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Research Article

IMPLEMENTATION OF BIO-GAS RESOURCES TO DECREASE ENERGY CONSUMPTION OF VILLAGE INSTITUTES; A CASE STUDY OF HASANOĞLAN VILLAGE INSTITUTE[1]

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ABSTRACT

Village institutes have been one of the most effective institutions in raising the country's education level since the Republic period. Increasing the quality of education in these schools is also directly related to the support of energy resources. In this study, the increase in rural building stocks is forcing the use of renewable energy sources such as biofuels to maximize the energy requirement from bio-sources. The aim of this study is to apply bio-fossil resources in a village institute to reduce energy consumption. Hasanoglan Village Institute, which is located in Ankara, has been chosen as a case study. In this study, the potential of bio-gas use is presented.

Keywords: *Renewable energy, Village institutes, Bio-gas, Bio-mass*

[1]*Bu çalışma 2-3 Mayıs 2019 tarihlerinde Çanakkale/TÜRKİYE'de gerçekleşen* ***"4. Uluslararası Rating Academy Kongresi: Köy Enstitüleri ve Eğitimde Yeni Arayışlar"*** *temalı kongrede sunulmuş aynı isimli bildirinin gözden geçirilmiş halidir.*

1. INTRODUCTION

Organic wastes exist in the environment naturally and are generally used for various methods such as production of pyrolysis and biogas without efficient transformation and polluting the environment, improper storage, incineration or inefficient use. As a result of these processes, organic waste cannot be completely degraded and becomes a threat to the environment, ecosystem and human health although it has an important place in the national economy. Bio-gas, can be offered as new generation energy resource, is one of the less polluting gas than other gases. Bio-gas is an organic waste and a mixture of methane and carbon dioxide as a result of anaerobic fermentation and produced by the bacterial decomposition with colorless, odorless, bright blue flame burning. Ratio of produced bio-gas varies according to the composition of the organic waste used, the temperature and pH of the environment. Generally, 60-80% of methane gas (CH_4), 20-46% of carbon dioxide (CO_2), 0-2% of hydrogen sulfide, small amounts of nitrogen (N_2), water vapor and hydrogen (H_2) exist in the structure. Bio-gas is a clean energy source which is obtained from anaerobic treatment with suitable bacteria from some specially grown plants, domestic wastes, agricultural and all kinds of organic waste (Bilgin, 2003; Ekinci, 2007, Koçer *et al.,* 2006).

In Turkey, first studies on bio-gas was conducted in Eskisehir region in 1960 with the help of the Fertilizer Research Institute of Soil and Water Research Institute (Koçer *et al.*, 2006). Between the years of 1980 and 1986, Central Soil Water Research Institute (Village Services in Ankara Research Institute) continued researches on bio-gas production from cattle, sheep and chicken fertilizers in Ankara region (Bilgin, 2003). Nowadays, Directorate General of Renewable Energy was established a report under the management of the Ministry of Energy and Natural Resources (Directorate General of Renewable Energy, 2013). According to a report in 2013, two companies which processes the organic wastes from cattles, sheep and chicken exist in Turkey whilst thirty-four companies use wastes from household and food industry. The current facilities are located in West and Central Anatolia of Turkey. Futhermore, it is planned to construct twelve facilities in the near future. The total power in the current facilities are 111.23 MW, however, total capacity will be increased to 222.99 MW with the new constructed facilities (Bio-gas Report, 2011).

In order to support such activities, the Turkish Government issued a Law on the "use of renewable energy sources for the production of electrical energy" in the Official Gazette No. 25819 on 10th May of 2005 (Official Gazette, 2006). In this law, the government gives information about the use of electricity which can be produced by alternative sources, incentives to be given and pricing. According to this law, people can sell their electricity which is produced from renewable energy sources including bio-gas. Constructed facilities for biogas production in Turkey usually aim to assess the domestic waste or municipal waste as well as the food industry, however, the number of enterprises engaged in agriculture and animal husbandry have not yet reached a sufficient level. Furthermore, it is obvious that if similar studies can be performed in schools that provides education based on technology, agriculture and animal husbandry, such as the Village Institutes, the data and resources will reach large numbers. Moreover, students who will learn bio-gas production systems will contribute greatly to the dissemination of education. The advantages of fertilizer, which constitutes an important problem in herd management, as a means of recycling, make the use of a biogas attractive.

