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Full Length Research Paper

Analysis of biogas production in Turkey utilising three different materials and two scenarios

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It is a reality for many developing countries, such as Turkey, that a lack of comprehensive evaluation of agricultural and animal potentials can prevent these sectors from becoming optimised to its maximum economical efficiency. Very high input costs, especially for fuel, fertiliser and electricity, result in decreased production; in combination with increased production costs, these are typical reasons for lack of market expansion, with neither the agricultural sector nor the agricultural industry functioning efficiently. Therefore, utilisation of agricultural and animal wastes and biogas, obtained from fermentation of organic fertiliser, has great future potential, as removal of these substances can otherwise be a serious problem. In this study, we evaluated two different scenarios for biogas and energy production in Turkey: the utilisation of waste from tomato and pea paste production and the utilisation of cattle manure.

Key words: Biogas, agricultural waste, animal waste, tomato waste, pea waste.

INTRODUCTION

The world population continues to increase rapidly, while energy consumption is increasing as well (Sözer and Yaldız, 2006). Decreases in fossil fuel sources are causing substantial increases in energy costs, which result in a parallel increase in production costs. In addition, climate change is a growing concern around the world and stakeholders are aggressively seeking energy sources and technologies that can mitigate the impact of global warming. Renewable energies have been identified as a prime source of 'clean' energy, as they emit few or no net GHGs (Green House Gases) into the atmosphere. As a result, it is necessary for both developed and developing countries to work hand-in-hand to find alternative energy sources and to spread their use. In many countries, especially developed nations, biogas has been produced according to the needs and conditions of the country. Different methods, namely aerobic and anaerobic, can be used for successful biogas production from various raw materials, such as agricultural, industrial and municipal organic wastes (Xinshan et al. 2005).

The advantages of anaerobic biogas production processes over conventional aerobic processes are a low energy requirement for operation, low initial investment cost and low sludge production (Kim, 2006). Therefore, biogas from anaerobic digestion processes is a good source of clean renewable energy.

Anaerobic digestion can be developed for different temperature ranges, including mesophilic temperatures of approximately 36°C and thermophilic temperatures ranging from 55°C to 60°C. Conventional anaerobic digestion is carried out at mesophilic temperatures, that is, 35 - 37°C. The thermophilic process is more sensitive to changes in ambient conditions than the mesophilic process (Bouallagui et al., 2003).

Currently, the fact that countries such as Turkey cannot effectively utilise their agricultural potential, means that their agricultural sector cannot function in an economically optimal manner. As in many countries, a vast number of animal, agricultural and food-related wastes are produced in Turkey (Aliba et al., 2007) . These organic wastes cause a great number of health problems in the places where they are stored as a result of pollution of underground water and the environment (Yaldız, 2007). Hence, the use of organic wastes in biogas production would provide a means for their disposal as well as an added benefit of energy production. Importantly, the first biogas production in Turkey dates back to

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Table 1. Thermal electricity generation by energy resources (10^6 kWh).

	2002	2003	2004	2005	2006
Coal	4093.0	8663.0	11998.1	13246.2	14216.6
Lignite	28056.0	23589.9	22449.5	29926.3	32432.9
Fuel oil	9505.0	8152.7	6689.9	5120.7	4232.4
Motor oil	270.9	4.4	7.3	2.5	57.7
Natural gas	52496.5	63536.0	62241.8	73444.9	80691.2
Hydraulic	33683.8	35329.5	46083.7	39560.5	44244.2
Other	1294.3	1305.0	1228.0	635.1	424.8
Gross production	129299.5	140580.5	150698.3	161956.2	176299.8

the fuel crisis of the 1970s (Aliba , 2004; Türker, 2007).

Turkey has the potential to produce 3 billion cubic metres of biogas from animal wastes alone, but production is currently limited due to inefficient and badly organised (such as Chinese type reactors and operation parameters) national sources. Furthermore, previous attempts at biogas production have not been carried out correctly (Kızılaslan and Kızılaslan, 2007; Karakuz, 2007).

