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Research Article

Energy and Fuel Cost Analysis for Four Different Degree-Day Regions in Turkey

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Abstract

Turkey, which has great importance in the world energy market, has one of the world's fast-growing economies. Due to the rapidly increasing number of buildings and demand for higher living standards, urgent precautions are needed to increase the energy efficiency in the buildings in Turkey. The use of energy standards is expected to increase in Turkey and therefore programs that would complement and increase the existing standards should be introduced. Major cities can play an important role in enhancing energy efficiency. These efforts will have a positive long-term effect on Turkey's economic and social development. In the present study, selecting a sample architectural plan ;, the yearly energy needs and the optimal yearly amounts to be used when using different types of fuel were calculated based on the wall cross-section of the architectural project selected in accordance with 4 different degree-day regions in Turkey, and the yearly heating expenses for different types of fuel were determined. Additionally, determining the approximate initial investment costs for different types of fuels, the total cost including the total heating and the initial investment costs for 5, 10 and 15 years of operation was presented in TL.

Keywords: TS 825, Yearly Energy Needs, Fuel Cost Analysis

Türkiye'deki Dört Farklı Derece Gün Bölgesi için Enerji ve Yakıt Maliyeti Analizi

Özet

Dünya enerji piyasasında büyük öneme sahip olan Türkiye dünyanın hızla gelişen ekonomilerinden birine sahiptir. Yeni binaların sayısı hızla büyüdüğü ve insanlar daha iyi yaşam standartları istediğinden dolayı Türkiye'deki binalarda enerji verimliliğini artırmak için önlemlere acilen ihtiyaç duyulmaktadır. Türkiye'de enerji standartlarının kullanımının artması beklenmektedir ve bunun için standartları tamamlayan ve artıran programların gelmesi gerekmektedir. Türkiye'nin baz şehirleri enerji verimliliğini artırmada önemli rol oynayabilir. Bu çabalar Türkiye'nin ekonomik ve sosyal kalkınması üzerinde uzun vadeli olumlu sonuçlar doğuracaktır. Bu çalışmada örnek bir mimari plan seçilerek; Türkiye'nin 4 farklı derece gün bölgesine göre seçilen mimari projenin duvar kesiti üzerinden yıllık enerji ihtiyacı ve farklı yakıt türleri kullanılması durumunda yıllık kullanılması gereken miktarları hesaplanmış, farklı yakıt türleri için yıllık harcanacak ısınma giderleri belirlenmiştir. Ayrıca farklı yakıt türleri için yaklaşık ilk yatırım maliyetleri de belirlenerek 5,10 ve 15 yıl sonra ısınma ve ilk yatırım maliyetleri toplamı için ödenmesi gereken toplam TL miktarları verilmiştir.

Anahtar Kelimeler: TS 825, Yıllık Enerji İhtiyacı, Yakıt Maliyet Analizi

1.Introduction

The International Energy Agency (IEA) estimates an increase of 53% in global energy consumption within the next ten years. This situation is an outcome of the significant increase in industrial and urban activities resulting from intense national development and the striking levels of population increase in recent years (Ong, Mahlia, and Masjuki, 2011). While the energy demand is expected to increase due to the rapid growth of new buildings, especially in developing countries, the use of energy efficiency technologies has not received enough attention yet(Hui, 2000).