In this research, Hasanoğlan Village Institute (currently used as Hasanoğlan Atatürk Science High School) which is located in Ankara/Turkey, is selected as a case study since there are many courses in the Hasanoğlan Village Institute, such as animal husbandry, animal husbandry, agriculture and weaving. Moreover, the environment of the Institute is still available for the purpose of courses counted above. To this aim, the purpose of this paper is to produce the bio-gas energy by revitalizing the studies and to obtain a large part of the school's energy demand by bio-gas resources. This study also aims to increase the energy efficiency of educational buildings, as well as decreasing energy consumptions with the use of renewable energy resources.

2. METHODOLOGY

2.1. Bio-gas production

Bio-gas mainly consists of CH_4, CO_2, small amounts of H_2S, NH_3 and H_2, CO, O_2, halogenated compounds (chlorides, fluorides etc.) and silicones. Once the biogas is obtained, the energy is saturated with water vapour which is highly diluent. The first production of biogas contains many chemical components with different volumes which is shown in Table 1.

Table 1. Biogas components

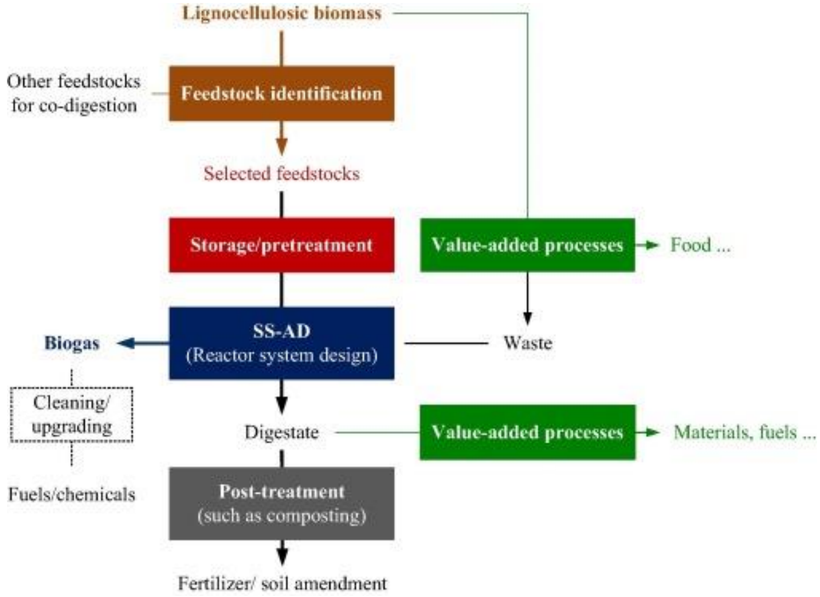
Components	Volume (%)
Methane	50-80
Carbon dioxide	20-50
Hydrogen sulfide	0,0005-0,0002
Ammonia	0,0005-0,0001
Nitrogen	0-3
Hydrogen	0-5
Water	0-1

(Painuly, 2001)

Bio-gas is a gas mixture which is lighter than air and has a density of 0.94 kg / m^3 according to air, octane number is about 110, combustion temperature is 700 ^oC, flame temperature is 870 ^oC and thermal value is 5.96 kWh/m^3 which depends mainly on CH_4 + CO_2 concentrations (Bayrakçeken, 1997). Gas composition is not stable but also varies according to the ambient temperature, water quantity, acidity (pH) and the composition of the used fertilizer.

Bio-gas can be used instead of natural gas after purification and quality improvement processes (U.S. Department of Energy, 2002). Table 2 compares the features of bio-gas and natural gas while Figure 1 depicts the solid-state anaerobic digestion (SS-AD) bio-gas production steps.

Figure 1. Overall perspectives for further research in SS-AD of lignocellulosic biomass



(Ge *et al.*, 2006)

Table 2. Comparison of bio-gas with natural gas

Features	Natural Gas	Bio-Gas
Compound (volumetric %)	95-98	55-65
Molecular weight	16.04	26.18
Density (kg/m^3)	0.82	1.21
Thermal value (MJ/m^3)	36.14	21.48

Various factors affect bio-gas production, such as raw material, capacity and location of the plant, storage and transportation of bio-gas and the transport and distribution of the manure from the plant to the field (Bilgin, 2003). Therefore, the environmental plan should be designed correctly. The organic wastes (raw material) which are used in biogas production can be examined under 3 main headings: animal wastes (livestock manure, slaughterhouse waste and wastes from processing animal products), vegetable wastes (wastes generated during the processing of various crops) and city and industrial wastes with organic content (sewage, paper-food industry waste, household waste) (Koçer *et al.,* 2006).

