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The Development of Anaerobic Digestion Technology and the Potential of Biogas in Moroccan Regions of Doukkala-Abda, Chaouia-Ourdigha & Tadla-Azilal

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***Abstract*— The lack of energy resources and wastes piles not exploited in Moroccan rural areas, represent major problems that prompt us to develop methods to take advantage of such wastes. The goal of our research is to implement an innovative leading-edge technology for the management and enhancement of rural waste with double stakes: 1- methanisation of organic waste which is a source of a clean and renewable energy. 2- The production of organic fertilizers. I other words, the first step of our work consists of evaluating the energy potential of existing biomass resources in the most famous agricultural regions in Morocco, namely DOUKKALA-ABDA, CHAOUIA-OURDIGHA and TADLA-AZILA, including the provinces of SAFI, EL JADIDA, EL YOUSSOUFIA, SETTAT, BERRCHIDE, KHOURIBGA, BEN SLIMANE, FKIH BEN SALEH, TADLA & BENI MELLAL. The biomass potential from DOUKKALA-ABDA region is about 5, 6 million tons per year. This biomass potential can theoretically generate more than 0,14 'Mtep' of biogas energy per year. The biomass potential of CHAOUIA-OURDIGHA region is about 5,1 million tons per year. This biomass potential can theoretically generate 0,13 Mtep of biogas energy per year. The biomass potential of TADLA-AZILA region is about 5,8 million tons per year. This biomass potential can theoretically generate 0,19 Mtep of biogas energy per year. With a total of 0,46Mtep per year such potential can encourage business executives and investors to establish a biogas network in these regions and; consequently, contribute to the self-sufficiency of energy in Morocco**

Keywords- ***biomass; biogas; energy potential; biogas; renewable energies; waste;***

I. INTRODUCTION

In rural areas, the lack of energy resources becomes a central concern for each country. It is a crisis that involves a considerable human workforce [1]. More than 40% of the population lives in rural areas and whose primary needs keep increasing: cooking, water pumping and the home heating. The problematic and stakes related to energy in rural areas prompt public and private actors to a profound reflection on the vectors of change that can improve the living conditions of rural populations. Methanisation technology was introduced to Morocco in the early eighties by the intermediate of pilot digestor of research and development or demonstration projects. More than 350 digestors have been made to contribute to solving energy problems in rural areas. The volume produced by the digestors ranged between 10 and 180 m^3. Approximately 45% of existing fermenters (digestors) do not work properly mainly due to technical problems: (1) poor construction, (2) lack of maintenance, (3)operators' carelessness, (4) lack trained users (5) bad composition of the introduced mixture [2]. The methanisation is a technique of energy converting of biomass which is considered an important process in the concept of sustainable development. It allows the recovering of organic resources such as: organic waste, agricultural waste, sewage sludge, manure. In order to obtain the biogas (precisely methane) the gas has a high calorific ability that can be used for heating, generating electricity, cooking, or even turned into biofuel, replacing thus fossil energy sources [3] [4] . This current work suggests a the development of this technology for the treatment of and the recovering of rural waste. In the beginning, we carried out a meticulous evaluation of energy potentials of biomass resources existing in regions known for agricultural activities, namely the regions DOUKKALA-ABDA, CHAOUIA Ourdigha-and-TADLA AZILAL, counting provinces: SAFI, El Jadida, EL YOUSSOUFIA, SETTAT, BERRCHIDE, KHOURIBGA, BEN SLIMANE, fkih BEN SALEH, TADLA and Beni Mellal. In the second step of this work, we will proceed with the construction of biogas plants installation in order to develop its operating parameters and optimize its productivity. We chose the region of Khouribga as pilot project then the process will includes all Moroccan countryside [5].

II. BIOMASS AND BIOMETHANISATION TECHNOLOGY

A. Biomass

Biomass is a set of organic substance coming from animals or plants; it is the biodegradable fraction of products, wastes and farming residues (animals and plants substances), of sylviculture and related industries, residues and vegetable waste of industry. We distinguish four main constituents: [6] biomass made up of wood and green waste, glucide/sugar biomass such as cereals, sugar beet, sugar cane, oil producing biomass, rich in lipid/fat like colza, sunflower [7], oil palm tree etc… a fourth axis is that of the recovery of energy (in the form of biogas) in the domestic and industrial waste treatment process [8].

