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Projected potential of Landfill gas in Çukurova region

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ABSTRACT

Municipal solid waste (MSW) is increasing in parallel with population surplus. Removal of this waste is essential due to not only bad smell and image pollution but also the formation of dangerous methane gas during the disposal. Methane can be used as an energy source because of its calorific value. Waste management strategies aiming at converting domestic wastes from a threat in terms of environment, human health, and transforming wastes into an input for the economy need to be widespread in Çukurova Region. In this study, the potential of MSW in Çukurova region is presented according to the base year of 2014 data using the projection of population who are supposed to live in this region. For this evaluation, LandGEM modeling tool is used, and the projected gas generation is provided. Since there is a disposal facility established in Adana, the parameters used for modelling are different for Adana and Mersin. A bioreactor was established in Adana Metropolitan Municipality Integrated Solid Waste Disposal Facility thus wet inventory landfill type is chosen when modeling the landfill gas (LFG) generation. On the contrary, inventory conventional landfill type is chosen for Mersin. Results have shown that the electricity generation of Çukurova region could reach approximately 55 MW maximum capacity in case of using suitable disposal plants.

1. Introduction

For the time being, the basic energy requirement is met with the use of fossil fuels [1]. Fossil fuel reserves are rapidly declining, especially oil and natural gas reserves approaching to critical levels [2]. Scientists have had to accelerate the search for renewable energy sources because of rising energy demand, declining oil reserves, and accompanying climate changes, along with the rapidly growing population in recent years [3]. For using energy sources effectively scientists use some new technologies such as nanofluid [4], impinging jets [5], structured surfaces [6]. In our country, because of having limited fossil fuel reserves, 70% of energy consumption had to meet by imports [7]. From this point, it has become compulsory for our country to turn to renewable energy sources. Biomass has attracted a great interest in the world while it can be transformed into energy with variety of ways, such as transesterification, fermentation and anaerobic digestion in search of this new source [1,8,9]. Generally, it is possible to distinguish energetic cycles of biomass into two groups: biochemical and thermochemical. The biochemical cycle involves biomethane (oxygen-free digestion) and fermentation. Thermochemical cycle includes gasification, pyrolysis, esterification and direct burning.

Biomass sources can be divided into two groups

- Classical biomass (agricultural waste)
- Modern biomass (municipal solid waste) [2]

Disposal of municipal solid waste (MSW) that arises naturally as the result of our vital activities is a very important issue in terms of harm to human health and ensure maximum economic contribution [10]. In this context, energy production technologies from municipal solid waste are an issue to be emphasized strongly in the world. Rapid population growth, unplanned urbanization, living standards and the development of technology leads to the formation of very large amounts of waste all over the world [11]. If the wastes can be properly classified and numerically expressed, there is a chance of direct

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Note: This study was presented at International Advanced Researches and Engineering Congress 2017 (IAREC'17) return to the economy. The classification can be made as open dumping, landfill, composting, reuse, recycling, recovery, and incineration [12].

The most commonly used method is to store the MSW in the landfills. However, eliminating solid wastes does not mean that remove MSW from the eye. It is necessary to evaluate the storage gas which may cause an explosion, poisoning by spreading to the surrounding area. Landfill gas (LFG) is generated by the decomposition of solid waste under anaerobic conditions, and can be recovered through the operation of gas collection and control systems that typically burns the methane gas. The most important feature of the storage gas is the energy content due to the methane content. There are four main ways to recover energy from the storage gas. These are direct heating, electricity generation, chemical feedstock and purification to pipeline quality. The average lower calorific value is around 19.75 MJ/m^3 [10].

In the Climate Change Action Plan of the Ministry of Environment and Urbanization, until the end of 2023, it was aimed to establish integrated solid waste disposal facilities throughout the country and to dispose of all municipal waste in these facilities [13]. Because of this utilization of MSW and LFG is an attractive subject for the scientists.

Çakır and Günerman [14] investigated the use of landfill gas as potential energy and electricity provided from municipal solid waste (domestic, industrial, medical waste and sewage sludge) stored regularly in Harmandali Solid Waste Landfill Area, within the boundaries of the contiguous area of İzmir.

Kankılıç and Topal [15] calculated a waste heat boiler and concluded that heat of waste gas should be used for the production of the electricity in energy production sectors from landfills.

