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An Investigation on Provincial Production & Consumption of Electric Energy: A Case Analysis for Ankara

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Abstract

Energy is one of the most important factors affecting the country's economy in developing countries. Factors such as interdependent relations, external dependence in primary energy sources such as natural gas and oil, international treaties to reduce carbon emissions, and the amount and availability of domestic conventional resources lead countries to renewable energy sources. In this study, the production sources and sectoral consumption places of the electric energy in Ankara in 2019 were examined. In addition, the share of renewable energy sources in production has been investigated. Economic and environmental analysis of electric energy consumption has been made. As a result, it was determined that 9.55 TWh of electricity was produced in 2019, and this value meets 68% of the 14 TWh consumption value.

1. Introduction

Energy is the basic requirement of life, which enables the formation of socioeconomic activities in the modern world. Fossil fuels that meet most of this need compared to the increasing energy need on a global basis are gradually decreasing. In the world, especially in the twentieth century, the intensive use of fossil fuels such as oil, coal and natural gas have caused the effects of ozone depletion, acid rain and global warming [1]. It is also known that fossil fuels will be an ultimate reserve and these fuels will run out in the coming years. Nature with limited resources makes fossil fuel-based energy consumption unsustainable. As a result, humanity has increased the trend towards renewable energy based on nature.

Renewable energy is an important issue today and is expected to continue to play an important role globally in the future. Today, most countries are developing policies and trying to set accessible targets in this area. Renewable energy has an important place in meeting the energy needs of countries with domestic resources, reducing dependency on foreign resources, diversifying resources with ensuring sustainable energy use and minimizing the damages caused by energy consumption [2].

Renewable energy can be classified as solar energy, wind energy, hydraulic power energy, geothermal energy, biofuel energy, hydrogen energy, wave and current energy and tidal energy as seen in Table 1.

Table 1. Energy sources.

Renewable E.S.		**Non-Renewable E.S.**	
Hydrogen	Wind	Oil (LPG, Gasoline, Diesel)	Nuclear (Thorium, Uranium, Plutonium)
Solar	Hydraulic	Coal (Lignite, Coal, Charcoal, Coke, Air Gas)	Methane hydrate
Geothermal	Wave		Natural gas (LNG)
Biofuel (Biomass, Biodiesel/ Bioethanol, Biogas)	Tidal	Unconventional natural gas (Sand gas, Coal mine methane, Shale (rock) gas)	

Approximately 20% of the energy consumed in the world today is obtained from renewable sources. Currently, despite the high dependence on fossil fuels, renewable

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energy use has been increasing steadily over the years. In recent years, Turkey is following the global trend of significant progress in the field of renewable energy. According to data from 2019, the share of electricity production in renewable energy in Turkey was 44% [3].

Fossil fuels are the energy source that has originated from living organisms such as animal and plant remained under the ground for millions of years. These are fuels formed by the fossilization under high pressure in airless environments in the layers of the Earth's crust. Fossil fuels can be used in various fields such as operating factories, electricity generation, operating vehicles, comfort heating and meeting kitchen needs.

On the other hand, climate change has become one of the most important reasons to support renewable energy. Climate change is the most controversial and known environmental problem today. Climate change occurs with a combination of natural and anthropogenic factors that slowly increase the temperature in the atmosphere. The global warming pollution is constantly measured, and CO_2 equivalent gases are given to all gases causing the climate change. Renewable energy such as fossil energy is used as electricity generation, heat generation and vehicle fuels. One of the latest developments common to all renewable energy sources is that different technologies are expected to emerge in the future. In recent years, renewable energy transfer and CO_2 capture technologies have been developed [4].

The natural process that causes the gases in the earth's atmosphere to be permeable to the incoming sun rays and to be less permeable to the rays reflected from the ground, and to cause the place to heat up more than normal, is called the greenhouse effect. Global warming is the phenomenon of increasing the temperature of the earth by intensive increase in greenhouse gases (CO_2, CH_4, N_2O, O_3, CFCs and H_2O) as a result of unnatural activities [5]. Supply-demand imbalances in the quality of energy causes additional CO_2 emissions due to exergy destruction and these exergy destructions are not possible to return. CO_2 emission amounts for different energy sources are given in Table 2 [6]. In this table, emission values generated by renewable energy sources result from the installation of plants, production and assembly of materials and waste disposal processes.

Table 2. CO_2 emission of different energy sources.

Energy Sources	CO_2 Emissions (ton / GWh)
Natural Gas	499
Lignite	1054
Coal	888
Fuel-Oil	733
Nuclear	66
Hydraulic	26
Geothermal	38
Solar PV	85
Wind	26
Biofuel	45

When we examine the literature on energy analysis, the scarcity of resources is remarkable. Bastianoni et al. stated that the energy sector is responsible for 92% of the total greenhouse gas production by evaluating the thermodynamic analysis of Ravenna region of Italy and the entropy waste production of greenhouse gases [7]. Liu et al. conducted an energy analysis of the ecological economic system for Liaoning province and stated that non-renewable resources constitute 74% of the total consumed energy [8]. In a similar study performed in Turkey level, it was found that energy production in Karabük province can meet 45% of its power consumption, and the share of renewable energy in the total energy production has been calculated as 32% [9].

