INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH
Igoud Sadek et al., Vol.3, No.1, 2013

Renewable Energy Potential Generated by Organic Waste in Algeria

Igoud Sadek*‡, Souahi Fatiha**, Sebti Aïcha*, Mansouri Noura**, Chouikh Amar***

*Development Unit of Solar Equipments "UDES"

**National Polytechnic School "ENP"

*** National Office of Sanitation "ONA"

Igoud_sadek@yahoo.fr, fsouahi@yahoo.fr, aicha_seb@yahoo.fr, mansourinoura@yahoo.fr, amarchouikh@yahoo.fr

‡Corresponding Author; Igoud Sadek, Development Unit of Solar Equipments "UDES", National Road Nbre 11, PO Box 386, Bou-Ismaïl, 42415, Tipasa, Algeria, 00 213 24 41 01 33, Igoud_sadek@yahoo.fr

Received: 14.11.2012 Accepted: 09.01.2013

Abstract-Renewable energy contributes strongly to the sustainable development for witch waste-to-energy conversion represents an important opportunity. This is due availability of waste, their low cost and the necessity of their collection and treatment. This paper contributes to promote waste-to-energy conversion threw organic waste methanisation. We have evaluated the potential of renewable energy generation and the CO_2 sequestration. Three types of waste are studied : 1)urban solid waste which are estimated at 8.5 million tons per year, 2) sewage sludge quantified at more than 338 103 tons per year, and 3) cow dung estimated yearly at 33 103 tons. These wastes are mobilizable, widely available in urban and rural areas and increased continuously. Results indicate that the last of energetic valorization of these wastes induces a significant losses estimated at 1.7 million m^3 of biogas production and 3.57 TWh of electricity generation. This situation leads the sequestration of 2.05 million tons of CO_2 which is estimated without recording the greenhouse gas emission induced by the wastes degradation in public dumps.

Keywords-Organic waste, methanization, biogas, energy equivalence, CO_2 sequestration.

1. Introduction

The industrialization and the modernization of human society have induced the waste concentration in urban areas and their discharged in natural sites in important quantities. This situation induced significant air, water and soil pollutions which have required their specific management and valorization.

In Algeria, the solid waste management sector does not take into account systematic treatment and recycling of waste. Also, it is not completely supported except the use of some technical landfill centers. Waste management cycle begins by the collection, ensured at 80%, the transport and finally discharging at public dumps. The proliferation of waste without treatment is a harmful to public health, environment and leads to an important loss of recyclables, energy and money. This phenomenon is particularly noticeable in urban areas where the solid waste quantities increase with population growth [1]. Also, it is amplified with the concentration of Algerian population in the north particularly in megacities and coastal areas.

The same management exists concerning the rejected wastewater which are at the beginning of sewage sludge production in the 123 wastewater treatment plants (wwtps) accounted by 2011 [2]. In these plants, especially where activated sludge treatment process is applied, sludge is mechanically dehydrated, then transported and discharged at landfill sites [3]. At medium-term, this management will be more difficult to handle because of the increase of sludge production. Indeed, Algerian government, towards the Five-Year Plan (2010/2014), plans to treat all rejected wastewater, estimated at 1.2 billion m^3 per year, by the building of 40 new wwtps [2].

Livestock manures are the last studied waste and they are selected in a different context. Indeed, Livestock manures are widely available in rural areas but not concentred in specific locations. Also, they are used as organic fertilizers especially cattle dung produced from the 1.5 million heads recorded in 2009 [4]. So, their evacuation is not problematic because of their perfect integration in agricultural crops. The main interest of their energetic conversion before their utilization as fertilizes encourages the use of this renewable resource for the energy autonomy of the rural population remote from the distribution networks of conventional energy.

This paper evaluates the energetic conversion potential of these three types of humid wastes through methanisation scenarios where is calculated the biogas production and its conversion into electric and thermal energy.

