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Bioenergy potential from agriculture residues for energy generation in Egypt

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ABSTRACT

Recently, biomass represents about 14% of primary energy consumption and expected to provide 50% of world total primary energy consumption by 2050. This paper clarifies an appraisal of the possibilities available in Egypt to become one of the countries of the production of bioenergy, especially from the crop remnants of agriculture production. Egypt annually produces a large amount of biomass of up to 40 million tons. Unfortunately, instead of the possibility of exploiting these wastes to contribute to the energy sector and economic growth, about 52% of these wastes are disposed of by direct burning, which may cause many environmental problems. The only widespread form of biomass use in Egypt is biogas used in rural areas. In addition, the potential theoretical energy from the most important crop residues available in Egypt is evaluated according to previous studies. It is found that energy of 189.76 PJ/year can be produced from dry crop residues of 12.5 million tons/year. For livestock residues, specifically cattle manure, it is estimated in this study that the potential biogas in Egypt of 7.2 million head of cattle is 53.2 million m^3 / day with a total potential energy of 699 TJ per year. However, the potential of bioenergy depends largely on the availability, geographical distribution and accessibility of the actual waste. The most likely areas for these potentials are Middle Delta and Upper Egypt. This could potentially develop a long-term strategy for the smart use of vital waste available for bioenergy production to be economically profitable and sustainable.

1. Introduction

Since the beginning of the 21st century, the global energy demand has increased dramatically as a result of industrial development and population inflation around the world. Fossil fuel (coal, oil and natural gas) is the main source of energy that considered limited source and susceptible to run out [1,2]. About 80% of the total energy used worldwide is derived from fossil fuels and 20% from renewable energy sources [3], which are represented in wind farms, solar power, hydropower and bioenergy plants. The importance of this renewable sources represented in reducing the reliance on fossil fuels, reducing carbon emissions and increasing energy security [4,5]. These sources have the ability to maximize the system overall efficiency [6]. Bioenergy has all the possible characteristics to face the challenges associated with increasing the use of fossil fuels and to reduce greenhouse gas emissions [7,8]. It is considered a vital and reliable source of energy [9]. Bioenergy can be obtained from a variety of raw materials available in different forms [10].

Global biomass production has been estimated at 146 billion metric tons [11]. The use of bioenergy and the type of production varies from country to country [12]. In developed countries, bioenergy is used to produce electricity or liquid energy [13]. Europe uses biomass for bioelectricity production, which produces about 196 TW h using combined heat and power plants [14]. In developing countries, bioenergy is used for cooking and heating [15]. About 79% of the world's total biomass conversion to thermal energy is from Asia and Africa [16].

To convert biomass into energy, it needs certain techniques which sometimes are complex [14]. There are many criteria that must take into consideration to choose the right technology such as; techno-logical robustness, environmentally harmless, and social admissibility [17]. Biomass gasification is considered the enabling technology for modern bioenergy conversion systems [14].

America, Germany, Spain and Denmark have great experience in biomass co-generation and CHP plants [18]. Since 2010 the use of biomass for energy production has increased by 2% per year. In 2015, the total energy demand from biomass was about 60 exajoules (EJ) [19].

Germany now is one of the most important countries that have been able to exploit the energy in the production of electric energy. In 2013, the electricity production rate of bioenergy reached about 7% and this

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percentage is increasing annually [20]. In Spain, biomass potential represents 20% of the total primary energy demanded. There are many practical studies on olive oil industry wastes as a source of biomass for generating electrical and thermal energy [21–23]. Many researchers have also focused on wood biomass, which can be converted into different forms of energy (electricity, heat, bio-fuels) and is widely available in most countries of the world [24–27]. The world's three largest practical biomass power plants are the Ironbridge power plant located in the UK with 740 MW capacity, the bio-fuelled power plant located in Finland with 265 MW capacity and the Polaniec biomass power plant located at Polaniec in south-east Poland with 205 MW capacity [28].

Biomass systems for gas-based electricity are acquiring a number of potential advantages [29]. Its operational efficiency is much higher than direct burning systems in merchant use and is comparable with high-efficiency coal-based systems [30]. In addition, it reduces the CO_2 emissions and presents an attractive manner to use agricultural and forestry remnant that can renew rural economies and decrease power dependency [18,31].

Egypt is one of the countries that has a lot of untapped energy sources. The available energy resources are limited to the oil and natural gas that feeds the power plants [32].

Each year, Egypt produces huge amounts of solid wastes. In 2012, this quantity reached 89 million tons / year and still increasing [33]. These wastes could be a hidden treasure for countries, if used optimally. Solid wastes can be recycled and used as energy source rather than disposed in landfills or burned [34]. Due to the need for alternative sources of energy, converting these wastes to energy is the best solution for energy generation and waste disposal.