Kurt and Koçer [16] determined the average dry biomass amount per year and its thermal (calorific) value for Malatya City.

Metin et al. [17] evaluated the municipal solid waste statistics and management practices including waste recovery and recycling initiatives. The results indicate that the household solid waste generation in Turkey, per capita, is around 0.6 kg/year, whereas municipal solid waste generation is close to 1 kg/year.

Turan et al. [18] stated that approximately 25 million ton of MSW are generated annually in Turkey. About 77% of the population receives MSW services. In spite of efforts to change open dumping areas into sanitary landfills and to build modern recycling and composting facilities, Turkey still has over 2000 open dumps.

There are some studies about evaluating the potential of MSW in different locations of Turkey in literature [19−23] but there is no study about potential of LFG production in Çukurova region from Municipal Solid Waste. On the other hand, this study is different from the other studies in literature by considering using two different types of biogas reactor according to given MSW values. The aim of this study is to determine the biogas potential in the Çukurova region and offering an opinion to establish new plants in the region.

The research presented in this paper mainly addresses following aspects; Section 1 describes the evaluation of biomass, disposal of MSW and how to handle it, and the state-of-the-art literature of MSW in Turkey, Section 2 depicts the status of solid waste disposal in Çukurova region, the composition of the MSW and the variation of the disposal activities year by year in the region. Also, the method of energy extraction from MSW by landfilling is introduced. This method involves a mathematical model, known as LandGEM, which estimates the LFG production for the cities based on the yearly variation of MSW data and operating parameters of landfill design. For electricity production, an analytical model is presented to estimate it from the data of LFG production and its conversion to power in a gas motor. In the rest of the paper, results and discussion are organized in Section 3 which presents the model estimations and the detailed discussion along with feature selection process. In Section 4, concluding remarks and suggestions for future directions are presented at the end of the paper.

2. MSW Data and Landfill Modeling

In Çukurova region, there is only an integrated disposal facility belonging to Adana Metropolitan Municipality. Figure 1 illustrates solid waste disposal map for Çukurova region.

Figure 2 shows the disposal methods of waste in the cities of Adana and Mersin.

The composition of the waste sent to the Adana Metropolitan Municipality Integrated Solid Waste Disposal Facility in 2013 is presented in Figure 3. The composition of the wastes is 65% kitchen wastes, 8% plastic wastes, 1.9% glass wastes, and 2.4% paper wastes. Metal derivatives are around 2.5%. Other wastes from rubber, leather, textiles, ash, stone, and soil account for about 24% of all municipal waste [13].

More than half of the household waste is stored in the Solid Waste Landfill Area operated by the Mersin Metropolitan Municipality constitutes kitchen wastes (Figure 4). The municipal waste accounts for about 12% plastic, 10% paper, and cardboard. Glass is 6% and metal derivatives are around 5%.

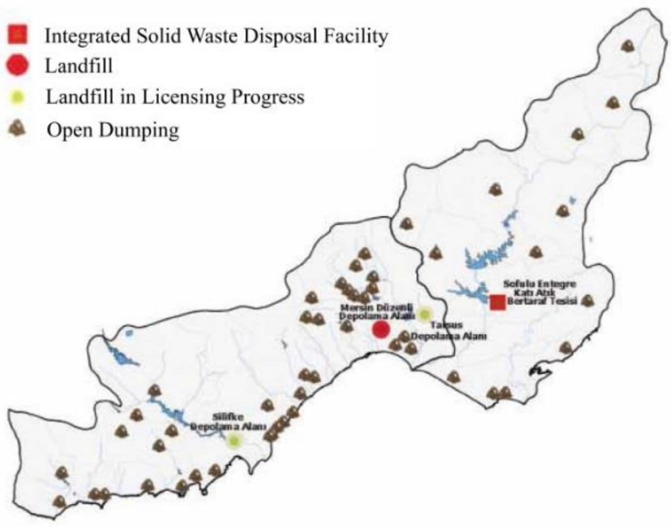

Figure 1. Çukurova region solid waste disposal map [24]

