. The comparison of the number of equipment to be used in each system, the capacities of the devices used, and the initial investment cost is shown in Table 4 and Table 5. In the cost calculation, the current prices of the devices are taken into account.

3.1. Central System Elements and Device Selection

The hardware and equipment to be used in the central system were selected and determined according to the total energy requirement of the building. The properties, capacities, dimensions, and quantities of the system elements are shown in Table 4. In the cost calculation, the current and real prices of the devices are taken into account.

Table 4. Equipment used in the central system

Device Name	Calculated Value	Calculated Device	Selected Device
Boiler (W)	135256	155544	197200
Expansion tank (L)	205	205	250
Chimney (cm^2)	1025.46	1025.46	1026
Circulation pump (m^3/h)	7.25	7.25	7.25
Patent black pipe, Aluminum foil pipe ins.	in various sizes	in various sizes	in various sizes
Strainer, Non-return valve			
Chimney valve, ball valve			
Radiator, Corner rad. valve, Rad. union			

3.2. Individual System Device Selection

The equipment and equipment to be used in the individual system, which is another option to be used for the heating of the building, are also determined according to the total energy requirement. The properties, capacities, dimensions, and quantities of the system elements are shown in Table 5. In the cost calculation, the current and real prices of the devices are taken into account.

Table 5. Equipment used in the individual system

Device Name	Calculated Value	Calculated Device	Selected Device
Combi boiler (W)	13108-17284	13108-17284	24.000
Pex pipe	15mm	15mm	15mm
Pex pipe fittings	15mm	15mm	15mm
Flat collector	in various sizes	in various sizes	in various sizes
Radiator, corner rad. valve., Rad. union			

3.3. Annual Fuel Consumption and Cost Calculation

Natural gas will be used as fuel in both systems to be compared for the heating of the building. Considering the annual total heating energy need, the annual fuel consumption was determined using Equation 5. The annual fuel consumption and annual fuel cost according to the annual heating energy requirement in the central system are shown in Table 6, and in the individual system, the annual fuel consumption and annual fuel cost according to the annual heating energy requirement per flat in the individual system are shown in Table 7.

Depending on the annual heating energy need of the building, the annual natural gas and annual fuel costs are calculated by considering Equation 5 and Equation 6, respectively.

Table 6. Annual fuel consumption and annual fuel cost according to the annual heating energy requirement in the central system

Annual Heating Max. Need, (W)	Annual Fuel Consumption By (m^3)	Annual Fuel Cost My (TL)
374294372	35882	208115

Table 7. Annual fuel consumption and annual fuel cost according to the annual heating energy requirement per apartment in the individual system

Floor	Home No	Annual Heating Max. Need (W)	Annual Fuel Consumption By (m^3)	Annual Fuel Cost My (TL)
Ground floor	Home 1	36630480	4184	20920
	Home 2	35969280	4109	20543
1st floor	Home 3	45887280	5241	26207
	Home 4	46548480	5317	26585
2nd floor	Home 5	46217880	5279	26396
	Home 6	46548480	5317	26585
3th floor	Home 7	46548480	5317	26585
	Home 8	45556680	5204	26018
Loft	Home 9	13819080	1578	7892
	Home 10	21753480	2485	12424

Central and individual heating systems were compared in terms of initial investment cost. For this, the equipment to be used in both systems and their costs are taken into account. Table 4 shows the materials used for the central system and their quantities, and Table 5 shows the materials used for the individual system and their quantities. A comparison of the costs of central heating and individual heating systems is given in Table 8. After determining the annual fuel consumption calculated with Equation 5, the annual fuel consumption cost was found by using Equation 6.

Table 8. Costs of central heating and individual heating systems

Heating type	Initial investment cost (TL)	Natural gas consumption (m^3/year)	Heating cost (TL/year)	Total cost (TL/year)
Central heating system	261687	35882	179409	441096
Individual heating system	289670	44031	220155	509825

As can be seen from the natural gas consumption and a cost table for the total heating of the building in Table 4 and the comparison in Figure 6, individual heating systems have higher costs than central heating systems in terms of both initial investment and heating cost. In this case, central heating systems are more advantageous in terms of the total cost.