To better understand energy sources and their end use, energy flow diagrams, also called Sankey diagrams, are created that visualize complex relationships [10].

In this study, the place of traditional and renewable energy sources in Ankara in terms of production and distribution of energy consumption to the usage areas as well as environmental and economic analysis of energy production and consumption was investigated.

2. Method

Turkey, in terms of solar potential is quite favorable compared to European countries. The average annual sunbathing time of Ankara is 2506 hours, and the average annual solar radiation is 1389 Wh/m^2 [11]. Figure 1 shows Ankara's solar energy potential [12].

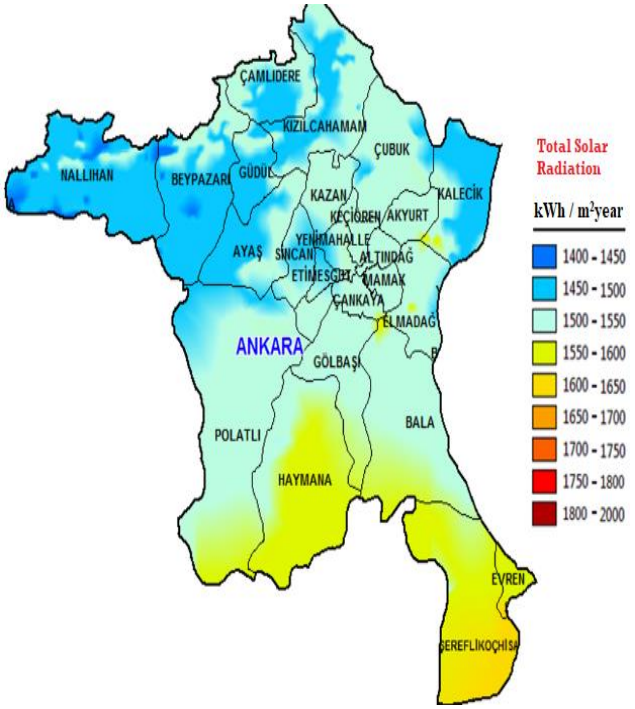


Figure 1. Ankara global solar radiation distribution.

When the sunshine duration values (hours) and global radiation values (kWh/m^{2}day) given in Figure 2 are analyzed, it is observed that the solar radiation values differ during the year and months and increase in the south and east and increase in July-August [13].

Sun rays come to the city center of Ankara (39.56 N, 32.52 E) with the lowest angle of 26.7° (in winter), the steepest 73.5° (in summer), 61.9° in spring and 39.5° in autumn. Kocer et al. (2016) calculated the annual optimum angle of inclination for Ankara provinces and districts as 34 ° ±1. In addition, it was calculated as 15 and 56° for six-month periods, and 62°, 23°, 6° and 49° for seasonal (winter, spring, summer, autumn) periods, respectively, and solar radiation values were found for optimum slope angles [14]. Although Ankara had 27 MW solar power plant installed capacity as of 2019, the ratio Ankara in Turkey's installed capacity is only 0.5% [15]. Figure 3 shows the wind power plant installable areas of Ankara.

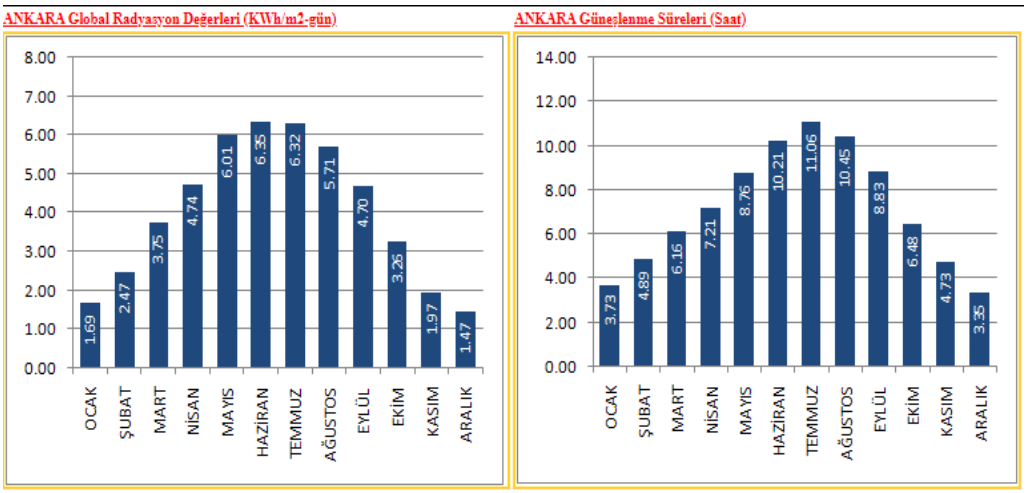


Figure 2. Ankara province global radiation values (kWh/m^{2}day) and sunshine time (hours).