As in the rest of the world, in Turkey it is necessary to utilise renewable energy sources to close the gap in an increasing energy deficit. Energy production using biogas seems to be one of the most potentially favourable sources. Even considering only the animal husbandry sector, the amount of manure produced is currently a problem for farms, not a benefit and it cannot be used efficiently (Ulusoy et al., 2006). The caloric value of 1 m^3 of biogas is 5,000 kJ, which is equivalent to that of 0.7 litres of natural gas; hence, lack of use of biogas is a serious energy loss. Other important points include the environmental contribution and economical value of organic manure obtained as process output of biogas production (Kaygusuz and Türker, 2002).

Pea production and growing tomato for tomato paste are very common in the Bursa region. The removal of waste from these processes is a serious problem and a current source of pollution. However, there is significant potential for biogas production in this industry as well.

Unfortunately, there are currently no economical and professionally designed biogas plants in this region to utilise this potential.

Therefore, the aim of this study was to build a modern mid-scale biogas plant in Bursa for energy production utilising wastes from two different sources: the regional food-processing plants (especially pea and tomato wastes) and the animal manure of the facility, which has a capacity of 1000 animals.

METHODOLOGY

Electricity production and consumption in Turkey

In 2006, the electricity production of Turkey was 176.3 TWh, according to the energy resources given in Table 1. Of this total amount, 50.94 TWh (29%) was produced using fossil fuel-based sources. In addition, 46% was derived from natural gas, which is obtained from outside sources (TSY, 2007).

In Figure 1, CO_2 emission values due to fuel consumption by various sectors are given. It is obvious that electricity production is responsible for the largest amount of CO_2 emissions, 90 million tonnes. This is because 29% of the electricity produced is from fossil fuel-based sources.

In order to meet the requirements of the Kyoto Protocol and also the EU criteria, evaluation of the use of organic agricultural wastes for biogas and increasing energy and electricity production in Turkey are highly necessary, as the use of renewable energy sources will decrease the green house effect.

In this way, Turkey can reduce the effects of pollution caused by agricultural and industrial wastes.

According to 2006 values, 24.1% of the 143.07 TWh of electric energy consumption was in houses, and 54.7% was in industry (TSY, 2007) . For both areas of usage, electricity is vitally important. Hence, new and different methods need to be found and applied for electricity production. Likewise, it is also absolutely necessary that national sources should be used very efficiently.

Furthermore, again according to the 2006 values, 4.44 TWh of electricity was used in agricultural areas (TSY,2007), mainly for the two important elements of agricultural production: crop production (e.g., irrigation) and crop processing, preparation and marketing.

Increases in the cost of these operations ultimately lead to increases in crop prices.

Land potential of Turkey

In Turkey, the ratio of the agricultural population to the total population is 35%, which is a very high ratio. This high rural population is the main reason for the high and heavy population pressure on this sector and also the high level of unemployment.

Values of sown areas and garden crop products in Turkey according to year are given in Table 2 (TSY, 2007). As seen from the Table, 19% of the total arable land is not used because of fallowing. In other words, 19% of the sown area is used once every two years. In countries where advanced agriculture techniques are applied, the lands are not fallowed, increasing efficiency. One of the techniques that make this possible is alternative crop production for renewable energy. In Turkey, besides other agricultural techniques, the use of energy crop production should be investigated in order to reduce fallow land areas.

In Turkey, approximately 4 million hectares of land cannot be used because of fallowing, while nearly 2 million hectares of land cannot be used because of quotas established by the European Community. However, these 2 million hectares of land are irrigable and highly efficient areas. These areas have enough substructures to grow both energy agriculture plants as well as other vegetables.

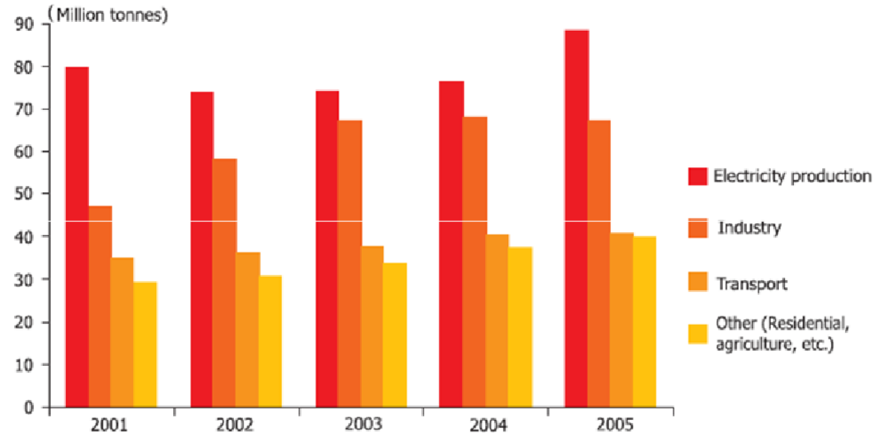


Figure 1. CO_2 emission values due to fuel consumption according to sector.