B. Biomethanization

Biomethanization or anaerobic digestion of organic substances is not a new concept. This phenomenon happens when micro organisms decompose the organic substance in anaerobic mode. That is to say, without oxygen and in specific conditions such as the temperature and the pH. These reactions occur naturally in the environment. The marshes and landfills which generate biogas are a good example. Biomethanization technologies tend only to reproduce these reactions under optimal conditions [9].

The byproducts of anaerobic digestion are of course the biogas, as well as the digestat. The biogas consists of 50 to 75% of methane, 25 to 45% of carbon dioxide and of some minor gas (less than 2%), such as hydrogen sulphide [10] (H2S), hydrogen, water, oxygen, ammonic (NH3) and nitrogen. Typically the production of methane is at almost 60%. The biogas can be used to produce heat, electrical energy as it can be injected in a network of natural gas or even be liquefied. The biomethanezation also produces the digestat, a sewage sludge which possesses a solid and liquid phase [11] [12]. The solid phase can be exploited through manuring on agricultural land or it can be transformed into compost. Regarding the liquid phase, it can also be spread on fields as fertilizer or it can be dealt to reduce the charges in organic substance and conventionally be injected in the sewage networks. The digestat contains more or less the same quantity of fertilizers as the intrants, such as azote, phosphor and potassium [13].

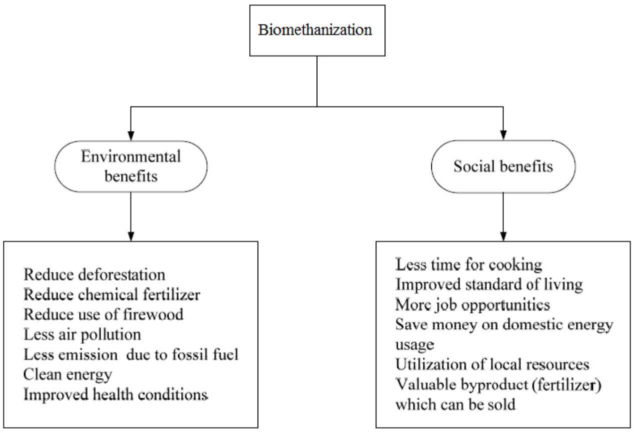

Figure 1. Representation of biomethanization benefits

C. Design and construction of digester

The volume of the digestor essentially depends on retention time (RT) and the quantity of the available substrate. [14]. This quantity must be composed of digested matter and water. The cow dung requires a substance / water mixture with a 1:1 ratio [15].

The retention time (RT)) indicates the time spent by the waste material in the digestor. It is noticeably shorter than the total time required for the complete digestion of feed material [16].

The digester volume (Vd) is calculated according to the formula:

$$Vd\,(l) = Sd\,(l/days) * RT\,(days) \quad (1)$$

$$Vd = 0{,}95 * Vc \quad (2)$$

$$Vc\,(l) = [Sd\,(l/days) * RT\,(days)] / 0{,}95 \quad (3)$$

(Sd) is a daily fermentation slurry arisings,
(Vc) is the volume of construction of the digestor,
(Vd) represents 95% of construction volume (Vc), [17].

On a farm in the region of Khouribga, following the approved model specifications by the national project biogas development such as described in a handbook, [18] we built a digestor with a capacity of 20 m^3 dome (Figure I). Fitted with an irrigation system to ensure a smooth mixture and drain out of gas, and a system of temperature monitoring. Biogas is quantified with a pressure gauge [19]. Biogas product contains water steam which is removed via a pet cock installed at the lowest point of the pipe. The biogas is then purified by removing the H_2S gas through a filter composed of iron oxide. The purified biogas supplies the gas engine that is used to start water pumps for agricultural use [20].

