

Evaluation of the biogas potential of organic waste in the northern provinces of Morocco

Mohamed Elamin Afilal^{1*†}, Arthur Bakx², Naoual Belakhdar¹ and Yves Membrez²

¹ Laboratoire de Biologie des Plantes et Microorganismes,
Université Mohamed 1^{er}, 60000 Oujda, Maroc
http://sciences1.univ-oujda.ac.ma/Labos/Biologie_Plante.htm

² EREP, SA, Switzerland, - www.erep.ch

(reçu le 18 Novembre 2009 – accepté le 20 Juin 2010)

Résumé - Notre travail se focalise sur la promotion et l'introduction de la technologie de biogaz comme solution innovante de gestion des déchets organiques et aussi comme source d'énergie propre et renouvelable. Dans cet article, nous présentons le potentiel en substrat fermentescible des trois régions de la rive méditerranéenne du nord du Maroc, à savoir: la région orientale, la région Hoceima-Taza-Taounat et la région Tanger-Tétouan avec l'estimation de la valeur énergétique potentiel en biogaz, pour un développement durable de ces communes. Les déchets retenus sont le fumier issu de l'élevage, les résidus des céréales, les déchets industriels et enfin les déchets ménagers et des abattoirs. Le potentiel en biomasse fermentescible dans la région orientale, comprenant les provinces d'Oujda, Berkane, Nador, Jrada et Taourirt, est de l'ordre de 4,8 millions de tonnes/an dont 78 % en déchets d'élevage. Ce potentiel de biomasse peut générer théoriquement plus de 0.09 Mtep/an, sous forme de biogaz. Le potentiel en biomasse fermentescible dans la région Hoceima-Taza-Taounat, est de l'ordre de 7,8 millions de tonnes/an dont 75 % en déchets d'élevage. Ce potentiel de biomasse peut générer théoriquement plus de 0.13 Mtep. Le potentiel en biomasse fermentescible dans la région de Tanger-Tétouan, comprenant les provinces de Chefchaoun, Larache, Tanger et Tétouan, est de l'ordre de 6,7 millions de tonnes/an dont 81 % viendraient de la fermentation des déchets d'élevage. Ce potentiel de biomasse peut générer théoriquement plus de 0.11 Mtep.

Abstract - Our work focuses on the promotion and introduction of the biogas technology as innovating solution to manage organic waste and also as a clean and renewable energy. In this article we present the digestible substrate potential in the form of its biogas energy content present in the three regions along the Mediterranean coastline of Morocco, namely de regions of Oriental, Hoceima-Taza-Taounat and Tanger-Tétouan. The organic waste identified are solid manure from animal keeping, the residues of crop growing, industrial organic waste, household organic waste and slaughterhouse waste. The biomass potential from the Oriental region, including the provinces of Oujda, Berkane, Nador, Jerada and Taourirt is about 4.8 million tons a year of which the manure part represents 78 %. This biomass potential can generate theoretically 0,090 Mtep per year of energy in the form of biogas. The biomass potential from the Hoceima-Taza-Taounat region is about 7.8 million tons a year of which 75 % manure, corresponding at 0,130 Mtep of energy per year issued from the biogas produced during the digestion process. The potential in the region of Tanger-Tétouan is about 6.7 million tons a year (81 % manure) representing 0,110 Mtep of biogas energy per year.

Mots clés: Biogaz - Déchets organiques - Energie renouvelable - Gestion de déchets.

* afilalamin@yahoo.fr

† http://sciences1.univ-oujda.ac.ma/Labos/Biologie_Plante.htm

1. INTRODUCTION

Morocco is limited in its fossil energy resources and is therefore very much dependant on importations of carbon, petrol and even electricity. The dependency on fossil energies is constantly rising, from 93% in 1994 to more than 95% today. The electricity consumption increases at 8 % growth rate a year [1].

To reduce its dependency, Morocco has defined in its National Plan on Renewable Energies and Energy Efficiency (Plan National de Développement des Energies Renouvelables et Efficacité Energétique, 'PNDEREE'), an increase of the contribution of renewable energies at the horizon of 2012 of 20% on the national electricity balance and of 10% on the total national energy balance [2].

Today, thanks to the continuing energy constraints (such as the increase of the national energy consumption and the high costs of fossil energy), the increasing importance of appreciating local potentials, the consequential evolution of renewable energy technologies and its strong global growth resulting in a strong and continuing decrease of its costs, represents for Morocco great advantages to make good use of its renewable sources for significantly representing its part in the national energy balance in the years to come.

The biogas technology has been introduced in Morocco in the beginning of the '80 by installing digesters in use for R&D or demonstration projects. The Chinese and Indian type digesters were mostly used [3, 4].

Morocco has all interest in developing the biogas technology for the treatment of the solid waste and wastewater, because its potential is substantial and it is increasing regularly following the demographic expansion of the country and increase of the living standards [5, 6].

