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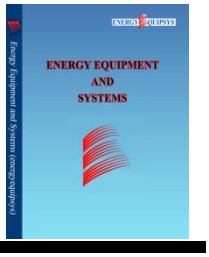

Valorization of municipal solid wastes through biogas production in Iran

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ABSTRACT

Iran is a developing country with a population of over 80 million. The total daily MSWs production in Iran is about 50 million kg. Most of the MSWs in this country is being disposed of in the landfills. Some of the landfills are located in the urban area or near to sea, river, and forest. In this regard, the management of MSWS becomes a concern in Iran. One solution to manage MSWs and mitigate their environmental impacts is to capture the biogas production. Thus, this research presents the potential biogas generation from MSWs in Iran. The findings of this study illustrated that Iran's daily energy generation potential from MSW is equal to 31,676 barrels of crude oil. The yearly biogas potential generation from MSWs resources is equal to 13.4 million barrels of crude oil equivalent. Overall, the results of this research show that there is a tremendous potential to generate energy and reduce the environmental impact of MSWs in Iran through converting them to the biogas.

Keywords: Energy Production, Environmental Impacts, Renewable Energy, Resource Conservation.

1. Introduction

Iran is a developing country with a population of over 80 million [49]. This country is the fourth tremendous producer of crude oil and natural gas all over the world [4]. Figure 1 shows the percentage of energy production from different resources in Iran. Approximately, 99% of energy generation resources in this country supplies from non-renewable and only one percent from renewable-based resources. Figure 2 illustrates the contribution of different sectors in total energy consumption in Iran [30]. The transportation sector consumes the highest percentage of energy use in Iran.

On the other hand, Iran has an enormous potential for using renewable energy resources like biomass, solar, wind, and geothermal [46]. Biomass is one of the main renewable energy resources and is considered a sustainable energy resource [50]. 59.2% of total renewable resources in the European Union in 2015 belongs to Biomass [44]. The global potential of energy generation from biomass is estimated 8-fold larger than the total world energy demand [3]. Figure 3 illustrates the potential of bio-energy generation from biomass wastes in Iran.

Biomass resources can be divided into three different categories including first, second and third generations [31]. The ideal feedstock for biofuel generation should be low cost and emissions and high yielding; first-generation biofuels are against the food security and the greenhouse gas savings is less in the first-

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generation biofuel compared to the second and third generations [9]. The main technologies applied to convert biomass to energy are biochemical such as biogas, biodiesel, and bio-ethanol or thermochemical such as gasification and pyrolysis.

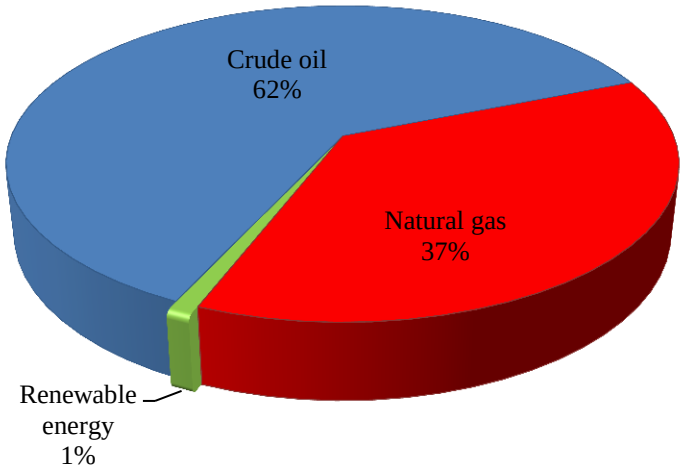

Fig. 1. The percentage of energy generation from various sources in Iran [34]

