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Electricity generation potential of municipal solid wastes produced in the province of Edirne

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Abstract
As a result of Turkey's economic growth, industrial development has accelerated across the country and this has ultimately led to the environmental sector and waste management gaining importance. In Turkey, where there is a depletion of natural resources, the expansion of energy demand, and the orientation in environmental technologies, waste is no longer a problematic issue that needs to be eliminated; but it has become a source of raw materials whose processing and recycling can be achieved with today's technology. In the scope of sustainable development, the waste hierarchy includes the three priority targets. These are prevention of waste production, reuse, recycling, or recovery respectively. The method for non-recoverable wastes is landfilling with energy recovery if possible. In this context, this study aims to investigate the electricity generation potential of the solid wastes disposed at the Edirne Solid Waste Landfill Facility. When the amount of waste to be sent to the facility, which was assumed to have a 20-year economic life, increases by 5% in parallel with the population profile, it is seen that electricity production will go up rapidly until 2040. However, the results of the study present that the potential of methane production will fall as the stored waste age increases so that a significant decrease in electricity production should be expected from 2045 onwards. Once it is considered that the facility continues to produce electricity for a hundred years beyond 2040, the electricity generated from the facility will contribute to the electricity network and provide the avoidance of approximately 25 thousand tons of CO2 on a national basis.

Keywords: Electricity generation potential; Methane production; Solid waste, Waste age

1. Introduction

It is specified in the waste hierarchy that there are five steps in waste management; reducing waste at the source, reuse of materials, recycling, energy recovery, and landfilling. However, municipal solid wastes are disposed of in unsanitary or unhygienic conditions in many parts of Turkey. For instance, they are buried under the ground without taking any precautions in the Safranbolu district of Karabuk, which was included in the World Heritage by UNESCO-the United Nations Educational, Scientific, and Cultural Organization. This practice causes fires, especially with the effect of the increasing temperature in summer. This situation affects health and the environment adversely by creating soil, air, and water pollution [1-3]. Solid wastes produce air contaminants, such as methane, carbon monoxide, carbon dioxide, volatile organic compounds (VOCs), dioxin and furan (PCDD and PCDF), etc., when they are unsanitary disposed of without engineering layers [4]. When these harmful components are inhaled, they increase the risk of developing illnesses such as respiratory diseases and cancer [5, 6]. At the same time, methane, which has the potential to generate electricity in such situations, is released into the atmosphere without being recovered in terms of energy production and this creates a global warming effect. In cases where there is no impermeable cover layer under the disposal site where the waste is discharged, the contaminated water leaking due to the moisture content of the waste and the effect of rainfall creates pollution by mixing with underground water sources. In this context, for example, in the Corlu district of Tekirdag province, although significant health problems related to leachate contamination have not been reported yet, it was shown that the health hazards related to the use of groundwater for water supply to the public should be taken into account [7]. In the province of Edirne, solid municipal wastes have started being disposed of in the landfill, with the commissioning of the new solid waste landfill facility. With the installation of mechanical segregation equipment in the facility, it is planned to separate the wastes that can be recycled and bring them into the economy. For this purpose, in this project, the electricity generation potential of solid wastes produced in Edirne was calculated and the electricity generation profile, which emerges during the economic life of the facility and following the completion of waste acceptance, was examined by discussing its weaknesses and strengths.

2. Research area and methodology

The province of Edirne, which is located in the Thrace part of the Marmara Region, was chosen as the study area. It is surrounded by the Aegean Sea in the south, Bulgaria in the north, Greece in the west and Kırklareli in the east as shown in Fig. 1. The province has a surface area of 6 000 km^2 and hosts approximately 411 thousand people [8].

Figure 1. Map of Edirne

The solid waste produced in Edirne is disposed of in the Edirne Solid Waste Landfill Facility. There is no practice for recycling dry recyclable wastes (glass, plastic, textile, metal, etc.) or biodegradable organic wastes (food waste) throughout the province. It is planned to prevent sending of recyclable wastes to the landfill site by adding mechanical segregation equipment to the storage facility in the near future. In this study, the electricity generation potential of solid wastes to be sent to the facility was calculated by using *the first-order degradation method* [9]. According to the first-order degradation method, the amount of gas produced at the landfill (Equation 1) depends on many factors such as the amount of waste, the emission generation potential (Y), the emission generation rate constant (a), and the age of waste [9]. The emission generation rate constant (a) refers to the moisture content that depends on the precipitation or leachate circulation. In some landfills, leachate is collected and discharged back to the site to accelerate biodegradation and thus achieve earlier methane emissions. The emission generation potential (Y), is a function of the waste composition.

The biogenic carbon emission generated by the storage of wastes is not included in the greenhouse gas emission inventory because it is biomass-based and biomass should be evaluated as having a zero-carbon emission factor [10]. In other words, the composition of carbon dioxide (CO_2) mixed into the atmosphere with the decomposition of stored solid wastes is carbon-neutral. The effect of landfill sites on climate change arises only from methane gas that cannot be retained (escaped) by the landfill site gas collection system.

