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RESEARCH ARTICLE

Electric tariffs and thermal energy storage systems for buildings

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Abstract: Thermal energy storage methods are systems that can be an alternative to the systems used especially in residential heating in our country. These systems shift the electricity demand to night and they constitute an electricity use strategy that is both effective and efficient. In this study, the ten-year price changes of the fuels used for heating in our country, the change in the real electricity consumption of a province over time, the electricity tariffs were examined and cost calculations were made in case of heating a space. It is seen that fuel prices have increased significantly in recent years, and thermal energy storage systems (TES) are 20-40% less costly than other systems until 2020, and 40-55% less costly than natural gas in 2021 and 2022.

Keywords: Thermal Energy Storage, Electric Tariff, Energy Efficiency, Heating

1. Introduction

Energy production, which plays an important role in providing the basic needs of human beings for life, is the most important issue with the increasing primary energy demand in proportion to both population growth and increasing industrialization. It has also emerged that it is necessary to support the transition to clean energy in total energy production and to provide support for the development of its sub-components wind turbines, batteries, electrolysers and other technologies. According to the 2050 projection, it is expected that the first role of coal in power capacity will pass to natural gas by 2030, and then solar photovoltaic panels and wind systems are expected to gradually replace coal and natural gas [1,2]. In our country, according to the 2021 TEIAŞ (Turkish Electricity Transmission Corporation) December power report, it is seen that the total electrical installed power capacity has increased to 99,819.6 MW, the total number of power plants is 10457, and natural gas ranks first in total installed power [3]. It is known that with the investments made in renewable energy in recent years, the installed power from solar energy has increased by 7.80% and wind energy by 10.6% compared to the total power [4].

A three-dimensional model is designed for a thermal storage device used in a space heating. It was observed that the brick and outlet air temperatures in the system increased up to 1002 K and 835 K, respectively, and 40.4% of the total electric heating energy was used for charging in natural convection. [5]. In the city of Nova Scotia, it has been determined that by applying incentive programs for homeowners who heat their homes with electricity to switch from conventional electric heaters to electric thermal storage systems, savings in the range of 41-48% are achieved in ETS systems compared to conventional heating systems, with a payback period of less than 8 years [6]. By using the wind farm and thermal energy storage system together in Prince Edward Island of Canada, 5.15 MW of the residential heating demands were met. In the study, in which simulations were made on the model created with the real housing demand profile, a load model was defined and it was aimed to offer energy, maintain the comfort level and increase the efficiency of the electricity distribution network in case the customer demand changes [7]. In the numerical study on the feasibility of the central thermal storage system, different models were developed using the TRNSYS program. [8], Annual heating cost and unit storage capacities are examined in numerical models made to manage the heating and electricity demand of central electric thermal storage systems in Quebec [9].

2. Materialals and Methods

2.1. Thermal energy storage

Energy storage can be done in 4 different categories: chemical, mechanical, thermal and electrical. Synthetic natural gas and hydrogen are used in chemical energy storage, flywheel, compressed air etc. in mechanical en-

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ergy storage, battery, fuel cell, electrochemical capacitor, magnetic and conductive in electrochemical energy storage, thermo-chemical, sensible heat and latent heat in thermal energy storage are used (Figure 1) . Thermal energy storage (TES) with sensible heat is obtained by increasing or decreasing the temperature difference in materials with low heat transmission coefficient but also high specific heat and density, by performing charging and discharging processes. In heating processes, it is preferred to use materials that can store energy at high temperatures. It is possible for them to preserve the stored energy for a long time with a good insulation and to perform heating in the space for a long time during use.

2.2. Electric Tariffs

The most important parameter in thermal energy storage systems is the tariffs determined by the electricity supplier companies. In the our country, electricty pricing is made according to many different parameters such as the type of electricity usage, places of use, distribution and transmission system users [10]. In Table 1, there is a sample electricity tariff table published by EPDK (Republic of Türkiye Energy Market Regulatory Authority) in certain periods [10]. In tariff pricing, distribution system users are divided into industry, business, residential, agricultural irrigation, lighting, low voltage and medium voltage users. In our country, household subscribers with a single

Table 1. Activity based tariffs approved by EPDK and approved as March 1,2022 [10]

