

# Potential Methane Generation Capacity on the Landfill Gas Extraction Systems at the Landfill in Niš

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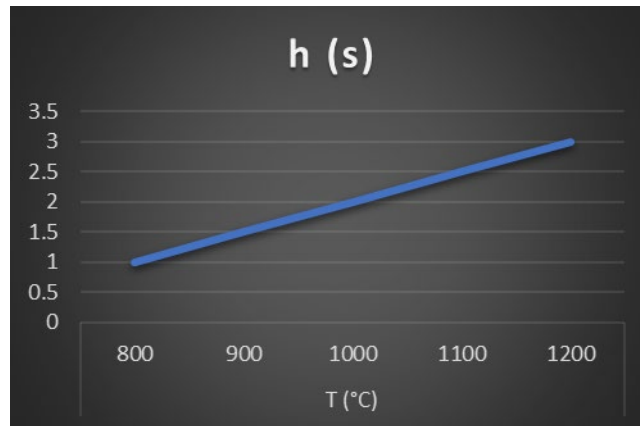
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**Abstract:** Systems for the production of electricity require the previous collection of gas from the organic matter of municipal waste. Collection of landfill gas is done by a degassing system. In the case of the Niš landfill, this system was partially built by installing biothorns for the evacuation of landfill gas into the air. The paper presents the results of testing landfill gases, which include: determination of the volume fraction of methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>), hydrogen sulfide (H<sub>2</sub>S), carbon monoxide (CO) and hydrogen (H<sub>2</sub>). Measurements were made at the control points at the exit from the biothorn, at the closed and rehabilitated fields S 2 and S 3, simulated results at the control point of the pilot project of the active system, at the exit from the horizontal and vertical drain, at the active field S4, Niš landfill. Measurements were performed using the electrochemical method, with a GEM TM 2000 Plus gas analyzer, once a month. The LandGEM emission model was used to estimate the energy potential of methane. The paper concluded that the most energy-efficient method for waste disposal is the use of an active degassing system. Using an active landfill gas extraction system, a 1MW power plant can be built.

**Keywords:** Methane, gas extraction systems, gasification, electricity

## 1. Introduction

Requirements regarding economic and thermodynamic performance of plant and system components, in terms of conversion, distribution and consumption of different types of energy are continuously studied. The basis for the study of energy systems are conservation of mass and the First Principle of Thermodynamics. [1]. The disposal of municipal waste produces landfill gas (LFG), which mainly includes methane, a greenhouse gas, therefore its management is very important. [2]. The carbon footprint is used as an indicator of greenhouse gases at the landfill. Carbon footprint emissions are generally expressed as CO<sub>2</sub> equivalents quantify the main sources of emissions and represent (CO<sub>2</sub>e), which consists of the emission of fuel components: carbon monoxide (CO), hydrogen (H<sub>2</sub>), various hydrocarbons - methane (CH<sub>4</sub>), and non-combustible components of water (H<sub>2</sub>O), nitrogen (N<sub>2</sub>), carbon dioxide (CO<sub>2</sub>) [3]. The legal obligation to collect and burn landfill gas obligates the burning of gas for energy purposes with the creation of economic profit. Systems for obtaining energy require preliminary gas collection. A passive landfill gas extraction system was installed at the Niš landfill, built from horizontally perforated pipes (biothorns). During the research, an active extraction system was also used, which collects gas instead of the system, using one vertical pipe in the well (probe). The gas is further evacuated towards the power generation station through interconnected systems of horizontal pipes (main gas collectors), placed above the landfill cover layer. The gas is extracted, compressed, dried and directed to the gas engine via the compressor plant. For safety reasons, it is recommended to install a high-temperature torch. The torch must be insulated, which increases its efficiency. Gas combustion is achieved at a temperature of 1200°C for at least 3 seconds. The pressure change in the condenser significantly affects the economy of the generator operation. Bearing in mind that a change in condensation pressure of 1kPa leads to a change in the degree of utilization of 1% [4]. The pressure change in the condenser occurs due to the temperature change per unit volume of the condenser. The following graphic shows the dynamic analysis of the system for saturation temperature [5].



Graph 1. Dynamic analysis of the system for saturation temperature

## 2. Methodology

The method of analysis, synthesis and optimization REPRESENT a great role in the reliability of energy systems. The method of the Second Law of Thermodynamics is one of these methods [6]. The emission software model LandGEM, developed by the American Environmental Protection Agency (EPA) [https://www.epa.gov/landfills/municipal-solid-waste-landfills] was used to estimate the amount of landfill gas at the Bubanj landfill in Niš. ]. The first edition of the software was created in 1991. and is based on the first-order decay rate equation. The model determines the amount of gas during landfill operation and several years after closure. It gives higher values, because it does not take into account the different content of organic matter, but the total amount of waste (the part is inert). The basic model used by the software requires constant amounts of disposed waste (IPCC Tier 1 model).