The calculations were made by using these equations [9] given below:

$$Methane\ production\ (t) = R * a * Y * e^{-a(t-x)} * DW \quad (1)$$

where,

"t" is the year for which emission is calculated,
"x" is the year of the landfill,
"R" is the normalization factor,
"a" is the methane production rate constant,
"Y" represents the potential to produce methane in x years,
"DW" is the amount of domestic solid waste disposed of at the landfill in x, and
"e" is the logarithmic value.

$$R = 1 - e^{-a}/\mathrm{a} \quad (2)$$

where,

"R" is the normalization factor,
"e" is the logarithmic value, and
"a" is the methane production rate constant.

$$Y = MDF(x) * BiOK(x) * BiOKF\ F * 16/12] \quad (3)$$

where,

"Y" represents the potential to produce methane in x years,
MDF(x) represents the methane correction factor in x,
$BiOK_{(x)}$ is the degradable organic carbon in x
$BiOK_F$ represents the proportion of biodegradable organic carbon degraded in x
F represents the volume of methane in the landfill gas, 16/12 shows the conversion of carbon (C) to methane (CH_4).

$$BiOK_{(x)} = (0.4 \bullet K) + (0.17 \bullet L) + (0.15 \bullet M) + (0.3 \bullet N) \quad (4)$$

where,

$BiOK_{(x)}$ is the degradable organic carbon in x,
F represents the volume of methane in the landfill gas, 16/12 shows the conversion of carbon (C) to methane (CH_4).
K is the ratio of paper and textile in the solid waste;
L represents the proportion of organic digesters in solid waste that are not green waste, park waste, or other food waste;
M represents the proportion of food waste in solid waste and
N represents the proportion of wooden waste content in solid waste.

The municipal solid waste composition of Edirne was obtained from the reports published by the Ministry of Environment and Urbanization as 25%, 25%, 20%, and 0%, respectively [11]. Landfill gas, which contains approximately 50% CH_4 and 50% CO_2 by volume, continues to be produced for a while as long as there is waste acceptance in the site and after the site is closed. In the life cycle analyses, the duration of the emission inventory should be determined as the period during which the site receives waste and one hundred years after the waste acceptance is completed [12-14]. For this reason, although it is assumed that the capacity of the landfill site in Edirne will be filled in 2040 in this study, the analysis period has been extended until 2140.

In a site equipped with a landfill gas collection system, landfill gas is collected by a well and pump system to be burned in a gas engine. For the efficient collection of the gas produced from the site, it is important to cover the site with layers that avoid the gas escaping from the surface. For this, it is recommended to use cover layers containing sand, gravel and geomembrane combinations depending on the type of waste sent to the site [15, 16].

3. Results

When calculations are made within the scope of the first-order degradation method, the degradable organic carbon ratio (BiOK (x)) and the methane production potential (Y) of solid wastes in Edirne are obtained as 0.17 and 0.06 t CH_4 per 1 ton of waste respectively. The methane production from the site was calculated between 2020 and 2140, and it is shown in Fig. 2.

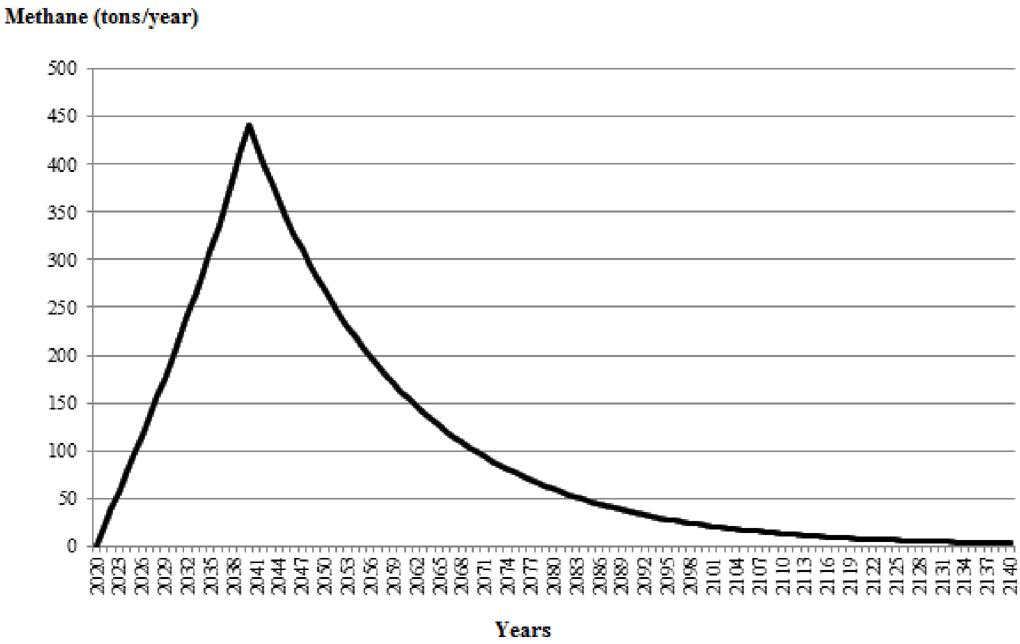

Figure 2. The methane production profile of the Edirne solid waste landfill facility

The graphic given in Fig. 2 shows that the methane produced from the Edirne Solid Waste Landfill Facility will be at the highest values between 2040 and 2045, but will decrease dramatically afterward. It can also be seen from Figure 2 that methane production will continue for about 80 more years following the closure of the site. Depending on the emission values given in Fig. 2, the electricity generation potential is shown in Table 1. The electricity that can be produced from the site was calculated considering the electricity generation potential of methane and the amount of methane collected from the site [17, 18].

