

# Waste-to-Bioenergy Potential and a New Market in Turkey

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In this study, it is aimed to present a general information in regards to energy demand of Turkey and potential and contribution of biomass including organic wastes to meet this demand. In this regard, the current energy demand of Turkey and future projection are presented. In addition, the amount of various organic wastes and potential biomass resources are summarized in depth. Turkish legislation for renewable energy including incentives for renewable energy production is also presented. As it will be noticed in the report that Turkey is a big and promising market especially for biogas sector and the potential number of future biogas plants are estimated to be around 3,000 assuming an average installation power of 500 kW for each plant. This corresponds to an economic circulation of almost 9 billion EUR assuming an average CAPEX of 3,000 EUR per kW installation. Even though incentives for biomass based renewable energy in Turkey is lower than Europe, investment in biogas in Turkey attracted many big farms and dairy companies producing significant amount of organic waste such as cattle and chicken manure since these companies are legally obliged to manage their wastes in an environmentally friendly manner. As a result, significant number of European biogas providers now directed their attention to a new market in Turkey.

## 1. Turkey's energy profile

Turkey's demand for energy and natural resources has been increasing due to economic and population growth. UNDP forecasts a population of 85 million for 2023, which coincides with the 100th anniversary of the Republic of Turkey. This Figure aligns

with the 84.3 million inhabitants expected by the Turkish Statistical Office. In recent years, Turkey has recorded the fastest growth in electricity demand among OECD members, with an annual growth rate of 5 % since 2002. Turkey's energy use is expected to increase by 50 % over the next decade. Turkey's installed capacity has exceeded 88 GW as of January 2019, which represents a threefold increase in 15 years [7]. As of the end of the first half of 2018, 28,5 % of electricity production was obtained from natural gas, 36,4 % from coal, 22,4 % from hydropower, 6,3 % from wind, 2,3 % from geothermal, 2,4 % from solar energy and 1,6 % from other sources [8]. Figure 1 shows annual development of Turkey's installed capacity and the distribution of primary energy resources for the years 2007 and 2017.

Two main characteristics of the Turkish energy markets are growing energy demand and dependency on imports. Turkey, in line with its local and national energy strategy, is taking necessary steps to reduce this dependency.

The main elements of our energy strategy can be summarized as follows (Republic of Turkey, Ministry of Foreign Affairs):

1. Taking into account increasing energy demand and import dependency, prioritization among energy supply security related activities;
2. Within the context of sustainable development, giving due consideration to environmental concerns all along the energy chain;
3. Increasing efficiency and productivity, establishing transparent and competitive market conditions through reform and liberalization;
4. Augmenting research and development on energy technologies.

Through application of these four basic principles, it is aimed for the following goals;

1. Diversification of supply routes and sources for imported oil and natural gas;
2. Increasing the ratio of local and renewable energy in our energy mix;
3. Increasing energy efficiency;
4. Adding nuclear to our energy mix.

RES (Renewable Energy Sources) are also commonly accepted as the key for future life in Turkey as in the whole world. Biomass is considered as one of the most promising RES. It is considered as an alternative to conventional energy and has significant potential in Turkey. Biomass can be burnt directly or it can be converted into solid, gaseous and liquid fuels using conversion technologies. Direct burning of dried animal manure, wood, or processed wood products, hold a significant share of the heating for people in Turkey. Biomass to energy conversion projects are currently widespread and biogas projects/investments have been blooming fast. The potential number of biogas plants in Turkey are estimated to be around 3,000.