Environmental problems become more apparent as a result of this high demand for energy. Carbondioxide (CO_2), which is an example of pollutants, is widely known as a hazardous substance on human health (Oh and Chua, 2010). Additionally, carbondioxide causes the average global temperature to rise with the effect of greenhouse (Lau et al., 2009). It is estimated that the Earth's average surface temperature will increase by approximately 1.1–6.4°C by 2100, if necessary steps are not taken to reduce the emission of CO_2 and the other greenhouse gases (Anonymous, 2007). An increase of 2° C in the average global temperature will have irreversible effects on the environment, cause serious health problems, lead to significant damage to natural ecosystems and affect the sustainability of global agriculture (Anonymous. 2005). Turkey has one of the world's fastest growing economies and also has significant effect on the global environment and the world energy market. The energy saving potential in the construction industry is enormous in the world because energy consumption in buildings constitutes a significant part of the total energy consumption (Hui, 2000). Therefore; fossil fuel consumption, energy generation costs and environmental pollution can be reduced by designing buildings where optimum energy conservation strategies are implemented. Providing thermal insulation to the external walls will allow reaching zero (or close to zero) energy building. The construction sector (residential, industrial and commercial buildings) is a sector that consumes relatively large amount of energy. However, this high consumption can be reduced by implementing appropriate and effective insulation strategies. With effective insulation, less energy is required for space cooling in summer and less heat is needed to keep the house warm in winter, resulting in significant energy savings (Xu et al., 2005). As a result of the implementation of this energy efficiency technique, the use of natural resources (oil and gas reserves) is reduced for energy generation and the consumption rates are slowed down. As a result of this, greenhouse gas emission is also reduced (Dixon, Abdel-salam, and Kauffmann, 2010). Insulation in buildings is regarded to be a simple but highly effective technique that can be applied to residential, commercial and industrial buildings. Thermal insulation materials are highly effective in reducing the heat transfer coefficient on the walls of buildings. The heat insulator consists of composite materials or materials with high thermal resistance that demonstrate the ability to reduce the heat flow rate (Aditya et al., 2017). Consequently, thermal insulation will keep hot air /cold air inside the house and prevent heat transfer to or from the the environment (Al-sallal, 2003). For this reason, the selection of suitable insulation materials and the calculation of the optimum wall thickness are two important factors in wall insulation. Thicker insulation reduces the heat loss, however, it also increases insulation and investment costs. Therefore, determining the optimum insulation thickness that minimizes the total cost for insulation and energy consumption throughout the life of the building is very effective (Çomaklı K; Bedri Yüksel, 2004). Thermal inertia, which is a measure of materials' heat storage capacity, is one of the main parameters that affect the thermal performance of a building. The effective use of thermal mass inertia in a building can make the conditions within the building more comfortable by significantly reducing daily temperature fluctuations (Gregory et al., 2008). This can be achieved by selecting suitable construction materials. Various materials including fiberglass, mineral wool and foam are typically used as insulators. Another significant advantage of building insulation is cost-saving. Additionally, the use of thermal insulation provides other benefits including fire protection, personal comfort, condensation control and sound control (Aditya et al., 2017).

There are many studies in the literature on the calculation of optimum insulation thickness (OIT) to estimate the conduction charges under static conditions based on the degree-day (DD) method. Alsayed and Tayeh (2019) calculated the OIT for the external walls of a building based on the life-cycle cost (LCC) analysis with different DDs. The results indicated that the optimal thickness ranged between 0.4 and 0.9 cm for all situations. Dombayci et al. (2017) selected four different climatic zones in Turkey to analyze the energy conservation potential and OIT based on the DD method and an LCC analysis. The results indicated that with two different insulation materials, the minimum and maximum thicknesses were calculated for the temperate and cold climatic zones, respectively. Cyrille Vincelas and Ghislain (2017) investigated the most economical combination between the external wall thickness and the optimum insulation material for their building. The DD concept and the P1 - P2 economic analysis were used to calculate the OIT, energy saving and the payback period (PP) for the buildings in this region. While the minimum values of OIT (7.6 cm) and energy conservation (48 $ = m2) were obtained for various soil blocks and mineral wool, PP (3.23 years) was the highest value for the same wall structure. In the study conducted by Kurekci (2016), the OIT of building walls was determined using the heating and cooling DD values for all city centers in Turkey. In the study, the calculations were made based on four different fuels and five different insulation materials. As a result of the study, the total net savings were calculated based on the fuels, insulation materials and the OIT.

Building energy saving standards and regulations are policy measures widely used to monitor energy consumption in buildings. These can be useful in overcoming certain important market barriers and enable low-cost energy efficiency opportunities to be included in new buildings. This is especially important in developing countries where the number of new buildings is rapidly growing and the use of efficient technologies is not encouraged by the market and energy costs (Hui, 2000). In the present study, a province was selected for each of the 4 degree-day regions in Turkey. The yearly energy needs and the total expenses in the case of using different types of fuel were calculated in TL for a sample architectural project with fixed cross-sections. The total heating expenses in TL after 5, 10 and 15 years of operation were compared by calculating the approximate initial investment costs for 5 different types of fuel.

