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Viability Study of Biomass Power Plant Fired with Rice Straw in Egypt

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Abstract

This paper investigates the potential of rice straw for producing energy in Egypt. It is estimated that about 3.1 million tons/year of rice straw are disposed by burning directly in the open field causing environmental problems. The present study was undertaken to assess the performance of rice straw power plant to specify the amount of the power, and GHG mitigation relative to the disposal rice-straw in energy production. The results indicate that rice straw can provide an annual net electric energy output of 2,447 GWh/year. The plant can reduce CO_2 emissions of (1.2 M ton CO_2/year).

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Keywords: Biomass power plant; Agricultural residues; Rice straw; life cycle co_2 emissions; Egypt.

1. Introduction

In the three past years, Egypt witnesses discontinuity in electricity service, especially in the summer where millions of air-conditioning units and fans, pile additional pressure on the power system. Egypt depends mainly on the Egyptian Electricity Holding Company (EEHH) for the electricity service. Moreover, the electricity generation plant is fed with oil (17%) and natural gas (83%) [1]. Therefore, the power shortfall problem has been exacerbated by declining of the Egyptian crude oil production and

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natural gas reserve Fig.1 [2]. Furthermore, the energy sector is the largest source for the GHG emissions contributing by 46% of the national carbon emissions at the end of 2010 [3]. Nevertheless, Egypt has a great potential of renewable energy sources, especially solar, wind energy and biomass [4, 5, 6], but their overall contribution is still very limited [1]. As a result, the Government of Egypt is pursuing a strategy plan aiming to achieve a contribution of renewable energies by 20% of the total electricity generation by the year 2020, and to diversify its energy source through the development of new and renewable energy resources.

Egypt has a good potential for biomass resources but very limited work has been done to quantify this potential for power generation. The main sources of biomass waste in Egypt are agricultural waste (crop residues), followed by municipal solid waste, animal waste, and sewage waste [7]. Wheat, maize, rice and sugar cane are crop residues major sources (see Table 1). In particular, rice straw represents the largest amount of unutilized crop residue. According to FAO, Egypt is the largest producer of rice in Africa, with supplying 5.9 million tons of rice in 2013 (more than 22% of rice production in Africa) [8]. It is estimated that about 3.1 million tons/year of rice straw are disposed by direct burning in open field (see Table 1). Therefore, it is interesting to study the option of establishing a rice straw fired power plant in Egypt. Despite the presence of many studies for utilization of rice straw for power production in many countries in the world [9], the main objective of the present paper is to make a first evaluation regarding the feasibility of a rice straw fired power plant in Egypt. However, the proposed plant aims to quantify the amount of power produced from 3.1 million ton of rice straw, annual and monthly energy production, as well the GHG mitigation from the disposal rice-straw in energy production.

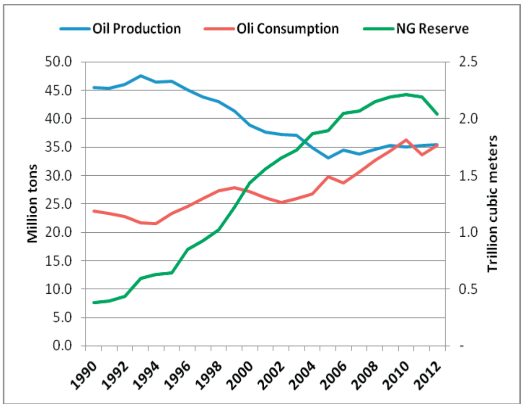

Fig. 1. Egypt oil production and consumption, NG reserve 1990-2012.

Table. 1. Rice straw viability in comparison with the others four major crops residues in Egypt

Crop residues	Production (million tons/year) [7]	Current usage	Un utilized amount (million tons/ year)
Rice straw	5.0	Few amount for animal fodder and Composting	3.1
Wheat straw	8.2	Almost totally used as animal fodder	0.082
Maize residues	6.7	Almost totally used as animal fodder	0.67
Sugar cane residues	4.8	Used as fuel in sugar factories	0.69
Cotton stalks	1.3	Fuel in rural area	0.65