1 m^3 of biogas produces energy equal to 0.56 kg of fuel oil, 0.46 kg of liquefied petroleum gas and 0.62 m^3 of natural gas. Table 3 represents the thermal value of the biogas (with a metane rate of 60%) compared to other fuels (General Directorate of Electrical Power Resources Survey and Development Administration, 2008).

Table 3. Comparison of biogas with other fuels

Name of the fuel	Thermal value (kJ/kg)	Equal value of bio-gas
1 kg of lignite coal	27196	0.79 kg
1 kg of fuel-oil	38492	0.56 kg
1 kg of mixed cast gas	46024	0.46 kg
1kg of propane gas	46024	0.46 kg
Liquefied petroleum gas	46024	0.46 kg
1 kg diesel	42676	0.50 kg
1 kg natural gas	34518	0.62 kg
1 kg Soma coal	19664	1.09 kg

(General directorate of electric power resources survey and development administration, 2008)

The amount of produced bio-gas varies on the raw material used. Berglund and Börjesson (2006) concluded that the raw material in the bio-gas reactor contains high amounts of oil while another study reported that the addition of rumen content to the raw material in the reactor provides more bio-gas production (Budiyono *et al.,* 2010). Furthermore, Bilgin (2003) used fertilizers as organic wastes and reported that the produced bio-gas value varies according to the type of the animal and the size of the plant. Table 4 shows the amount of biogas that can be obtained according to the number of poultry and cattle (Bilgin, 2003).

Table 4. The amount of biogas to be obtained at the plant to be installed depending on the number of animals

Number of animals	Plant size (m^2)	Wet fertilizer need (kg)	Bio-gas production (m^3)
2500 chicken	15	200	17
50000 chicken	300	4000	340
10 cattle	10	150	5
100 cattle	100	1500	50

Storage and discharge of animal wastes are two of the most important problems of agricultural enterprises. The produced agricultural wastes can be used as fertilizer, on the one hand, the biogas production can be obtained from agricultural resources. The amount of wet manure demand in the facility should be calculated according to the capacity of the enterprise. 5-6% of live weight (average 10-20 kg / day) in bovine animals, 4-5% in sheep-goats (average 2 kg/day), 3-4% in chickens (average 0.08-0.1 kg/day) fertilizer is obtained. The average amount of manure produced in a facility is 3.6 tons / head and 0.022 tons / head per annum on average for cattle and poultry, respectively. Accordingly, biogas can be obtained from 1 ton fertilizer; 33 m^3/year for cattle and 78 m^3/year for poultry (Directorate General of Renewable Energy, 2013). The heat value of the gas obtained from bio-gas reactors is 4700-5700 kJ / m^3. For best production of bio-gas, it is required to have 7-9% solids content in in-plant fertilizer water mixture. In cases where this rate increases, the transactions for the disintegration of the raw material require additional financial expenditure.

Reactors are divided into two main groups as small and large volume bioreactors according to their volumes. Small volume bioreactors include heap type, fixed roof (Chinese type), floating indoor (India type), balloon and bag type while large volume reactors are in general, fully mixed, piston flow, lagoon type reactors and centrigas systems (Öztürk, 2005). These reactors include anaerobic contact project (ACR), anaerobic filters (AF), upstream anaerobic sludge reactors (UASB), fluid bed reactors, expandable granular sludge reactors (EGSB), acid phase reactors, internally stirred reactors (IC), hybrid reactors and full-blend digesters which can be called anaerobic lagoon digesters (Türker, 2008). According to the working principles, reactors are divided into two groups as low and high speed reactors. Low-speed reactors are lagoons, complete mix digesters, and horizontal or vertical shaped sludge reactors which have mesophilic bacteria. Fast reactors are mix digesters, contact digesters, hybrid reactors, fixed film reactors and gas production is provided by thermophilic bacteria. The evaluation of the produced energy in bio-gas plants varies according to the transport distance. If energy is produced from manure, it is reported that there is a loss of produced energy at distances of 700 km more than slaughterhouse wastes (200 km) (Berglund and Börjesson, 2016).