2. Organic Waste Methanisation

The interest in methanisation process was the aim of several studies conducted at the Agriculture School of Algiers (now the National Agronomic Higher School) where, in 1938, Ducellier and Isman introduced the pre-fermentation to optimise this microbiologic process. That work has been considered as the beginning of the biogas production mastery in the world [5]. Now, these studies are particularly undertaken by the Development Center of Renewable Energy and its Research Units in collaboration with universities [6, 7, 8, 9 and 10]. Unfortunately, these studies are not taken into account by industrials. Only one digester was installed at Baraki wwtp, located in Algiers, where biogas is used for the digester heating. This should be changed due to the Algerian government incentive policies for renewable energy use [11].

3. Methodology

The methanisation process has been considered for the assessment of the renewable energy generated from the three organic waste. The choice of this process is justified by the technical flexibility of the process considering especially the substrate nature and its volume. That allows treating MSW discharged at dumps using industrial plants. Also, sewage sludge methanised in medium digesters integrated into the wastewater treatment process of plants. And animal manures digested in home digesters into small farms.

The biogas volume (*BV*) production is estimated from the Organic Waste Quantity (*OWQ*), Dry Matter (*DM*), Volatile Matter (*VM*) and a specific Coefficient Conversion (*CC*) as follows :

$$BV = OWQ \,.\, DM \,.\, VM \,.\, CC \tag{1}$$

This approach was only used for the assessment of the energetic conversion of sewage sludge. For the other waste, biogas productions is estimated by the consideration of a rate conversion. In scientific literature, this rate varies from 100 to 300 m^3 per ton of MSW according to the quantity and composition of the organic fraction. This rate is estimated at 200 m^3 of biogas per ton of MSW without considering the paperboard fraction [12]. Cattle dung conversion rate is estimated at an average of 0.611 m^3 of biogas per ton of dung according to experimental studies [7].

Electric and thermal energy generated from biogas production are evaluated by the use of cogeneration system with 80% of efficiency. A part the energy generation, cogeneration allows the reduction of energy cost and greenhouse gas emission [13].

For each type of waste, the biogas volume production (*BVP*) is converted to electric energy (*EE*) and thermal energy (*TE*). The lower calorific value (*LCV*) of biogas, estimated at 6 kWh per m^3, the electric efficiency (*EE*), evaluated at 35%, and the thermal efficiency (*TE*) fixed at 45% of the cogenaration engines [13] are considered for the calculate as follows :

$$EE = BVP \,.\, LCV \,.\, EE \tag{2}$$

$$TE = BVP \,.\, LCV \,.\, TE \tag{3}$$

The sequestration assessment of the Greenhouse Gas (GHG) emissions is obtained by using the ratio of the carbon dioxide emitted per unit of electricity generation, estimated at 574 g/kWh [14].

4. Results and discussions

4.1. *Potential of Renewable Energy Generated from Municipal Solid Waste*

During 2009, the quantity of MSW collected was estimated at 8.5 million tons whith an organic matter between 60% and 65% [15]. The scenario of the MSW energetic valorization require first the installation of waste sorting centers for the organic matter recovery. Then, the installation of industrials digesters for the methanisation of the organic matter of MSW. That would allowed to produce 1.700 million m^3 of biogas ''Table 1'' composed by an average of methane between 50% and 70% [16]. Biogas cogeneration would allowed to generate 3.5 TWh of electricity and to preserve the emission of 2.04 millions of CO_2.

Table 1. Renewable energy generation from Algerian municipal solid waste

Year	Population (million inhabitant)	Municipal waste (10^6 tons)	Potential of renewable energy generation			GHG Sequestration (10^3 t CO_2)
			Biogas (10^6 m^3)	Thermal energy (GWht)	Electricity (GWhe)	
2009	35	8.5 [9]	1 700	5 508	3 570	2 049.90
2020	44.3	13.6 [11]	2 720	7 290	5 859	3 363.06

The increase of MSW, in the future, could generate a biggest quantity of electricity estimated at 5.85 TWh in 2020 [17] and 6.82 in 2050 [1].

In return, the lack of the MSW energy conversion could cause GHG emission estimated at 3.36 million tons, in 2020, and 3.91 million tons of CO_2 emission, in 2050, which could be preserved.

4.2. Algiers Case Study

The assessment of collected MSW is undertaken in 57 municipalities which composed 16 daira of Algiers province.