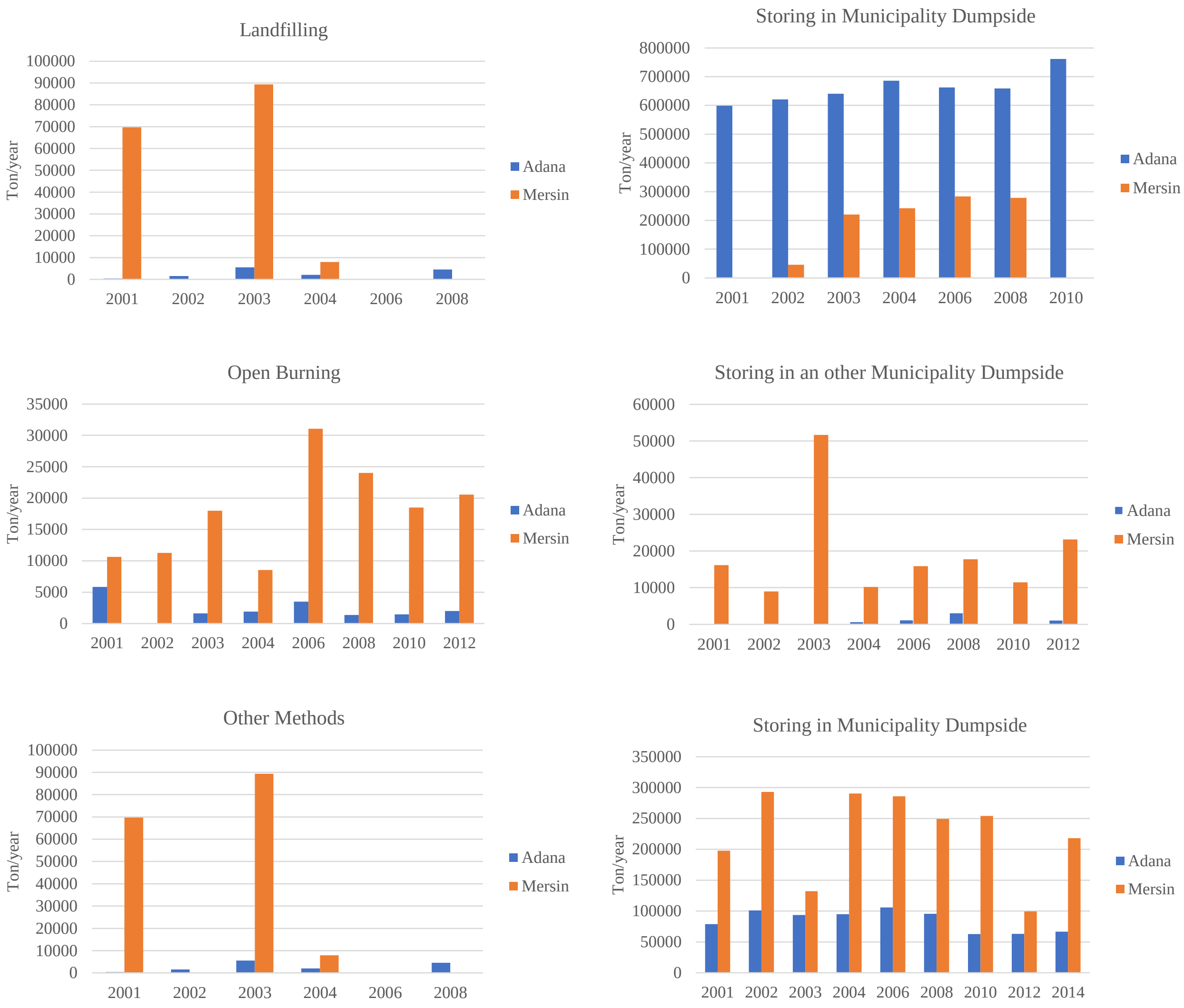

Figure 2. Disposal methods of the wastes in Adana and Mersin [24]