For economic Renewable Energy Source (RES) investment, a wind speed of 7 m/s or more and a capacity factor of 35% or more are required [16]. Average absolute percentage errors for the test data in the wind speed estimation made in MATLAB by taking the historical 30 years wind speed, humidity, pressure, temperature and precipitation amount data obtained from the General Directorate of Meteorology Affairs for sample districts in Ankara province are 9,48% for Çubuk, 7,77% for Keçiören, 7,88% for Polatlı, 6,83% for Bala, 8,02% for Şereflikoçhisar and 5,41% for Haymana [17].

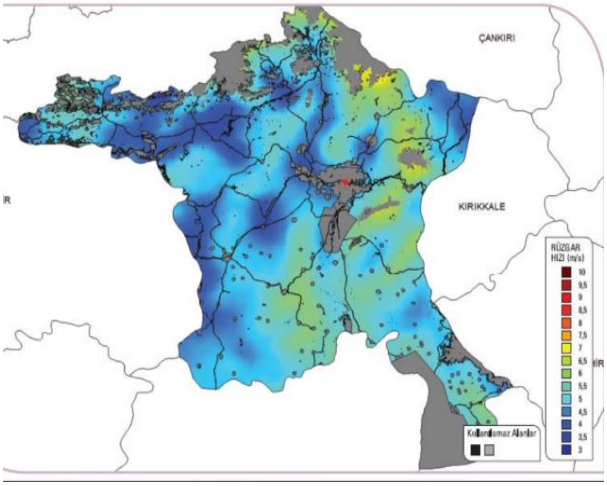


Figure 3. Wind power plant installable areas of Ankara.

Although there is no wind power plant currently installed in Ankara, there are projects planned to be built.

The theoretical hydroelectric potential of our hydraulic resources, which holds the most important place in the renewable energy potential of our country, is 433 billion kWh, and the technically available hydroelectric potential is 216 billion kWh and the economic hydroelectric energy potential is 140 billion kWh / year [18]. Although Ankara had a hydroelectric power plant installed capacity of 304 MW by the year 2019, the ratio of Ankara in Turkey's installed capacity was 1.07% [19].

Biofuel energy is fuel obtained from recently living organisms. Organic substances and biogas yield in biofuel production are given in Table 3, equivalent energy values for animal/plant waste amounts for Ankara province are given in Table 4 and equivalent for municipal and forest residues energy values are given in Table 5 [20].

Table 3. Organic matter and biogas yields.

Organic Matter Type	**Biogas Yield (m^3 / ton)**	**Source**
Cattle Manure	45	[21]
Kitchen Waste	30	[22]
Small Cattle Manure	60	[23]

Table 3. (Cont.) Organic matter and biogas yields.

Organic Matter Type	Biogas Yield (m^3 / ton)	Source
Domesticated Poultry Manure	70-90	[24]
Wastewater Treatment Sludge	310-800	[25]
Food Waste	50-480	[22]
Vegetable and Fruit Waste	45-110	[21]
Agricultural Wastes	20	[24]
Poultry Manure	310-620	[23]
Sugar Beet Meal	147,1	[26]

Table 4. Equivalent energy values for animal/plant waste amounts.

	Number of Animals (Pieces) / Crop Production (Ton)	Waste Amount (Ton)	Energy Equivalent (TOE/ Year)
Cattle	13.631.000	17.469.453	15.376.587
Small Cattle	10.652.000	12.376.785	3.525.390
Poultry	13.956.000	3.429.963	2.699.417
Field Crop	23.707.000	22.360.580	18.950.380
Garden Plant	43.498.000	7.686.060	4.598.154
Vegetables	27.161.000	23.036.800	18.009.426

Table 5. Equivalent energy values for municipal and forest residues.

Municipal Wastes	
Amount of Municipal Waste Suitable for Biomethanization (Ton/Year)	926.598
Amount of Municipal Waste Suitable for Incineration (Ton/Year)	758.125
Forest Wastes	
Industrially Not Evaluated (Ster/Year)	64.481
Total Energy Equivalent (TOE/Year)	14.508

According to the data obtained from the studies conducted, the kitchen waste value per capita is approximately 1 kg [21]. 60% of this waste is organic waste. Organic waste amount from Ankara is given in Table 6. Ankara's 2019 population was 5,639,076 [27]. According to this information, the total kitchen waste potential is approximately 5,639 megatons. The amount of gas per person in the domestic wastewater treatment plant varies between 15-22 liters / person. The methane percentage of the gas generated is 65%, and its energy value is 22.4 MJ / m^3 [28].

Table 6. Organic waste amount in Ankara province.

Organic Waste Type	Total Amount of Organic Waste (TOE / Day)
Kitchen Waste	5,60
Wastewater Treatment Sludge Waste	858,70
Agricultural Waste	113.857,40
Animal Fertilizer Waste	59.181,90
Forest Waste	39,70
Municipal Waste	2,10
Total	173.945,49

Although Ankara had 61 MW biomass power plant installed capacity as of 2019, the ratio Ankara in Turkey's installed capacity is 7.44% [29].