Figure 1 shows that, since the sixties, the amount of waste generated has significantly increased.

Between 1960 and 1977, a slight increase was recorded which is estimated at 15.62%. However, since 1985 until 2005, the amounts of the generated quantities of MSW have strongly increased by 60% to reach almost 1.17 million tons [18].

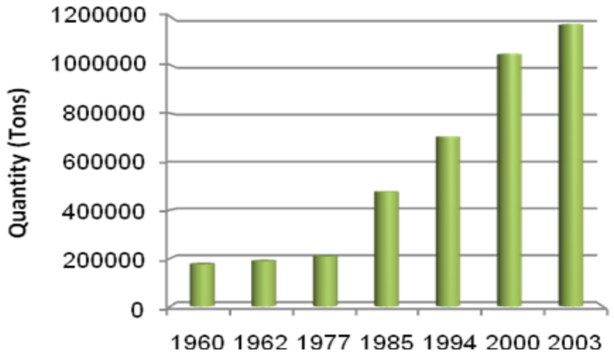

Fig.1. Evolution of the municipal solid waste collected in Algiers [18]

Data indicated that, in 2003, collected MSW was evaluated at 3 700 tons per day [18]. With a population estimated at 3 700 000 inhabitant, each habitant had daily produced 1 kg of solid waste.

''Table 2'' shows that total MSW collected had an energetic potential to produce 224.82 million m^3 of biogas convertible in 607 MWh of thermal energy and 472 MWh of electricity. This energy input could have preserved 270 tons of CO_2 emission.

In fact, this estimation, acording to the 1.12 million tons of MSW, was below the reality because only 80% of MSW was collected.

Table 2. Renewable energy generation from Algerian municipal solid waste

Municipalities' location	Number of municipalities	Municipal solid waste collected (10^3 Tons)	Potential of renewable energy generation			GHG sequestration (t CO_2)
			Biogas (10^6 m^3)	Thermal energy (MWh_t)	Electricity (MWh_e)	
Algiers center	07	150.01	30.00	81.00	63.00	36.16
Bouzareah	04	54.75	11.55	31.18	24.25	13.92
Cheraga	04	66. 43	13.28	35.85	27.88	16.00
Zeralda	05	45. 28	9.05	24.43	19.00	10.90
Draria	04	45. 26	9.05	24.43	19.00	10.90
Birtouta	03	22. 61	4.52	12.20	9.49	5.44
Bab El Oued	06	105.85	21.17	57.15	44.45	25.51
Hussein Dey	04	120.08	24.01	64.82	50,42	28.94
Bir Mourad Raïs	04	97.27	19.45	52.51	40.85	23.44
Baraki	04	103.44	20.68	55.83	43.42	24.92
El Harrach	03	42.80	8.56	23.11	17.97	10.31
Dar El Beïda	06	142.51	28.50	76.95	59.85	34.35
Rouiba	03	125.00	25.00	67.50	52.50	30.13
Total	57	1 121.30	224.82	607.00	472.08	270.92

From table 2, we can note that MSW quantity variation is not related to municipalities number per daira, which is simply an administrative division, but of the inhabitants number living per municipalitie.

For example, Birtouta had the smallest MSW quantity, estimated at 22.61 thousand tons, compared to Rouiba which had 125 thousand tons of MSW.

The biggest MSW quantity collected, which is estimated at 150 thousand tons, is generated by Algiers center.

4.3. Potential of Renewable Energy Generated from Sewage Sludge

Sewage sludge methanisation is conducted in hermetic and heated digesters (i.e. generally between 30-38°C) for energy conversion, stabilization and sanitsization [16, 19, 20]. This process is known as the most technically-mature and cost-effective processes which still one of the promising sludge treatment [20].

Our study is restricted at the data of National Office of Sanitation (ONA). ONA managed 68 wwtps of the 123 existing ones using especially activated sludge with extended aeration. Remaining treatment plants used principally lagoon process and they are managed by the local authorities, the building operators and the stock company in major cities [3].

Figure 2 shows that, between 2008 and 2010, total volume of wastewater treated by ONA had increased from 700 to 104 million m^3 which represented a growth rate of 33% [3].