For bio-gas production, reactors operate at psychophilic temperature (12-20 °C), at mesophilic temperature (20-40 °C) and at thermophilic temperature (40-65 °C). Organic wastes are kept under thermophilic conditions, the destruction of weed seeds, which is a major problem in the fertilization process, occurs at a higher rate than the mesophilic conditions (20, 26). In the reactors which operate under thermophilic conditions, the heating energy is higher than the mesophilic and the reactor volume is smaller. Therefore, mesophilic temperature range (35-37 °C) is the most preferred ranges (20, 25, 27). At the hydrolysis stage and reaction stage with acidogenic bacteria, the pH of the medium is 5.2-6.3, however, pH should be between 6.7-7.5 at the stage of methane gas formation (Guo and Guo, 2010). Carbon / Nitrogen (C/N) ratio is also effective for the formation of methane gas in the reactor. Carbon is necessary for bio-gas formation and nitrogen for the development and regeneration of anaerobic bacteria. C/N ratio in animal manure based reactors varies on the type of animal. In general, the value is between 15/1-30/ 1 (approximately average value is manure, 22 in cattle manure, 14 in poultry manure and 25 in pigeon manure). However, this value should be 10-45 at the reaction stage with hydrolysis and acidogenic bacteria and 20-30 at the stage of methane gas formation (Guo and Guo, 2010). The presence of mineral ions, heavy metals and detergents in the waste has a toxic effect by preventing the growth of micro-organisms. While heavy metals such as copper, chromium, nickel, zinc, lead in low concentration affect the bacterial growth positively, high concentrations of toxic effects can be produced in process. Detergents and disinfectants (such as soap) have also been reported to reduce methane production (Öztürk, 2005). Apart from these factors, the duration of digesters, water ratio, and the effect of inhibitor and alkalinity can also affect the bio-gas production.

Another important factor is that wastes pollutes the environmental, the earth and underground water resources. Micro-organisms consume more oxygen to de-compose organic matter in contaminated waters. The consumed amount of oxygen by micro-organisms (bio-chemical oxygen demand=BOG) is an important criteria for the determination of environmental pollution. It has been reported that BOG is higher in the wastes obtained from livestock than the daily waste produced by people (Karaman, 2006). Obviously, it is possible to reduce BOG value in animal wastes by bio-gas production. Organic wastes can be transformed into the energy by using them in reactors and fertilizer which can be used in soil. A study reported that fertilizers, which are used in agriculture, leave salt to the soil while fermented manures that passing through bio-gas reactor does not leave any residue (Alçiçek and Demiruluş, 1994). Another study showed that the weed seeds in animal fertilizers lose their germination property and the smell of manure and the destructive effect of fresh manure decrease while the fluidity increases. Methane gas can be obtained from bio-gas units and can be converted to electricity and heat energy. 500- 2000 kWh /1000 kg energy can be produced from various reactors (Ardıç and Taner, 2012). In order to ensure complete combustion in methane gas, the bio-gas should be mixed with air at a rate of 1/7. A variety of bio-gas-powered vehicles have been produced and methane gas can be purified or used directly in any of the gasoline-powered engines. By mixing the produced gas to natural gas, it is possible to reduce the current cost and bio-gas can be used during the production of chemicals in the use of fuel cells (Çanka Kılıç, 2011).

2.2. Case Study

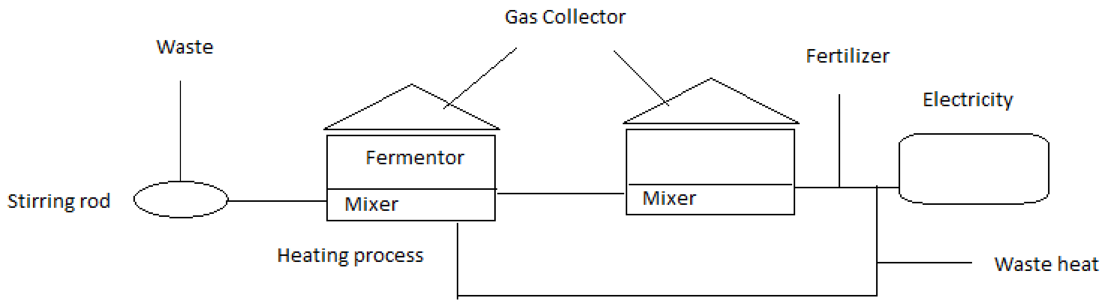
The aim of this paper is to create an environment where the energy level of living beings can be provided according to the climatic conditions. Solar, wind and underground surface waters from indirect sources, indirectly located in a gas and bio-energy systems and their data are evaluated. Hasanoğlan Village Institute which is located in Ankara is selected as a case study for the research (Figure 2).