### 2.1. Calculation for calculating the amount of methane produced

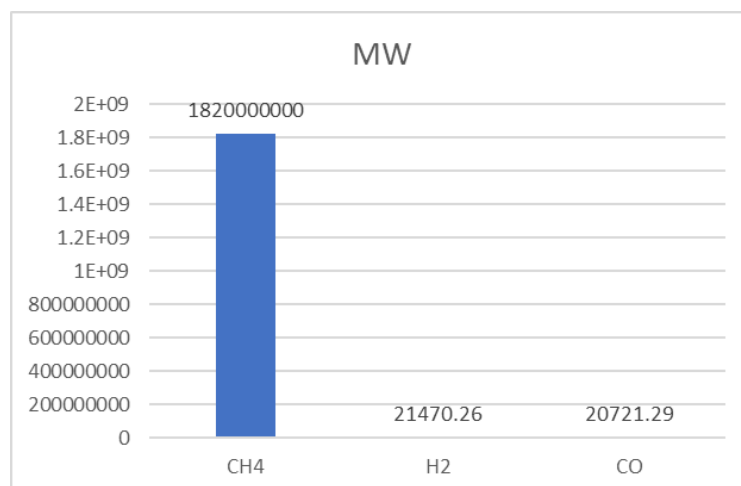
The annual amount of methane produced can be determined according to the equation [7]:

$$QCH_4 = \sum \sum kLo(Mi \& 10)e^{-kti} \quad (1)$$

## 3. Results and discussion

### 3.1. Passive system for landfill gas degassing

Measurements of temperature and atmospheric pressure of biogas were made by inserting a probe with a sensor into the biethorn at a depth of 2m for 3 minutes. Atmospheric conditions during the measurement were; outside temperature 32°C, relative humidity 45%, wind speed 3km/h, atmospheric pressure p = 1005 mbar, visibility good, no precipitation. If values for heat capacity (Lo) are entered into equation (1). the potential value for energy use shown in graph 2 is obtained..



Graph 2. Potential for energy utilization of methane on biethorns for 2023.

### 3.2. Simulation of an active biogas degassing system

Landfill gas degassing (Figure 1b).