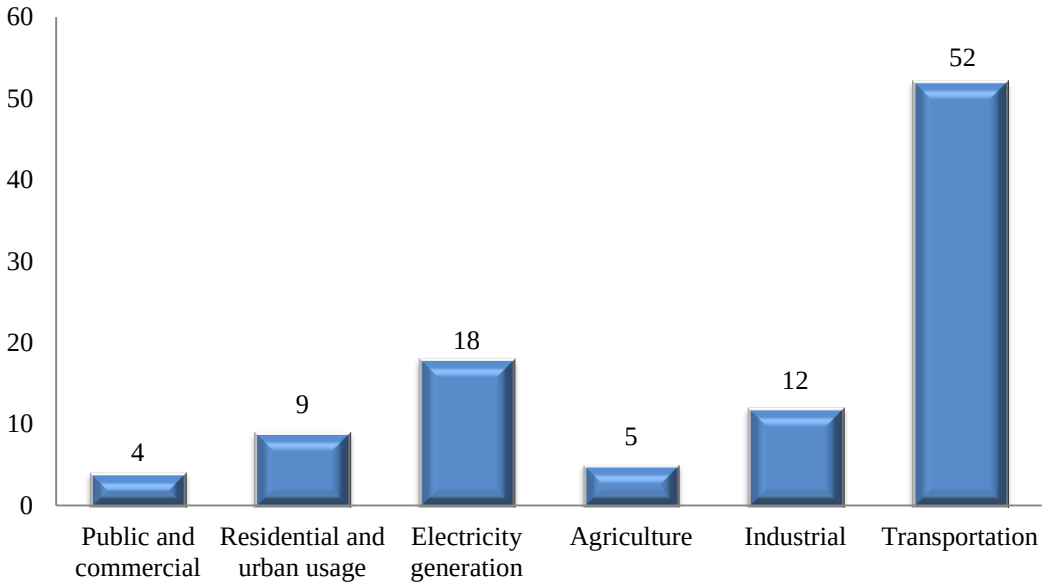

Fig. 2. The contribution of different sectors in total energy consumption in Iran [30]

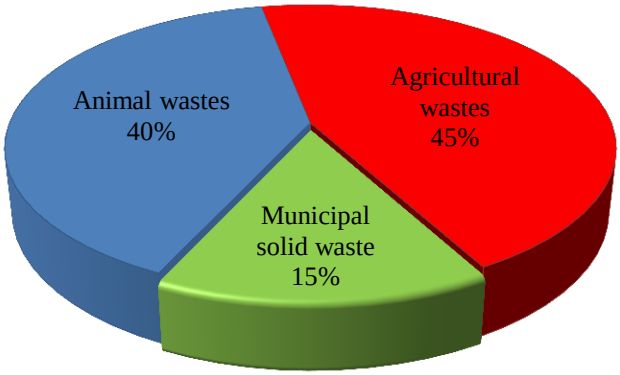

Fig. 3. Potential of bio-energy generation from biomass wastes in Iran [19]

2.Environmental impacts in Iran

Iran is facing several environmental challenges like fossil resource depletion, large amounts of pollutants emissions, water scarcity and industrialization [14,16]. Iran has a heavy dependence on fossil fuel recourses and its economy mostly relies on fossil-based products [2]. Consequently, this country is among the ten countries with the largest quantity of GHGs and also has the greatest amongst the Middle East countries [40, 45]. So, this country has faced with some major environmental challenges [35]. Figure 4 illustrates the GHG emissions in Iran for a period of eight years starting from 2006. The quantity of yearly GHG emissions per farmer in Iran was reported to be 7.6TonCO_2eq (Ministry of energy of Iran, 2013).

3.Municipal solid waste management

Municipal solid waste (MSW) management is typically referred to waste collected by local authorities or municipalities [20]. It generally includes household, garden and commercial wastes [43]. According to the report of the World Bank in 2012, it is estimated that the yearly global MSW production to be 1.3 billion tonnes with a daily average of 1.2 kg per capita and it will reach 2.2 billion tonnes per year by 2025 and 4.2 billion by 2050 [18,12]. MSW management is a major environmental challenge in both developed and developing countries [28].

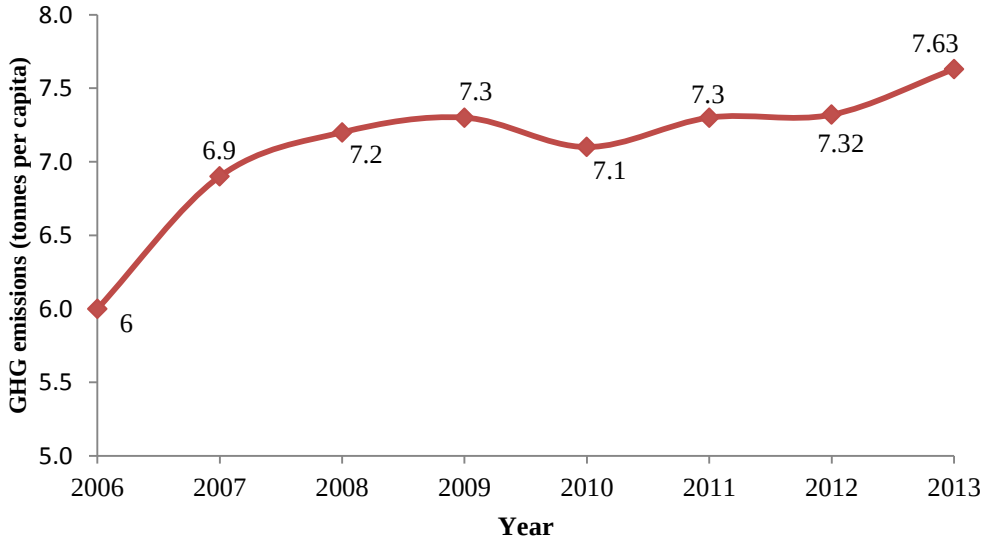

Fig. 4. GHG emissions in Iran from 2006 to 2013 [36]