2. THE REGIONS

The Oriental region is the second region of the kingdom in terms of surface. The total surface is 82'820 km², which corresponds to 11.6 % of the total surface of Morocco. The region is composed of one 'prefecture' (Oujda – Angad) and 5 'provinces' (Jerada, Berkane, Taourirt, Figuig and Nador). Its capital is Oujda. The region counts 1'769'000 inhabitants, 6.6 % of Morocco's population, and when spread over its vast surface, giving a density of 21.4 inhabitants/km². Nevertheless, three urban areas accommodate themselves about 2/3 of its population: Oujda, Greater Nador and Greater Berkane.

The agriculture, like everywhere in the country, occupies a considerable place in the regional economy, especially in the northern part where besides cereal growing, industrial cultures, vegetable crops and arboriculture occupy important amounts of surface. In the southern part animal keeping is the dominating activity of the rural society. At the Mediterranean coast, the fishery is prospering, especially due to the production increase at the harbour of Béni N'sar [7].

Thanks to its geographical situation, Tanger-Tétouan is one of the most privileged regions of Morocco, spread over a surface of 11'570 km², 1.6 % of the country, for a population of 2'545'000 inhabitants (density 213 inhabitants / km²). Its capital city is Tanger.

Its flat surface, its important rain fall and fertile soils being able to receive all kinds of cultures, make Tanger-Tétouan one of the most important agricultural regions of the country. Its agriculture is very intensive; with less than 17 % of Morocco's usable

agricultural surface, the region produces up to 40 % of the economical value of the agricultural production of the country.

Its geographical situation and its port infrastructures have facilitated the relations with the exterior, also privileging its industrial and touristic development, making it the second industrial region of the country [8].

The region of Taza-Al Hoceima-Taounate is situated between the Oriental region and the region of Tanger-Tétouan. Its surface is 24'155 km² for a population of 1'830'000 inhabitants (density 75 inhabitants / km²). Its capital city is Al Houceima. Its natural environment is very diverse and rich. Its diversity in relief results in a multitude of climate zones: sub-humid, humid, semi-arid and arid. The region serves as a reservoir zone of subterranean and surface water resources, like the ephemeral streams Inaouen, Ouergha, Rhis, Nekkour.

Agriculture takes an important place in the region with cereal growing and arboriculture, animal breeding (10 % of the national potential). Also the fishery is important, its contribution being estimated at about 19'916 tons a year [9].

3. DEFINITION OF DIGESTIBLE PRODUCTS

Anaerobic digestion is the transformation of organic matter into biogas, principally composed of methane (CH₄) and carbon dioxide gas (CO₂), by a microbial consortium functioning in the absence of oxygen.

In general, almost every non-toxic organic matter can be treated by anaerobic digestion, except ligneous and fibrous materials like wood. Every substance is not equally easily digestible and, also depending on the concentration of organic components, its potential methane production differs one product to another. The dry matter content distinguishes whether it's a liquid or solid digestion.

The following schema indicates the different sources of digestible products/ waste.

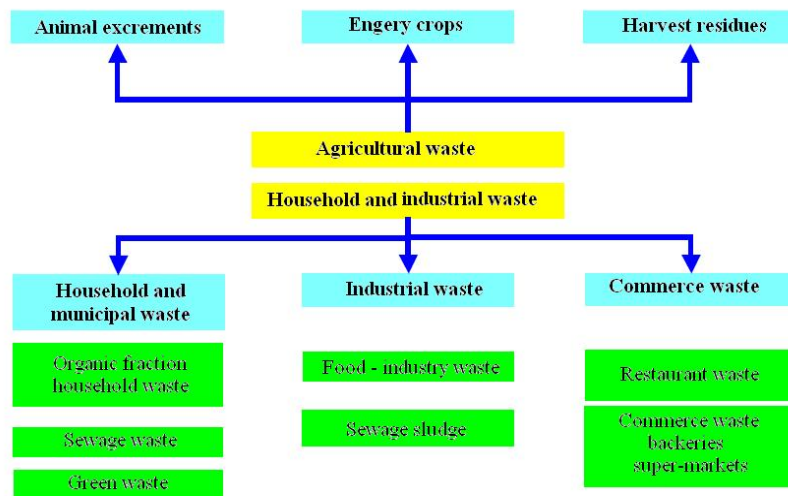


Fig. 1: Schema indicates the different sources of digestible products/ waste

Two principal groups can be defined, notably household / industrial waste and agriculture originated waste.

The latter can be subdivided in animal excrements, energy crops and harvest residues. The three sub-groups of the household / industrial waste are household and municipal waste, industrial waste and waste issued from commercial activities [10, 11].

4. GOALS

Every business is looking permanently to create value. How arriving to create added value? Many enterprises forget however that the waste they are producing can have a high value. It can serve as raw material again [12].

