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Application of Biogas Technology in Turkey

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Abstract**—**The potential, opportunities and drawbacks of biogas technology use in Turkey are evaluated in this paper. Turkey is dependent on foreign sources of energy. Therefore, use of biogas technology would provide a safe way of waste disposal and recovery of renewable energy, particularly from a sustainable domestic source, which is less unlikely to be influenced by international price or political fluctuations. Use of biogas technology would especially meet the cooking, heating and electricity demand in rural areas and protect the environment, additionally creating new job opportunities and improving social-economical conditions.

Keywords**—**anaerobic digestion, agricultural biogas plant, biogas, biomass, methane, waste

I. Introduction

THE production of biogas-methane (CH_4) through anaerobic digestion (AD) from biomass, namely energy crops, agricultural and crop residues, and organic fraction of municipal wastes (OFMSW), offers significant advantages such as:

- Treatment and disposal of animal wastes and crop residues are possible, and the end product is valuable biogas,
- Biogas is a clean source of energy, with a high calorific value,
- The digestate resulting from digestion process is not a waste, it can further be utilized as a fertilizer, without posing any adverse effect on the environment and public health,
- Biogas can further be used for heating purposes, can be converted to electricity and fed to the grid, can be used as fuel in vehicles, and can substitute natural gas after up-grading (gas cleaning).

Conversion of crop residues, energy crops and animal wastes (e.g. manure) to biogas has found a wide application, particularly in Europe in the last decade. There exists a great amount of recent literature summarizing the current state of applications from various regions of the world as well [1-9]. Turkey has a great potential of biomass and production of bio-energy from biomass energy seems to be a major potential for source of energy. The total recoverable bio-energy potential in Turkey was estimated to be around 16.92 Mtoe (million tonnes of oil equivalent), based on the recoverable energy potential from agricultural residues, livestock farming wastes, forestry and wood processing residues and municipal wastes [10].

The share of renewable energy sources to primary consumption is estimated to be 1.5 % in 2008. This share has not actually changed since 2006. Additionally, the contribution of energy production share of animal waste and plant residue to primary energy consumption in Turkey ranged from 1.2 % in 2006 to 1.0 % in 2008 as well [11]. In 2006, the share of biogas-waste power plants to the total electricity generation was reported to be less than 0.1 %, while for 2008, this share is forecasted to be 0.15 %. It seems that, despite Turkey has a great potential of biomass to produce renewable energy and the law on utilization of renewable energy resources for the purpose of generating electrical energy has been brought into action in 2005 (Law No: 5346), the share of renewable energy in energy production is still low.

Biogas production potential in Turkey was estimated to be around 1.5 to 2 Mtoe [12]. However, since the share of the renewable energy in energy production is so low, the possible contribution of biogas to this share can also be ignored. Preliminary research activities using pilot-scale plants were initiated almost three decades ago by the General Directorate of Rural Services [13]. These preliminary investigations covered production of biogas only from animal manure. However, these activities were somehow terminated in 1987. Besides, no research activity was encountered on production of biogas from agricultural residues and/or energy crops. There also exists not much data in literature about applications of biogas technology in Turkey as well [14-19].

Therefore, the objective of this paper is to inform the readers about the potential of biomass available that could be used for biogas production, and the advantages and constraints of applications of biogas technology in Turkey.

II. BIOMASS POTENTIAL OF TURKEY

Biomass can be utilized to generate electricity, heat, as fuel in vehicles or as a substitute of natural gas after up-grading. In rural areas of Turkey, additional advantages are heating of houses and use for cooking as well. Use of biomass results in a decrease in greenhouse gas emissions, decreases the dependence of Turkey on foreign sources of energy, and reduction in the amount of waste that must be sent to landfills. In addition, biomass is a reliable source of energy, since it already exists in available amounts in Turkey. The available agricultural and animal residues in Turkey were estimated to account for 22 to 27 % of energy consumption of Turkey [10]. However, due to technological and economical constraints, utilization of biomass to produce energy has currently no wide application.

As production of primary energy from renewable sources is expected to grow rapidly over the next two decades, Turkey should also profit from the huge amount of biomass economically available for production of energy. Biological production of biogas from biomass (via AD), namely from agricultural residues, crop residues, energy crops and organic municipal wastes seems to be an alternative to contribute to the share of renewable energy production. Therefore, information will be provided in this section of the paper about the potential of animal waste, crop residues and organic wastes in Turkey, which can theoretically be utilized to generate a sustainable source of energy using biogas technology by AD.