So, quantification and characterization of MSWs are one of the crucial elements of its management strategy [51]. Figure 5 illustrates the different MSW management methods. Rajaeifar et al. (2015) studied the various MSW management scenarios namely i) anaerobic digestion, ii) landfilling combined with composting, iii) incineration, IV) incineration combined with composting, and V) anaerobic digestion combined with incineration. The results indicated that the last scenario was the environmental scenario to manage MSWs.

MSW landfills are the third-greatest source of methane emissions in the US produced by human activity, with the share of about 18.2% in 2012 [41]. Resource conservation and the need for mitigation of environmental impacts associated with energy production from fossil fuels resources have increased the attention to renewable energy sources like biogas [22,17]. In some country like Malaysia, retrofitting current landfills to recovery methane is of great interest due to it needs less investment and time compared to the standard energy generation waste incinerator [12].

4.Municipal solid waste in Iran

Iran has a population of 80 million [49]. The MSWs generation rate in this country has increased in recent years [42,52]. The increase in the quantity of MSW mostly caused by rapid population growth, economic development, industrialization, and urbanization [24]. The total daily municipal solid waste production in Iran is about 50 million kg. A significant amount of MSWs is recyclable in Iran; however, only 8% of them is recycled [6]. Most of the municipal solid wastes in Iran are disposed to various landfills across the country [13]. Currently, some landfills in Iran are using biogas recovery systems including Shiraz and Mashhad sites [29].

5.Biogas

Biogas is a renewable fuel with 60-70% methane, produced by anaerobic digestion of organic materials via synergistic metabolic activities of hydrolytic, acidogenic bacteria and methanogenic archaea [21,23,47]. The process occurs in four phases including hydrolysis, acidogenesis, acetogenesis, and methanogenesis [32]. Figure 6 demonstrates the anaerobic digestion process. Upgraded biogas can be applied to all applications designed of natural gas, and it is well known as an eco-friendly alternative fuel, which can reduce natural gas and oil.

Table 1 displays the biogas production in some leading countries. In some countries, corn is cultivated largely for biogas production [38]. Germany and Italy, the pioneers of biogas technology in the world, cultivate more than 2,282,000 and 1,172,000 ha of corn annually just to be co-digested in large farm biogas plants [8].