Figure 2. Construction of digester by dome in the region of khouribga

III. REGIONS

A comprehensive study of the regions covered has proven importance in what follows; we identify each region with its riches,

A. Doukkala-abda region

DOUKKALA-ABDA Region covers an area of 13285 Km^2, a 1, 9% of the total area of the kingdom. This region is delimited in the north by Settat province, and in the east by Kalaa Sraghna, in the south and south east by Marrakech city and in the south west by Essaouira province. It enjoys a important geostrategic location with a maritime façade of 350 Km on the Atlantic Ocean.

The DOUKKALA –ABDA region includes the province of Safi, youssoufia, Sidi Bennour and El Jadida with 2 046 000 inhabitants in which 56% are subject to El Jadida province against 44% for Safi province.

The DOUKKALA-ABDA region enjoys significant economic potentials and likely to launch its economic and social development. These potentials are capable of a modern agriculture, in fact, the DOUKKALA –ABDA region has 12,7% of cows, 8,9% of ovines and 1% of gouts, compared to the nation as a whole[21].

Fishing occupies a pro-eminent position in the regional economy. In addition to that, naval construction activity set up in Safi has ranked this city first world capital in sardines.

B. Tadla-azilal region

Situated in the centre of Morocco, between two lands of phosphate and the Atlas in an area of 17125 km^2, TADLA AZILAL region is limited by kalaa Sraghna province and al Hawez to the west, by Khouribga and Settat to the north, Errachidia and Khenifra to the east and Ourzazat to the south.

TADLA-AZILAL region comprises currently 3 provinces: Beni Mellal, Fkih ben saleh and Azilal.

The TADLA-AZILAL population reaches 1516200 inhabitants approximately 4, 6% of the country total population [22].

Agriculture is the dominant activity in the region, it is one of the pillars of Moroccan economy, with agricultural area (SFA) which reaches 259600 ha, representing 80% of the whole land.

Irrigated lands reach 126000 ha. in the region, 49% of (SFA). We notice that on the national level almost 74, 9% of the rural population was involved in this sector and thus taking part in the local market sufficiency by means of food products: cereals, sugar, meat, milk … [23].

C. Chaouia ourdigha region

This region is situated between the Casablanca Marrakech poles, delimited in the east by the Atlantic Ocean.

The region has a surface area of 16751 Km2, that is to say 2, 4% of the total area of the kingdom. This region is delimited by Rabat to the north, and Sale Zemmour Zair Province to the north west, Casablanca to the North east, TADLA AZILAL region to the west, Marrakech province to the South, and DOUKKALA ABDA region to the South east.

CHAOUIA OURDIGHA region comprises nowadays four provinces: Settat, Berrechid, Benslimane and Khouribga. It is considered among the most well-known agricultural regions in Morocco, known for their cereal production and breeding. Farming represents the dominant activity in the region with a utilized agricultural area of 933009 ha, 63% of the land is situated in Settat province, 23% in Khouribga province and 14% in the province of BenSlimane [24].

IV. METHOD

The aim of this work focuses on testing the energy potential of biomass resources existing in the most well-known agricultural regions in Morocco [25], namely DOUKKALA-ABDA, CHAOUIA-OURDIGHA and TADLA-AZILA. This study will serve as a basis in decision making on development of renewable energies in the country.

The determination of energy potential in biogas is carried out in two stages:

A. Determination of quantities of wastes and residues in the regions under study

For this, we made reference to statistics collected by regional agricultural department from different establishments: the monograph of regions, the yearbook of statistics published by the high commission [26].

The study takes into account animals' excreta (bovine, ovine race, goat) which can be recoverable for metanization, cereal residue, leguminous plants, market gardening, agro-industrial residue, the organic fraction of household refuse [27] [28].

B. Calculation of energy potential and potentail in biofertilizers

The calculation is carried out by applying to the quantities of raw materials a specific biogas yield. So it is expressed in KWH of energy under the form of biogas per ton of fresh substance [29].

V. RESULTS AND DISCUSSION

Many studies focus on the determination of the pollution potential of organic waste; however they may have great value, by recycling and using them as a feedstock.
Our goal in this work is the evaluation and establishment of appropriate to take into account in determining the energy potential of waste [30].
The following chart shows a summary of the quantities of waste.