2.1 Animal waste

Anaerobic digestion of animal waste and manure is a common method to treat these wastes and to produce biogas in centralized or agricultural biogas plants [4, 20-22]. Biogas is then converted to

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power and heat in combined heat and power (CHP) facilities and can further be utilized. The quantity of raw material available from animal dung in Turkey was reported to be 13.8 million tonnes in 2007 [23]. In an earlier work from 2006, the total calorific values for animal wastes, namely cow, sheep and poultry in Turkey were estimated to be approximately 47.8, 3.6 and 8.7 PJ per year, respectively [10]. The outline of the number of animals, the amount of manure, and the amount of biogas that can theoretically be produced is also displayed in Table 1 [24]. Obviously, the amount of manure and the theoretically available amount of biogas depends on the quantity of animals. However, no current data was encountered about the manure and corresponding amount of biogas theoretically available. According to the data currently available, the total amount of biogas that can be produced from animal manure in Turkey is theoretically more than 3 10^9 m^3/year. This biogas normally contains a methane composition of between 60 to 70 % as well, which is higher than those reported for energy crops [25].

Anaerobic digestion (AD) of animal manure in Turkey would result in a safe way of disposal of these wastes and production of valuable biogas, which can easily be utilized for heating and cooking in rural areas. Direct combustion of animal manure means an ineffective way of biogas utilization. Use of animal manure as fertilizer in agriculture also results in odour problem and contamination of groundwater sources, which poses a serious threat to public health. However, animal waste is frequently used as fertilizer in agriculture in Turkey, which makes use of it as a source of energy difficult. Some small-scale agricultural biogas digesters are operated with animal manure in Turkey, since research on biogas has been initiated almost three decades ago. However, no concrete data could be encountered in literature about the number/specifications of such plants. It should also be considered that lack of knowledge of biogas technology (e.g. know-how), poor infrastructure, and economical constraints in rural areas might have prevented a wider application of biogas technology as well.

TABLE I
THE AMOUNT OF BIOGAS AVAILABLE

Animal waste	Animal number	Total amount of manure (t $year^{-1}$)	Amount of available biogas (m^3 $year^{-1}$)	Hard coal equivalent (t $year^{-1}$)
Cow	11054000	39794400	1313215200	1181894
Sheep-Goat	38030000	26621000	1544018000	1389616
Poultry	243510453	5357230	417863937	376078
TOTAL	292594453	71772630	3275097137	2947587

2.2 Crop residues

The anaerobic digestion of crop residues and energy crops is a common method for production of biogas [26-30]. The application of anaerobic fermentation processes for production of biogas from energy crops has significantly increased in Germany, since the renewable energy sources act (EEG) has been enforced in 2000 [25,31]. Crop residues, agricultural wastes or energy crops (such as maize and sugar beet) can be converted to biogas-methane (CH_4) as mono-substrates or they can be mixed with animal manure and then digested (co-digestion). The types of crops are highly relevant, because the biogas yield obtained per cubic meter of reactor volume is dependent on the energy density and biological degradability of the applied crop. Typical methane yields of various crops are given in Table 2 [31]. Obviously, economic production of biogas depends on the high gas yields of the feedstock.

TABLE II
METHANE YIELDS OF SOME CROPS

Type of crop	Methane yield (m^3 t ODM^{-1})	Methane yield* (m^3 $ha^{-1}yr^{-1}$)
Root crops		
Forage beet + leaf	456	5800
Potato	276	2280
Grain crops		
Maize	410	5780
Wheat	390	2960
Barley	360	2030
Rape	340	1190
Green forage plants		
Ryegrass	410	4060
Alfalfa	410	3965
Clover	350	2530
Marrowstem kale	255	1680

(ODM: organic dry matter)