Similarly, Ankara had 1958 MW thermal power plant installed capacity as of 2019, and the ratio of Ankara in Turkey's installed capacity is 4.18% [30-31].

Residential heating, greenhouse cultivation and industry are involved in the direct use of geothermal energy. It is seen that geothermal energy is used in residential heating and tourism in Ankara as depicted in Figure 4. Geothermal energy is at 80 ºC, and 2500 houses are heated in Kızılcahamam, a district of Ankara. Thermal tourism and balneology applications of geothermal energy are also available in Haymana. Energy efficiency can be achieved in the districts by increasing the use in Ankara's Ayaş, Beypazarı, Çamlıdere, Çubuk, Etimesgut, Gölbaşı, Güdül, Haymana, Kahramankazan, Kızılcahamam, Mamak, Polatlı, Pursaklar, Sincan and Yenimahalle districts that have geothermal energy [32-33].

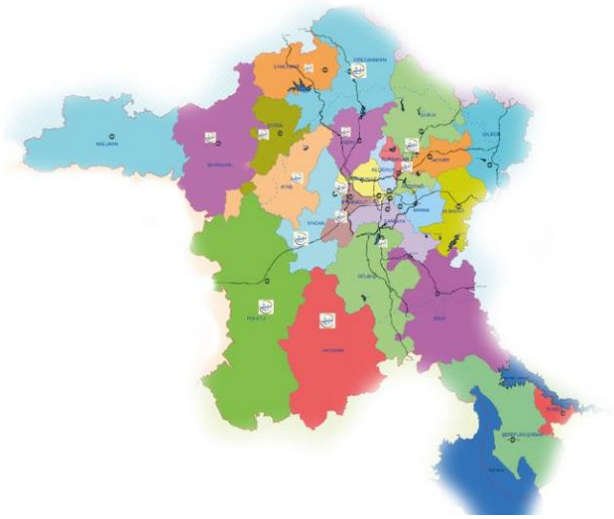


Figure 4. Geothermal energy map of Ankara province.

3. Research Results

The share of renewable energy-based power generation in the licensed power plants in Turkey is 45%

(38,425.02 MW) as seen in Figure 5. The biggest share among these resources is hydraulic energy with 34% (28,494.4 MW). Hydraulic energy is followed by wind energy with 9% (7,520.3 MW) and geothermal energy with 2% (1,514.7 MW). The largest share in non-renewable energy sources belongs to natural gas with 31% (25,935.43 MW).

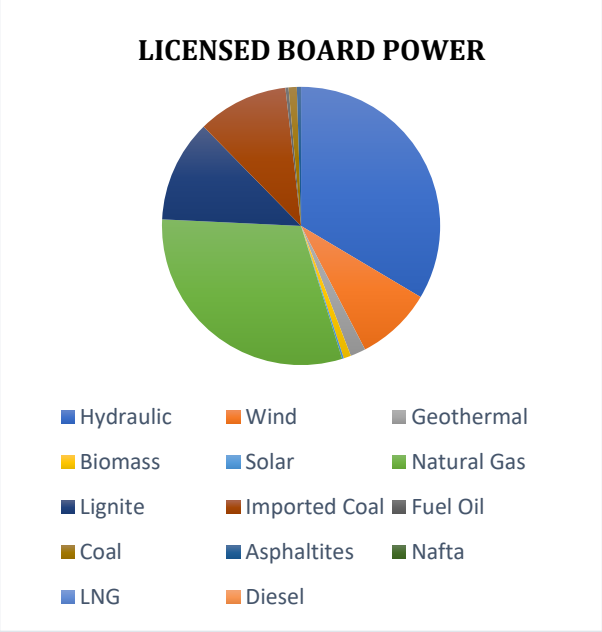


Figure 5. Turkey licensed potential installed capacity of 2019.

In the unlicensed power generation plants, the biggest share has solar (photovoltaic) energy with 97% (5,666.25 MW) as seen in Figure 6.