2. Material and Method

2.1. Material

Degree-day regions are created by including the cities in our country with similar climate conditions within the same zone. The map of Turkey was divided into 4 different degree-day regions by considering their temperature statistics for recent years, location by longitude and latitude, altitudes and climates (Yeşildal & Geliş, 2020). Figure 1 shows the degree-day regions in Turkey.

A total of 4 cities located in each of the 4 different day-degree regions (Erzurum, İzmir, Konya and Trabzon) were included in the present study. The same architectural project was evaluated for each of these cities and their yearly heating expenses were calculated in accordance with the TS-825 standards. The sample building has a story height of 2.8 meters and a gross volume of 1975.9 m^3.

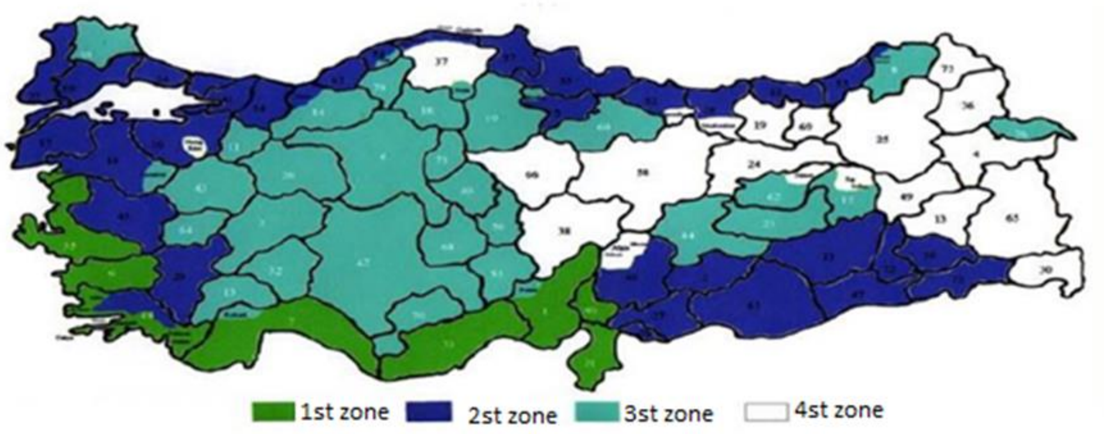

Figure 1. Degree-day regions in Turkey (Anonymous, 2020k)

Table 1 shows the surfaces used in the architectural project calculations and their surface areas.

Table 1 The surfaces used in the Project Calculation and their surface areas

Surface	Surface Area (m^2)
Wall Exposed to Outside Air	298
Wall Contacting Soil	61
Hipped Roof	118
Floor Contacting Soil	118
Balcony Door and Window Facing the Exterior	28
Exterior Door-Metal (Heat-Insulated)	2

Additionally, Figure 2 shows the fixed cross-section in the sample architectural plan used for each degree-day region, further detailed in Table 2.

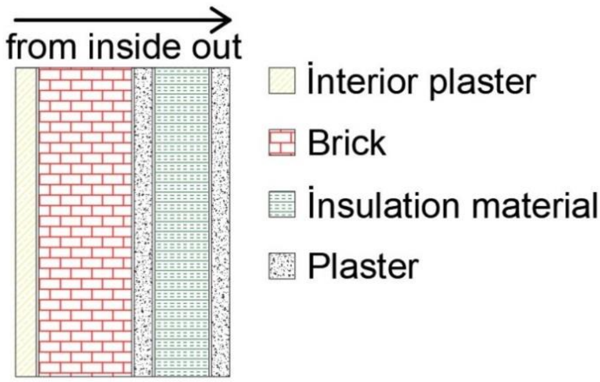

Figure 2. View of the cross-section

Table 2. Materials used in the cross-section and their properties

Material	Thickness(cm)	Thermal Conductivity (W/mK)
Interior Plaster	2	1
Brick	13.5	0.35
Exterior Plaster	1	1
Thermal Insulation Lath (EPS)	7	0.035
Finish Plaster	1	1.6

After the yearly heating expenses of the sample building were determined in accordance with the TS-825 standards for 4 different cities, the total heating costs in TL for the heating systems after 5, 10 and 15 years of operation were compared by considering the initial investment costs. There are many types of fuel in the world, however, very few of them are suitable for use in buildings. Fossil fuels such as coal, natural gas, fuel oil and LPG are the primary examples. Fossil fuels originate from the conversion of dead plants and animals in deep soil as a result of heat, pressure and chemical effects. Fossil fuels provide energy as they possess high levels of carbon. The types of fuels selected in the present study are natural gas, coal, electricity, fuel oil and LPG.