Table 2. Turkey's area of cereals and other crop products (ha) (TSY,2007).

	1995	2000	2005	2007
Sown Area	18464000	18 207000	18 148000	16 945000
Fallow Land	5124000	4 826000	4 876000	4 219000
Area of vegetable gardens	785000	793000	806000	815000
Total Arable Land	23588000	23 826000	23 830000	21 979000
Total utilized agricultural land	39 212000	38 757000	41 223000	39 505000

In fact, many regions of Turkey have the substructure necessary for a potential second crop production each year.

In this study, instead of energy agriculture plants, the uses of vegetable wastes already available as unused materials (tomato puree and pea waste) were investigated. For this objective, two different scenarios were studied.

POTENTIAL OF THE MATERIALS

Tomato production in Turkey

About 20% of the 9.5 million tons of tomatoes grown annually in Turkey are processed, with the remaining amount being used for fresh consumption. Of the processed tomatoes, 80% are used to produce tomato paste, 15% are used to produce canned tomatoes and the rest are used to produce items such as ketchup and tomato juice (TPT, 2008). Turkey's industrial tomato production values are given in Table 3 (TPPT, 2005; Keskin and Umut, 2004; TSY, 2007).

Bursa, located in the Marmara Region of Turkey, has 429,323 ha of fields, 40% of which are suitable for agriculture. These fields are usable for almost all kinds of agricultural products. Currently, 58% of these fields are used for field plants and 11% for vegetables (Anonymous, 2007).

In 2006, a total of 906,000 tonnes of tomatoes for tomato paste were grown, with an efficiency of 5,230 kg/da in the Bursa region. According to the literature, 10-15 % of tomato waste (90000 tonnes) is produced from the total amount of tomato for paste processing (TSY, 2007; Anonymous, 2007).

Pea and selected leguminous vegetable production in Turkey

In Turkey, vegetables such as peas, broad beans, cowpeas and

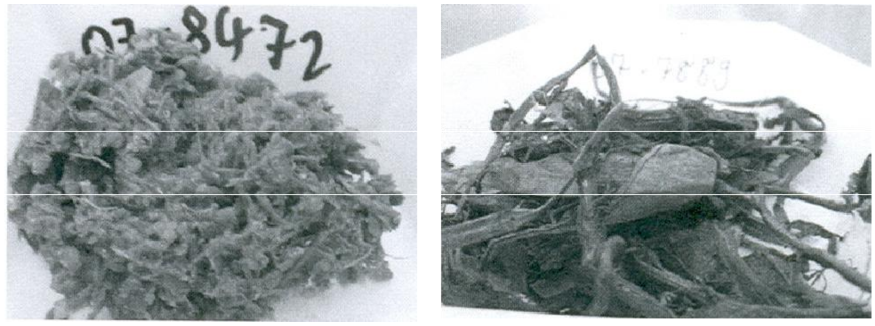
Table 3. Turkey's tomato, industrial-type tomato and tomato paste production (1000 tonnes).

	Tomato		
Year	Total production	Industrial type production	Paste production
2001	8425	1300	240
2003	9820	2000	320
2005	10050	2983	270
2007	9945	2973	240

calavence are grown intensively, especially in the western regions. According to 2007 values, 203,827,000 tonnes of product were processed (Table 4). In order to get this product, harvested crops are selected in the local storage area. After this selection process, the grains are taken (Table 4), and the remainder of the vegetables that cannot be used are classified as waste. This waste is about the 10 times the amount of product, at 2,038,270,000 tonnes (TSY, 2007).

Tomato and pea waste potential in Bursa

The waste potential of Bursa and its main production areas are given in Table 5. We can see from the table that the Karacabey district has good potential in terms of available tomato plants. Considering also animal farmsteads, this area has a significant potential for energy production. Only 15,000 tonnes of tomato waste are used according to records from the Agricultural Directorate of



a **b**

Figure 2. Tomato puree (a) and Pea waste (b) used for analysis.