The quantity of agricultural residues, including straw, stalks, kernels, shells and tree pruning were reported to be 17.2 million tonnes per year in 2007 in Turkey [23]. In another study, the total amount of agricultural residues, including annual crop residues (cereals, maize, cotton, rice, tobacco, sunflower, groundnuts, soybeans), perennial residues (kernels, shells and tree prunings) and agro-industrial residues (cotton-ginning, seed oil industries, olive oil industries, rice industries, corn industries, wine and kernel factories), were reported to be about 50-65 million tonnes [10]. The authors stated that the total calorific value of the field crop residues was calculated to be approximately 228 PJ for the year 2002-2003. Besides, the total calorific value of the fruit residues was calculated to be 75 PJ. In summary, it can be concluded that, the total calorific value of the agricultural biomass in Turkey for 2002-2003 amounted to 303 PJ [10]. In addition to crop and fruit residues, energy crops can also be used for production of biogas. In Germany, maize and sugar beet are often used in agricultural biogas plants for production of biogas. In Table 3, recent production data of some crops in Turkey are given (unit is ton) [32].

TABLE III
FIELD CROP PRODUCTION OF TURKEY

Crop	2005	2006
Maize	6000000	5360000
Sugar beets	15181247	14452162
Beets for fodder	165000	158771
Alfalfa	2100000 (Green)	1814990 (Green)
	2400000 (Dried)	2820225 (Dried)
Clover	16 (Green)	11300 (Green)
	5 (Dried)	10839 (Dried)
Wheat	92500000	84900000
Barley	36500000	36498000
Rye	1300000	1312000
Triticale	110000	77642
Sorghum	200	229

The Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electricity aims to increase the use of renewable energy sources to generate electricity, to reduce greenhouse emissions and to diversify the energy-mix. However, there exists no particular legislation in Turkey about use of biomass as a source of energy at the moment. Furthermore, another question also rises whether these crops should partially be used for bio-energy production when economically feasible or only for nutritional purposes. For Turkey, the first option should actually be AD of animal manure and crop residues to generate biogas.

2.3 Municipal waste

The organic fraction of the municipal solid waste (OFMSW) can also be converted to methane via AD process [33-35]. Use of landfill gas generated from garbage is practiced in Turkey [36]. However, conversion of garbage to biogas through AD process has not been a common procedure. In an earlier study from 2000, it was reported that from about 8.3 million tonnes of bio wastes collected annually in Germany, 7.1 million tonnes were treated by composting, while 1.2 million tonnes were treated in anaerobic digestion plants [6].

In 2006, 25.28 million tonnes of municipal solid waste was collected and 38 % of the municipal solid waste collected was disposed in disposal and recovery facilities [37, 38]. Approximately, 10 million tonnes of municipal waste were disposed of in controlled landfills, while 29 000 tonnes of compost were produced in composting plants. Furthermore, 46.8 % of the collected municipal waste was disposed of in dumps of the municipalities. The scope of this paper is actually not to discuss solid waste management practices in Turkey. On the other hand, nearly half of the municipal solid waste collected in 2006 was disposed in dumps without receiving any pre-treatment or recovery. After simple sorting and recycling practices, the remaining amount of solid waste (the organic fraction of the municipal waste) would represent a high amount of biomass, which could be converted to biogas, and then could further be utilized for CHP production. In addition to land filling and incineration, production of biogas from the organic fraction of the municipal solid waste should also be considered in Turkey as an alternative means of waste disposal and energy recovery. Furthermore, co-digestion of the organic fraction of the municipal solid waste with wastewater sludge would be an additional opportunity to dispose wastewater sludge and also to gain energy from it [39].

III. ADVANTAGES OF BIOGAS TECHNOLOGY

Since Turkey is dependent on foreign sources of energy, due increasing energy demand, use of biogas technology will provide a safe way of waste disposal and gain of renewable energy, particularly from a sustainable domestic source, which is less unlikely to be influenced by international price or political fluctuations. The main advantage of biogas technology would be appropriate disposal of a huge amount of organic waste produced and at the same time recovering energy from it. In Turkey, household wastes are disposed of in landfills. However, it is possible to recover energy from these organic wastes by biogas technology instead of burying them in landfills.

In rural areas, use of wood and animal manure for heating is a common procedure. However, deforestation is also a great concern. In addition, animal manure could also be utilized as fertilizer in agriculture. Therefore, at a first glance, production of biogas from animal waste and crop residues would provide a sustainable heating source in rural areas in Turkey, without exploitation of forests. Biogas can also be used for lightning purposes. Biogas production would also result in decrease of the odour problem resulting from direct application of manure in agriculture and decrease the risk of contamination of groundwater sources as well as the risk of endangering the public health. In some regions of Turkey, especially in spring and summer, the temperature is relatively high and the biogas digesters operated in these regions will probably not require heating, and they can be operated at ambient temperatures, saving energy costs. On the other hand, in some regions temperatures fluctuate much during the year and biogas digesters should be heated. This will definitely require additional energy input or the output will eventually decrease. These regional factors should be considered carefully before design and operation of agricultural biogas plants.