	1/3/2022	Activity Based Consumer Tariffs(kr/kWh)					Total Tariffs Excluding Power Fee (kr/kWh)			
Transmission System Users	Transmission System Users Receiving Energy from the Incumbent Supply Company	Retail One-Time Energy Cost	Retail Daytime Energy Fee	Retail Peak time Energy Fee	Retail Night time Energy Fee	Distribution Fee	Single Time	Daytime	Peak time	Night time
	Consumer	370,0212	374,5341	590,2971	200,3921	0,0000	370,0212	374,5341	590,2971	200,3921
Distribution System Users	Distribution System Users	Retail One-Time Energy Cost	Retail Daytime Energy Fee	Retail Peak time Energy Fee	Retail Night time Energy Fee	Distribution Fee	Single Time	Daytime	Peak time	Night time
	Medium voltage						Medium voltage			
	Double-Term						Double-Term			
	Industry	157,3709	159,3408	253,5227	83,3267	14,5454	171,9163	173,8862	268,0681	97,8721
	Public and Private Services Sector and Other	179,7944	181,6169	286,0048	98,5597	22,6686	202,4630	204,2855	308,6734	121,2283
	Residence	130,2756	132,4429	211,3815	69,3172	22,4532	152,7288	154,8961	233,8347	91,7704
	Agricultural Activities	134,8303	136,2335	216,3321	72,2270	18,6693	153,4996	154,9028	235,0014	90,8963
	Lighting	165,5392				21,7570	187,2962			
	Single-Term						Single-Term			
	Industry	156,8345	158,8053	252,9872	82,7910	16,0666	172,9011	174,8719	269,0538	98,8576
	Public and Private Services Sector and Other	183,0499	184,8724	289,2603	101,8147	28,2765	211,3264	213,1489	317,5368	130,0912
	Residence	131,3609	133,5284	212,4659	70,4019	27,7239	159,0848	161,2523	240,1898	98,1258
	Agricultural Activities	136,3465	137,7497	217,8485	73,7424	23,2453	159,5918	160,9950	241,0938	96,9877
	Lighting	168,5589				27,1401	195,6990			
	Low voltage						Low voltage			
	Single-Term						Single-Term			
	Industry	166,9128	168,8825	263,0643	92,8686	24,8584	191,7712	193,7409	287,9227	117,7270
	Public and Private Services Sector and Other(30 kWh/day ve below)	133,7425	190,8402	295,2280	107,7829	33,6884	167,4309	224,5286	328,9164	141,4713
	Public and Private Services Sector and Other(30 kWh/day ve above)	189,0181	190,8402	295,2280	107,7829	33,6884	222,7065	224,5286	328,9164	141,4713
	Residence (8 kWh/day ve below)	79,4622	137,0507	215,9889	73,9241	32,9483	112,4105	169,9990	248,9372	106,8724
	Residence (8 kWh/day above)	134,8829	137,0507	215,9889	73,9241	32,9483	167,8312	169,9990	248,9372	106,8724
	Agricultural Activities	139,8998	143,5746	221,4022	77,2958	27,6811	167,5809	171,2557	249,0833	104,9769
	Lighting	174,2104				32,2661	206,4765			