Table 3 shows the lower heating values (Aytaç and Teoman, 2006) and unit costs (Anonymous, 2020 a,b,c,d,e,f,g,h,i,j) of these types of fuels. Unit costs were taken from related websites for each city and the mean values were used.

Table 4 shows the approximate initial investment costs of different heating systems, which were calculated approximately by considering the labor-tool and equipment market value lists based on the Construction Unit prices by the Ministry of Environment and Urban Planning for the year 2020 (Anonymous.

2017). The initial investment costs were calculated by considering the same heating system for each degree-day region and panel radiator height was determined as the only changing parameter for the regions. The costs were calculated by considering the central heating system for heating with LPG, fuel oil, natural gas and coal, and the individual electrical boiler system for heating with electricity.

Table 3. The types of fuels used in the present study and their unit cost

	Lower Heating Value	**Efficiency**	**Unit Cost**
Natural Gas	$34.542*10^3$(kJ/m^3)	0.93	1.5323 TL /m3
Coal	$25.122*10^3$(kJ/kg)	0.65	1.1 TL/kg
Fuel oil	$40.164*10^3$(kJ/kg)	0.80	2.46 TL/kg
LPG	$46.475*10^3$(kJ/kg)	0.92	9.08 TL/kg
Electricity	$3.6*10^3$ (kJ/kWh)	0.99	0.5375 TL/kWh

Table 4. Initial investment costs for different heating systems

Degree-Day Region	**City**	**Initial Investment Costs**				
		LPG	Electricity	Fuel Oil	Coal	Natural gas
4	Erzurum	30.000.00	25.000.00	30.000.00	25.000.00	30.000.00
3	Konya	29.000.00	24.000.00	29.000.00	24.000.00	29.000.00
2	Trabzon	28.000.00	23.000.00	28.000.00	23.000.00	28.000.00
1	İzmir	27.000.00	22.000.00	27.000.00	22.000.00	27.000.00

2.2. Calculation Method

Notation and formulation, which are used within the scope of TS-825 standards, were used as the calculation method.

U: Total heat transfer coefficient of the building components (W/m^{2}K)

A: Area of building surfaces (m^2)

T_{in} and T_{out}: Indoor and outdoor temperatures (°C)

Using the variables above, the heat loss of a room through conduction and convection is calculated with Equation 1.

$$Q = \sum UA(T_{in} - T_{out}) \quad (1)$$

The total heat transfer coefficient (U) shown in Equation 1 is calculated using Equation 3.

$$R'_{total} = R'_{in} + \sum R'_{conduction} + R'_{out} \quad (2)$$

$$U = \frac{1}{R'_{total}} \quad (3)$$

Equation 4 is used to determine the heat loss from the building component through conduction.

$$H_T = \sum AU + IU_I \quad (4)$$

Equation 5 is used to calculate total U*A

$$\sum AU = U_D A_D + U_p A_p + U_k A_k + 0.8 U_T A_T + 0.5 U_t A_t + U_d A_d + 0.5 U_{ds} A_{ds} \quad (5)$$

Equation 6 is used to calculate heat loss resulting from natural ventilation.

$$H_V = \rho.c.V' = \rho.c.n_h V_h = 0.33 n_h V_h \quad (6)$$

Equation 7 is used to calculate total heat losses.

$$H = H_T + H_V \quad (7)$$

With H(θ_i-θ_e) representing heat losses and ηay (ϕ(i,ay)+ϕ(s,ay) representing heat gains, Equation 8 is used to calculate Q_{month}.

$$Q_{month} = \left[H(\theta_i - \theta_e) - \eta_{month}\left(\phi_{i,month} + \phi_{s,month}\right)\right].t \quad (8)$$

Finally, Equation 9 is used to calculate the yearly heating energy needs.

$$Q_{year} = \sum Q_{month} \quad (9)$$

Equation 10 shows the calculation of yearly fuel requirement.

$$Yearly\ amount\ of\ fuel = \frac{\theta_{year}}{(lower\ heat\ value\ of\ the\ fuel\ to\ be\ used) * \eta fuel} \quad (10)$$

3. Findings

Table 5 shows the yearly amount of fuel determined in accordance with TS-825 standards for the sample architectural project used in the cities located in 4 different degree-day regions and the yearly amounts of use for 5 different types of fuel that were determined accordingly.