Figuere 2. Hasanoğlan Village Institute, location (left) and building (right)

Bio-gas can be produced from agricultural wastes in the campus of Hasanoğlan Village Institute since scientific agriculture courses were given in this school in the first years of Republic. Futrhermore, raw metarial of bio-gas plant is considered to be supplied from Hasanoğlan Village where the campus is located in. Manure obtained from livestock in the village will be used for bio-gas production.

Figure 3 shows the considered bio-gas plant for the Hasanoğlan Village Institute. The case plant is taken from the reference (Kaya and Öztürk, 2012). Since the energy requirements of the Hasanoğlan Village Institute are considered to be approximately 500 m^3, the reactors are recommended according to these values. Small volume bio-reactor is chosen for the study.

Figure 3. Biogas plant and production processes used in livestock enterprises



(Öztürk, 2005)

Depending on the farm and agricultural waste capacities of the Hasanoğlan Village Institute, the amount of the produced energy may vary, however, general data is used for the study. Annual potential biogas production is obtained from Eq.1 (Kemausuor et al., 2014).

$$y_{biogas} = P_{live} \text{ X } y_{man} \text{ X } c_{ts} \text{ X } \eta_{rec} \text{ X } y_{BMP} \quad (1)$$

where y_{biogas} shows potential biogas production from manure, P_{live} is livestock population, y_{man} is produced manure, c_{ts} depicts total solids concentration in the organic fraction, η_{rec} is recoverability of the manure and finally, y_{BMP} is methane potential.

Energy capacities and electricity consumption for the purpose of heating and cooling are determined according to the data. The type of reactor in biogas production facilities varies according to the capacity, the percentage of solids, the number of steps, the operating temperature and the feeding patterns. 6-12 m^3 of family type is sufficient, while in farm type this value is between 50-150 m^3, type of village is 100-10000 m^3 (Germany, America, Denmark and Switzerland) (Bilgin, 2003). In the study, this value is estimated to vary between 12 m^3 and 150 m^3 for the Hasanoğlan Village Institute. Reactor loading was taken as 1.66 kg/m^3 /day and 170 m^3 /day gas production from 250 livestocks was assumed per ton of manure (Kaya and Ozturk, 2012). η_{rec} and c_{ts} were calculated as 0.2 and 12 gTS/100g for livestocks, respectively. A 41 m^2 floor area was selected for the bio-gas facility. Floating balloon type biogas plant was preferred since it is cost-effective, easy to design, easy to transport.

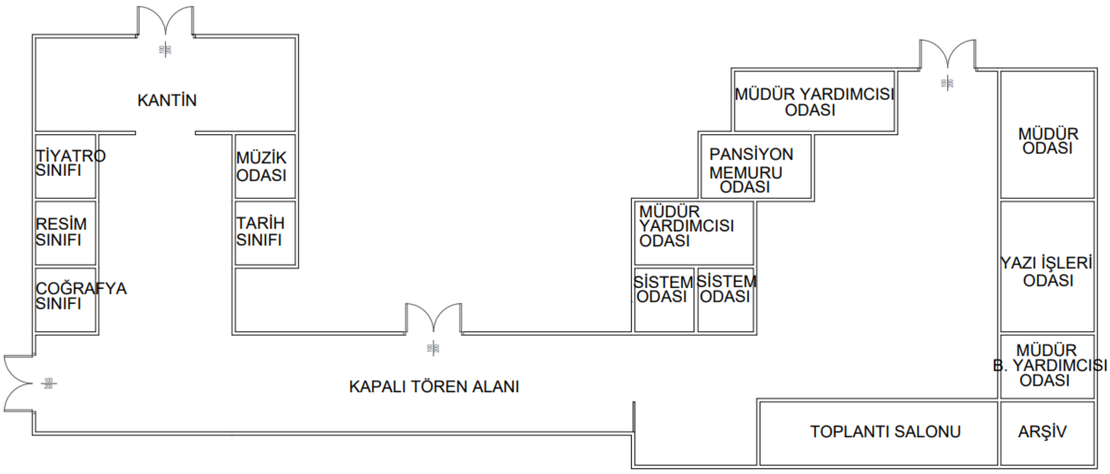
A 150 m^2 building in the campus of Hasanoğlan Village Institute was selected to compare the energy consumptions before and after implementation of bio-gas plant in the campus. Floor plans, cross-sections and side wives were all drawn in AutoCAD and dimensioning, energy and cost analyses were performed in a Building Energy Simulation (BES) tool for the building. DesignBuilder (2019) dynamic simulation software, v4.2.054, was used for modelling and simulation of the Village Institute. DesignBuilder lays on EnergyPlus simulation engine and uses FORTRAN programming language to develop simulation engine.