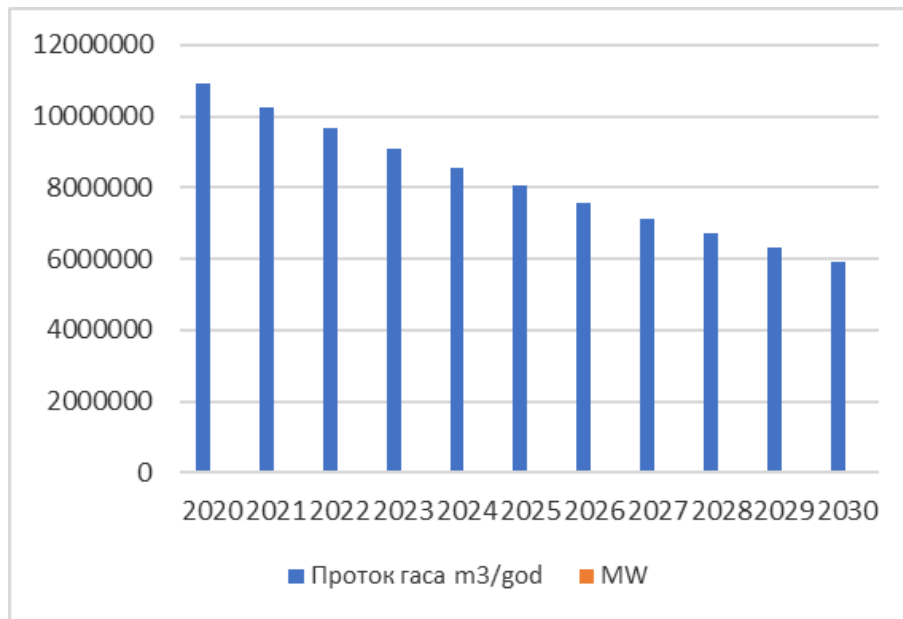
a) Layout of the biogas degassing probe



b) View of the horizontal connection of biogas degassing pipes

Figura 1. Landfill gas degassing

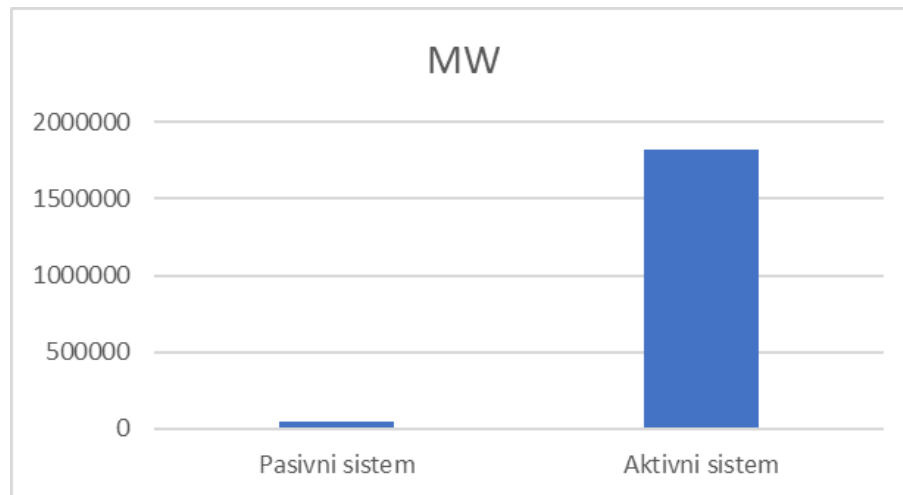
Estimated quantities of landfill gas range between 2000-4000 tons per year for the period between 2020 - 2030 year. A desulphurization system and an active carbon system are provided for gas purification to pure methane, as natural gas. The model assumes that the mean proportion of methane in landfill gas is 50%, varying from 30-70%, during the year. Valorization of LFG, for energy utilization by years, is shown in (graph 3).



Graph 3 Valorization of LFG, for energy utilization by years

The landfill does not have a sealing lining at the base of the landfill, which leads to heat losses and lateral leakage of landfill gas into the surrounding soil. In contrast to the passive system, the produced biogas has a significant carbon dioxide content (25-45%), which reduces the thermal power due to the volume it occupies. Its purification (hydrogen sulfide is emitted) reduces the volume of the produced gas, but increases its thermal power [ 9]. Gas flow and temperature ie. the calorific value of landfill gas varies seasonally. The largest production of landfill gas is achieved after the rehabilitation of the landfill, after 2017, and amounts to 298.78 m<sup>3</sup>/h. Ten years after the closure of the landfill, the amount of gas decreases by 30%, and after 20 years by more than 50%. Combined with an average methane content of 50%, it is expected that the utilization of

electricity as well as boilers with a fluidized bed [10] should not be more than 1.75-2.15 kWh/ m<sup>3</sup>. On average, from segment S4 of this landfill, in the next 10 years from the closing of the cassette and the construction of the plant for obtaining energy from waste, a total of 168,473,905 kWh of electricity can be valorized in ideal conditions of exploitation [11]. Taking into account the efficiency of the active landfill gas collection system, the amount of electricity produced is 151626514 kWh. In accordance with the REGULATION ON FEE FOR INCENTIVES OF PREFERRED ELECTRICITY PRODUCERS ("Official Gazette of RS", No. 50/2024) Fee for privileged producers of electricity - Fee for renewable energy sources. It is calculated as the product of the total energy used and the price of 0.801 din/kWh. Fee for the improvement of energy efficiency - calculated as the product of the total energy used and the price 0.015 din/kWh. Revenues from electricity for the period at the annual level amount to RSD 12,372,723.5 or €10,556,931. Gas temperature and flow rate have a great influence on the energy efficiency of the system for obtaining electricity [12]. The electric power obtained from active and passive systems for 2023 is shown in graphic 4.



Graph 4. Electric power of the active and passive system for 2023

For the power generation process, the gas is purified through a steam generator (HRSG) and the heat recovery is used to generate steam that is sent to steam turbine for the production of electricity in one process cycle. The cooled gas is then cleaned, it is compressed and used as fuel in a combustion gas turbine that drives an electric generator. Shut down compressed and used as fuel in a combustion gas turbine that drives an electric generator. The the exhaust gases are then passed through a second HRSG to pre-produce additional steam and clean the gas before it is emitted to the atmosphere. [13].

## 4. Conclusion:

Based on the above, the following is reached:

- Landfill gas (LFG) is produced by the decomposition of the organic part of solid waste [14].
- LFG is a greenhouse gas, the recommendations are to release it into the air, or to collect it for energy production.
- Landfill gas extraction systems can be:

Passive and active

- Advantages of an active landfill gas extraction system:
  - The technology is considered Best Available Technique (BAT).
  - The degree of efficiency of the passive system is 0.55%, while the degree of efficiency of the active system is 0.90%
    - Direct contact with disposed waste increases gas efficiency
    - Gas temperature directly depends on the amount of oxygen in the waste [15]
    - Active gas extraction system, electricity production equivalent to approximately 1MW [16,17]
    - Analysis of landfill gas, the required amount of air for complete combustion, thermal power of fuel, quantity and composition of combustion products and combustion temperature [18].

## Nomenclature

### Latin symbols

QCH <sub>4</sub>	–	annual amount of methane produced, amount of methane (m <sup>3</sup> /year),
I	–	increment (1 year)
J	–	increment
n	–	initial year of waste disposal
k	–	rate of methane generation (yr <sup>-1</sup> )
Lo	–	potential methane production capacity (m <sup>3</sup> /t)

### Superscripts

M <sub>i</sub>	–	mass of waste deposited in that year (t),
e	–	speed of heat transfer of the working body [8].

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