Figure 3 shows the yearly energy needs of the cities located in 4 different degree-day regions. As shown in the figure, the city with the highest energy needs is Erzurum, which is located in the 4th degree-day region, while the city with the least energy needs is İzmir, which is located in the 1st degree-day region.

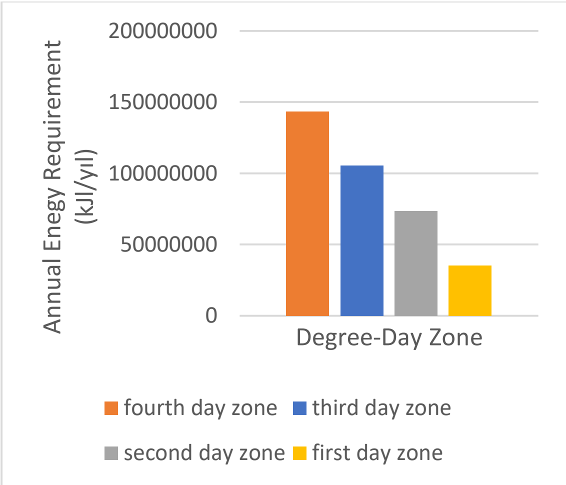

Figure 3. Yearly energy needs for different degree-day regions

Figures 4 and 5 show the yearly amounts of fuel required for 4 different sample cities located in different degree-day regions based on different types of fuel and the corresponding costs in TL. It was determined that the region with the highest heating costs was the 4th region while the 1st region had the lowest heating costs. It was calculated that the yearly heating expenses varied by different heating systems in the sample architectural plan. The yearly heating costs were listed from high to low as LPG, electricity, Fuel Oil, Coal and Natural Gas.

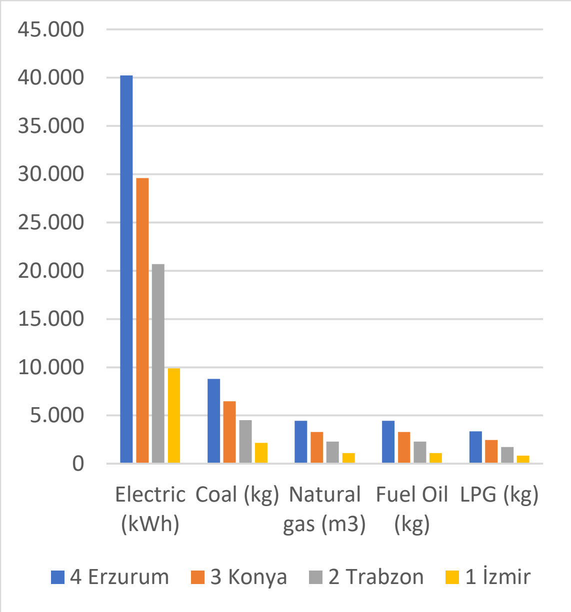

Figure 4. Required types and amounts of fuel for different degree-day regions

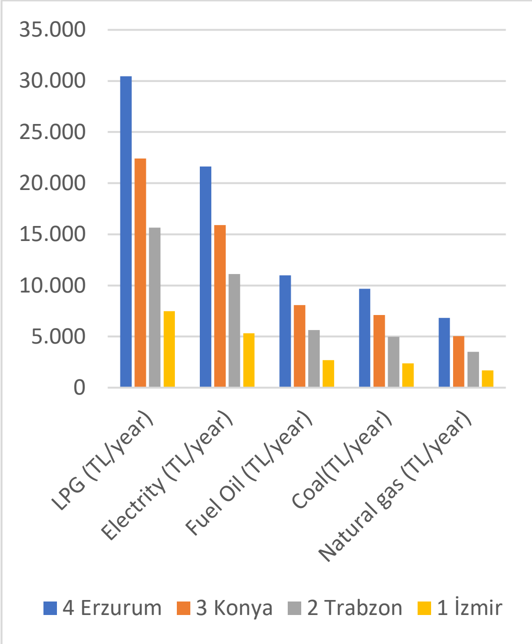

Figure 5. Heating costs of different types of fuel in different degree-day regions