Table 4. Turkey's pea, bean, cowpea, broad bean and calavence production (1000 tonnes).

Selected Leguminous vegetables					
	Pea (green)	Cowpea	Broad beans	Calavence	Total
2001	60 000	12 000	45 000	41 000	158 000
2003	54 000	14 000	44 000	52 000	110 000
2005	122 000	13 500	49 000	54 000	238 500
2007	87 743	14 101	43 273	58 710	203 827

Table 5. Estimated amount of production for tomato waste and pea waste.

Place	Tomato Waste (tonnes)	Pea Waste (tonnes)
Center	600	1700
Karacabey	9000	3000
Mustafakemalpa a	4000	800
Yeni ehir	1400	500
Total	15000	6000
Estimated	90000	60000

Bursa, and the remaining 75,000 tonnes are wasted (90,000-15,000) and currently unused. Also, there are 60,000 tonnes of pea waste, of which only 6,000 tonnes is used.

Description and analysis of tomato puree and pea waste

The materials for analysis were tomato puree and pea waste, shown in Figure 2. The samples were frozen prior to analysis. The delivered materials were analysed without further treatment in tests according to DIN 38414-S8 for the determination of the biogas and methane production (Table 6). Dry matter, organic dry matter and ash content were determined according to DIN EN 12880 and DIN EN 12879 and used as reference parameters for gas production. The test temperature was 38^{o}C. The pea materials were cut in 2-cm-long particles with scissors. The loading rate of the tomato was 2.90 and 3.33 kg dry matter/m^3 whereas the loading rate of pea was
3.04 and 3.11 kg dry matter/m^3.

The quantities of gas produced (Nl/kg dry matter) from tomato puree and pea waste are given in Table 7. Gas was produced using the following standard conditions: dry gas, air pressure 1013 mbar and temperature 0^{o}C. The analyses were repeated two times. The results from each test differed from the average by a maximum of 2% for tomato puree and 1% for pea waste. The results were obtained from the analysis of one single sample. Therefore, if the chemical composition of the sludge were to change, the gas production would change also.

For tomato and pea, the diagrams of gas production (related to fresh material, dry material, organic dry matter and Chemical Oxygen Demand (COD)) over time are presented in Figure 3 and Figure 4. The tests were terminated after 32 days.

For tomato puree, gas production of 417 Nl biogas/kg COD was measured, and 85% of this gas production was reached after 18 days. For pea waste, the gas production was 440 Nl biogas/kg COD, and 85% of this gas production was reached after 10 days.

OVERVIEW OF BIOGAS SCENARIOS

After collection of data based on industry, a model of biogas production from two different crops was carried out. These crops were tomato and pea waste. The model is based on a dry process carried out under mesophilic conditions (Figure 5).

Considering the potential of Bursa, 15,000 tonnes of tomato waste could be used for biogas production, for a potential yield of 1.35 million m^3 of gas. If this gas were used to generate electricity, it would be possible to obtain 2.36 million kWh of electric energy and 2.27 million kWh of heat energy (Table 8) (Anonymous, 2007). Consider the example of a biogas plant built to meet the electricity needs of a milk processing plant in Karacabey: using manure from the 1000 milk cows the plant currently has and the tomato waste of the Karacabey district, it would be possible to obtain2.8 million kWh of electric energy and 2.99 million kWh of heat energy (Table 9).

Biogas production for scenario 2

Results of questionnaires administered in the Bursa Region indicate that 6,000 tonnes of pea waste are obtained per factory. Since there are about 10 plants in this region, a total of 60,000 tonnes of pea waste is estimated to be generated for this scenario in this region.

If the 60,000 tonnes of pea waste were instead processed for biogas production, 4.92 millions m^3 of gasses could be obtained. If this gas was used to generate electricity, it would be possible to obtain 8.61 million kWh of electric energy and 8.26 million kWh of heat energy (Table 10) (Anonymous, 2007).

Table 6. Test parameters and test results.

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Table 7. Test results.

Analysis	Tomato	Pea
Dry matter (%OS*)	22.6	18.7
Organic dry matter (%OS)	21.8	16.9
Ash content (%OS)	0.87	2.67
Biogas production after 32 days (mean values)		
Gas production from fresh material (NI biogas/kg)	94	82
Gas production from dry matter (NI biogas/kg)	417	440
Gas production from organic dry matter (NI biogas/kg)	434	513

* OS= Original substance = fresh material.