Many studies are interested in the chemical characterisation of organic waste. Some of them had as principal goal the determination of the pollution potential.

In this work the goal is more the evaluation of the energy potential of the waste and so to show the positive side of waste, to consider it as a energy source and not only as source of pollution(13,14).

The study enables us to establish the suitable criteria to take into account in order to determine the potential of any farm or city in our region, serving as a decision making tool.

5. METHOD

The biogas energy potential has been determined in two stages:

5.1- Determination of the quantities of residues and waste in the region, referring to statistic data from different establishments: the monographs of the different regions and the 2008 statistic directory of Morocco. The harvest residues retained are cereal straw, plant residues of leguminous vegetables and sugar beet leafs. The animal excrements taken into account are bovine, ovine, caprine and equine manure. The industrial waste investigated concerns mostly slaughterhouse waste. Figures on industrial waste were taken from other studies [15, 16, 17].

5.2- Translation of the quantities identified into biogas potential, based on literature data and experience feedback, notably data taken from our research partner, the consultancy bureau EREP SA from Switzerland, specialist in the field of biogas [18, 19, 20].

6. RESULTS

The following **Table** shows a summary of the waste quantities found.

Table 1: Waste quantities found

Region	Residues agricultural (T/year)	Manures mobilized (T/year)	Sewage sludge (T/year)	Organic fraction Municipal waste	Slaughterhouse waste (T/year)
Oriental region	1'316'410	1'959'755	1'452	299'702	8'400
Region Tanger-Tetouan	565'670	2'993'845	333	365'161	10'500
Region Al-Hoceima	1'563'160	3'229'860	1'220	280'539	7'900
Total northern regions	3'445'240	8'183'460	3'005	945'401	26'800

In terms of quantity, the amount of manure represents 65 % of the total identified, followed by the harvest residues (27 %), whereof mainly cereal residues in the form of straw. The organic fraction of the household waste represents 8 % of the total.

At regional level, the quantities of secondary sludge from sewage treatment plants, slaughterhouse waste as well as the waste issued from the fish transformation industry when looking at the amount of fish transformed, are negligible compared to the three main types identified.

To determine the mobilization and energy potential of the identified organic waste sources, following elements were taken into account:

- o The prevent the double counting of the amount of straw identified, main component of cereal harvest residues, the data on residue production is not taken into account, because the quantity is already counted into the amount of manure identified, of which straw is a part.

- o The slaughterhouse waste and fish industry waste are put together under the name of industrial waste.

- o The organic fraction of the household waste and the sewage sludge are taken together under the name of urban waste. From the household waste, only the part from urban regions is taken into account, since the collecting in rural zones is more difficult than in urban zones.

- o From the manure, only the production on the farm, so only the part which can be collected easily is taken into account.

The following **table** shows the energy potential of the organic waste identified for anaerobic digestion of the three northern regions of Morocco.

Table 2: Energy potential of the organic waste

Region	Harvests residues (MWh)	Manures (MWh)	Urban waste (MWh)	Food industry Waste (MWh)	TOTAL (MWh)
Oriental region	11'630	999'980	154'900	2'370	1'168'880
Region Tanger-Tetouan	11'450	1'288'390	158'640	2'970	1'461'450
Region Al-Hoceima	18'550	1'426'700	49'270	2'220	1'496'740
Total northern regions	41'630	3'715'070	362'810	7'560	4'127'070

The total energy potential of northern Morocco is estimated at 4'178'060 MWh or 330 ktep, (0,33 Mtep).

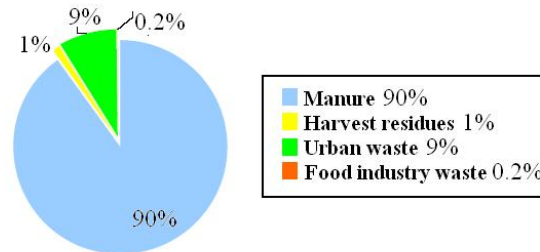
7. CONCLUSIONS

The total yearly theoretical energy potential of northern Morocco is estimated at 4 178 060 MWh or 330 ktep, the energy proportion issued from the manure quantities represent hence 90 % of the total, followed by the urban waste, actually the organic

fraction of the household waste, at 9 %. The harvest residues represent hardly 1 % of the total.

In the rural zones, the main organic product available is manure, in urban regions the organic fraction of the household waste.

According to CDER (National Centre on Renewable Energies), the methane potential in Morocco of animal excrements, the food industry the municipal solid waste and wastewater is estimated at 1 billion m³ of biogas per year, or 500 ktep per year. This corresponds at 4 % of the total energy consumption in Morocco in 2005, which was 1230 ktep (3).