Table 5. Yearly amounts of use for different types of fuel

Degree-Day Region	City	Yearly Fuel Needs (kj)	Amount of Natural Gas (m^3)	Amount of coal (kg)	Amount of electricity (kwh)	Amount of Fuel Oil (kg)	Amount of LPG (kg)
4	Erzurum	143410490	4464.270394	8.782.40	40.238.63	4.463.28	3.354.08
3	Konya	105462999	3.282.99	6.458.51	29.591.19	3.282.26	2.466.57
2	Trabzon	73736223	2.295.36	4.515.58	20.689.18	2.294.85	1.724.54
1	İzmir	35237910	1.096.93	2.157.96	9.887.18	1.096.69	824.143649

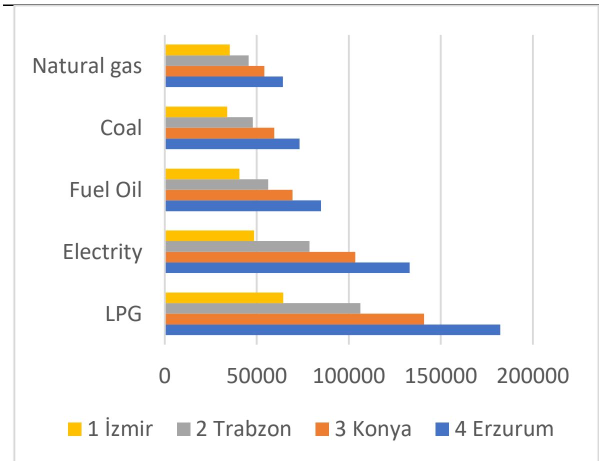

Figure 6. The sum total of initial investment costs and 5-year heating expenses for different degree-day regions

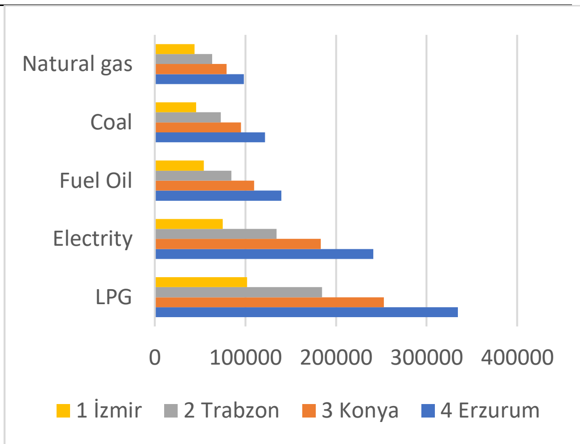

Figure 7. The sum total of initial investment costs and 10-year heating expenses for different degree-day regions

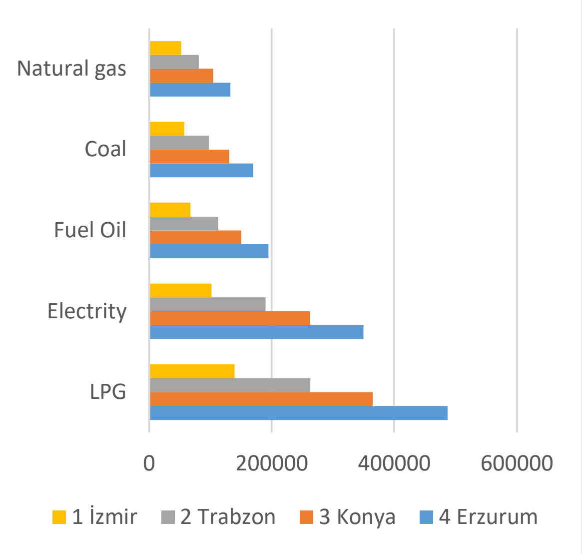

Figure 8. The sum total of initial investment costs and 15-year heating expenses for different degree-day regions

Figures 6, 7 and 8 show the total heating costs after 5, 10 and 15 years of operation in consideration of the initial investment costs. As can be understood from the graphs, the type of fuel with the lowest cost is natural gas while LPG has the highest cost. To summarize the results, Erzurum is located in the 4th degree-day region and has a yearly energy need of 143.410.490 kj. Konya is located in the 3rd degree-day region and has a yearly energy need of 105.462.994 kj. Trabzon is located in the 2nd degree-day region and has a yearly energy need of 105.462.994 kj. İzmir is located in the 1st degree-day region and has a yearly energy need of 35.237.910 kj. For all of the cities, the most expensive fuel option is LPG. Considering our fuel economy, it would be more advantageous to use coal, which is 5 times cheaper compared to LPG. However, due to the difficulty of use and considerable storage space requirement of coal, the most logical option is to use natural gas, which also has a relatively lower heating cost. Natural gas is a type of fuel that has high combustion efficiency and presents high comfort conditions.