Table 8. Amount of biogas, electricity and heat yield that can be obtained from tomato waste.

Place	Tomato paste quantity (tonnes)	Gas yield(90m^3/ton)	Electric yield(1,75 KWh)	Heat yield (1,86 KWh)
Centre	600	54000	94500	90720
Karacabey	9000	810000	1417500	1506600
M.K.Pa a	4000	360000	630000	604800
Yeni ehir	1400	126000	220500	211680
Total	15000	1350000	2362500	2268000
Estimated	90000	8100000	14175000	15066000

Again, consider the construction of a biogas plant to meet the electricity needs of a milk processing plant in Karacabey. Using manure from 1000 milk cows and the pea waste of the Karacabey district, it would be possible to obtain 2.26 million kWh of electric energy and 2.17 million kWh of heat energy (Table 11).

APPRAISAL OF THE RESULTS

The analysed materials showed a continuous but slow release of gas during the fermentation test. It is important to include a high percentage (96%) of organic dry matter (oDM). This is the amount that can be processed for biogas. The analysed material is suitable for use as a co-substrate in a biogas plant.

The connection between energy and agriculture

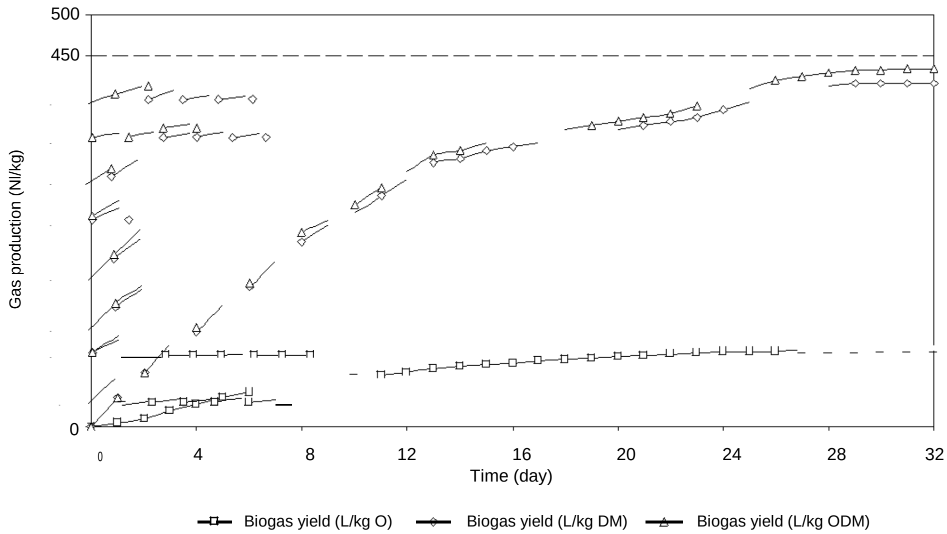

Figure 3. Daily biogas production quantities of tomato waste.