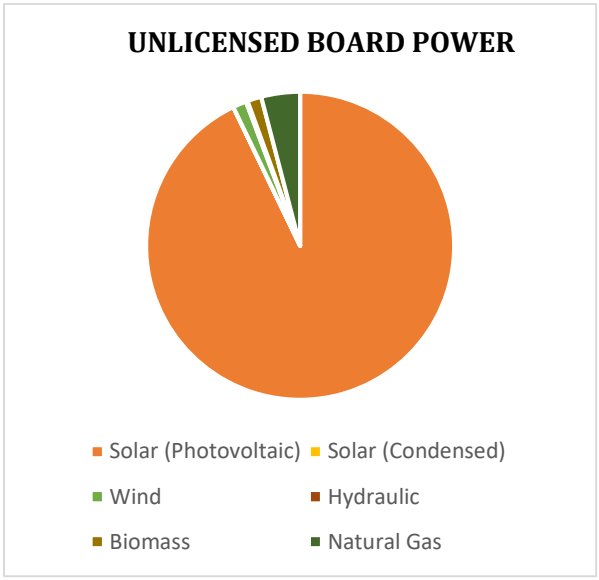
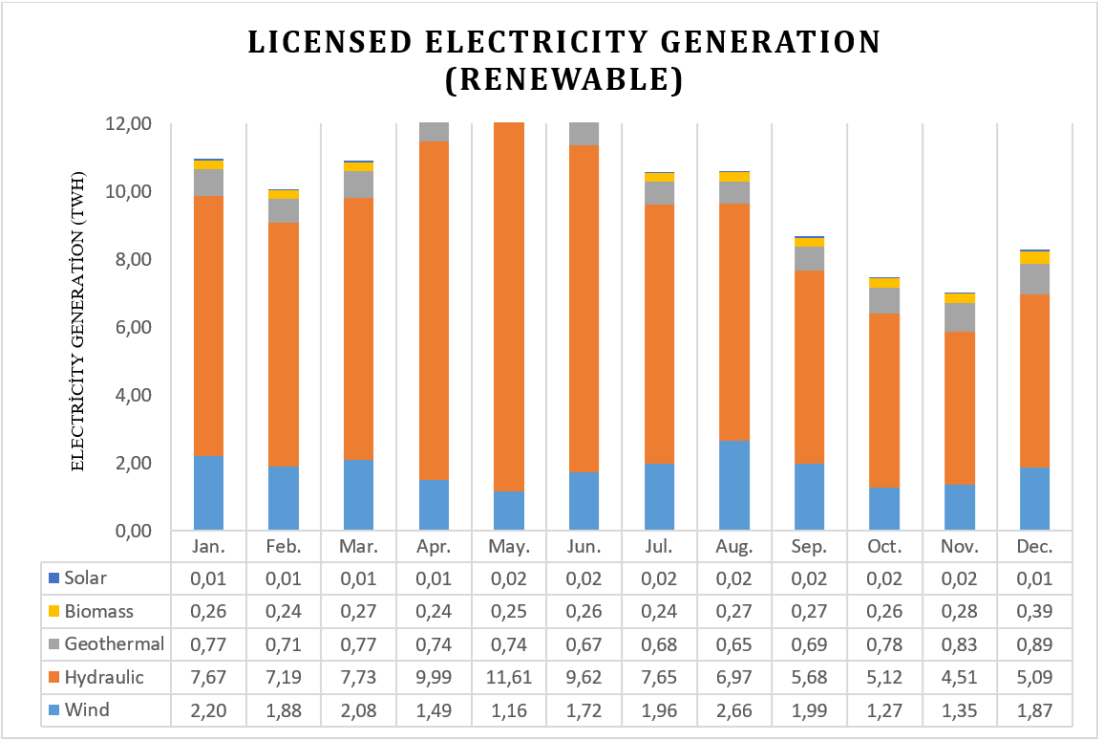


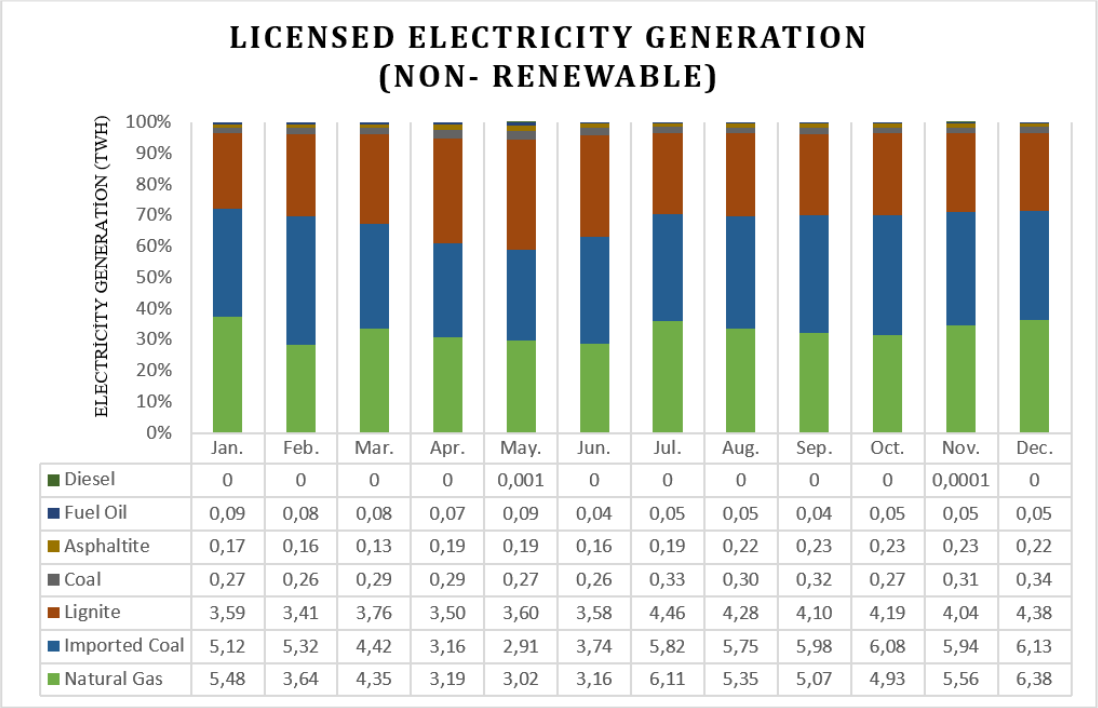
Figure 6. Turkey unlicensed potential installed capacity of 2019.