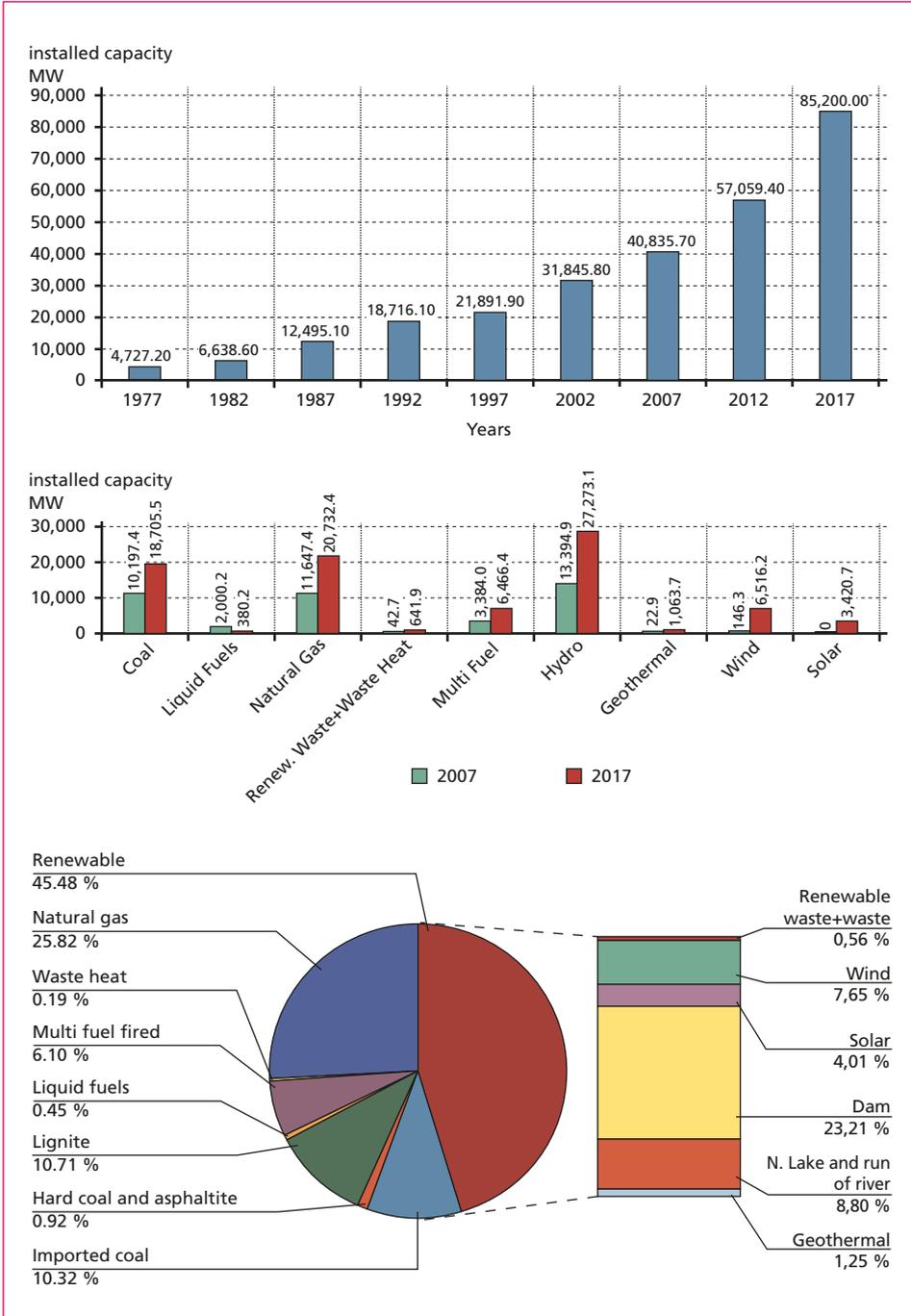


Figure 1: Annual development of Turkey's installed capacity and distribution of primary energy resources for the years 2007 and 2017

Source: TEİAŞ, Türkiye Elektrik İletim A.Ş.: <https://www.teias.gov.tr/tr/i-installed-capacity, 2017>

## 2. Biomass potential in Turkey

Amongst the alternative energy strategies, biomass resources especially use of organic wastes for biogas based energy production has been gaining significant attention in recent years. The total installed power of registered 100 biomass based energy plant (31 biogas plant , 26 landfill gas, 43 waste heat, biomass combustion, pyrolytic oil energy centrals) is 646 MW. There is a significant room for new projects in Turkey. General review for biomass resources focusing on organic wastes for biogas production is given below.

