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Potential evaluation of biomass-based energy sources for Turkey

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ABSTRACT

Turkey has great potential with respect to renewable energy sources (RES) and, among such sources, "biomass energy" is of particular importance. The purpose of this study is to determine the primary electrical energy potential obtainable from the biomass potential, according to different biomass source types. In this study, the biomass sources of municipal solid wastes, energy crops, animal manure and urban wastewater treatment sludge are evaluated. For each source, individual biogas and biomass energy potential calculations are made. Methods for energy conversion from wastes applicable to the conditions of Turkey, and technical and economic parameters are used. As a result of the calculations made, the total primary energy value of biogas obtainable from the examined sources is 188.21 TWh/year. The total primary energy value related to the potential of the evaluated biomass sources is 278.40 TWh/year.

1. Introduction

The usage of domestic and renewable energy sources (RES) by countries is important for the development of energy policies that decrease dependency on foreign sources. Power plants using renewable energy decrease dependency on foreign sources and are less damaging to the environment when compared to other energy sources.

Turkey's geographical location makes it a strategic energy hub for Europe by providing oil and natural gas from the energy-rich Middle East and the Caspian Sea to Europe. The oil and natural gas pipe lines which provide the fuels, and the straits of the country play an important role in fuel supply. In Turkey, the greatest share of electricity is generated from thermal power plants consuming natural gas, oil and imported coal. Although considerable potential is present in the form of lignite and coal, oil and natural gas reserves are negligible when compared to world reserves [1].

Almost all the natural gas and oil of the country has been imported from neighboring countries, many of which have had unstable regimes for many years. Conflicts both between and internal to these countries have been intensifying and these events pose a threat to Turkey's heavy dependence on imported energy resources. Without good relations with the neighboring energy importing countries, Turkey will face problems in supplying predicted energy demands. More than half of the primary energy consumption in Turkey is met by imports and the share of imports has increased each year. Therefore, Turkey has to supply energy demands using domestic and renewable resources; diversification of resources and a shift from conventional to renewable energy must be realized. Renewable energy must be given first priority as a key way for reducing Turkey's heavy dependence on imported energy.

RES are commonly accepted as the key for future life, not only for Turkey but also for the whole world. This is primarily because RES have some advantages when compared to fossil fuels. Renewable energy power plants have far less environmental impacts than fossil-fuel fired power plants. Usage of these technologies reduces the amount of carbon dioxide produced. RES can contribute to reducing dependence on energy imports and permit diversification of the energy supply. This will not only reduce Turkey's dependence on imports of fuel for producing energy, but will also ensure a continued local source of energy. In the developing countries, RES are more important because many of these nations do not have scarce fossil energy sources such as crude oil and natural gas [2,3].

Biomass is one of the most promising RES. It is considered as an alternative to conventional energy and has significant potential in

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Turkey. Biomass is generally regarded as a low status fuel, and it offers considerable flexibility of fuel supply due to the range and diversity of fuels that can be produced. 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.

Various studies have given a value to the biomass potential of Turkey and the energy value it has. In such studies, it is seen that while a biomass potential energy value is given, the detailed data used to obtain such a value is not given. Kaygusuz [4], determined that the total recoverable bioenergy potential of Turkey is about 16.92 Mtoe (196.779 TWh). This estimate is based on the recoverable energy potential of the main agricultural residues, livestock farming wastes, forestry and wood processing residues, and municipal wastes that are given in the literature. In the same study, the municipal solid waste potential is determined as 1300 ktoe (15.119 TWh), animal waste potential as 2350 ktoe (27.330 TWh) and dry and moist agricultural residue potential as 4810 ktoe (55.940 TWh). In the study, the value of the animal manure potential was determined by using some statistical data. For the other sources; while the potential values were given, the data used were not stated.

Ediger and Kentel [5], have determined the overall biomass energy potential of Turkey as 17.2 Mtoe (200.036 TWh). In the study, the biogas potential from the source of cattle, sheep and poultry manure was determined as 3.30 billion m^3/year, and the landfill gas (LFG) potential as 600 million m^3/year. In the study, the animal manure potential value was determined by using some definite data. There were no calculations related to the other potentials.