Hydraulic power comes first in renewable licensed electricity generation. As can be seen in Figure 7, an increase in the production amount is observed with the increase in the water carrying capacity of the rivers especially in the spring months. Natural gas and imported coal lead to the production of electricity from the non-renewable energy sources as shown in Figure 8.



	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Solar	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,01
Biomass	0,26	0,24	0,27	0,24	0,25	0,26	0,24	0,27	0,27	0,26	0,28	0,39
Geothermal	0,77	0,71	0,77	0,74	0,74	0,67	0,68	0,65	0,69	0,78	0,83	0,89
Hydraulic	7,67	7,19	7,73	9,99	11,61	9,62	7,65	6,97	5,68	5,12	4,51	5,09
Wind	2,20	1,88	2,08	1,49	1,16	1,72	1,96	2,66	1,99	1,27	1,35	1,87

Figure 7. Licensed production of electricity from renewable energy in Turkey in 2019.



	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Diesel	0	0	0	0	0,001	0	0	0	0	0	0,0001	0
Fuel Oil	0,09	0,08	0,08	0,07	0,09	0,04	0,05	0,05	0,04	0,05	0,05	0,05
Asphaltite	0,17	0,16	0,13	0,19	0,19	0,16	0,19	0,22	0,23	0,23	0,23	0,22
Coal	0,27	0,26	0,29	0,29	0,27	0,26	0,33	0,30	0,32	0,27	0,31	0,34
Lignite	3,59	3,41	3,76	3,50	3,60	3,58	4,46	4,28	4,10	4,19	4,04	4,38
Imported Coal	5,12	5,32	4,42	3,16	2,91	3,74	5,82	5,75	5,98	6,08	5,94	6,13
Natural Gas	5,48	3,64	4,35	3,19	3,02	3,16	6,11	5,35	5,07	4,93	5,56	6,38

Figure 8. Licensed production of electricity from non-renewable energy in Turkey in 2019.

Electricity generation in Ankara was 9.55 TWh annually as reported in detail in Figure 9. This value refers to 3% of Turkey's equivalent production [34].

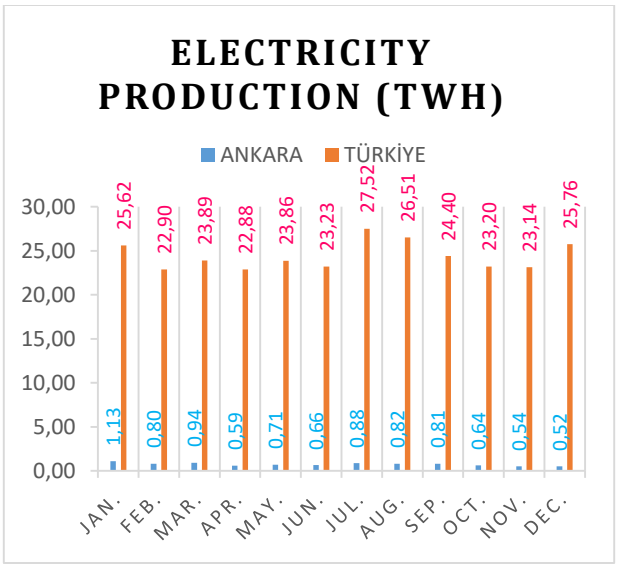


Figure 9. Electricity production in Ankara, 2019.

Photovoltaic solar energy has the largest share in unlicensed installed power as shown in Figure 10.

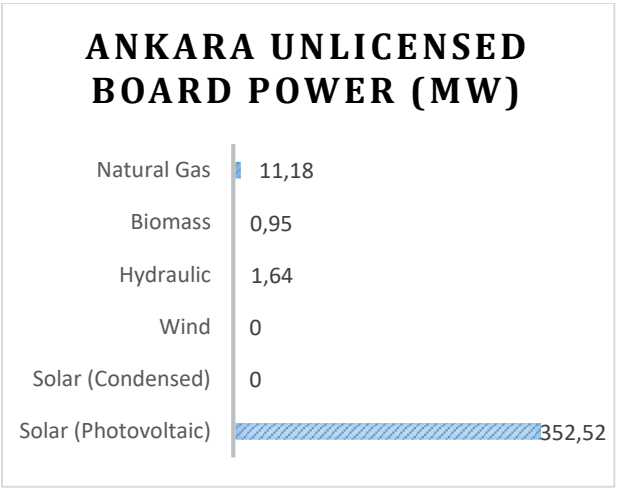


Figure 10. Ankara 2019 unlicensed installed power.

Ankara's annual electrical energy consumption was 14 TWh as reported in detail in Figure 11.