### 2.1. Municipal waste

According to statistical data, in 2016, the total amount of municipal waste (household waste plus waste similar to household waste) was about 32 million t/a corresponding to 1,17 kg per person (0.427 tons/person/year) waste production [10]. Of these, only 6 % were recycled, 64 % classified and 30 % illegally dumped. Landfill gas recovery facilities already exist at 34 landfills. There are currently six composting plants and two bio-methanization plants where separately collected organic waste is treated, plus six mechanical-biological plants for mixed waste. Accordingly, of the total waste accumulation of 74,320 t/d, about 126 t/d are treated biologically, 4,250 t/d mechanically-biologically, 274 t/d thermally, and the remaining amount of 69,670 t/d are landfilled. The amount of municipal waste is estimated to be around 30 million t/a in 2018 and to 33 million t/a in 2023. From today until 2023, the recycling rate is to be successively raised to 35 %, with the remaining waste to be landfilled in a controlled manner. The aim is, during the same period, to increase the amount of mechanically treated household waste to 11 % and the thermally treated amount to 8 %, while the landfill rate to decrease from today 88.7 % to 65 %.

Taking into account that about 40 % of the theoretically obtainable gas value can be obtained practically, the LFG developed over a period of 20 years will be 19.42 billion m<sup>3</sup>. Accordingly, the annual value of the LFG potential of municipalities given waste services is 0.97 billion m<sup>3</sup>/year. The lower heating value (LHV) of LFG is accepted as 5 kWh/m<sup>3</sup> by considering the values of 19 – 23 MJ/m<sup>3</sup> (5.27 – 6.38 kWh/m<sup>3</sup>) and 17.20 MJ/m<sup>3</sup> (4.77 kWh/m<sup>3</sup>) given for LFG. When the energy value of LFG potential is calculated for 5 kWh/m<sup>3</sup> LHV, it is approximately 4.85 TWh [5].

Applications including those for obtaining LFG by storing MSW in landfill sites, and for generating biogas with anaerobic digestion by degrading their organic compounds, have become widespread. Besides these methods, the generation of electric energy through the incineration of MSW is also possible.

### 2.2. Animal manure

Anaerobic digestion of animal waste and manure is a common method to treat these wastes and to produce biogas in centralized or individual biogas plants. The number of biogas plants in Europe has greatly increased. Between 2009 (earliest EBA data) and

2016, the total number of biogas plants rose from 6,227 to 17,662 installations (+ 11,435 units). Growth was particularly strong from 2010 to 2012, reaching double figures every year. Most of that growth derives from the increase in plants running on agricultural substrates: these went from 4,797 units in 2009 to 12,496 installations in 2016 (+ 7,699 units, 67 % of the total increase). Agricultural plants are then followed by biogas plants running on sewage sludge (2,838 plants), landfill waste (1,604 units) and various other types of waste (688 plants). There are 290 plants producing electricity and heat in Austria. Although the number of biogas plants in Europe has been stabilizing since 2015, the total Installed Electric Capacity (IEC) is on the rise. The IEC increased in Europe from 4,158 MW in 2010 to 9,985 MW in 2016 (+ 5,827 MW). In 2016 alone, the IEC increased by 858 MW (+ 9 %). Growth in Installed Electric Capacity (IEC) since 2011 has been mainly due to the building of plants running on agricultural substrates: such plants went from 3,408 MW in 2011 to 6,348 MW in 2016 (+ 2,940 MW – 56.5 % of the total increase) [1]. Most of the European companies now direct their attention to international markets due to the saturation of biogas market in Europe. Turkey in this manner is a virgin market with significantly low number of existing biogas plants and huge capacity of organic waste material for biogas investments. Number of bovine animals by type and races are given in Table 1 and Table 2. As can be seen in Table 1, there are 17,220,903 bovine animals which creates 62 million tons of animal manure per year (assumption: 3.6 ton wet manure/head/day). This corresponds to a total of 2.05 billion m<sup>3</sup> of biogas per year (assumption: 33 m<sup>3</sup> biogas/wet ton of manure). Table 1 also shows the number of sheep and goat by type and races which is 46,117,399 in total. This corresponds to an average manure production of 32.3 million tons per year which has a biogas potential of 2.85 billion m<sup>3</sup> per year (assumption: 58 m<sup>3</sup> biogas/wet ton of manure). The biogas potential of horses, asses, mules, camels and pigs (276,210 animals in total) are neglected.