Another significant outcome will be economic and social development in rural areas, where biogas plants are installed. The construction and operation of such plants will definitely provide new job opportunities, especially for local people, which can improve the social-economical conditions in these areas, too. Mostly, centralized agricultural biogas plants are operated in Europe. If several farmers come together in a specific region, they can operate small-sized centralized agricultural biogas plants, to treat animal waste, gain energy and valuable fertilizer. However, specific legislations for establishment and operation of such plants should be brought into action. Operation of agricultural biogas plants have been an additional income for farmers in Germany in the last decade.

AD of organic fraction of the municipal solid waste can be practiced by municipalities as an alternative means of waste disposal. Production of biogas and then further conversion to heat and electricity in CHP plants would mean safe disposal of waste and feeding of electricity to the grid. Since such AD plants should be located relatively close to residential areas, transport of heat should also be no great concern to residential areas or industrial facilities.

At the moment, there exist 5 plants with licence producing energy from landfill gas with a total production capacity of 31.55 MW in Turkey [40]. There exists one plant with a licence of energy production from biomass having a capacity of 5.66 MW, which is being constructed. In addition, 9 biogas plants have obtained licence for electricity production with a total production capacity of 17.59 MW. 4 of these plants are operating now, with a total production capacity of 6.12 MW.

IV. CONSTRAINTS OF BIOGAS TECHNOLOGY

There has been previous pilot-scale research activities previously carried out by some state agencies in Turkey. Some research is being carried out at the moment in some research institutions as well on production of biogas from animal waste. However, research attention should also be directed to gain biogas from crop residues and organic fraction of the municipal solid wastes as well. It is also difficult to obtain current data about the quantities of manure, crops residues and organic fraction of municipal solid waste, which are economically available for biogas production by AD process, since no research has recently been conducted on this topic. Lack of research in biogas technology, particularly on the topics of design and construction of biogas digesters for different regions of Turkey and use of crop and agricultural residues, seems to be an important gap that should be fulfilled, despite research on methane production from animal and agricultural wastes has been initiated long ago in Turkey [41].

Since it is theoretically possible to construct and operate agricultural biogas plants in rural areas, where infrastructure is assumed to be poorer at first hand, low-cost and simple design for biogas digesters should be considered. For this, involvement of the private sector is also required. On the other hand, there exists no exclusive legislation on solely biomass use, which may hinder interest and involvement of the private sector [42]. Lack of know-how and consultancy services that could be provided by private sector seem to be limiting factors at the moment.

Another drawback is the low conversion efficiency of biogas to electricity in gas engines. The resulting loss heat can be utilized in cogeneration plants for further use, as long as biogas plant is located close to residential or industrial areas. If not, then use of heat can be realized on-site. An alternative would also be to clean-up and use of biogas as a substitute of natural gas. Upgrade of biogas (removal of CO_2 and H_2S) requires additional investment as well. Use of biogas as fuel in vehicles is another option.

V. CONCLUSION

Production of biogas from different types of biomass offers a great opportunity to reduce CO_2 emissions and therefore to protect the environment. As Turkey is carrying out accessing negotiations with the EU and is willing to join EU in near future, one objective of Turkey should be to increase to share of renewable energy sources to primary energy production, since the EU is aiming to achieve this target as 20 % by 2020. Due to availability of biomass sources, Turkey has theoretically the capability to produce biogas from these sources, as long as legislation procedures for production and conversion of biogas have specifically been identified and implemented. Technological and infrastructural constraints, which may particularly be encountered in rural areas, can be overcome by involvement of both state agencies and private sector together. It is also obvious that more research activity should be conducted about applications of biogas technology in Turkey, considering the country specific conditions. Such research activities will probably result in more efficient efforts for the energy-policy-makers, so that Turkey can accelerate to diverse the energy-mix and increase the share of renewable energy sources in its primary energy production in near future.

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