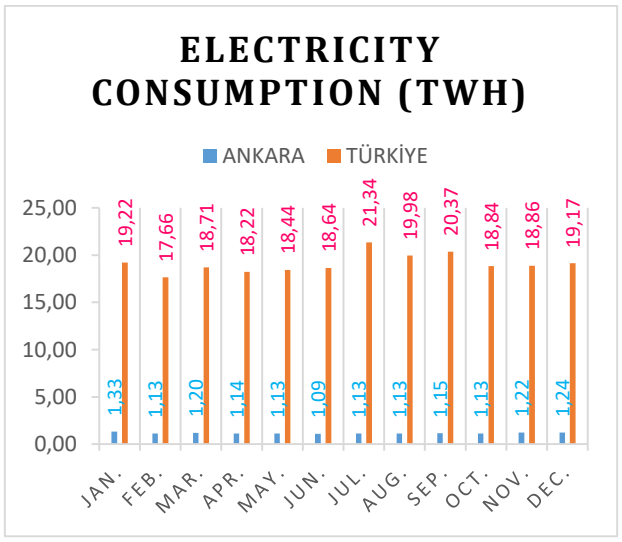


Figure 11. Electricity consumption in Ankara, 2019.

In Turkey, the share of electric energy usage was 6%. Of this consumption, 30% is in industry (Figure 12a), 38% is in the commercial (Figure 12b), 29% is in dwellings (Figure 12c), 2% in illumination (Figure 12d), and 1% in agricultural irrigation (Figure 12e) is used.

It is seen from the graphs that electricity consumption is distributed proportionally throughout the year in industrial, commercial and residential buildings. This usage decreases due to the increase in day length in summer months, and agricultural irrigation increases because of hot summer temperatures.

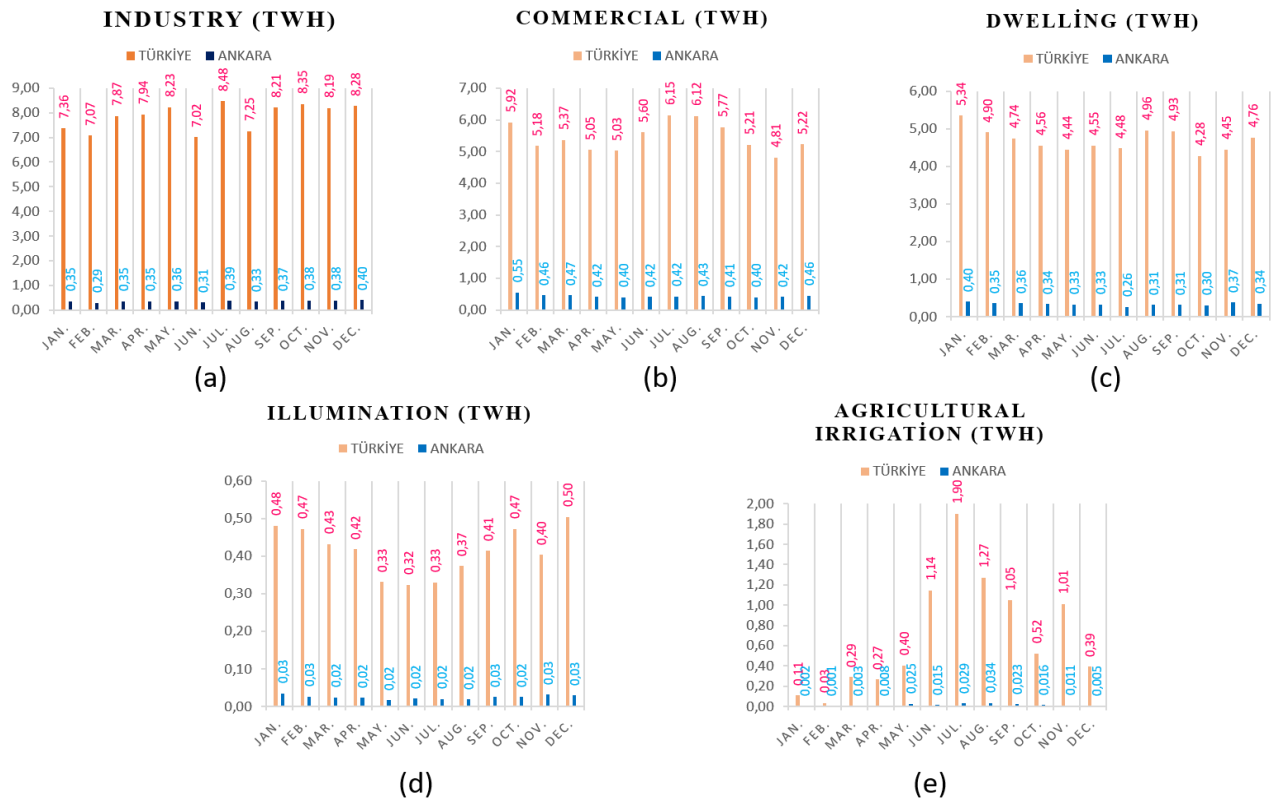


Figure 12. Distribution of electrical energy usage by sectors in Ankara,2019.