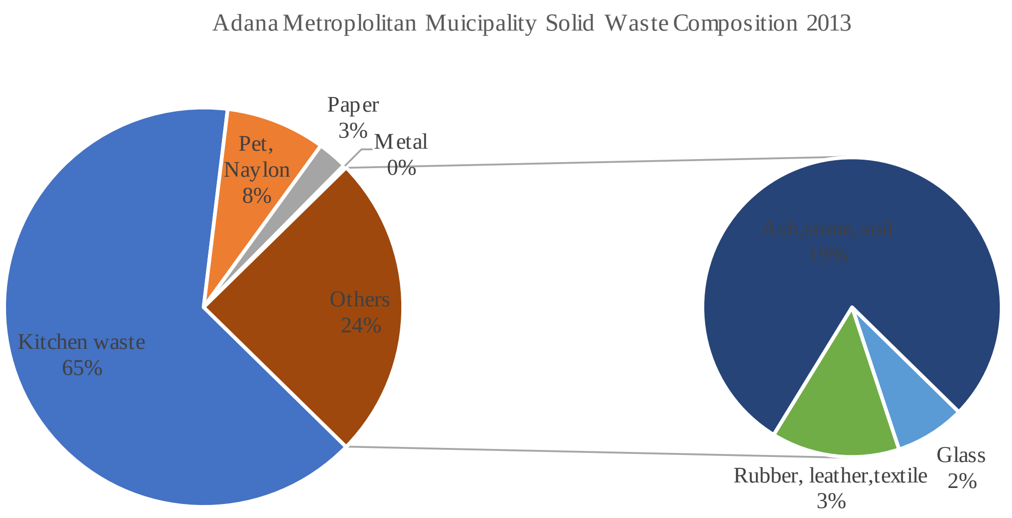

Figure 3. Adana Metropolitan Municipality Solid Waste Composition

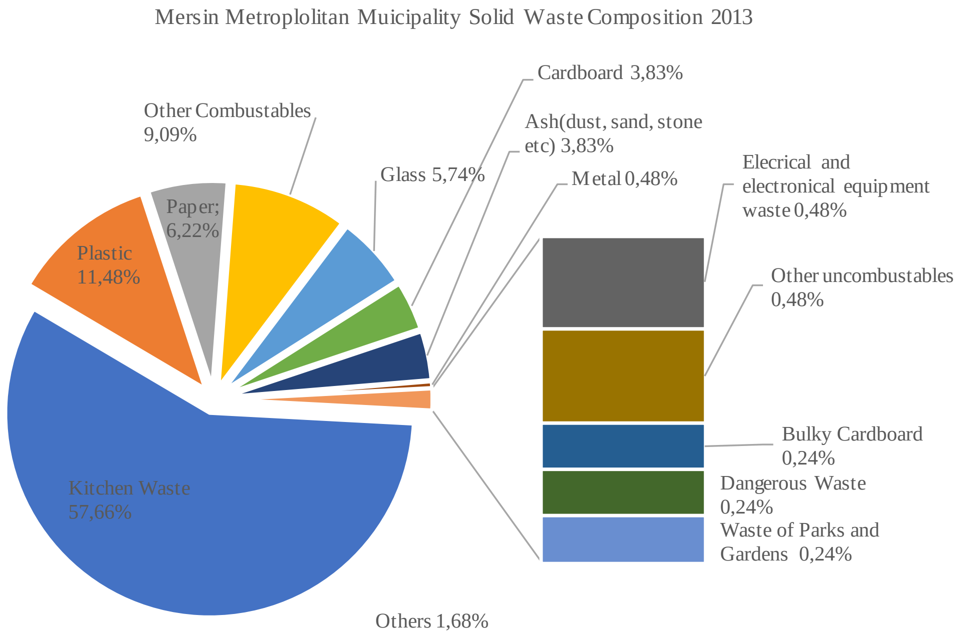

Figure 4. Mersin Metropolitan Municipality Solid Waste composition, 2013

2.1. Modeling Tool

Emissions Model (LandGEM) was used for the estimation of LFG emission rates. This study is based on the MSW data collected by Ministry of Environment and Urbanization of Turkey. Data on waste generation for 2014 were statistically made by the Turkish Statistical Institute (Turkstat) for Adana and Mersin [25].

2.2 Amount of Municipal Solid Waste

It is accepted that in this study, as the population of the necessity increases, it increases linearly in the solid waste to be disposed. For this reason, the population increase projections given by Turkstat data for the years 2013−2023 were used. The mass of waste accepted in the i^{th} year is projected according to Eq. (1):

$$M_i = M_{i-1}\frac{P_i}{P_{i-1}} \tag{1}$$

where

P_i is the estimated population at the i^{th} year,

P_{i-1} is the population of the previous year,

M_i is the estimated municipal solid waste at the i^{th} year,

M_{i-1} is the municipal solid waste of the previous year [3].