The electricity generated from landfill gas replaces the electricity need to be met from the national network. In other words, electricity generated from landfill gas meets the electricity need to be drawn from the national network. On the other side, as it is known, while providing electricity for the national network, consisting of coal, oil and renewable resources, there will normally be some carbon emission ($CO_{2\text{-}e}$) depending on the type of the energy source used. This emission is expected to be higher, especially in countries that use oil and its derivatives. However, when energy is obtained from landfill gas, the electricity, as much as the amount of electricity generated from landfill gas, will not need to be withdrawn from the national network. This causes a reduction in the amount of $CO_{2\text{-equivalent}}$ ($CO_{2\text{-}e}$) released into the atmosphere. This is called the *"avoided emission"*.

Table 1. Electricity generation potential in the Edirne Solid Waste Landfill Facility over 120 years

Amount of waste	**232.175 tons**	**The total amount sent to the landfill site between 2020-2040**
Electricity to be produced over 120 years	50.000 MWh	570 m^3 landfill gas produces 1 MWh energy
$CO_{2\text{-equivalent}}$ (CH_4 and CO_2) emissions avoided due to electricity generated from the site for 120 years	25.493 tons	Avoided emission values are calculated by considering the national emission factor (0.5 $CO_{2\text{-}e}$ kg / kWh)

According to the data from the Turkish Electricity Transmission Company (TEIAS), the electrical energy produced in Turkey is 304.801 GWh per year [18]. When this is proportioned by the greenhouse gas emission from electricity production in Turkey (CO_{2-e}), the national emission factor is calculated as 0.5 CO_{2-e} kg / kWh. The national emission factor was used in Table 1, where it is necessary to make this conversion.

The national electricity network consists of electricity generated from power plants. Some of these plants operate as a base-load source, such as fossil fuel power plants, while others are intermediate facilities, such as natural gas power plants, whose operation can be changed to meet the desired load at a specific time of the day. Since each power plant has a different emission rate, it is necessary to take all these sources into account in emission factors.

There are essentially two approaches to this issue. The first approach envisages using an average emission factor obtained by proportioning the total electricity consumption in the network to the total CO_{2-e} value. According to the second approach, the results should be interpreted by considering the marginal emission factor while calculating the amount of CO_{2-e} avoided in producing electricity from waste. In the marginal emission factor, electricity generation from base-charged electricity sources is excluded. In this case, the changes in the margin should be compared with, for example, the electricity generation from waste that reduces electricity demand from existing facilities or generates electricity from low carbon sources.

However, the structure of the network is extremely complex, determining the energy gain to be obtained by a project is difficult [19]. Determining the marginal emission factor based on the complex network resources is subject to uncertainty in the long term, especially in sectors where it is not clear what kind of combination electricity will be produced except a base-load. For a reasonable assessment of emission reductions, an emission factor suitable for the project purpose should be used. For this reason, the average emission factor was used in calculating the amount of CO_{2-e} avoided by electricity generation in this project (Table 1).

4. Conclusion and discussion

The use of solid wastes produced in Edirne for electricity generation prevents the unsanitary disposal of solid wastes and also contributes to the national electricity network through electricity generation, and thus, the emission of approximately 25 thousand tons of CO_{2-e} could be avoided by 2140.

However, landfills, even with electricity recovery, are not preferred in modern solid waste management practices and are replaced by new technologies. For example, the member countries of the European Union have created reduction targets and necessary strategies to achieve these targets to recycle organic wastes without sending them to landfills. Waste reduction and recycling should be priority targets, as envisaged by the waste hierarchy. For instance, the implementation of organic waste recovery with an anaerobic facility in Edirne province may cause a significant decrease in the amount of biodegradable waste to be sent to the landfill site. Since this reduces the amount of methane collected from the site, it will cause significant losses in the efficiency of the electricity planned to be produced from the facility.

As the amount of electricity to be generated from the Edirne Solid Waste Landfill Site will tend to decrease after 2045, as shown in Figure 2, the electricity generation on the site should be established on the basis of units. Thus, these units that will not be used in the process where production does not cover costs can be dismantled. However, since methane is 21 times stronger than carbon dioxide in terms of the greenhouse gas effect, the methane collected from the site should not be released directly into the atmosphere but should be converted into carbon dioxide by flaring.

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