TABLE I. THE QUANTITIES OF THE LISTED WASTE OF THE REGION

regions	Agricultural Residues (T/year)	Mobilized Manures (T/ year)	Sludge Sewage	Organic F Municipal waste(T/ year)	Slaughter-hous waste(T/ year)
Doukkala-Abda	2425181	2988927	2671	220968	4098,5
Chaouia-Ourdigha	1826844,3	2990429,1	2158	265980	12418,4
Tadla-Azilal	1124231,4	4364630	1584	205344	5725,6
Total of regions	5376256,7	10343986,1	6413	692292	22242,5

In quantity the manures represent 63% of the whole, followed by residue of harvest 33% in which cereal residue and the organic fraction of the household waste many represent (4 %)
At the level of the studied region, the quantities of 'STEP' sewage sludge and Slaughterhouse waste are insignificant.

A. *Total potential of methanization*

In order to give the equivalent of agricultural residues in biogas we tok into considerations the following points:

- The use of straw is integrated in the manure, given the fact that the straws are mainly composed of cereal residue. For this reason, we will not take into account the figures provided for the production of residue of cereal harvest.
- As to the Slaughterhouse residues, we take only stercoral substances and not the blood because of a hygienization to be implemented. The stercoral substance represents 88,2%
- Fish and Slaughterhouse waste are put together under the label of agri-food industry waste.
- The fermentable fraction of household waste and 'STEP' sewage sludge are put together under the label urban waste.
- Given the fact that the produced part of organic fraction of household waste in rural areas is difficult to get back, we considered only the collected part in urban areas. For this reason the quantity decreased by half.

TABLE II. PRESENT THEORIC ENERGETIC POTENTIAL OF ORGANIC WASTE FOR METHANIZATION.

region	Agricultural Residues (MWh)	Manure (MWh)	Organic waste and Sewage sludge (MWh)	Fish and Slaughterhous waste (MWh)
Doukkala-Abda	**54462,3**	**1473541**	**53409,1**	**17586,1**
Chaouia-Ourdigha	**14224,05**	**1474281,6**	**63789,8**	**4425,8**
Tadla - Azilal	**29650,5**	**2151762,6**	**49208,8**	**2040,6**
Total	**98336,85**	**5099585,2**	**166407,7**	**24052,5**

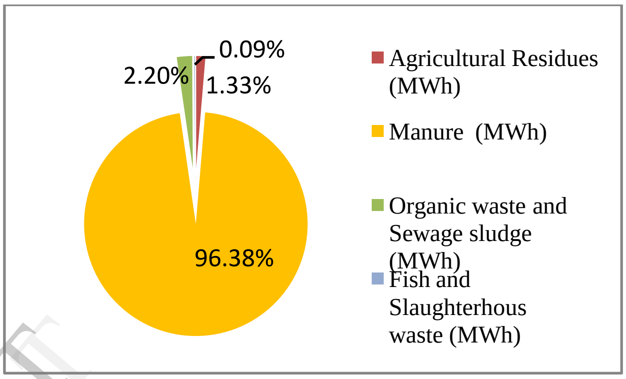

Figure 3. Potential of organic waste for methanization

The energy proportion stemming from the manure represents thus 96,38% of the whole, followed by agricultural waste, with 1,33%. The residue of harvest without cereal represents only 1% of the total energy potential.

VI. CONCLUSION

The use of renewable energy is obviously not new. It's the discovery of fossil fuels which has been the cause of their marginalization. Since then, multiple pollution, global warming, the risks of nuclear energy made people aware of the need for a sustainable economic development which respects the environment. Morocco enjoys a high potential of renewable energies which can respond to all energy needs without contributing to global warning. A part of the country richness is figured through this study which shows that the total theoretic energy potential of DOUKKALA-ABDA, CHAOUIA-OURDIGHA and TADLA-AZILA regions is estimated at 5'388'382, 25 MWH or 572015100,84 m^3 of biogas or 0,46 'Mtep' per year of biogas energy. Such encouraging potential will surely motivate great business executive and investors to develop biogas network in this regions and contribute to the independence of the country from consuming energy.

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