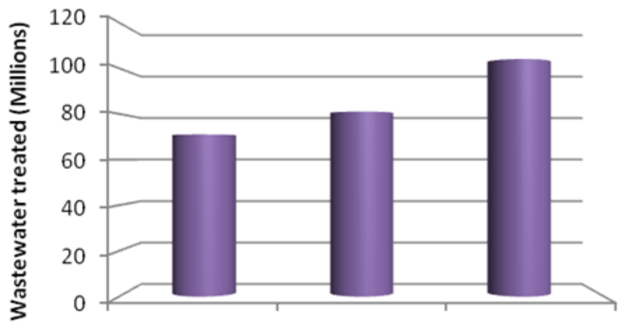

Fig.2. Evolution of the wastewater treated by ONA [3]

Table 3 shows that Oran area recorded the most important number of wwtps which allowed to treat the biggest wastewater volume, estimated at 21.13 million m^3 for a total volume of 103.63 million m^3.

Concerning sewage sludge, all wwtps produced yearly a quantity evaluated almost at 338 thousand m^3.

Through the scenario of the installation of a unitary system of biogas production and cogeneration in each wwtp, the total quantity of sewage sludge could produce a biogas volume of 7.82 thousand m^3 then converted into 16.43 MWh electricity and 21.13 MWh of thermal energy.

Table 3. Renewable energies generation from sewage sludge

Area location	Number of wwtp	Wastewater treated (10^6 m^3)	Conventional electricity consumed (kWh/m^3)	Sewage sludge produced (10^3 m^3)	Potential of renewable energies generation			GHG sequestration (t CO_2)
					Biogas (10^3 m^3)	Thermal energy (MWh_t)	Electricity (MWh_e)	
Oran	22	21.13	0.30	26.09	0.60	0.16	1.26	0.72
Saida	06	3.70	0.77	13.99	0.32	0.87	0.68	0.39
D-A Ouargla	03	13.62	0.20	3.26	0.07	0.20	0.42	0.24
El Oued	01	1.83	024	-	-	-	-	-
Constantine	03	5.22	0,76	16.54	0.38	0.10	0.80	0.46
Batna	01	5.00	0.74	1.95	0.04	0.12	0.09	0.05
Annaba	04	12.86	0.61	118.44	0.27	0.73	0.57	0.32
Chlef	03	6.03	0,80	33.44	0.77	2.09	1.62	0.93
Tizi -Ouzou	13	15.82	0.70	29.54	0.68	1.84	1.43	0.82
Sétif	08	10.07	0.61	11.41	0.26	0.71	0.55	0.31
Alger	04	8.29	0.95	83.19	1.92	5.20	4.04	2.32
Total	**68**	**103.63**	**0.29**	**337.91**	**7.82**	**21.13**	**16.43**	**9.43**

Beside of the financial advantages, this management system could contributed to the sequestration of 9.43 tons of CO_2 emission.

Concerning digested sludge, we should note that due to its high concentration on organic matter, it is considered as a good fertilizer for agriculture crops [21] and particulary for forestery plantations. Effectively, digested sludge allowes an important improvement for poor soils stability and fertility which leads to the increase of survival and growth rates of forest plantations and reforestation [6]. This kind of digested sludge recycling constitutes another advantage in supporting of the sustainable development, especially against desertification, poverty and climate change.

4.4. Potentiel of Renewable Energy Generated from Cattle

Livestock manures, especially cow dung, is not collected which makes difficult its quantity estimation. That, because Algeria's cattle farming is mostly concuced especially into free stall practiced in medium stables and family farms.

Figure 3 shows clearly that cattle farming activity started intensively since 1980 with 1.36 million heads to reach in 2009 1.65 million heads [4]. The free stall animal husbandry had required to considerate the half of the dung quantity produion which is estimated between 30 and 50 kg per day and per cow [22].

Between 2002 and 2009 "table 4", the number of cattle had slightly increased for the dung production estimated at 33 thousand tons.