Demirbaş [6,7], has determined the annual biomass energy potential of Turkey for crops, residues from the agro and wood industry, animal wastes and other as 32 Mtoe (372.160 TWh). In the study [6], the energy potential of animal manure was determined as 1.3 Mtoe (15.119 TWh) and total recoverable bio-energy potential of Turkey as approximately 17 Mtoe [7].

Özgür [8], determined the energy value of the agricultural waste potential of Turkey as 653–839 PJ/year (181.388–233.055 TWh/year), the animal manure potential as 49 PJ/year (13.611 TWh/year) and municipal solid waste (MSW) potential as 315 PJ/year (87.5 TWh/year). In the study, while potential values were given, the data used were not stated. Erdem [9], gives the economical and feasible biomass potential of Turkey as 196.7 TWh/year. The source types and data covered by this value were not stated.

With the cooperation of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the T.R Ministry of Environment and Urbanization, the "Turkish-German Biogas Project" commenced in 2010. The target of the project is to determine the biogas potential of Turkey obtainable from cattle, poultry (broiler and laying chickens), organic waste and food industry waste, and the share of energy this might generate for the energy consumption of Turkey. It is planned that this project will be finalized following the Green Economy principle in 2014. 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 is 115.9 PJ/year (32.194 TWh/year) and the technical biomass potential is 47.3 PJ/year (13.138 TW-h/year). The theoretical biogas potential of poultry in Turkey is 36.6 PJ/year (10.166 TWh/year) and the technical biogas potential is 36.2 PJ/year (10.055 TWh/year). The energy value of the total technical biogas potential is 83.5 PJ/year (23.194 TWh/year). In the same study, the theoretical biogas potential of energy crops is given as 300 PJ/year (83.333 TW-h/year) and the technical biogas potential as 75 PJ/year (20.833 TWh/year). The theoretical biogas potential of MSW is 22 PJ/year (6.111 TWh/year) and the technical biogas potential is 11 PJ/year (3.055 TWh/year). 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 220.4 PJ/year (61.222 TWh/year) [10].

Karayılmazlar, Saracoglu, Cabuk and Kurt [11], state the economical biomass energy potential of Turkey as 25 Mtoe/year (290.750 TWh/year). The animal manure source biogas potential is stated as 2.8–3.9 billion m^3 and 1.4–2 Mtoe (16.282–23.260 TWh/year). In the study, while the potential values are given, the data used are not stated.

Calculation of the biomass potential owned by Turkey according to different biomass source types, and of the energy value related to that potential according to the data used is critical.

2. The situation for renewable energy in Turkey

Energy from non-fossil sources, namely wind, solar, aero thermal, geothermal, hydrothermal and non-fossil sources like ocean, hydropower, biomass, LFG, wastewater treatment plant gas and biogas are defined as RES [12]. Turkey's renewable energy supporting mechanism is based on the "feed-in tariff" policy. This mechanism has been regulated under the scope of the "Law of renewable energy sources for the generation of electrical energy". According to this law, power plants that have been generating since May 18, 2005 or that are included in the scope of the law to be enforced before the end of 2015, may make use of the fixed price application for a period of 10 years. Plants that are supported under the scope of this law are: wind, solar, geothermal, biomass, gas obtained from biomass (including LFG), stream, tidal and wave, and hydroelectric generation plants of which the river type or reservoir area is under 15 square kilometers. In the case of the generation of mechanical and/or electro mechanic equipment that belongs to power plants with RES inside the country, an additional tariff is applied in addition to fixed prices. The feed-in tariff under the new legislation for Biomass including LFG is 13.3 Dolar-cent/kWh. This tariff could be 18.90 Dolar-cent/kWh at max if all equipments in the supporting mechanism are used [13].

Power plants with a Renewable Energy Certificate (REC) under this law, and persons who generate under the scope of unlicensed electric generation with REC, may make use of the RES Supporting Mechanism [14]. The installed power capacities belonging to plants supported by the RES supporting mechanism are given in Table 1 according to the source and plant type [15].