2. The plant specifications

Rice straw production is concentrated in the Delta region in Egypt (see fig (A.1)), where Delta region contributes by 99.5% of the Egyptian rice production. In particular, the following governorates: Dakahlia, Kafr El Sheikh, Sharkia, Behera, and Gharbia, are the largest rice cultivation areas respectively (see fig (A.2)) [10]. The plant is assumed to be located in the center of Delta region. This allows minimizing the transportation cost of rice straw. Fig.2 shows the plant layout and components. The rice straw is delivered to the plant in rectangular bales where storage bales accommodate extra rice straw that is not immediately fed to the plant. Rice straw's moisture content has a big role for determining the plant performance and efficiency; it is highly variable and dependent on the weathers condition of the plant location. In the present study the maximum value of the moisture content (20.5%) for the Egyptian rice straw bales [11] is used to simulate the plant model. The rice straw is completely burned out in the furnace and the ash is collected in the ash container and sent back to the fields to be used as fertilizer. In this study, the grate furnace fired boiler is used for the plant modeling. Grate furnace is the most relevant technology when using rice straw as fuel for power and heat production [12]. The flue gas passes through the super heater and economizer heating up the water/steam for the turbine. The flue gas is cleaned in the filter and then sent to the stack.

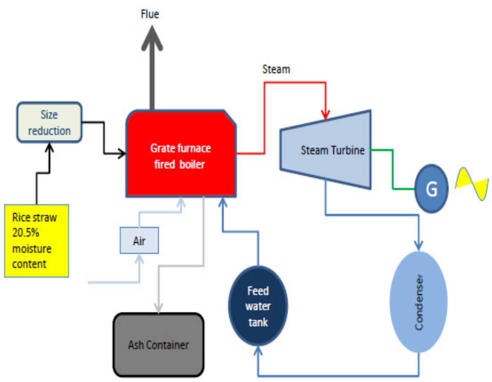

Fig. 2. Rice straw power process flow diagram.

Table 2 Plant specifications data.

Rice straw	Quantity [million ton/year]	3.1
	Carbon [%] [9]	38.24
	Oxygen [%] [9]	36.26
	Hydrogen [%] [9]	4.88
	Nitrogen [%] [9]	0.87
	Moisture content [%] [10]	20.5
	Higher heating value(HHV)[MJ/kg]	15.6
Output	Annual energy output [GWh/y]	2,477
	Ash amount [ton/y]	155000
	Net heat rate in [MMBtu/MWh]	13.94
	Boiler efficiency [%]	72.2
	Net thermal efficiency [%]	24.5

3. Results and Discussion

The analysis of the energy yield and the life cycle emission of the proposed biomass power plant have been carried out using National Renewable Energy Laboratory's (NREL) SAM software [13]. The specifications and output data of the plant are shown in Table 2. From this table, the calculations indicate that the unutilized amount of 3.1 million tons/y of rice straw are able to produce 2,477 GWh/y of electric energy. As a result, the electricity produced in the plant can be used for fossil fuels use reduction. Based on the country- fossil fuel consumption for electricity generation of 230 toe/GWh [1], the plant could be able to reduce the use of fossil fuel by amount of 569,710 toe/year. The variation of the monthly net energy production of the proposed rice straw plant is shown in Fig. 3. It can be seen that the monthly production is nearly constant. The results show that the high power amounts are reached over the year in autumn season. The lowest amount is in winter season (minimum in February). This is due the boiler surface heat losses are depending on the ambient wind velocity and temperature difference between boiler surface and ambient [14]. When wind velocity increases and ambient temperature decreases surface loss increases and the boiler efficiency is decreased. The results indicate that the plant can provide significant amount of ash about (155000 ton/year) that can be used in fertilizing process.

3.1. Power Plant life cycle analysis (LCA) of CO_2 emissions

Rice straw electricity generation is considered carbon neutral (zero emissions) as CO_2 emissions generated by combustion is generally absorbed during the lifecycle of the rice production. However, the LCA model calculates the greenhouse emissions for the rice straw supply chain which includes the transportation and the preprocessing of the rice straw. The greenhouse emissions of the proposed rice straw-fired plant are shown in Fig.4. The model assumes that rice straw was not dedicated to power but is residues food cultivation. Therefore CO_2 emissions due to cultivation and harvesting are neglected. It has been assumed that the maximum distance to transport the rice straw from the farm gate to the power plant is 75 mi. Also we assume that Diesel-powered vehicle for truck transport. The results show that the plant LC emission of 10.9 g CO_2 kWh^{-1}. Life cycle GHG emissions of rice straw to electricity production are compared to the existing fossil energy systems in Egypt. Based on the country-specific emission factor (EF) of 450 g CO_2 kW h^{-1} [15], the plant can reduce CO_2 emission by 439 g CO_2 kWh^{-1}. In addition, local air pollution of 3.2 million tons of CO_2 from direct burning of rice straw [10] could be mitigated by using rice straw as energy source.