REFERENCES

- [1] M.E. Afilal, M. Auriol et Y. Filali-Meknassi, '*Bilan sur les Sources d'Energie Renouvelables au Maroc. Chapitre du livre, - Les Energies Renouvelables au Maroc – Le débat est lancé-*', UNESCO, 196 p. ISBN: 9954-8068-2-2, 2007.
- [2] Rapport, '*Centre d'Information sur l'Energie Durable et l'Environnement du Maroc, Présentation Générale sur les Energies Renouvelables*', http://www.ciede.org.ma/siedcc/siedcc/InfosTechniques/ENR_PresGen.html
- [3] G. Roller, '*Etude sur le Cadre Organisationnel, Institutionnel et Législatif pour la Promotion des Énergies Renouvelables*', Rapport préfinal – Version longue, Juillet/Décembre 2007, Ref. N°81087707, Project N°2003.3505.9-000.00, Project Title: Renewable Energies and Energy Efficiency Country: Morocco., 2007.
- [4] A. Amahrouch, M. Jlaidi, O. Benchikh et M. Moubdi, '*Maintenance des Digesteurs à Biogaz*', Publié par l'UNESCO et le CDER, Vol. 4, Dépôt légal N°1251/1995.
- [5] M.E. Afilal et A. El Rhammad, '*Valorisation des Résidus de Plantes Médicinales par Fermentation Méthanique*', H. Greche et A. Ennabili (Edition), '*Recherches sur les Plantes Aromatiques et Médicinales*', Actes du Congrès International des 22-24 Mars 2007, Mezraoua (Taounate) & Fès, Maroc, p.276-280, 2007.
- [6] M.E. Afilal, M. Mouncif et A. Benyamna, '*Valorisation des Déchets Organiques par Fermentation Méthanique*', Revue des Energies Renouvelables' CER'07, pp. 9 – 12, Oujda, (2007).
- [7] Document, '*Monographie Environnementale de la Région Orientale*', Publié par le Haut Commissariat du Plan, Royaume du Maroc, 2002 et 2008.
- [8] Document, '*Présentation de la Région Tanger – Tétouan*' sur: <http://fr.wikipedia.org/wiki/Tanger-Tétouan>
- [9] Document, '*Présentation Taza - Al Hoceima – Taounate*' sur: http://fr.wikipedia.org/wiki/Taza-Al_Hoceima-Taounate

- [10] Document, 'Article 3 de la Loi Marocaine, N°28-00 Relative à la Gestion des Déchets et à leur Elimination', Publié par le Ministère de l'Aménagement du Territoire, de l'Eau et de l'Environnement, Dépôt légal: 0336-2007.
- [11] Rapport, 'Définition des Déchets Organiques' sur:
www.science-decision.fr/cgi-bin/topic.php?topic=BUR
- [12] R. Moletta, '*La Méthanisation*', Editions Tec et Doc, Publication Lavoisier, 2008.
- [13] Oleksandr Tretyakov, 'Estimation du Potentiel Energétique des Déchets Agricoles comme Source d'Approvisionnement Décentralisé pour l'Espace Rural, (Exemple de la Région de Kharkiv, Ukraine)', Cyberge, Aménagement, Urbanisme, Article 431, mis en ligne le 14/11/2008, modifié le 26/11/2008.
URL: <http://www.cyberge.eu/index20573.html>. Consulté le 30/11/2008.
- [14] A. Mlaouhi, Z. Alouini et D. Depeyre, 'Evaluation et Perspectives du Potentiel de Biogaz à Partir des Déjections Animales en Tunisie', Revue des Régions Arides, N°14, pp. 115 – 132, 2003.
- [15] M. Rafrafi, E.M. Kabil and B. Droussi, 'Design and Application of an Innovative Composting Unit for the Effective Treatment of Sludge and other Biodegradable Organic Waste in Morocco', Morocomp (Life TCY05/MA000141) 'Annexe 5: Evaluation de la Production des Résidus Agricoles au Maroc', Université Chouaib Doukkali, Faculté des Sciences, El Jadida, 2006.
- [16] Document, 'Annuaire Statistique du Maroc 2008',
- [17] Rapport, 'La Production d'Energies Renouvelables en Milieu Rural en France',
sur: www.france.cuma.fr/dossiers/international/proaerenewsletters/unite-4-biogaz.pdf
- [18] Y. Membrez et C. Tacchini, 'La Situation de la Méthanisation en Suisse', Revue des Energies Renouvelables, CER'07, pp. 19 – 22, 200è.
- [19] Document, 'Données de Bases pour les Méthaniseurs à la Ferme en Allemagne', Edition, Mars 2005 sur : www.nachwachsende-rohstoffe.de
- [20] Etude Record, 'Potentiel et Facteurs d'Emergence de la Récupération du Biogaz et des Gaz Fatais', N°02-0415/1A, 259 p., 2004. (www.record-net.org)