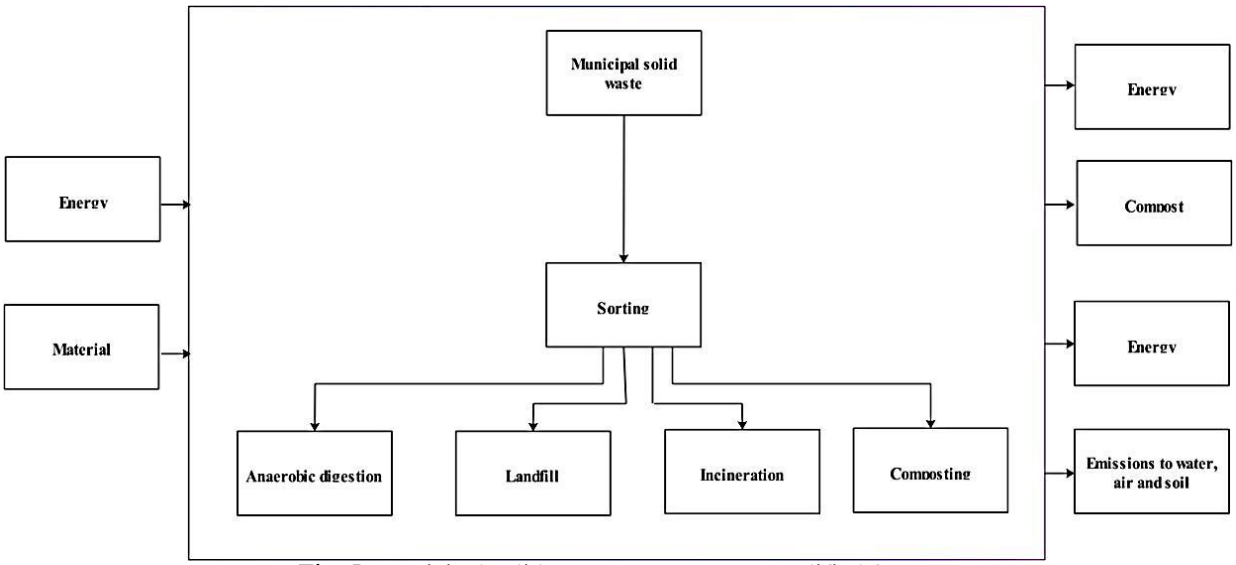

Fig. 5. Municipal solid waste management; modified from [43]

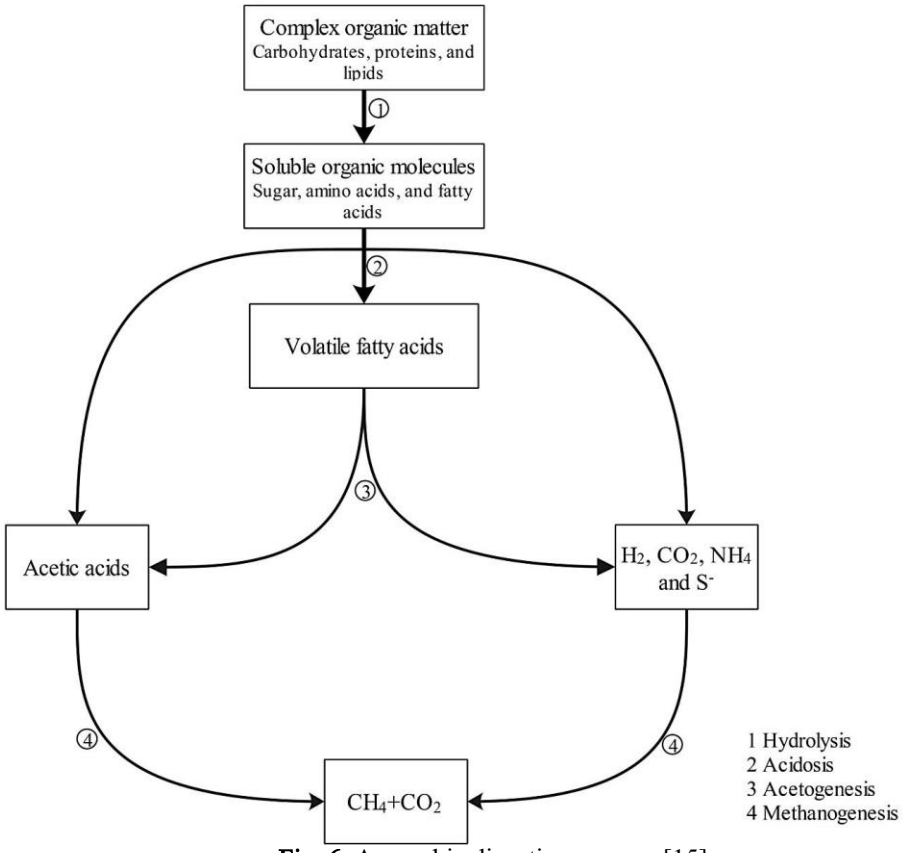

Fig. 6. Anaerobic digestion process [15]

Table 1. Biogas production in some leading countries [26,48]

Country	Biogas production (billion m^3)	Year
China	15	2014
Germany	13.5	2013/14
United States	8.48	2014
UK	3.16	2013
Thailand	1.3	2014
India	0.81	2014
Canada	0.79	2014
The Netherlands	0.52	2012
Korea	0.43	2013
Brazil	0.29	2013

6.Current status of biogas generation in Iran

The possibility of energy production from biomass in Iran is equal to 140 million barrels of crude oil which were reported to be 13% of total crude oil production in Iran in 2010 [29]. Noorollahi et al. (2015) studied the potential of biogas production from Iranian livestock manure and they reported that there is a considerable opportunity to produce renewable energy from this recourse in Iran. Despite the great potential and advantages of biogas production in Iran, there has not been much attention paid to the development of this technology [32]. There are only some landfills like Mashhad, Tehran, and Shiraz which are recovering biogas [43].