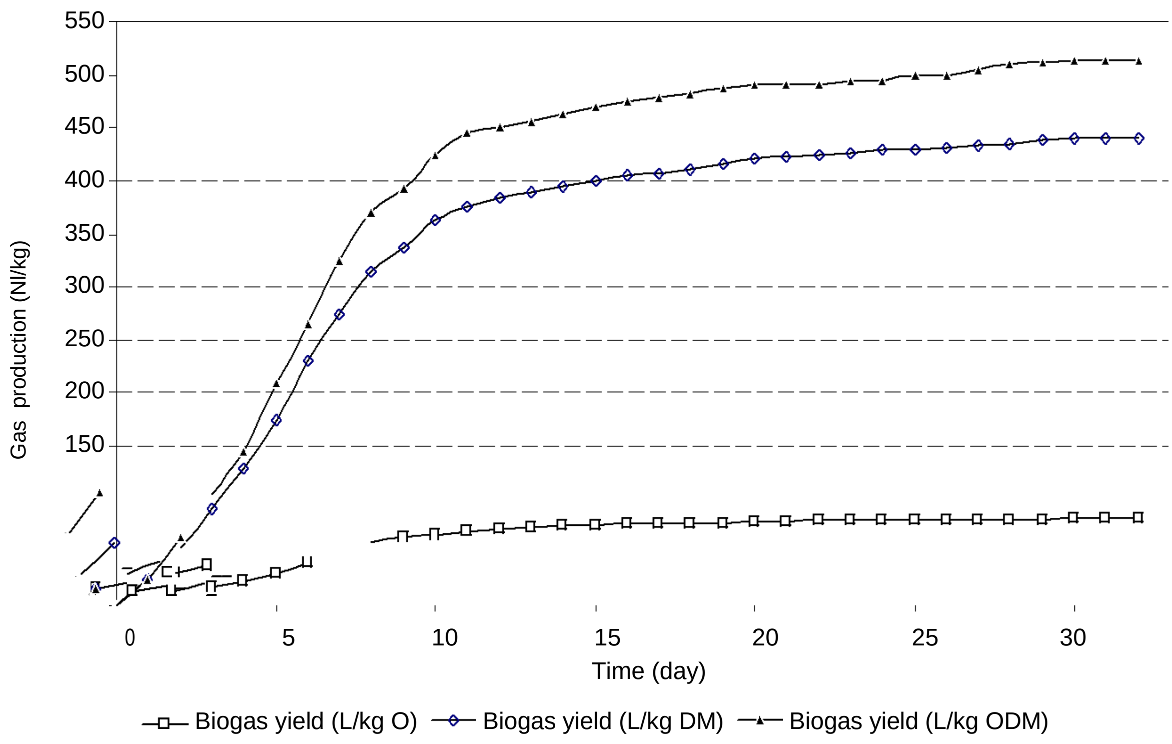

Figure 4. Daily biogas production quantities of pea waste.

Table 9. Amount of biogas, electric and heat yield that could be obtained from tomato waste for a pilot plant.

Material	Quantity (tonnes)	Gas Yield (m^3)	Electric Yield (kWh)	Heat Yield (kWh)
Tomato paste	9,000	810,000	1,417,500	1,506,600
Dairy waste	32,000	800,000	1,400,000	1,488,000
Total	41,000	1,610,000	2,817,500	2,994,600

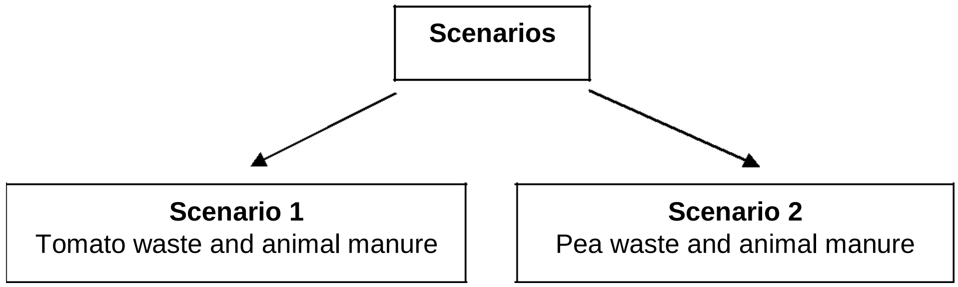

Figure 5. Scenarios for the biogas production.

Table 10. Amount of biogas, electricity and heat yield that can be obtained from pea waste.

Place	Pea Waste quantity(tonnes)	Gas yield(82 m3)	Electric yield (1,75 KWh)	Heat yield (1,86 KWh)
Centre	1700	139400	243950	234192
Karacabey	3000	246000	430500	413280
M.K.Pa a	800	65600	114800	110208
Yeni ehir	500	41000	71750	68880
Total	6000	492000	861000	826560
Estimated	60000	4920000	8610000	8265600

Table 11. Amount of biogas, electric and heat yield that can be obtained from pea waste for a pilot plant.

Material	Quantity (tonnes)	Gas yield (m^3)	Electric yield (kWh)	Heat yield (kWh)
Pea waste	6000	492000	861000	826560
Dairy waste	32000	800000	1400000	1344000
Total	38000	1292000	2261000	2170560

Table 12. Biogas and equivalent energy values for sample biogas plant using corn silage, tomato, pea and animal manure.