In Figure 13, the electricity production & consumption values for Ankara in 2019 are shown on the Sankey diagram. In 2019, the electricity consumption of Ankara was provided by 0.8 TWh from self-licensed generation, 8.75 TWh from self-licensed generation, and 4.45 TWh from the interconnected network.

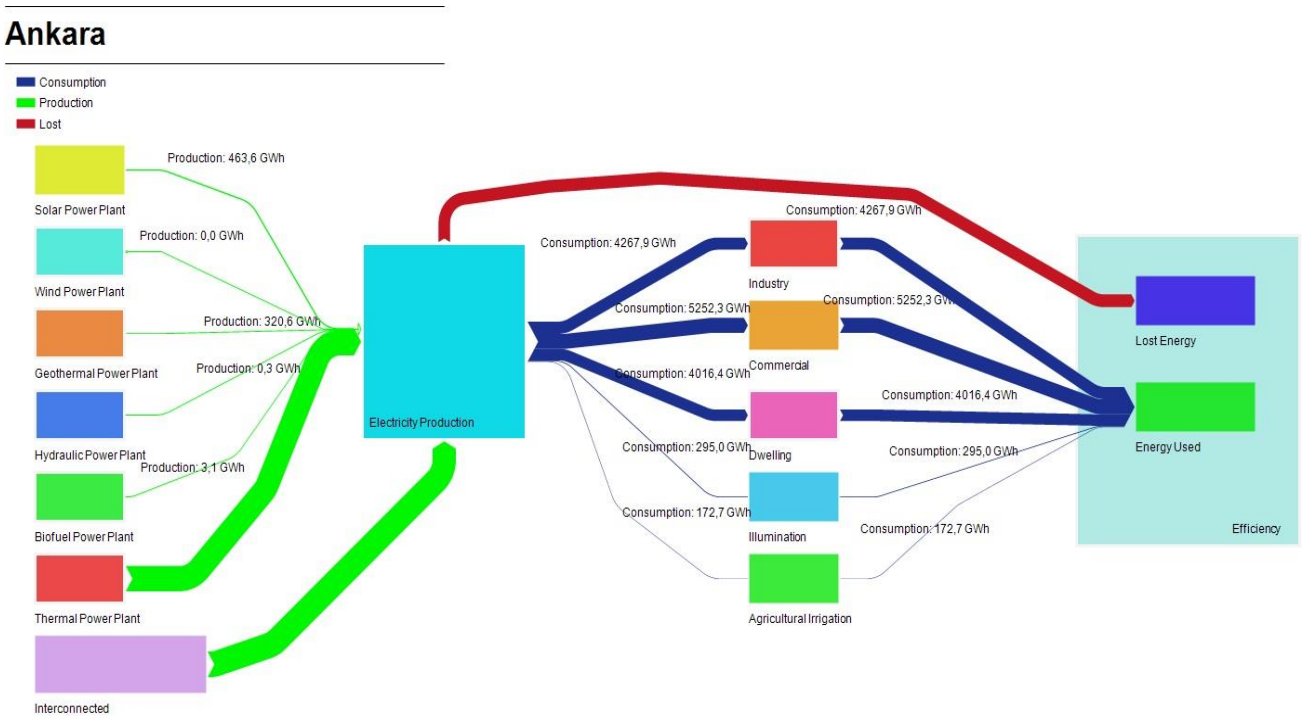


Figure 13. Ankara 2019 electricity production/consumption values SANKEY diagram.

4. Conclusion

Ankara's electricity production and consumption in 2019 were 9.55 TWh and 14 TWh, respectively, and the ratio of electricity production to electricity consumption is 68%.

Ankara's 787.6 GWh of electricity generation in 2019 was from renewable energy sources. 22,934 tons of CO_2 emission occurred in the consumption of electricity produced from these sources. Considering that other consumption of 13,216.4 GWh was from fossil origin sources in 2019, approximately 11 million tons of CO_2 emission occurred from these sources.

While Enerjisa Ankara Başkent electricity unit price in 2019 was 0.5375 TL/kWh for dwellings including taxes, this value is 0.7148 TL/kWh for commercial houses [35]. It is known that electricity consumption is 4.3 million MWh for dwellings and illumination and 9.7 million MWh for commercial, industrial and agricultural irrigation. While there was a pricing of 2.3 billion TL for dwellings and illumination, this expense was 6.9 billion TL in industry, commercial and agricultural irrigation.

Efforts should be made to reduce losses and leakages that occur during the transmission and distribution of electrical energy. Projects developed within the framework of the energy efficiency law should be supported. Solar energy use should be encouraged, especially in organized industrial zones and street lighting.

It is thought that Ankara, which is in a central location close to energy resources, can reduce existing CO_2 emissions with its support programs to renewable energy sources. It is expected that the rooftop PV panels will become the green cities that produce their own energy by producing electricity from renewable energy sources such as the widespread use of geothermal resources in regional heating and electricity production.

Declaration of Ethical Standards

The materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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