It can be seen in Table 1 that there is not sufficient capacity despite the RES supporting mechanism. In Turkey, there are no aero thermal, oceans, stream, tidal and wave energy systems connected to the grid. As of the end of November 2013, Turkey has 21874.3 MW hydroelectric, 310.8 MW geothermal, 224.0 MW biomass/waste, 2694.6 MW wind installed powers. The total installed power value of Turkey is 62663.9 MW [16]. The ratio of the installed power value of natural gas power plants within the total installed power is about 32%. The ratio of installed power capacity for hydroelectric power plants within the total installed power is about 35%. While the ratio of all renewable energy sources within the installed power is about 40%, the ratio of hydroelectric plants within the RES is about 87%.

Licensing priority and grid connection priority are given for RES; the license fee is reduced to 1% for a RES plant and the plant in its first eight years of operation is exempted from annual license fee [17]. In Turkey, there are no plants that generate electrical energy with the incineration method by using dried wastewater treatment

Table 1
The installed power capacities of RES with REC supporting mechanism.

RES	2011		2012		2013		2013 (unlicensed)	
	No of plants	Installed power (MW)	No of plants	Installed power (MW)	No of plants	Installed power (MW)	No of plants	Installed power (MW)
Hydro	4	21.04	44	929.54	14	216.61	62	29.64
Wind	9	469.10	22	685.00	3	75.90	88	36.06
Geothermal	4	72.35	4	72.35	6	140.35	0	0.00
Biomass	3	45.25	8	73.40	15	101.10	1	0.50
Solar	0	0.00	0	0.00	0	0.00	172	52.90
Total	20	607.74	78	1760.29	38	533.95	323	119.10

sludge. However, there are applications for the use of wastewater treatment sludge as a supplementary fuel in the cement industry.

98% of natural gas in Turkey is imported and, according to the agreements in force, the main provider is Russia with a rate of 52%. 51% of the imported gas is used for the purpose of electric generation [18]. The dependency rates for petroleum and coal are 90% and 20% respectively. The lignite coal reserve of Turkey which has not yet been converted corresponds to about 10,000 MW installed power [19]. Turkey has 48,000 MW wind, 600 MW geothermal installed power potential and 380 billion kWh/year solar energy potential [20].

The main target according to the 2010–2014 strategic plan of the Ministry of Energy and Natural Resources (MENR) is to realize renewable energy generation at a rate of 30% of the total electrical energy supply by 2013. To meet this target, the construction of 5000 MW hydroelectric stations must be completed by 2013, the wind energy installed power must be increased to 10,000 MW by 2015 and the installed power of geothermal must be increased to 300 MW, again by 2015 [21].

In law no. 6094, it is stated that the total power of generation plants using REC solar energy which are connected to the transmission system until the end of 2013 must not be higher than 600 MW [13]. This expression is important from the point of determining a target related to solar plants targets. It is also stated that within the six months after the law is enforced, the transformer stations which depend on solar energy power plants will be connected until the end of 2015 and their connection capacities must be determined. Following this provision, 27 regions were determined and the process of determining the transformer numbers for each region was completed; accordingly, capacity values to be connected to transformers will be 600 MW in total. It can be seen that no target power or rate has been determined in relation to biomass sources.

3. Electric generation methods using biogas and wastes

Energy can be generated from biomass and waste by using many different technologies by means of indirect or storable interim methods. These technologies can be examined in two groups; biological and thermal methods. Biological methods include: fermentation and thermo-chemical methods divided into subgroups including incineration, gasification and pyrolysis. About 90% of energy generation from waste across the globe is realized by means of the incineration method. Direct incineration is a widely used method in converting waste to energy. Today, many power plants using waste have direct incineration systems. In such plants, as long as the steam temperature and pressure increases, the efficiency of the plant is raised [22].

Heat and electric generation methods using solid biomass and waste are divided into two groups; generation based on incineration, and generation based on gasification techniques.

Generation based on incineration: In incineration, the chemical energy of converting fuel to heat energy is transmitted to a heat exchanger and the secondary fluid in the heat exchanger expands in a turbine or a similar system, forming the mechanical energy.

Generation based on gasification: In gasification, materials were being reacted at high temperature with a controlled amount of oxygen and/or steam, without combustion and a fuel called syngas is produced [23].

4. Energy potential of biomass sources

The primary electrical energy potential of MSW, agricultural crops, animal manure and urban wastewater treatment sludge, have been studied.