4. Discussion and Conclusions

In the present study, yearly cost of 5 different types of fuel was calculated for a building and compared for 4 cities (Erzurum, İzmir, Konya, Trabzon) located in 4 different degree-day regions in Turkey based on the same architectural plan. The results obtained in the study are summarized below.

- Since the yearly energy needs and heat loss of 4 different degree-day regions are different, it is more efficient in terms of cost and the amount of fuel, when a different insulation material is used for the building and the conditions of the region are suitable.
-
- Based on the graphs, it can be said that LPG is the type of fuel with the highest cost in terms of unit price despite the fact that small amounts of LPG are required to be used as fuel. It is the most unsuitable type of fuel for all of the regions in terms of cost.
- Since electricity is a valuable type of energy that is costly and requires large amounts of fuel in all of the 4 regions, it should not be used for heating purposes. Additionally, it has higher yearly heating costs compared to other types of fuel.
- Although fuel oil appears to be a practical type of fuel due to its high lower heating value and low yearly total amount of fuel consumption, it is unfavorable due to its high cost.
- Coal has the second least yearly amount of fuel consumption in 4 different regions. Due to its low unit price, it is the most suitable type of fuel for all 4 regions in terms of yearly heating costs.
- Although natural gas has a lower yearly amount of fuel consumption compared to coal and the heating expenses of the two types of fuel are very close to each other, it is the most suitable type of fuel overall for all 4 regions as it does not require any storage.
- When the total heating costs after 5, 10 and 15 years of operation were calculated by considering the initial investment costs, the type of fuel with the lowest cost was found to be natural gas while the type of fuel with the highest cost was found to be LPG.

REFERENCES

Aditya, L., Mahlia, T. M. I., Rismanchi, B., Ng, H. M., Hasan, M. H., Metselaar, H. S. C., … Aditiya, H. B. (2017). A review on insulation materials for energy conservation in buildings. 73(February), 1352–1365. https://doi.org/10.1016/j.rser.2017.02.034

Al-sallal, K. A. (2003). Comparison between polystyrene and fiberglass roof insulation in warm and cold climates. 28, 603–611.

Alsayed, M. F., Tayeh, R. A. (2019). Life cycle cost analysis for determining optimal insulation thickness in Palestinian buildings. Journal of Building Engineering, 22, 101–112.
https://doi.org/10.1016/j.jobe.2018.11.018

Anonymous. (2005). World Wildlife Fund. 2 °C is Too Much. Retrieved from https://www.worldwildlife.org/initiatives/climate

Anonymous. (2007). Intergovernmental Panel on Climate Change I. Climate Change 2007: Synthesis Report. Retrieved from https://www.ipcc.ch/people/sabin-guendehou/

Anonymous. (2017). T.C. Çevre ve Şehircilik Başkanlığı, Yüksek Fen Kurulu Başkanlığı, İnşaat Birim Fiyatlarına Esas İşçilik-Araç ve Gere. Rayiç Listeleri.

Anonymous.(2020a).http://www.izmirgaz.com.tr/tr/Abonelik-Hizmetleri/Tarifeler/Dogalgaz-Bedeli-konut-serbest-.htmle.

Anonymous.(2020b).http://www.tki.gov.tr/depo/2020%20YILI%20TEMMUZ%20AYI%20ANAL%C4%B0ZL%C4%B0%20F%C4%B0YAT%20L%C4%B0STES%C4%B0%20(1).pdf.

Anonymous.(2020c).https://gazelektrik.com/tedarikciler/aras-elektrik/birim-fiyat.

Anonymous.(2020d).https://gazelektrik.com/tedarikciler/coruh-aksa-elektrik/birim-fiyat.

Anonymous.(2020e).https://gazelektrik.com/tedarikciler/gediz-elektrik/birim-fiyat.