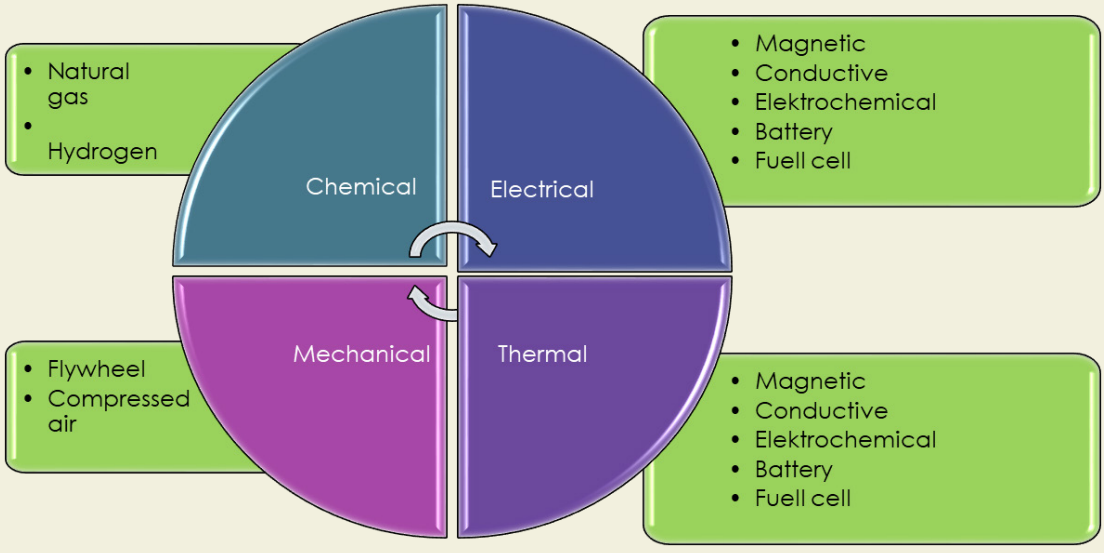

Figure 1. Energy storage methods

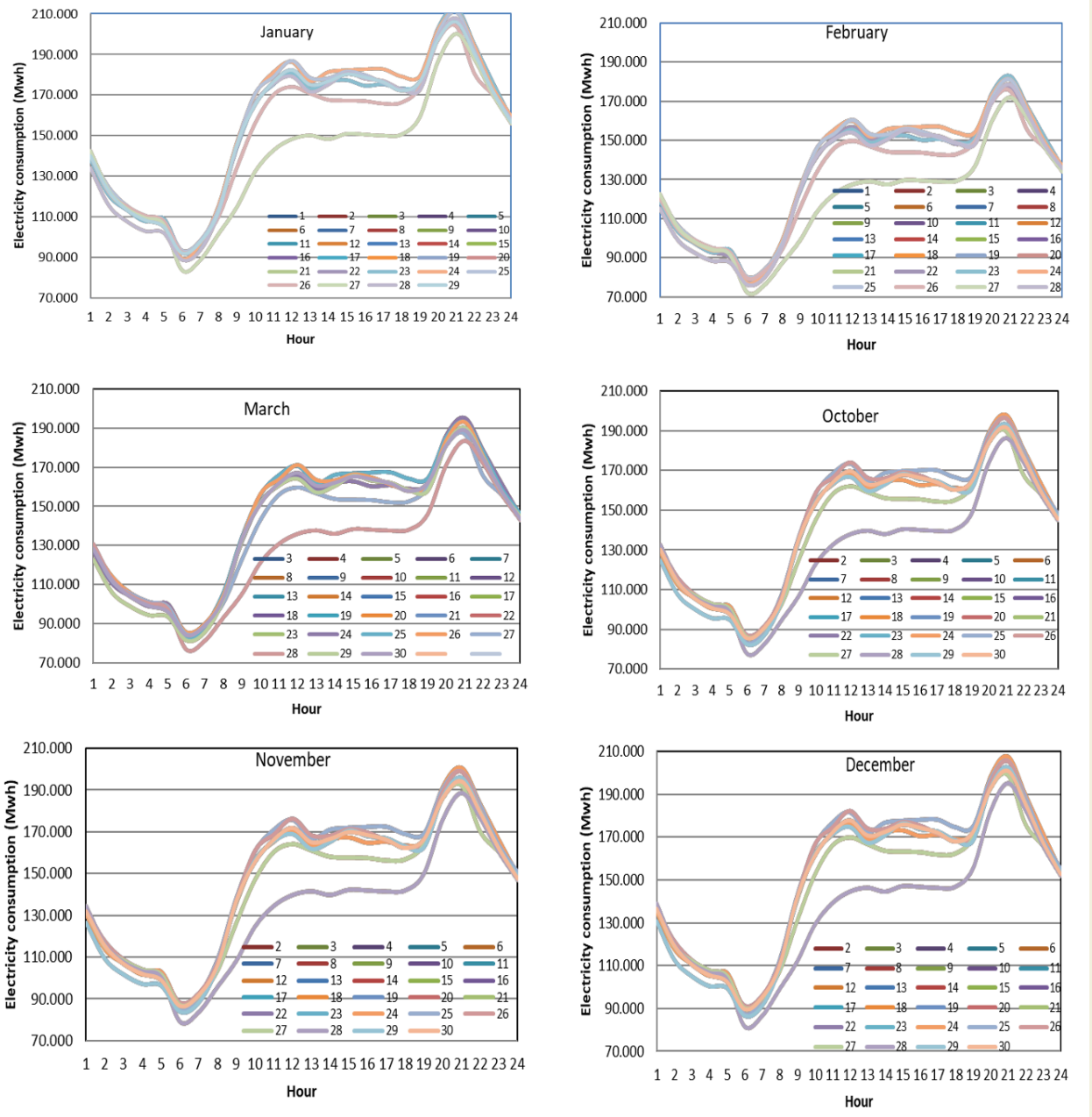

Figure 2. Hourly electricity consumption for a province [11]