4.1. Municipal solid waste energy potential

For the population within the boundaries of municipalities that are given waste services in Turkey, the LFG potential can be calculated. There are 3225 municipalities in Turkey and 3129 of them are given waste services. The population within the boundaries of municipalities that are given waste services is 57,800,347. The average MSW amount per person for the summer and winter months are 1.15 kg/person/day [24]. When this average value is considered, the annual MSW amount per person is approximately 0.42 tons/person.

For a period of 20 years, the LFG generation amount obtainable per ton has varied between 60 and 290 m^3/tons depending on the methane amount it contains. 50–60% of this waste contains organic matters and 50% of the gas to be obtained from the waste is methane [25]. The annual waste amount for the population within the boundaries of a municipality that is given waste services is 24,276,145 ton/year. Considering that the total MSW developed over a period of 20 years is 485,522,900 tons and the LFG generation is 100 m^3/tons [26], the LFG developed will be approximately 48.55 m^3. 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^3. Accordingly, the annual value of the LFG potential of municipalities given waste services is 0.97 billion m^3/year.

The lower heating value (LHV) of LFG is accepted as 5 kWh/m^3 by considering the values of 19–23 MJ/m^3 (5.27–6.38 kWh/m^3) [27] and 17.20 MJ/m^3 (4.77 kWh/m^3) [28] given for LFG. When the energy value of LFG potential is calculated for 5 kWh/m^3 LHV, it is approximately 4.85 TWh.

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.

The LHV of solid waste for incineration process is between 2000 and 2500 kcal/kg [29]. In the study realized by the İstanbul Metropolitan Municipality İSTAÇ A.Ş., the LHV of packing wastes was determined as 2167–3750 kcal/kg and for mixed waste as 1160–1669 kcal/kg. The total of solid wastes such as paper,

cardboard, pet, bag, tetra-pack, textile, diaper-pad and other combustible materials in İstanbul was determined as 41.10%. Additionally, it was determined that 54.09% of these organic materials contained combustible materials [30].

By considering that the incineration process can be realized in areas which have a good working and controllable waste management system, the energy value of wastes that are incinerated for the metropolitan municipalities in Turkey, can be calculated. The population of the 16 metropolitan municipalities that are given waste services in Turkey is 33,102,608. The average MSW amount per person during the summer and winter months are 1.15 kg/person/day [24]. The annual waste amount for the population of the 16 metropolitan municipalities that are given waste services is 13,903,095 ton/year.

Taking into account the LHV of solid waste composition, the content of waste with a 40% convenient LHV in the incineration process was evaluated. In this case, the waste amount used in the incineration process was 5,561,238 ton/year. The LHV of MSW was determined as 9.0 MJ/kg (9 GJ/ton) [31]. When the energy value corresponding to the waste amount for the 9.0 GJ/ton (2,500 kWh/ton) LHV is calculated, it is found at approximately 13.90 TWh/year. The energy values related to the incineration of MSW are given in Table 2.

4.2. Energy potential of energy crops

According to the 2011 crop production statistics [32], 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 6858 m^3/hectares [33]. If this value is accepted as the biomass generation potential, there will be a 27.549 billion m^3 biogas potential. The LHV of the biogas is stated as about 6 kWh/m^3 [34]. The primary energy value obtainable for a 6 kWh/m^3 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. The data relating to the biogas potential of energy crops are given in Table 3.

The LHV of 1 kg dry matter (wholly dewatered) is 18 MJ. In general, the biomass yield is set forth as 13–20 tons dry matter/hectare per year [33]. For 4,017,197 ha of land used for purpose of energy crops, the biomass yield is accepted as a total of 10 tTS/ha, and a total of 40,171,970 tons of solid matter will be obtained. The total solid waste value is found by subtracting the biomass value from the value of dry matter. In this study, the LHV of dried biomass is accepted as 18 MJ/kg (18 GJ/ton) when making the necessary calculations. When the energy value of 40,171,970 tons/year and total solid biomass potential for 18 GJ/ton (5000 kWh/ton) dried biomass LHV is calculated, it is found at approximately 200.85 TWh/year.