7.The potential of biogas production from MSWs in Iran

Biogas can be used to a wide range of industries, which can save fossil fuels consumption [39]. Biogas is accounted for a remarkable percentage of renewable energy consumption in the world [53]. Germany, with

8,726 bioreactors plants is the greatest producer of biomethane in Europe [10]. Italy is the second greatest producer of biogas in Europe with 1,700 bioreactors plants [5,33]. There are around 4 and 27 millions biogas plants in India and China, respectively [7]. In Austria, about 400 agricultural bioreactors plants are currently used [1,25].

MSW management has been one of the most important environmental challenges throughout regions of Iran [27,41]. The total daily MSWs production in Iran was about 50 million kg [11]. The share of organic fraction of municipal solid waste is estimated at 71%. The share of volatile solids (VS) of MSW is approximately 95.39%. Accordingly, Iran's daily biogas production potential from MSW was determined to be 9,820,401 m^3. Moreover, Iran's daily MSW potential was equal to 31,676 barrels of crude oil. The annual potential of biogas production from MSWs resources is equal to 13,386,740 barrels of crude oil. The results of this study highlighted that the there is a considerable potential to generate energy and reduce the environmental impact of MSWs in Iran through converting them to the biogas. Scarlat et al. (2015) studied the potential for energy recovery from MSWs in Africa. They concluded that in the case of full MSWs collection, the electricity production could reach 122.2 TWh in 2025, compared to 661.5 TWh electricity use in Africa in 2010.

8.Conclusions

This study evaluated the potential of valorization of municipal solid wastes through biogas production in Iran. This country has tremendous fossil-based energy resources; however, it has faced some environmental challenges like polluted air and municipal solid waste management. In this regard, valorizations of municipal solid wastes through biogas production can contribute to the mitigation of environmental impacts and moving toward sustainable renewable generation. Therefore, this study evaluated the potential of biogas production in the country level. The results showed that there is a remarkable potential to produce energy from MSWs in the region. Moreover, converting the MSWs to the biogas can contribute to the reduction of the environmental impacts. If Iran is going to use the MSWs to produce biogas, more research is needed to establish the appropriate biogas plans in different geographical regions of the country. Moreover, there need to do further research on the economical analysis of energy generation from MSWs in this region.

Acknowledgment

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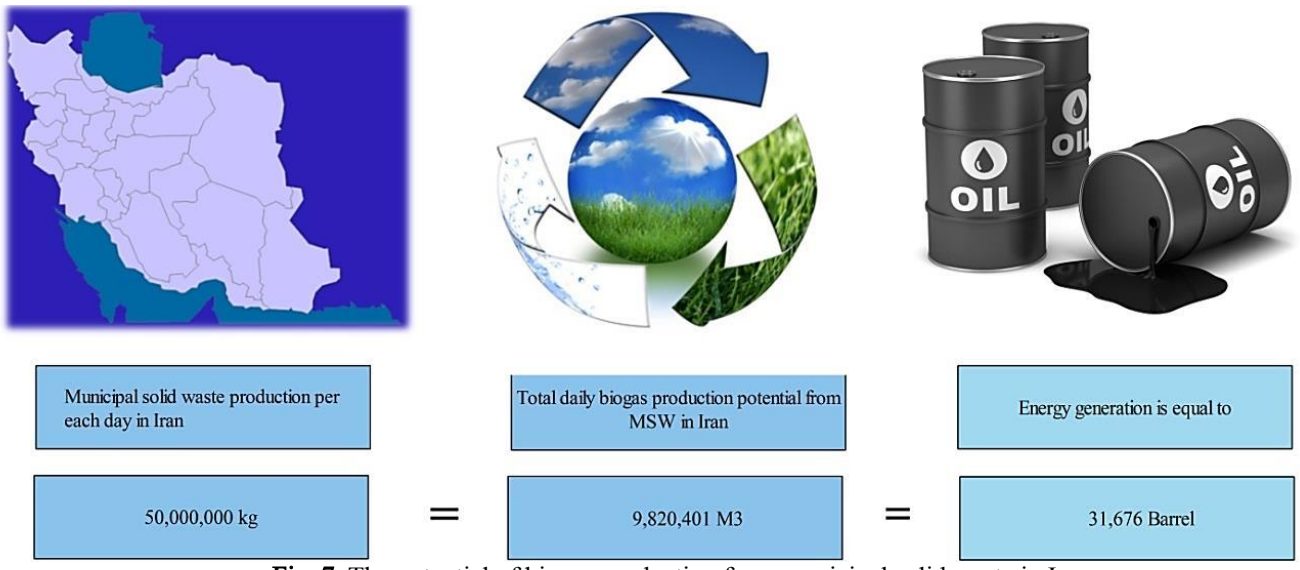

Fig. 7. The potential of biogas production from municipal solid waste in Iran

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