Anonymous.(2020f).https://gazelektrik.com/tedarikciler/mepas/birim-fiyat.

Anonymous.(2020g).https://portal.enerya.com.tr/DogalGazBirimFiyatlari/index.xhtml?city=07.

Anonymous.(2020h).https://www.aksadogalgaz.com.tr/Musteri-Hizmetleri/Fiyat-Tarifeleri/Satis-Tarifesi/TrabzonRize.

Anonymous.(2020i).https://www.aygaz.com.tr/dokmegaz/fiyatlar.

Anonymous.(2020j).https://www.palen.com.tr/evsel-musteri/tarifeler.

Anonymous.(2020k).www.İzoder.Org.Tr/Sayfa/30/Ts-825-Hesap-Programi. 8 Nisan 2020.

Aytaç, A., & TeOMAN, U. (2006). Yalıtım Kalınlığı ve Isıtma Maliyet, İlişkisi, Heating Cost on extarnal walls for energy saving, 21(4), 753–758.

Çomaklı K; Bedri Yüksel. (2004). Environmental impact of thermal insulation thickness in buildings. 24, 933–940. https://doi.org/10.1016/j.applthermaleng.2003.10.020

Cyrille Vincelas, F. F., Ghislain, T. (2017). The determination of the most economical combination between external wall and the optimum insulation material in Cameroonian’s buildings. Journal of Building Engineering, 9, 155–163.

https://doi.org/10.1016/j.jobe.2016.12.008

Dixon, G., Abdel-salam, T., Kauffmann, P. (2010). Evaluation of the effectiveness of an energy efficiency program for new home construction in eastern North Carolina. Energy, 35(3), 1491–1496. https://doi.org/10.1016/j.energy.2009.12.006

Dombayci, A., Atalay, Ö., Güven Acar, Ş., Yilmaz Ulu, E., Kemal Ozturk, H. (2017). Thermoeconomic method for determination of optimum insulation thickness of external walls for the houses: Case study for Turkey. Sustainable Energy Technologies and Assessments, 22, 1–8. https://doi.org/10.1016/j.seta.2017.05.005

Gregory, K., Moghtaderi, B., Sugo, H., Page, A. (2008). Effect of thermal mass on the thermal performance of various Australian residential constructions systems. Energy and Buildings, 40(4), 459–465. https://doi.org/10.1016/j.enbuild.2007.04.001

Hui, S. C. M. (2000). Building energy efficiency standards in Hong Kong and mainland China. Proceedings ACEEE Summer Study on Energy Efficiency in Buildings, 9, 189–200.

Kurekci, N. A. (2016). Determination of optimum insulation thickness for building walls by using heating and cooling degree-day values of all Turkey's provincial centers. Energy and Buildings, 118(825), 197–213. https://doi.org/10.1016/j.enbuild.2016.03.004

Lau, L. C., Tan, K. T., Lee, K. T., Mohamed, A. R. (2009). A comparative study on the energy policies in Japan and Malaysia in fulfilling their nations' obligations towards the Kyoto Protocol. Energy Policy, 37(11), 4771–4778. https://doi.org/10.1016/j.enpol.2009.06.034

Oh, T. H., Chua, S. C. (2010). Energy efficiency and carbon trading potential in Malaysia. Renewable and Sustainable Energy Reviews, 14(7), 2095–2103. https://doi.org/10.1016/j.rser.2010.03.029

Ong, H. C., Mahlia, T. M. I., Masjuki, H. H. (2011). A review on energy scenario and sustainable energy in Malaysia. Renewable and Sustainable Energy Reviews, 15(1), 639–647. https://doi.org/10.1016/j.rser.2010.09.043

Xu, X., Zhang, Y., Lin, K., Di, H., Yang, R. (2005). Modeling and simulation on the thermal performance of shape-stabilized phase change material floor used in passive solar buildings. 37, 1084–1091. https://doi.org/10.1016/j.enbuild.2004.12.016

Yeşilal, F., Geliş, K. (2020). Gümüşhane İklim Şartlarında Farklı Malzemeler İçin Yalıtım Kalınlıklarının TS 825 Kapsamında Değerlendirilmesi Evaluation of Insulation Thicknesses For Different Materials Under Climatic Conditions of. 10, 830–843. https://doi.org/10.17714/gumusfenbil.718215