term of low voltage prices the electricity they consume in their residences over this tariff. In addition, as can be seen from the Table 1, there are 4 different pricing options for all types of users and voltages: one-rate tariff, single time, daytime, peak and night (three- rate tariff). Residential users can choose one or three-time tariff pricing according to their preferences. As of 1.3.2022, a separate pricing option has been added depending on whether the consumption is below or above 8 kWh per day. In the one-time tariff, the electricity consumed for a day is calculated over a single price, while in the three-time tariff, it is calculated at 3 different prices. When the prices are examined, it is seen that the night tariff price is the cheapest, the day price is close to the single time price, and the peak price is the highest.

3. Results and Discussions

Hourly electricity consumption for a province in Turkey during the heating season (October – March) is shown in Figure 2 [11]. As can be seen, electricity demand increases from 06:00 to 12:00 in the morning and becomes constant between 13:00 and 18:00. The electricity consumption, which increases again after 18:00, reaches its maximum value around 21:00 and decreases again after 22:00. When looking at all the months, it is seen that the peak load occurs in the peak time (18:00-22:00) and the least electricity consumption occurs in the night time period.

All electricity planning is made according to the peak load occurring during these hours. By using these three-

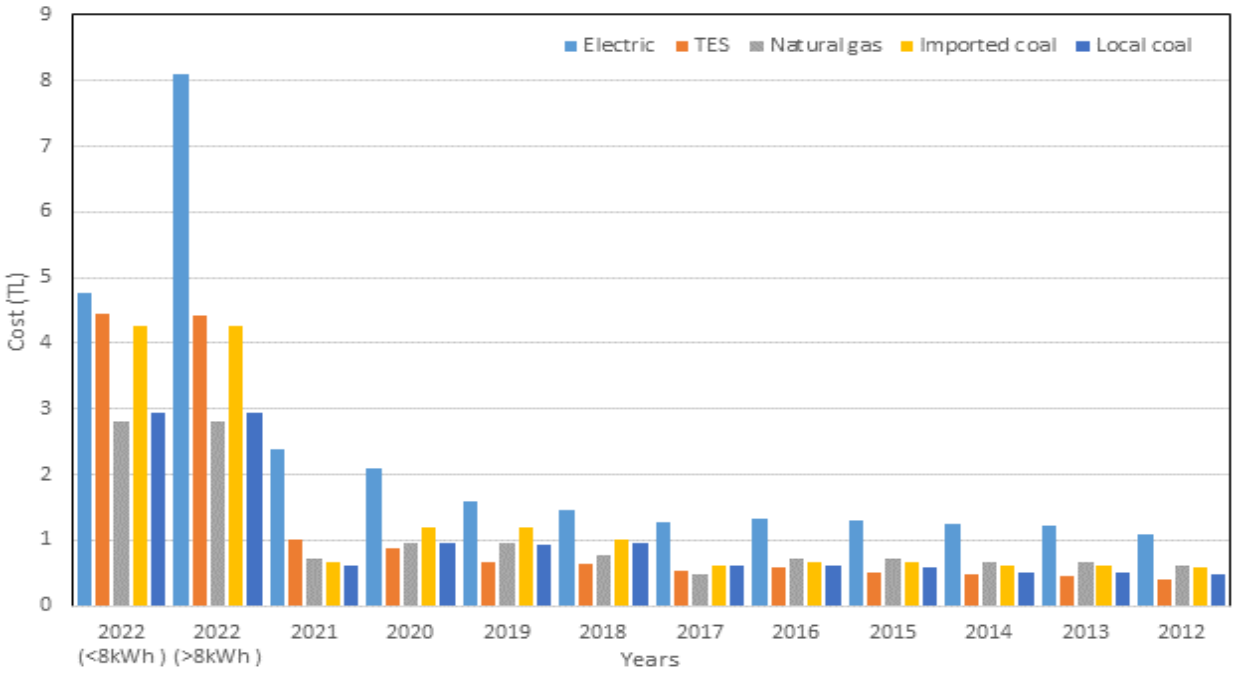

Figure 3. Heating costs for different fuels

Table 2. Variation of prices of different fuels by years TL(Turkish Lira)/kWh [10,12]