Material	Quantity (tonnes)	Biogas yield (m^3/ton)	Production of biogas (m^3)	Electric yield x1.75 (kWh)	Heat yield x1.68 (kWh)
Tomato waste	10000	94	940000	1645000	1579200
Pea waste	10000	82	820000	1435000	1377600
Dairy waste (1000)	32000	25	800000	1400000	1344000
Total	52000	-	2560000	4480000	4300800

is very strong. Particularly, mechanical energy usage in crop production is very important. Therefore, with these two scenarios and the use of corn silages as in European countries, an economic and efficient facility can be obtained, such as the one given in Table 12.

Although the energy crisis has been felt world wide, along with the subsequent global economic crisis, the market for renewable energy is still being intensively investigated in Turkey. It is obvious that in order to meet the requirements of the Kyoto Protocol and also the EU criteria, evaluation of organic agricultural wastes for use in biogas and electricity production in Turkey is highly necessary. In this study, a substructure analysis for such a sample facility was investigated.

In conclusion, there are currently 75,000 tonnes of unused tomato waste and 60,000 tonnes of pea waste in Bursa, which have a very important energy potential. But, even 10,000 tons tomato and pea waste have significant potential for producing income. By adding available animal manure, it would be possible to obtain 4.48 million

KWh of electric energy and 4.3 million kWh of heat energy, which are the two most important outputs of any pilot plant.

REFERENCES

Alibas K, Ulusoy Y, Tekin Y (2007). Biogas Production http://homepage.uludag.edu.tr/~ yahyau/biyogaz.htm.

Alibas K, (2004). Biogas Production and Systems, Biologically Renewable Energy Souces Symposium, 20-22 Oct. 2004 Ege University Proceedings Book, Bornova- zmir. pp.205-216.

Anonymous (2007). Records Agricultural Directorate of Bursa in Year of 2006 Activity Book.

Bouallagui H, Cheikh RB, Marouani L, Hamdi M (2003). Mesophilic Biogas Production From Fruit And Vegetable Waste In A Tubular Digester, Bioresource Techno. 86: 85-89.

Karakuz S (2007). Biogas in Point of View of Energy Crisis, Biyoyakıt Dünyası, April 2007/09, Issn: 1306-9373, S.70-71.Kaygusuz K., Türker M.F., 2002, Biomass Energy Potential in Turkey, Renewable Energy 26 P. 661–678, www.elsevier.com/locate/renene.

Keskin G, Umut G (2004). Tomatoes, Agricultural Economical Research Institute, N 13. Issn 1303–8346 http://www.aeri.org.tr/pdf/bks-5-13.pdf.

Kızılaslan N Kızılaslan H (2007). Turkey’s Biogas Energy Potential, Energy Sources, Part B, 2:277–286, Taylor & Francis Group, Issn: 1556-7249.

Kim JK, Oh BR, Chun YN, Kim SW (2006). Effects Of Temperature And Hydraulic Retention Time On Anaerobic Digestion Of Food Waste, J. Biosci. Bioengineering, The Society For Biotechnol., Vol. 102, No. 4, pp.328–332.

Sözer S, Yaldız O (2006). A research about the biogas production from cattle manure and whey mixtures. Akdeniz University, Agriculture Faculty Periodical, 19(2), pp. 179-183.

TPT (2008). Tomato Paste Production of Turkey, http://www.gidasanayii.com/modules.php?Name= News&File=Article&Sid=14254.

TPPT (2005). Tomato Paste Production of Turkey, http://www.gidasanayii.com/modules.Php? Name=News&File=Article&Sid=2550.

TSY (2007). Turkish Statistic Years, http://www.tuik.gov.tr/veribilgi.do, 2009.

Türker M (2007). Anaerobic Biotechnology: Tendency in Turkey and World http://www.Sdu.Edu.Tr/Sempozyum/2007/Gida/Sablon/Anaerobik%20biyoteknoloji.Doc.

Ulusoy Y, Ünal H, Aliba K (2006). Proses of The Biogas Production, Biyoyakıt Dünyası, A ustos 2006/08, Issn: 1306-9373, pp.58-63.

Xinshan Qi, Zhang S, Wang Y, Wang R (2005). Advantages of the integrated pig-biogas-vegetable greenhouse system in North China, Ecol. Eng. 24 (2005) pp. 177–185, www.elsevier.com/locate/ecoleng.

Yaldız O (2007). Biogas Technology and Investigation for Turkey, Biyoyakıt Dünyası, Nisan 2007/09, Issn: 1306-9373, pp.8-14.