Moreover, the solution technique of the program is based on the Predictor-Corrector Method. DesignBuilder (2019) has inputs like lighting and HVAC systems, occupancy and equipment schedules, construction materials and allows to determine heating and cooling load of the building. In this study, the energy is supplied from proposed bio-gas plant and the energy consumption is calculated and compared with the existing model.

The pay-back period is calculated from Eq.2.

Pay-back Period: Investment Cost/ Annual Cash Savings (2)

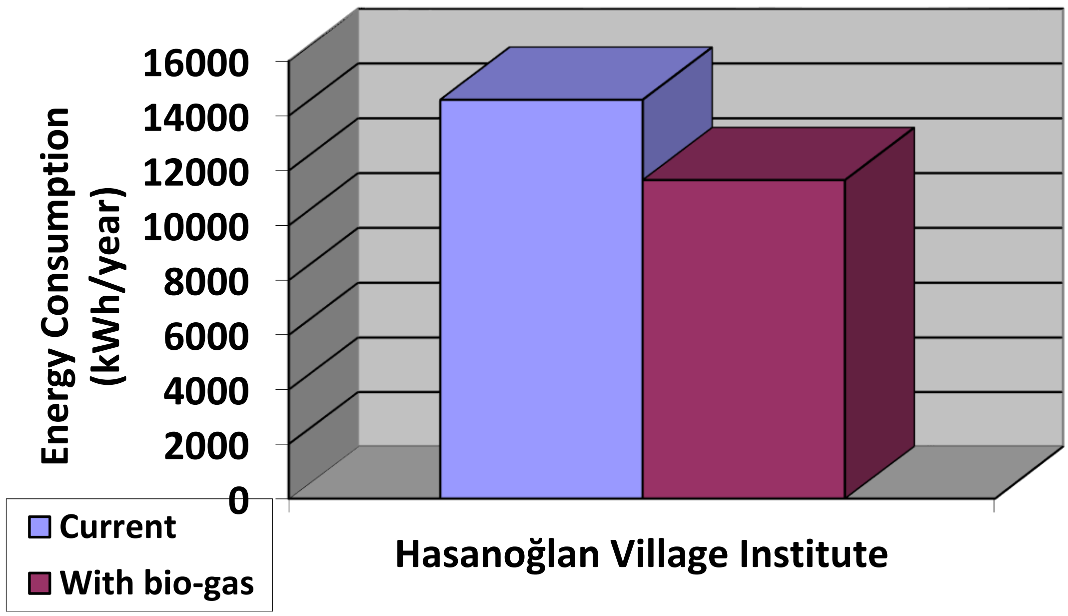
Figure 4. The plan of the case building in Hasanoğlan Village Institute



3. RESULTS

The Hasanoğlan Village Institute was modelled in a calibrated Building Energy Simulation tool, DesignBuilder (2019). The current energy consumption and the energy produced by bio-gas implementation were compared. Figure 5 compares the energy consumptions before and after implementing bio-gas production.

Figure 5. Comparison of energy consumption of Hasanoğlan Village Institute



The annual energy consumption of Hasanoğlan Village Institute is calculated as 14586 kWh/year. However, 20.1% of energy can be saved by implementing bio-gas production for the case building. Besides energy saving, wastes from organic origin can be re-used with the bio-gas production technology. Thus, the output of the bio-gas production becomes more valuable organic fertilizer since methane gas leaves from the system after bio-gas production. Furthermore, the solids of the wastes from the digester will be used to meet the demand for biogas which will increase in the future. The results show that 1 m^3 of bio-gas produces 10 kWh of energy. According to the calculations, it will be possible to produce 105000 kWh of electrical energy from 10500 m^3 of bio- gas. Knowing the electricity consumption per person is 2.562 kWh, the electricity generated from the bio-gas has the capacity to meet the daily energy need of 40984 people.