Years	Natural gas (TL/kWh)	Imported coal (TL/kWh)	Local coal (TL/kWh)	Fuel Oil (TL/kWh)	Retail One-Time Energy Cost (TL/kWh)	Retail Daytime Energy Fee (TL/kWh)	Retail Peak time Energy Fee (TL/kWh)	Retail Night time Energy Fee (TL/kWh)
1.03.2022 (<8kWh)	0.47	0.71	0.49	1.72	0.794622	1.37051	2.15989	0.739241
1.03.2022 (>8kWh)	0.47	0.71	0.49	1.72	1.348.829	1.370507	2.159889	0.7392
1.01.2021	0.12	0.11	0.1	0.18	0.397629	0.405797	0.703224	0.167946
1.04.2020	0.16	0.2	0.16	0.36	0.348202	0.355468	0.620066	0.14387
1.04.2019	0.16	0.2	0.156	0.39	0.263304	0.268803	0.469052	0.108664
1.01.2018	0.13	0.17	0.16	0.45	0.244666	0.243097	0.434817	0.106691
1.04.2017	0.079	0.1	0.1	0.14	0.214058	0.212672	0.382009	0.090337
1.07.2016	0.12	0.11	0.1	0.18	0.22102	0.219634	0.388971	0.097299
1.01.2015	0.12	0.11	0.096	0.18	0.216738	0.19934	0.36091	0.082684
1.07.2014	0.11	0.1	0.083	0.23	0.207728	0.191159	0.345038	0.080056
1.07.2013	0.11	0.1	0.083	0.23	0.203752	0.187183	0.340562	0.07658
1.04.2012	0.102	0.098	0.078	0.23	0.181647	0.166939	0.303092	0.06875896

time tariffs and thermal energy storage systems together, it aims to reduce the peak load and shift it to night hours when electricity demand is much less. In the study, the 10-year price distribution of the fuels used for heating was examined and the consumption costs for 1 kWh heating and the energy calculations in case of heating for 6 hours were made. The cost of the thermal energy storage system is calculated from the night tariff price. Table 2 shows the pricing of electricity and other fuels in the last 10 years between 2012-2022. Prices do not include additional payments such as taxes and distribution fee [10,12].

When Table 2 is examined, it is seen that electricity prices have increased in 10-year time change, and the price change for night and single time in all years except 2022 is between 55.98% and 62.42% [13]. In the 3-time tariff, it is seen that the price change is between 55.70% - 59.57% for day and night time, and the price change for night and peak times is between 75% - 77.51%. In the 2022 tariff, in