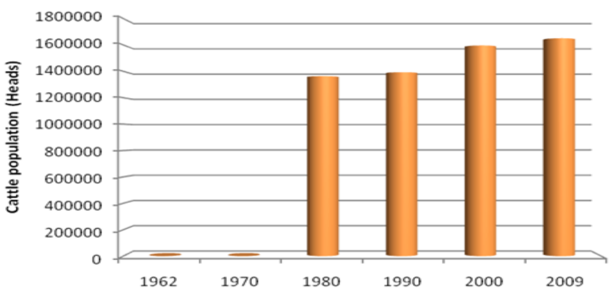

Fig.3. Evolution of cattle population [4]

Table 4. Renewable energy generation from cattle dung

Year	Cattle population (heads)	Cattle dung production (10^3 tons)	Potential of renewable energy generation			GHG sequestration 10^3 (t CO_2)
			Biogas (10^6 m^3)	Thermal energy (GWh_t)	Electricity (GWh_e)	
2002	1 551 568 [14]	31. 03	1.89	5.12	3. 98	2.28
2006	1 607 860 [14]	32. 15	1. 96	5.30	4.12	2.36
2009	1 650 000 [4]	33	2.01	5.42	4.23	2.42

The scenario of a family digeter and a small cogeneration system installation in each stables and familly farms where cattle farming is practiced could allowed to produce 2.01 million m^3 of biogas. This biogas volume could generated 4.23 GWh of electricity and avoid 2.42 thousand tons of CO_2 emission.

4.5. Potentiel of Renewable Enrgy Generated from Organic Waste Generatde in 2009

The consideration of the three organic wate produced during 2009 "Table 5" indicated that MSW had the most important share. Consequencely, this renewable ressource could allowed to generate the biggest quantity of electricity, evaluated at 3.57 TWh in 2009 and 5.54 TWh in 2030 [1].

Cattle dung came in the second position. Its production was estimated at 33 thousand tons convertible in 4.23 TWh of electricity. That represents an important energy supply for rural popullation which often cannot have an acces to the electricity network. For example a family digester of 15 m^3 allows producing an energy equivalent of almost 3 butane cans of 13 kg, or 1 ton of wood which can be preserved [9].

In last position, sewage sludge, estimated at 40.5 thousand tons, could have generated 16.43 MWh of electricity. However, in a financial point of view, this type of energy conversion can save until 50% of the operating budget in each wwtp.

Table 5. Renewable energy generated from organic waste in 2009

Organic waste type	Organic waste production (tons)	Potential of renewable energy generation			GHG sequestration (tCO_2)
		Biogas (m^3)	Thermal energy (MWh_t)	Electricity (MWh_e)	
Municipal solid waste	8.5 10^6	1 700 10^6	5 508 10^3	3 570 10^3	2 049.90 10^3
Sewage sludge	337.91 10^3	7.82 10^3	21.13	16.43	9.43
Cattle dung	33 10^3	2.01 10^6	5 446.71	4 236.3	2 440.11
Total	8.93 10^6	1 702.01 10^6	551.34 10^3	3 574.25 10^3	2 052.35 10^3

5. Conclusion

Undoubtedly, a significant increase of waste will be recorded in the future, especially MSW and wastewater. In the other hand, an important increase of energy consumption will be noticed. These two predictions could be solved by waste-to-energy technologies which represent an important opportunity for countries where the lack of waste treatment is a threat to the public health and environment equally a loss of recyclables, energy and money.

In this context, this study proposed the use of the methanisation process for the three types of humid waste and the cogeneration of the generated biogas.

We consider that MSW quantity, estimated at 8.5 million tons, would have generated 3.5 TWh of electricity and preserved 2.04 million tons of CO_2 emission.

However, this technology requires the installation of sorting centers, industrials digesters and cogeneration systems. Sewage sludge from wastewater and cattle dung quantities would have generated much less electricity, estimated respectively at 16.43 MWh and 4.2 GWh. In return, they would require fewer financial investments for the installation of small or medium digesters and cogeneration systems.

Acknowledgements

The authors wish to thank all who have contributed to this paper writting as well as the members of the scientific and organizing committees of EWRES 2012 (Antalya, TURKEY, 17-28 Sep).

References

[1] DLR German Aerospace Center, Concentrating Solar Power for the Mediterranean Region, Institute of Technical Thermodynamics Section Systems Analysis and Technology Assessment, 2005.