The investment cost of the bio-gas plant is calculated according to a study by Adeoti *et al.* (2000). The authors revealed that investment costs are approximately 65% of the total costs while facilities, installation, labour and land are accounted for the remaining 35%. The first costs of the construction of bio-gas plant in Hasanoğlan Village Institute is calculated as 1161.2 dollars (VAT included). The pay-back period is 3.95 years.

A comprehensive comparison is conducted in order to find which renewable energy resources is the most effective in this region. To this aim, each investment is assessed seperately for Hasanoglan Village Institute. Regarding to solar energy, ten PV panels (1.6 X 1 m, with standard 60 cells) with a total area of 16 m^2 were applied to produce electricity for the Village Institute. Considering the short total insolation hours of Ankara (2,8 hours/year), the pay-back period was calculated as 6.14 years. Another option was to add one three-bladed wind turbine to generate electricity (with 31 m height and 55kW rated power output). Although wind energy fulfills almost 79% of total energy consumption of case building, the location of Hasanoglan Village is not suitable for continous energy generation by wind energy. Renewable energy resources generally depend on climate and weather condition, however, the raw metarial of bio-gas always exist in villages.

Table 5. Comparison of bio-gas with other renewable energy resources for Hasanoğlan Village Institute

Renewable Energy Source	Implementation Type	Energy saving (%)	Investment Cost (TL)	Pay-back period (Years)
Bio-gas	Plant	20.1	1161.2	3.95
Solar energy	Solar Panel	8.1	16240	6.14
Wind energy	Wind Turbine	79.4	378855	11.24
TL: Turkish Liras, Labour charges are added to the prices, 1 $= 5.8 TL, 1£ = 7.57 TL, 1 € =6.55 TL				

As the number of people is not a value to be underestimated, the students and administrations should be aware of the capability of bio-gas production before coming to the farm, and should be informed about the necessary incentives to be given by the government and the uses and benefits of the bio-gas.

4. CONCLUSIONS

Educational structures are one of the most important equipment in the development of the country. The use of educational methods combined with theoretical sciences in education will have a major impact on the development of the new generation. Nowadays, the computer technology comes firstly to mind while life cycle in development is left in the second plan.

However, practical training for the vital return constitutes the infrastructure of the most important scientific studies. The education of teachers and participation of students in educational life are two main parts of the system. However, proper use of energy resources should be taught in order to disseminate education.

This study aimed to use renewable energy resources to decrease energy consumption of Village Institutes. Thus, additional energy and income management from agriculture and animal husbandry for the Village Institutes will be satisfied. Moreover, Village Institutes can be actively revived for education with the help of bio-gas production technology. The importance of using alternative energy instead of fossil-based energy resources can be understood. Increase of bio-gas production in Turkey will ensure a healthier environment with good converged planning and management, which will help to decrease Turkey's energy-dependence to foreign countries.

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REFERENCES

ADEOTI, O., AYELEGUN, T. A., OSHO, S. O., 2014, Nigeria biogas potential from livestock manure and its estimated climate value, Renewable and Sustainable Energy Reviews, 37, 243-248.

ALÇİÇEK, A., DEMİRULUŞ, H., 1994, Çiftlik gübrelerinin biyogaz teknolojisinde kullanılması Kullanılması, I. Ekoloji ve Çevre Dergisi, 13.

ANONİM, 2012, 5346 sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanun, 18 Mayıs 2005 tarih 25819 sayılı Resmi Gazete, (Access Date: 28.07.2012).

ARDIÇ, İ., TANER, F., 2012, Biyokütleden biyogaz üretimi. Erişim Adresi: http://www.emo.org.tr/ekler/14101ec47c52b48 _ek.pdf, (Date Access: 21.11.2012).

BAYRAKÇEKEN, H., 1997, Biyogaz Üretim Sistemi Tasarımı ve Uygulaması, Afyon Kocatepe Üniversitesi, Afyon/Turkey (in turkish).

BERGLUND M., BÖRJESSON, P., 2006, Assessment of energy performance in the life-cycle of biogas production. Biomass and Bioenergy, 30, 254-266.