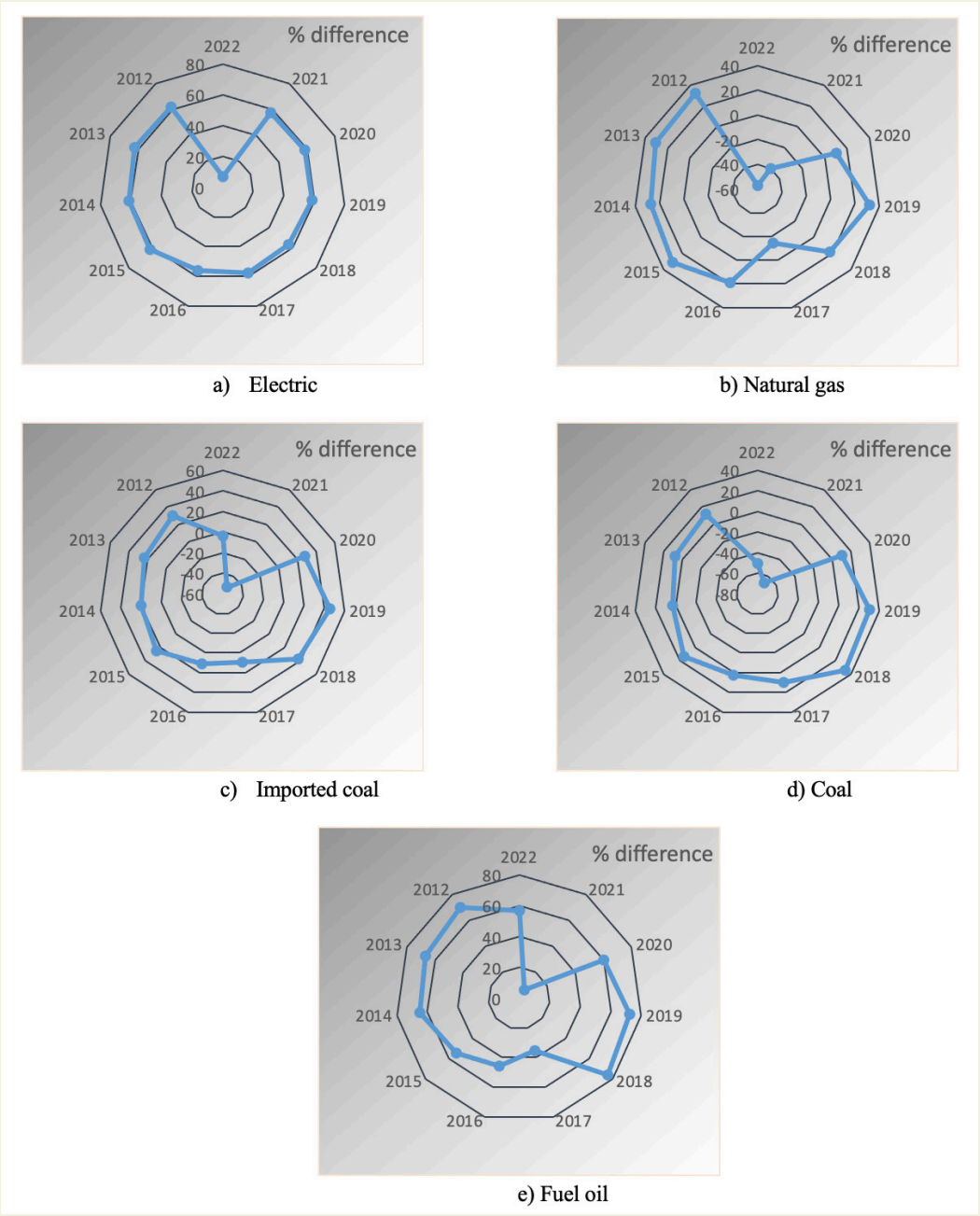

Figure 4. Cost differences of other fuels compared to thermal energy storage system

case of consumption below 8 kWh per day, it is observed that there is little difference (6.97%) between night and single time, 46.06% during night and day, and 65.77% in night and peak change. In the case of a daily consumption of more than 8 kWh, it is observed that it is 45.20% between night and single time, 46.06% during night and day, and 65.77% at night and peak change. The prices of all other fuel types have increased over the years, and the nighttime electricity tariff is 10%-39% compared to natural gas, 9.5%-52% for imported coal, 9.5%-67% for domestic coal, and 35% -76% for fuel oil.

If the space is heated with different fuels for 6 hours, the cost calculations according to the price change for 10 years are shown in Figure 3. In all billings up to 2021, it is seen that the thermal energy storage system is very economical, and the most expensive system is heating with electricity. It is seen that the cost difference for the two systems is around 55-62% in all years except 2022. (Figure 3). In the calculations made for the year 2022, it is seen that the consumption above and below 8 kWh is the effective parameter. Since the daytime and nighttime prices are close to each other for consumptions below 8 kWh, it is seen that an electric heater can be used instead of the energy storage system. The cheapest heating system is the natural gas system. Above 8 kWh, natural gas and coal make more economical heating.

As seen in Figure 4, when the thermal energy storage system used in the night tariff is compared with electricity, it is seen that the system has an advantage of 60% in all years, and the system is usable in terms of hours and price.

Compared to natural gas, it is seen that the energy storage system is 20%-30% cheaper

until 2019, and between 2020-2022, natural heating is 40%-57% cheaper. When imported and domestic coal are examined, it is seen that energy storage systems are advantageous at rates ranging between 2%-45% (imported coal 11-45%, domestic coal 2%-30%) until 2021, due to the increasing electricity prices in 2021-2022. It is seen that coal is less costly over the years. Fuel oil, which is imported and always expensive among fuels, is expensive in the range of 35-76% compared to electricity and seems to be the most disadvantageous system in terms of usability.

4. Conclusions

As can be seen from the results, energy costs are increasing for all fuels every year in our country as well as in the whole world. It is seen that the heating costs of the heat storage system and the electric heater are the same for consumptions below 8 kWh, and natural gas is more advantageous than these systems. In consumptions above 8 kWh, it is seen that the heat storage system is more advantageous than electricity heating, but it is also expensive compared to other heating systems. In order for these systems to be used effectively and in accordance with their purpose, it is obligatory to rearrange the peak and night tariffs and to provide incentive price updates.

5. Acknowledgements

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