Table 1: Number of bovine animals by type and races

| Cattle – Culture | Cattle – Cross-bred | Cattle – Domestic | Buffaloes | Sheep – Domestic | Sheep – Merino | Goats – Ordinary | Goats – Angora |
|------------------|---------------------|-------------------|-----------|------------------|----------------|------------------|----------------|
| head             |                     |                   |           |                  |                |                  |                |
| 8,419,204        | 7,030,297           | 1,593,005         | 178,397   | 32,513,293       | 2,681,679      | 10,698,553       | 223,874        |

Source: TÜİK, 2018

Table 2: Number of poultry animals by type

| Laying hens | Broilers    | Turkeys   | Geese     | Ducks   |
|-------------|-------------|-----------|-----------|---------|
| number      |             |           |           |         |
| 124,054,810 | 229,506,689 | 4,043,332 | 1,080,190 | 532,841 |

Source: TÜİK, 2018

As can be seen in Table 2, the number of poultry animals is 359,217,862 in total which has an annual manure production of 7,902,793 million tons (assumption: 0.022 ton wet manure/animal/year) corresponding to a biogas potential of 0.62 billion m<sup>3</sup> of biogas (assumption: 78 m<sup>3</sup> biogas/wet ton). If we consider the biogas potential of all the animal manure together, 5.52 billion m<sup>3</sup> of biogas potential is waiting to be economically exploited.

A project titled *Turkish-German Biogas Project* with the cooperation of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Turkish Ministry of Environment and Urbanization was commenced in 2010 was carried out. The target of the project was to determine the biogas potential of Turkey obtainable from cattle, poultry (broiler and laying chickens), organic waste and food industry waste. Within the scope of this project, studies related to the determination of the biogas potential of Turkey according to different source types were made. Accordingly, the theoretical biogas potential of cattle in Turkey was 115.9 PJ/year (32.194 TWh/year) and the technical biogas potential was 47.3 PJ/year (13.138 TW-h/year). The theoretical biogas potential of poultry in Turkey was 36.6 PJ/year (10.166 TWh/year) and the technical biogas potential was 36.2 PJ/year (10.055 TWh/year). The energy value of the total technical biogas potential was 83.5 PJ/year (23.194 TWh/year) [2].

### 2.3. Agricultural residues and energy crops

According to the 2011 crop production statistics, the total agricultural land of Turkey is 23,630,063 ha and the amount of fallow land is 4,017,197 ha. If the 4,017,197 ha of fallow land in Turkey was used for the purpose of sowing energy crops, estimation could be made of the potential biogas. The biogas potential of a biomass of 10 tTS/ha (total solids per ton/hectare) is approximately 6,858 m<sup>3</sup>/hectares [4]. If this value is accepted as the biomass generation potential, there will be a 27.549 billion m<sup>3</sup> biogas potential. The LHV of the biogas is stated as about 6 kWh/m<sup>3</sup>. The primary energy value obtainable for a 6 kWh/m<sup>3</sup> biogas LHV is 165.29 billion kWh/year. Accordingly, in the case of using the total fallow land, the obtainable biogas potential would be 165.29 TWh/year [5].

### 2.4. Wastewater treatment plant sludges

According to TÜİK [10], amount of wastewater discharged from municipal sewerage by receiving bodies was 4.5 billion m<sup>3</sup> in 2016 and 85 % of this discharge was treated serving to almost 61 million populations. The gas amount developed per person in the domestic wastewater pre-treatment plant varies between 0.015 and 0.022 m<sup>3</sup>/person/day. In the secondary treatment plants, this value is about 0.028 m<sup>3</sup>/person/day. The methane percentage of gas that develops in the plant is about 65 % and its LHV is approximately 22.4 MJ/m<sup>3</sup>. Considering that the population of 61 million whose wastewater was treated, the daily gas amount calculated for 0.025 m<sup>3</sup>/person-day is approximately 1,525,000 m<sup>3</sup>. This value is 0.56 billion m<sup>3</sup>/year annually. As the LHV of biogas is 22.4 MJ/m<sup>3</sup>, the energy value of the biogas potential is 12.5 billion MJ which corresponds to 3.61 TWh/year.