BİLGİN, N., 2003, Biyogaz nedir? Tarım ve köy işleri bakanlığı köy hizmetleri genel müdürlüğü, Ankara Araştırma Enstitüsü, Ankara/Turkey (in turkish).

BİYOGAZ, 2011, Türkiye'de biyogaz yatırımları için geçerli koşulların ve potansiyelinin değerlendirilmesi. Erişim adresi: http://www.biyogaz.web.tr/files/docs/dbfz_turk iye_ biyogaz_potansiyel_raporu.pdf, (Access Date: 20.04.2013).

BUDIYONO, I.N., WIDIASA JOHARI, S., SUNARSO, S., 2010, Increasing Biogas Production Rate from Cattle Manure Using Rumen Fluid as Inoculums. International Journal of Basic Applied Sciences IJBAS-IJENS, 10(1): 68-75.

ÇANKA KILIÇ, F., 2011, Biyogaz, önemi, genel durumu ve Türkiye'deki yeri, Mühendis ve Makine, 52 (617) , 94-106 (in turkish).

DESİGNBUİLDER, v6.1.0.006, http://www.designbuilder.co.uk/, (Access Date: 10.05.2019)

EKİNCİ, M.S., 2007, Tavuk gübresinden biyogaz üretimi için en uygun koşulların belirlenmesi, Yüksek Lisans Tezi, Gazi Üniversitesi Fen Bilimleri Enstitüsü, Ankara/Turkey (in turkish).

GE, X., XU, F., Lİ, Y., 2016, Solid-state anaerobic digestion of lignocellulosic biomass: Recent progress and perspectives, Bioresource Technology,1, 205.

GENERAL DIRECTORATE OF ELECTRIC POWER RESOURCES SURVEY AND DEVELOPMENT ADMINISTRATION, 2008.

GUO GUO, L., 2010, Potential Of Biogas Production From Livestock Manure in China, Department Of Energy And Environment Division Of Energy Technology, Chalmers University of Technology Göteborg, Sweden.

İLKİLİÇ, C., DEVİREN, H., 2011, Biyogaz oluşumunu etkileyen fiziksel kimyasal Parametreler, 6th International advanced Technologies Symposium, Elazığ, Turkey (in turkish). Journal Of Nation Of Geographic, 1945, Ankara.

KARAMAN, S., 2006, Hayvansal üretimden kaynaklanan çevre sorunları ve çözüm Olanakları, KSÜ. Fen ve Mühendislik, 9(2), 133-139.

KAYA, D., OZTURK, H. H., 2012, Biyogaz Teknolojisi Üretim-Kullanım-Projeleme. Umuttepe Yayınevi, 253 s. İzmit/Kocaeli (in turkish).

KEMAUSUOR, F., KAMP, A., THOMSEN, S. T., BENSAH, E. C., ØSTERGÅRD, H., 2014, Assessment of biomass residue availability and bioenergy yields in Ghana. Resources, Conservation and Recycling, 86, 28–37.

KOÇER, N.C., ÖNER, C., SUGÖZÜ, İ., 2006, Türkiye'de Hayvancılık Potansiyeli ve Biyogaz Üretimi. Doğu Anadolu Bölgesi Araştırmaları (in turkish).

PAINULY, J.P., 2001, Barriers to renewable energy penetration; a framework for analysis. Renewable Energy, 24, 73 - 89.

RESMİ GAZATE, 2005, 18 Mayıs 2005 tarih 25819 sayılı Resmi Gazete, (Date Access: 28.07.2012).

RESMİ GAZETE, 2012, 5346 sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanun, (Access Date: 28.07.2012).

TÜRKER, M., 2008, Anaerobik biyoteknoloji: Türkiye ve dünyada'ki eğilimler, Çevkor Vakfı yayınları, İstanbul/Turkey (in turkish).

ÖZTÜRK, M., 2005, Hayvan gübresinden biyogaz üretimi, T.C. Çevre ve Orman Bakanlığı Müsteşarlığı, Ankara/Turkey (in turkish).

U.S ENERGY DEPARTMENT, 2002, https://www.eia.gov/totalenergy/data/annual/previous.php, (Date Access: 10.05.2019).

YENİLEBİLİR ENERJİ GENEL MÜDÜRLÜĞÜ, 2013, Biyogaz, Yenilebilir Enerji Genel Müdürlüğü, Erişim adresi: http://www.eie.gov.tr/, (Date Access: 16.06.2013).