Although Egypt has significant potential for biomass energy resources, few studies have been conducted on bioenergy and its applications in combined power and heat plants in Egypt. Said et al. [35], has studied the biomass situation and its potential energy in Egypt. This study has included agricultural waste, municipal solid waste, animal waste and sewage sludge as sources of biomass. Nakhla et al. [32] has presented Egypt's various resources of biomass and the efforts in exploiting this biomass as energy projects. Some studies have focused on specific types of biomass and the possibility of converting it into electric and thermal energy as discussed in [36,37].

On the other hand, there are many small projects across Egypt where, the farmers use bioenergy as an environmentally friendly and cost-effective way to fertilize their farms and provide cooking gas for their homes. These small projects called biogas where animal fertilizer and crop residues are used and converted to methane. After methane production, the waste is converted to fertilizers used for fertilizing agricultural land [38].

In this paper, the status of bioenergy produced from agricultural waste and its important role in improving the energy situation in Egypt are comprehensively discussed. The main objectives of this study can be summarized as; (i) A review of the status of bioenergy in Egypt; (ii) Discussion of the electrical situation in Egypt, which produced from different renewable or non-renewable resources, (iii) Discussion of the Egypt's potential of agricultural residues in order to understand the current stage and its available amount, (iv) Evaluating the potential energy of available residues and review of the most important conversion technologies that used to convert the biomass into different forms of energy.

The rest of the paper is organized as follows: Sections 2 and 3 presents the general state of electrical energy and its sources in Egypt. A review of the biomass potential (crop residues and the production of livestock residues) in Egypt is presented in Section 4. Section 5 presents a review of the most important conversion technologies that used to convert the biomass into different forms of energy. Finally, the conclusions are presented in Section 6.

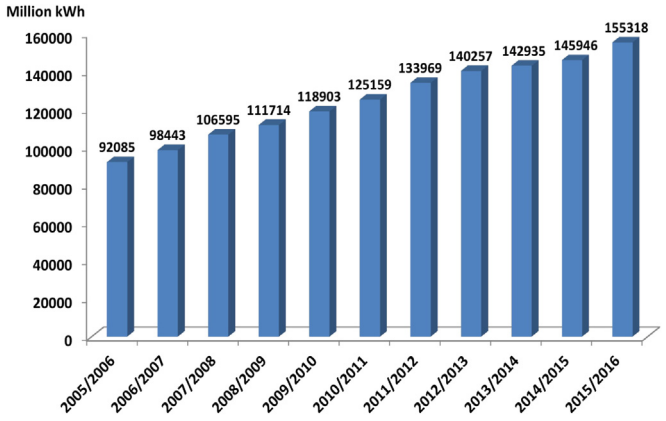

Fig. 1. Evolution of the amount of electricity consumed in Egypt from the period 2005 to 2016 [42].

2. Electrical energy status in Egypt

The increase in energy production in Egypt has become more important in recent years, especially with the exacerbation of power cuts, which peaked in 2014 due to the increased consumption and decline in natural gas production [39]. In this section, the situation of consumption and price of electricity in Egypt will be acquainted.

2.1. Electrical consumption

Egypt was an energy exporter for decades. It is one of the largest producers of oil and gas in Africa until few years when the amount of energy consumption has significantly increased [40]. The evolution of energy consumption in Egypt from 2005 to 2016 is shown in Fig. 1. From this figure, It can be observed the total electricity consumption increased by about 92,085 million kW h in 2005/2006 to about 155,318 million kW h for the year 2015/2016 with cumulative increase of 68.67% [41,42]. About 49.36% of total energy consumption for 2015/2016 consumed in economic activities only and about 47.23% was in household consumption, as shown in Fig. 2. [41,42].

2.2. Electricity price

Egypt's energy sector has recently faced a variety of conflicting and interrelated challenges [43]. The rise in electricity prices in recent years is considered one of these challenges. The average increase in the 2017 bills from the previous year 2016 was about 27% as shown in Fig. 3. From 0 to 200 kW h this represents low use bracket, from 201 to 350 kW h, it represents average use bracket, and from 351 to + 1001 kW h, it represents the high use bracket [44].

3. Electrical resources in Egypt

Different types of energy resources that used to generate electricity, whether non-renewable or sustainable. The average growth rate of the installed capacity during the period 2011/2012–2015/2016 is given in Table 1 [45]. It is clear that the electrical energy generated from renewable energy in Egypt is very weak compared to other sources of energy. The majority of Egypt's electricity supplies are generated from thermal stations (combined cycle, steam and gas) [42,45].

3.1. Non-renewable sources

Most of the electricity sector in Egypt heavily depends on fossil fuel materials. Table 2 depicts the energy profile in Egypt during the period from 2014 to 2017 [46].

Since the late twenty century, Egypt became the largest consumer of