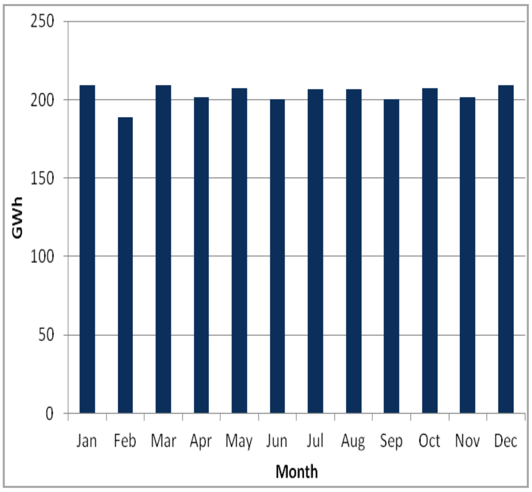

Fig.3. Plant monthly output energy

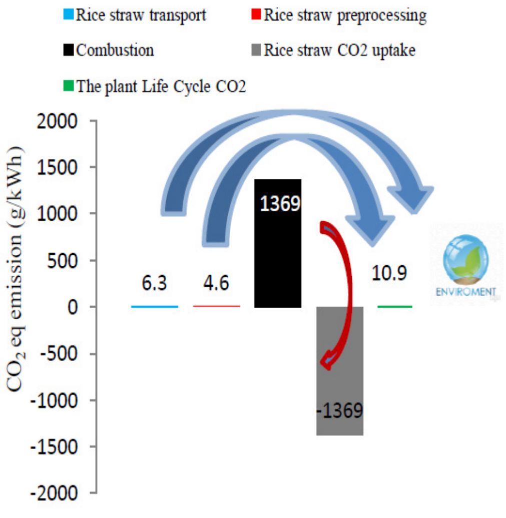

Fig.4. Rice straw power plant life cycle assessment

4. Conclusion and Recommendation

Energy generation using rice straw offers a promising solution to environmental and energy problems by reducing the emission of common greenhouse gases and saving in fossil fuel demand. The analyses have shown that it is technically viable to build up power plant using rice straw in Delta region in Egypt. This could allow reducing dependency on fossil fuels as well reduction of greenhouse gas emissions. However, there are a number of uncertainties connected to the plant that need to be further clarified before the plant can be realized. Uncertainty regarding rice straw availability requires that the plant can operate at different capacity and uncertainty of resulting electricity price making that an economic feasibility study is indispensable in order to determine the price of the electricity generation and the conditions which make this technology profitable and economically feasible.

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Biography

Suzan Abdelhady is a Research and Teaching Assistant in Electrical Engineering Department, Fayoum University, Fayoum, Egypt. Currently, she is conducting her PhD research in renewable energy technologies at the University of Rome 'La Sapienza', Rome, Italy. Her research interests are in assessment of renewable energy potentials in Egypt.

Appendix A

Fig (A.1). Rice cultivation area in Egypt.

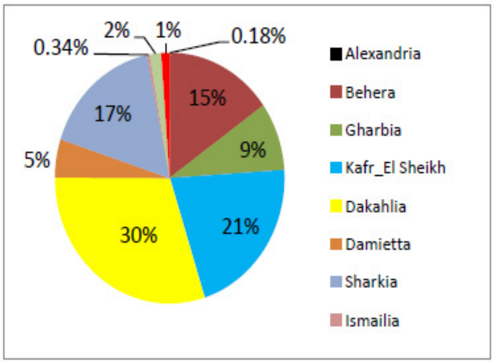

Fig (A.2). Distribution of the rice cultivation in Delta region in Egypt.