4.3. Energy potential of animal manure

According to the 2011 Turkish Statistical Institute livestock statistics [35], the total number of bovine animals (cattle and buffalo) was 12,483,969, sheep and goats 32,309,518 and poultry 241,498,538. The manure quantity varies depending on weight, species and nutrition. The manure yield is about 9.95 tons/year for cattle, 0.82 tons for sheep and goats and 0.03 tons/year for poultry. About 200 m^3/year of biogas is obtained from about 1 ton of dried manure from cattle, sheep and goats, and poultry. The LHV of the recovered biogas is 22.7 MJ/m^3 (6.30 kWh/m^3).

The dry manure rate in cattle is 12.7%, and 25% in sheep and goats, and poultry. The availability of dry manure for biogas generation is 65%, 13% and 99% respectively [36]. The total biogas value calculated by considering the animal numbers given in the 2011 Turkish Statistical Institute livestock statistics is 2.57 billion m^3/year. The data related to the biogas potential of animal manure are given in Table 4.

Accordingly, the energy value of 2.57 billion m^3/year biogas potential is 16.19 TWh/year for 6.30 kWh/m^3 [36] LHV. 79.8% of animal manure source biogas is obtained from bovines, 6.6% from sheep and goats, and 13.6% from poultry. The LHV of dried animal manure varies between 12 and 18 GJ/ton [37]. According to the calculations made by considering the 2011 Turkish Statistical Institute livestock statistics, the total usable manure amount is 12.90 million tons/year. When the energy value of 12.90 million tons/year of usable total dry manure potential is calculated for 15 GJ/ton (4166.66 kWh/ton) of dry animal manure LHV, it is found as approximately 53.74 TWh/year.

4.4. Energy potential of urban wastewater treatment sludge

The gas amount developed per person in the domestic wastewater pre-treatment plant varies between 0.015 and 0.022 m^3/person/day. In the secondary treatment plants, this value is about 0.028 m^3/person/day. The methane percentage of gas that develops in the plant is about 65% and its LHV is approximately 22.4 MJ/m^3 [38]. Considering that the population of the 16 metropolitan municipalities in Turkey is 33,102,608, the daily gas amount calculated for 0.025 m^3/person-day is approximately 827,565 m^3. This value is

Table 2
The energy value of incinerated MSW.

Population	33,102,608
Daily average waste amount (kg/person-day)	1.15
Annual average waste amount (ton/year)	5,561,238
LHV of mixed MSW (GJ/ton)	9
Energy value (TWh/year)	13.9

Table 3
Biogas energy value of energy crops.

Land (hectare)	4,017,197
Biogas yield (m^3/hectare)	6858
Annual biogas potential (billion-m^3/year)	27.549
Biogas LHV (kWh/m^3)	6
Energy value (TWh/year)	165.29

Table 4
The total biogas potential of animal manures.

Animal Kind	Bovine	Sheep and Goat	Poultry	Total
Number of animals	12,483,969	32,309,518	241,498,538	
The wet manure amount per unit (ton/year)	9.95	0.82	0.03	
Total amount of wet manure (million ton/year)	124.21	26.49	7.24	
Dry manure rate (%)	12.7	25	25	
Total dry manure amount (millions ton/year)	15.77	6.62	1.81	
Availability (%)	65	13	99	
Usable total dry manure amount (million ton/year)	10.25	0.86	1.79	
Biogas amount for 1 ton dry manure (m^3/year)	200	200	200	
Total biogas amount (billion-m^3/year)	2.05	0.17	0.35	2.57
Biogas LHV (kWh/m^3)				6.3
Energy value (TWh/year)				16.19

Table 5
Biogas energy value of urban wastewater treatment sludge.

Population	33,102,608
Biogas output (m^3/person-day)	0.025
Annual biogas potential (billion-m^3/year)	0.3
Biogas LHV (MJ/m^3)	22.4
Energy value (TWh/year)	1.88

0.30 billion m^3/year annually. As the LHV of biogas is 22.4 MJ/m^3, the energy value of the biogas potential is 6.76 billion MJ which corresponds to 1.88 TWh/year. The data related to the biogas potential of urban wastewater treatment sludge are given in Table 5.