2.3 LFG emission model

The most reliable method for calculating the available LFG production is to open test wells and measure the LFG collected in these wells. But this method is expensive. The main obstacle of this method is it can be applied only if there is enough waste in the storage area to produce LFG in large quantities. Having made realistic models solve this problem. These models typically require data such as storage time, the amount of waste stored, and the characteristics of the waste. One of these models is LandGEM which was developed by EPA [26]. The rate of formation of the CH_4 in the model is based on the first order deformation equation. The equation used in the model is as follows:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10} \right) e^{-kt_{ij}} \quad (2)$$

where

Q_{CH4} = annual methane generation in the year of the calculation (m^3/year),

i = 1 year time increment,

n = (year of the calculation) − (initial year of waste acceptance),

j = 0.1 year time increment,

k = methane generation rate ($year^{-1}$),

L_o = potential methane generation capacity (m^3/ton),

M_i = mass of waste accepted in the i^{th} year (ton),

t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (decimal years, e.g., 3.2 years).

The production of CO_2 is calculated from CH_4 production using the equation.

$$Q_{CO_2} = Q_{CH_4} \left[\frac{1}{P_{CH_4} / 100} - 1 \right] \quad (3)$$

where P_{CH4} = methane content percentage.

Table 1 indicates parameters used for the models. LFG is assumed to include 50% CH_4 and 50% CO_2 with an additional constituent of NMOC. LandGEM considers the landfill type whether it is conventional or else arid area, on the other hand, the values of k and L_o parameters were selected considering the primary factors affecting the CH_4 generation listed in [26].

Table 1. Operating Parameters used in the model simulation

City	Landfill type	k ($year^{-1}$)	L_0 (m^3/ton)	NMOC	Methane Content (%)
Adana	Inventory Wet*	0.70	96	CAA 4.0	CAA 50
Mersin	Inventory Conventional	0.04	100	CAA 4.0	CAA 50

*Adana Sofulu Disposal Facility has bioreactor

2.4 Energy Potential of LFG

Energy Content (EC) of LFG varies by gas quality. It's typically between 16–20 MJ/m^3 for low and medium-quality LFG also can be produced by effective pretreatment to a high quality (up to 30 MJ/m^3). LFG can be converted to electricity by various techniques such as gas turbines, steam turbines and micro turbines with a conversion efficiency of 25% to 30%. Also by using reciprocating gas engines to a conversion factor, η_{ec} 28% to 40 % [27].

Gross and Net Energy Potential (GNEP) (kWh) can be calculated based on the volume of LFG collected and its energy content (Eq. 4) [27].

$$GNEP = \eta_{gc} \times EC \times G_t \quad (4)$$

Net energy potential (kWh) (NEP) derived from LFG energy recovery system can be calculated by considering capacity factor conversion efficiency for electricity generation (Eq. 5) [13].

Capacity Factor (CF) for biomass energy systems ranges in 80% to 90% [27]. Net energy potential derived from LFG can be calculated by considering capacity factor conversion efficiency for electricity generation.

$$NEP = \eta_{ec} \times GNEP \times CF \times 8760 \quad (5)$$

3. Results and Discussion

In this study, it is assumed that the landfill site began to accept municipal solid wastes in 2014. The model has calculated the closure year according to the waste acceptance capacity.

As it is seen in Figure 5, the economic feasible lifespan of LFG energy recovery Project of Adana was ended at almost 2039. On the other hand, Mersin will last at the year of 2150. Total LFG potential for this period was calculated as 1.403×10^8 m^3 LFG for Adana and 7.609×10^7 m^3 for Mersin. Having known that Adana has the bioreactor system in disposal facility the factor accepted as 100 (Table 2) for gas collecting system. Due to problems that might occur during gas collection of the system in Mersin, the efficiency of gas collection system was considered as 80%. It's assumed that electrical energy will be produced from LFG; thereby capacity factor for LFG to electricity is 80% and energy conversion ratio is 30%. Maximum energy potential of the site Adana was calculated as 29.8 MW. Maximum energy potential of the site Mersin was calculated as 13 MW.