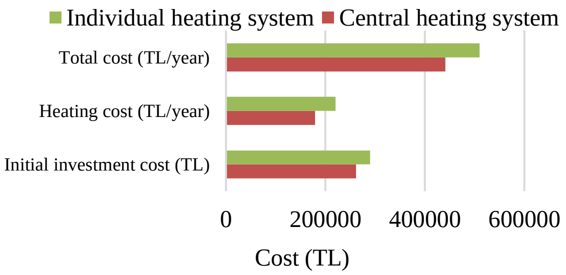

Figure 6. Cost comparison of central heating system and individual heating systems

In terms of the number of pieces of equipment that makes up the system, central heating systems contain more elements than individual heating systems. Despite this, the high total costs of individual heating systems are due to the heating devices (combi) in individual heating systems.
In terms of labor time and labor cost, individual heating systems are shorter and less costly than central heating systems.

3. CONCLUSION

While residences constitute a large share of energy consumption, a significant portion of this energy need is obtained from fossil-based energy sources. Considering the price imbalance in fossil-based energy types and the damage of fuels to the environment, it becomes clear that energy savings and efficient devices should be used. For this reason, in this study, central and individual heating systems used in the heating of houses, which have a large share in energy consumption, are examined.

In this study, central and individual heating systems for heating a reinforced concrete building consisting of 5 floors and 10 flats in the center of Kars, which are located in the 4th Region according to TS825, are compared. In order to determine the heating energy need of the building, thermal insulation, and heat loss were calculated. TS825 method and limit values were taken into account in the calculation of thermal insulation and heat loss. When calculating the heat losses, the heat loss of each room is taken into account, and the total heat loss for the apartments and the building has been determined as 131,331 W. According to the energy needs of the building, the annual fuel consumption amount has been calculated as 35,882 m^3 for the central system, and 44,031 m^3 for the individual heating system, and the annual fuel consumption costs are calculated as 179,409 TL and 220,155 TL, respectively.

All devices and materials to be used for both systems are taken into account while calculating the cost. The initial investment costs for the central heating system and individual heating systems have been found to be 261,687 TL and 289,670 TL, respectively. While the total cost was found 441,096 TL for the central heating system, it has been found 508,825 TL for the individual heating system.

According to the values obtained as a result of the study;
- It has been observed that individual heating systems have higher costs than central heating systems in terms of both initial investment and heating cost.
- It has been determined that central heating systems are more advantageous in terms of initial investment cost, fuel consumption, and total cost.

Although the initial investment cost of individual heating systems is higher, it has been determined that central heating systems are generally preferred due to operational problems and independent operation, optional temperature control, and fuel cost concerns in individual heating systems.

NOMENCLATURE

A	Area of the structure component [m^2]
a	Unit gap leakage [m^3/m h]
By	Annual fuel consumption amount (m^3)
c_p	Specific heat of water [J/kg °C]
C_{yak}	Fuel unit price (TL/m^3)
H	Layout state of the building, adjacent and split [Wh/m^3 °C)]
Hk	Boiler efficiency (%)
H_u	Lower heating value of the fuel (kcal m^{-3})
k	Heat transfer coefficient of the building component [W/m^2 °C]
l	Leakage gap perimeter [m]
Q	Total heat loss of the room [W]
q_i	Incremental heat loss [W]
q_s	Air leak heat loss [W]
q_o	Non-increasing heat loss [W]
Q_y	Annual heating energy requirement (kcal)
M_y	Annual fuel cost (TL)
R	Room feature [0.9]
Z_D	Combined increment coefficient [%]
Z_e	Corner increment coefficient [1]
Z_H	Direction increment coefficient [%]
ΔT	Indoor and outdoor temperature difference [°C]

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