[2] Five-year development program 2010/2014. http://www.mae.dz/photos/gov/programme.htm.

[3] Ministère des Ressources en Eaux, Bilan annuel d'exploitation, Office National de l'Assainissement, Algérie, 2010.

[4] FAOSTAT Food and Agricultural Organization - Agriculture data base, 2011.

[5] B. Lagrange, Biométhane. Tome 2. Principes. Techniques. Utilisations. Ed. EDISUD, 1979, pp. 246, France.

[6] S. Igoud, "Valorisation des boues résiduaires issues des stations d'épuration urbaines pour leur épandage dans les plantations forestières", Numéro spécial de la Revue des Energies Renouvelables, pp. 69 - 74, 2001.

[7] S. Igoud, I. Tou, S. Kehal, N. Mansouri et A. Touzi, "Première approche de la caractérisation du biogaz produit à partir des déjections bovines" Rev. Energ. Ren. Vol 05, pp. 123-128, Décembre 2002.

[8] F. Souahi., N. Mansouri, S. Igoud et A. Hellal, "Optimisation de la production de biométhane. Récents Progrès en Génie des Procédés, N° 92 , Ed. SFGP, 2005, France.

[9] S. Igoud, N. Said And R. Benelmir, "Design and sizing of a digester coupled to an air solar collector", Int Jour Energ Envir Econ , vol. 12, Issu 4, pp. 215-222 , 2006.

[10] S. Kalloum, H. Bouabdessalem, A. Touzi, A. Iddou., M.S. Ouali, "Biogas production from the sludge of the municipal wastewater treatment plant of Adrar city (southwest of Algeria) ", Biomass and bioenergy, Vol 35, pp. 2554-2560, 2005.

[11] Executive decree relating to the diversification costs of electricity production, Official journal of Algerian republic, Nbre 19, mars 2004.

[12] H. Prevot, " La récupération de l'énergie issue du traitement des déchets", Rapport pour le Ministère de l'Economie, des finances et de l'industrie, France, 2000.

[13] H. I. Onovwiona., V.I. Ugursal, "Residential cogeneration systems: review of the current technology". Renew Sustain Energy Rev (10), pp. 389-431, 2006.

[14] IEA International Energy Agency, CO_2emission from fuel combustion highlights, 2011.

[15] Sweepnet, Rapport pays sur la gestion des déchets solides en Algérie, le réseau régional d'échange d'informations et d'expertise dans le secteur des déchets dans les pays du Maghreb et du Mashreq, 2010.

[16] B. Lafarge, Procédés de fermentation méthanique, Ed. Masson. Coll, 1995, pp. 237 France.

[17] M. Tabet-Aoul, "Types de traitement des déchets solides urbains évaluation des coûts et impacts sur l'environnement", Rev. Energ. Ren. : Production et Valorisation - Biomasse, Production et valorisation, N° spécial, pp. 97-102, Juin 2001.

[18] S. Igoud, F. Souahi et A. Sebti, "Evaluation du gisement des déchets solides urbains d'Alger et proposition de leur valorisation énergétique par méthanisation", Conf Int Energ Ren, Algérie, November 2007.

[19] C. Yucheng, A. Pawłowski, "Sewage sludge-to-energy approaches based on anaerobic digestion and pyrolysis: Brief overview and energy efficiency assessment", Renew Sustain Energy Rev, Vol. 16, pp. 1657- 1665, 2012.

[20] R Kothari., V. Tyagi, A. Pathak, "Waste-to-energy: A way from renewable energy sources to sustainable development", Renew Sustain Energy Rev, vol. 14, pp. 3164-3170, 2010.

[21] L. Appels, J. Lauwers, J. Degrève, L. Helsen, B. Lievens, K. Willems, J. Van Impe, R. Dewil. "Anaerobic digestion in global bio-energy production: Potential and research challenges". Renew Sustain Energy Rev, vol.15, pp. 4295- 4301, 2011.

[22] C. Damien, "La bouse : historique, importance et écosystème", Th. Doc., Ecole Nationale Vétérinaire, Toulouse, 2001, France.