### 3. Renewable energy legislation in Turkey

The main piece of legislation governing the electricity sector in Turkey is the Electricity Market Law numbered 4628 (*Electricity Market Law*) which deals mainly with the following issues such as the actors of the electricity market, licenses required in order to operate in the sector, and the duties of the Energy Market Regulatory Authority (EMRA or EPDK). In addition to the main piece of legislation outlined above, the Law on the Use of Renewable Resources for the Generation of Electrical Energy (the *Renewable Energy Law*) was enacted in 2005. Renewable Energy Law governs the principles for the conservation of renewable resource areas and introduces further incentives for renewable energy projects. According to the Renewable Energy Law, the facilities within the scope of this law are required to obtain a Renewable Energy Source Certificate in order to benefit from the incentives provided under the law. The procedures for benefiting from the incentives are detailed in the Regulation on Granting of Renewable Energy Source Certificate (the *Renewable Energy Certificate Regulation*). The entities have to obtain a license from the EMRA in order to operate in the electricity sector. The types of licenses which may be granted by the EMRA consist of generation license, auto-generation license, auto generation group license, transmission license, distribution license, wholesale license and retail sale license. In addition to the incentives provided by the Electricity Market Law and the License Regulation, the Renewable Energy Law, which came into force on 18 May 2005 was enacted in order to provide more incentives for renewable energy resources. The facilities must obtain a Renewable Energy Source Certificate (REC) in order to benefit from the incentives provided under the Renewable Energy Law. According to the Renewable Energy Certificate Regulations, the entities should apply to the EMRA for obtaining REC and such applications should be reviewed by the EMRA within 30 days as of the date of the application. The REC is granted for a term of one year. The renewable energy resources covered by the Renewable Energy Law are wind, solar, geothermal, biomass, biogas, wave, stream, tidal, river and arc type hydroelectric generation facilities and hydroelectric generation facilities with a reservoir area of less than fifteen km<sup>2</sup> (Ozkan Law Office). Biogas plants are entitled to a 10-year guaranteed Feed-in-Tariff for the electricity produced (133 USD/MWh) [11]. In addition, plant operators can benefit from a bonus if the plant components and equipment were manufactured in Turkey (Fluidized bed steam boilers: 8 USD/MWh, Liquid or gas bed steam boilers: 4 USD/MWh, Gasification and gas cleaning group: 6 USD/MWh, Steam or gas turbines: 20 USD/MWh, Internal combustion engines or sterling motors: 9 USD/MWh, Generator and power electronics: 5 USD/MWh, Cogeneration systems: 4 USD/MWh) but this support is limited to the first 5 years of operation. This tariff could be 18.90 USD-cent/kWh at max if all equipment in the supporting mechanism are used. In order to benefit from this support scheme producer of renewable electricity (legal person) must apply for YEK-license at EMRA by 31 October of the year. On the other hand, also producer without YEK-license can obtain support for his generated electricity, but in this case plant may not exceed capacity of 1,000 kW<sub>e</sub> [11].

## 4. Conclusions

The total theoretical potential from the sources of cattle and poultry manure, agricultural residues, energy crops, agro-industrial residues and MSW is 796.4 PJ/year (221.222 TWh/year), and the total technical potential is estimated as 220.4 PJ/year (61.222 TWh/year) [2]. The number of biogas and biomass based energy centrals are only 100 and there is a big room for another 2,500 to 3,000 power plants running on biogas which corresponds to 9 billion EUR economic circulation in Turkey.

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## Acknowledgement

The authors wish to thank Tubitak-Caydag under the grant No 117Y220 and Eranet-Biogasmerna for the financial support of this study. The data presented in this article was produced within the project above, however it is only the authors of this article who are responsible for the results and discussions made herein.

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Bibliografische Information der Deutschen Nationalbibliothek

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.dnb.de> abrufbar

Thiel, S.; Thomé-Kozmiensky, E.; Winter, F.; Juchelková, D. (Eds.):

**Waste Management, Volume 9**  
– Waste-to-Energy –

ISBN 978-3-944310-48-0 Thomé-Kozmiensky Verlag GmbH

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Publisher: Thomé-Kozmiensky Verlag GmbH • Neuruppin 2019

Editorial office: Dr.-Ing. Stephanie Thiel, Elisabeth Thomé-Kozmiensky, M.Sc.

Layout: Claudia Naumann-Deppe, Janin Burbott-Seidel, Sarah Pietsch,  
Ginette Teske, Roland Richter, Cordula Müller, Gabi Spiegel

Printing: Universal Medien GmbH, Munich

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