It is possible to dry urban wastewater treatment sludge and then to recover energy by incinerating it. During the treatment process for wastewater, volumetric reduction is ensured by decreasing water and/or solid matter. The LHV of dried sludge that has a dry matter rate of 90% at the end of the treatment process varies between 9 and 12 GJ/ton [39]. The LHV of dried treatment sludge varies depending on the dry matter it contains and the content of organic matter in the dry matter. The LHV of dried wastewater treatment sludge that contains 95% dried solid content is 11 GJ/ton [40]. After the dewatering and drying processes of raw sludge with 1 ton dry matter content, a dried sludge that contains 95% dry matter is obtained at a rate of 4.2% of the first amount. The sludge amount that develops during treatment of wastewater varies between 1% and 6% of the wastewater [41].

In forecasts made by İSKİ (Water and Sewage Administration of İstanbul) for İstanbul, the domestic wastewater capacity per unit was 130–180 L/person-day in 1990 and it is estimated that this value will be 200–230 L/person-day in 2040. The common value is 200 L/person-day. According to this estimate, 70–80% of this household wastewater is going to reach the sewers [42]. Density of wastewater treatment sludge is accepted as 1.0 kg/liter [43]. When it is considered that the population of the 16 metropolitan municipalities in Turkey is 33,102,608 persons [44]; by using data including the daily water usage amount, the developed wastewater amount, the sludge formation amount, and sludge density, the amount of dried wastewater treatment sludge to develop can be determined. In calculating the dried sludge conversion, it is accepted that a dried sludge that contains 95% dry matter can be obtained at about a rate of 4.2% of the first amount after the dewatering and drying processes. Accordingly, the annual dried sludge amount for the population of the 16 metropolitan municipalities is $3.247.10^9$ kg/year.

The organic matter content in the dried wastewater treatment sludge which contains 95% dried matter is 50%, its LHV will be 11 GJ/ton. In this study, this value is accepted as the LHV of dried wastewater treatment sludge. According to these calculations, it is found that the annual dried sludge potential for the population of the 16 metropolitan municipalities is (3.247 million-ton/year); its energy value for 11 GJ/ton (3055.55 kWh/ton) of dried wastewater treatment sludge LHV is approximately 9.91 TWh/year. The data relating to the annual dried sludge potential are given in Table 6.

4.5. Biomass sources energy values

The biogas and biomass energy values related to the biomass sources used in this study are given in Table 7.

The biogas primary energy value given in Table 7 corresponds to an important installed power capacity. Conversion of that primary energy value to electrical energy by using a biogas engine is the most common application. These machines have high efficiency. Biogas engine electrical efficiency is 40.4% [45] and the annual working hours of a biogas power plant that uses animal and agricultural wastes, with conformity to the conditions of Turkey, are 8.000 h [46] (This means availability is 91%.), the calculated installed power will be 9.50 GW. The data related to the installed power capacity calculation are given in Table 8.

Table 6
Dried sludge energy.

Daily water usage amount (lt/person)	200
Annual water usage amount per person (lt/person)	73,000
Wastewater conversion rate (%)	80
Annual wastewater amount per person (lt/person)	58,400
Sludge conversion rate (%)	4
Sludge amount per person to develop annually (lt/person)	2336
Density of sludge (kg/lt)	1
Wastewater sewage sludge amount per person to develop annually (kg/person)	2336
Dried sludge conversion rate (%)	4.2
Dried sludge amount per person to develop annually (kg/person)	98.112
Population for 16 metropolitan municipalities	33.102.608
Annual dried sludge amount for the population of 16 metropolitan municipalities (kg/year)	$3.247.10^9$
LHV of sludge (GJ/ton)	11
Energy value (TWh/year)	9.91

Table 7
The biogas and biomass values related to the biomass sources used in the study.

Source	MSW	Agricultural crops	Animal manure	Urban wastewater treatment sludge	Total
Biogas energy value (TWh/year)	4.85	165.29	16.19	1.88	188.21
Biomass energy value (TWh/year)	13.9	200.85	53.74	9.91	278.4

According to the Turkish electrical energy 5-Year generation capacity projection which based on for two different generation projection, firm generation capacities (GWh) for the projection years have been given in Table 9.

According to the datas in Table 9, the share of biomass energy in Turkey's generation for the projection years change between 0.45 and 0.51. Secondary energy value of biogas was found as 76.03 TWh/year. When this value is evaluated with the datas given in Table 9, it is seen that a significant part of Turkey's electricity generation could be met by biogas energy.