Table 2. Parameters used for determination energy potential

City	η_{gc} (%)	EC (MJ/m^3)	G_t (m^3/year)	GNEP (kWh/year)	η_{ec} (%)	CF (%)	NEP (MW)
Adana	100	17.9	14.0×10^7	696.7	30	80	29.8
Mersin	80	17.9	7.6×10^7	302.7	30	80	13.0

The anaerobic fermentation system applied in the Adana Metropolitan Municipality Integrated Solid Waste Facility makes it possible to obtain methane gas and compost in the anaerobic environment through accelerating the natural decay process. Energy is generated from methane gas at the biogas plant. As of August 2013, more than 10 MW of energy is produced from the gas collected from the rehabilitated area and the gas obtained from the organic wastes. The total installed capacity of the biogas plant is 15.6 MW [10]. This result showed that Adana might need another solid waste facility since it has potential MSW to produce electricity. Currently, there is no integrated solid waste facility established in Mersin province. For this reason, a disposal facility in Mersin province has the potential to produce 13 MW of energy.

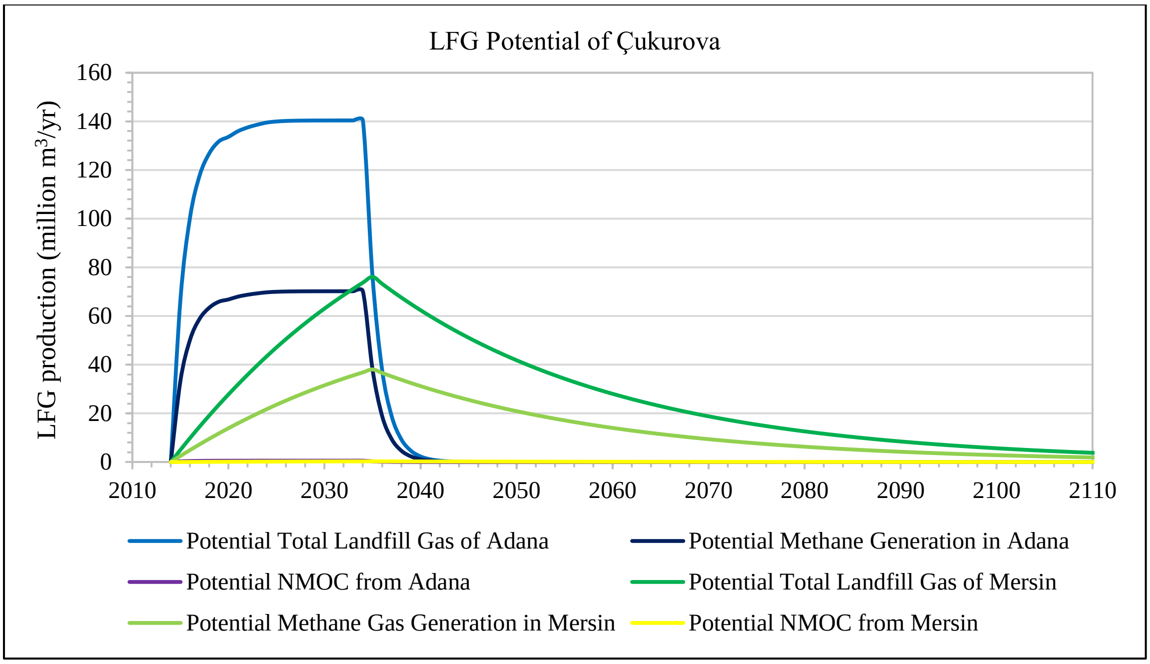

Figure 5. LFG Potential for Çukurova region

4. Conclusions

The rapid growth of the world population, changing the diversity of consumer goods and habits, has led to it to remain a serious waste problem. At the same time, research has been conducted on MSW shows that it has a significant economic value on both the national economy and human health.

The energy provided by municipal solid waste is a great prospect especially in meeting the local energy need. In terms of our developing country, getting the energy from MSW will both reduce our external dependency and create employment. Currently, there is no integrated solid waste facility established in Mersin province. For this reason, a disposal facility in Mersin province has to be established in a short time in order to gain energy from MSW.

Nomenclature

η_{ec}	: Electricity conversion efficiency
η_{gc}	: Gas collection efficiency
CF	: Capacity Factor
EC	: Energy Content
G_t	: Volume of LFG (m^3)
NEP	: Net energy potential (kWh)
MSW	: Municipal solid waste
LFG	: Landfill gas

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