5. Conclusions

In this study, potential values of the energy that could be obtained from biomass that is deemed as a RES are determined according to different source types in Turkey. MSW with an organic content, urban wastewater treatment sludge, energy crops, and animal manures form the general biomass types. For this reason, in our study, the potentials for such biomass types are determined. In the study, the biogas potentials obtained from different sources are leveled to the same energy value to ensure evaluation convenience.

As a result of the calculations made, the biogas potential obtained from MSW in Turkey is 4.85 TWh/year, in the case of using the total fallow land, the obtainable biogas potential will be

Table 8
Installed power capacity.

Biogas energy value (TWh/year)	Biogas engine electrical efficiency (%)	Secondary energy value (TWh/year)	Availability (%)	Installed power capacity (GW)
188.21	40.4	76.03	91	9.5

Table 9
Firm generation capacities for TEİAŞ scenarios [47].

Source		Firm generation capacity (GWh)				
		2013	2014	2015	2016	2017
Biomass	Scenario 1	1291.20	1423.80	1538.10	1538.10	1538.10
	Scenario 2	1291.20	1423.80	1538.10	1538.10	1538.10
Others	Scenario 1	285729.80	291131.70	322800.50	332576.30	341096.30
	Scenario 2	272674.90	277694.70	319434.20	324940.70	333460.70
Total	Scenario 1	287021.00	292555.50	324338.60	334114.40	342634.40
	Scenario 2	273966.10	279118.50	320972.30	326478.80	334998.80
Share of biomass	Scenario 1	0.45	0.49	0.47	0.46	0.45
	Scenario 2	0.47	0.51	0.48	0.47	0.46

165.29 TWh/year, the gas potential to be recovered from animal manure is 16.19 TWh/year and the biogas potential from wastewater treatment sludge that belongs to the 16 metropolitan municipalities is 1.88 TWh/year. The installed power capacity corresponding to the total of these biogas potentials is 9.50 GW. When this installed power capacity is compared to the existing installed power of Turkey at a value of 62663.9 MW, it corresponds to a significant rate.

The energy value related to incineration of MSW for the population of the 16 metropolitan municipalities that are given waste services is calculated at approximately 13.90 TWh/year. The dried biomass energy value in the case of using the total fallow land is found as 200.85 TWh/year. According to the calculations made by considering the livestock statistics, the energy value based on the total usable dry manure amount is found as 53.74 TWh/year. The annual dried sludge energy value for the population of the 16 metropolitan municipalities in Turkey is found as approximately 9.91 TWh/year.

The total biomass/waste installed power capacity of Turkey, as of the end of November 2013, was 224.0 MW at a rate of 0.35% of the total installed power. When the installed power capacity that corresponds to biogas potentials are compared to existing installed power value, it is determined that there is significant potential.

Using all of the energy sources in Turkey effectively is very critical. Obtaining these sources in a renewable and sustainable manner is an important factor for decreasing material dependency on foreign sources. Electricity generation from biogas sources provides an additional advantage as it ensures disposal of wastes. The planning of electrical energy generation systems is based on the principal of knowing the potential values of the existing primary sources that will meet the estimated load demand and ensure high reliability. Biomass energy, when compared to fossil fuel sources, is a clean and sustainable energy source with less air emission values, less waste in the environment and a decreased foreign dependency.

In the MENR's 2010–2014 strategic plan, targets include renewable energy generation at a rate of 30% of the total electric energy supply. To achieve this target, rates for some RES are given but no target related to biomass energy is determined. No target power or rate related to biomass sources for Turkey is stated. To decrease the high foreign energy dependency of Turkey, rich domestic and renewable energy sources of Turkey must be used and biomass energy shows promise for the decreasing this dependency. Policy makers have to define specific targets for biomass to electrical energy systems and incentive opportunities have to be given to investors.

Disposal of solid wastes into electrical energy by the incineration of wastewater treatment sludge is an important subject. High investment and operating-maintenance costs, the need for qualified personnel, the existence of problems with hazardous gas, and the formation of ash and slag are subjects that must be paid attention regarding a good working and controllable waste management system using the incineration process. For the purpose of converting urban solid wastes to energy, landfill sites and incineration processes must be compared carefully and a convenient method must be chosen.

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