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Optimal System for Collecting Landfill Gas - Landfill Meglenci, Republic of North Macedonia

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Abstract: The energy strategy of Republic of North Macedonia until 2040, in addition to the use of classic renewable energy sources and high criteria for environmental protection, also foresees the use of landfill gas that is produced in the open landfills on its territory. In addition to the large number of wild illegal landfills, the only legal landfill in North Macedonia is landfill Drisla near Skopje. In the Meglenci regional landfill near TPP (Thermal power plant) Bitola, which is planned to serve the southwestern part of the country, the efficient collection of landfill gas, which would be used as energy, is of great importance. This paper presents an analysis based on results obtained from theoretical and experimental research, with the aim of choosing the optimal system for the collection and conversion of gas in the Meglenci landfill. In doing so, the latest relevant data on the quantity and quality of the organic fraction from the waste, the conditions in the landfill, climatic factors and other input data were used in order to obtain data on the yield of landfill gas. Technologies that are available and applicable for the specific landfill have been studied, based on the data obtained from the mathematical model and the techno-economic analysis. The "collection" of greenhouse gases, such as landfill gas, is a legal obligation within the framework of environmental protection, but the possibility of using it as an energy source contributes to the energy system at the local level.

Keywords: Landfill gas, Methane production model, Waste to energy systems, Optimal solution.

1. Introduction

The Republic of North Macedonia has a low level of development in the sector of waste management. In 2024, 54 non-standard landfills [1] and one standard landfill Drisla, located southeast of Skopje, [2] were determined. According to the EU Directive on landfills [3] and the Strategy for the development of energy in the Republic of North Macedonia until 2040 [4], it is planned to close non-standard landfills and open centralized regional landfills. Accordingly, an analysis was made for the establishment of an integrated self-sustaining system for waste management in the Southwestern region of Macedonia - Meglenci, which will fulfill the requirements related to the control of gases that cause the greenhouse effect (GHG - greenhouse gases), [5], [6]. Also, a system for the extraction and utilization of landfill gas as a source of energy was proposed, where an analysis was made for the expected production of methane and the extent of its utilization through the Afvalzorg model [7]. An analysis of the economic benefit related to the capacity of the landfill and the quality of the produced landfill gas is also given.

2. Regional landfill Meglenci

The landfill Meglenci is located in the southwestern part of the Republic of North Macedonia (Fig. 1 and 2) in the immediate vicinity of the lignite mine "Suvodol", which has been out of operation for some time due to the excavated lignite reserves according to the previous deposits. The lifetime of the landfill is divided into: phase A (8 years, surface area 17500 m^2, real capacity 185000 m^3 waste) and phase B (16 years, surface area 25000 m^2, real capacity 395000 m^3 waste) [3]. The annual delivery of waste to the landfill is 37 522 $t/year$.

Figure 1 and Figure 2. Location of the landfill Meglenci on a Google earth map

3. Landfill Gas Production and Utilization Assessment

Landfill gas is a greenhouse gas (GHG – Greenhouse Gas) which consists mainly of generated methane and carbon dioxide as a result of the anaerobic biodegradation of municipal solid waste (MSW) in landfills, primarily of organic origin. LFG (Landfill Gas) is usually composed of methane (CH_4) (about 50%), carbon dioxide (about CO_2) (45%) and other minor elements, such as nitrogen (N_2), hydrogen sulfide (H_2S) and non-methane organic compounds (NMOC) (about 5%) [8]. The greenhouse gas emissions increase the temperature of the atmosphere and poses a threat to the environment and human health. Methane emitted by landfills is among the most significant contributors to the greenhouse effect with at least 28 times more global warming potential than carbon dioxide and accounts for about 20% of the global greenhouse gas impact on the atmosphere [9]. The rate of increase of CH_4 in the previous few decades is from 1 to 2% per year, with a tendency to increase if appropriate measures are not taken [10].

The amount of LFG produced and collected from a certain amount of waste varies depending on the parameters (temperature, moisture, composition of waste, structure of waste, disposal, distribution, bulking of waste, other local conditions, *etc*.). With more recent research on a projected time period of waste collection lasting 40-80 years, the expected production of LFG would be 50-100 m^3 per ton of waste [11].

To estimate the production and utilization of landfill gas, in previous researches [7], the single-phase model (Afvalzorg model) is usually used, which is upgraded and adjusted based on the characteristics of the landfill that is the subject of research [7]. Afvalzorg model is a first-order decay model based on the mathematical expressions of the IPCC (Intergovernmental Panel of Climate Change) and default parameters (DOC – degradable organic carbon, k – reaction rate constant...). The model is single-phase and during data processing it is assumed that organic matter decomposes at the same rate. This model is applied in the case where little or no detailed data on the composition of the waste is available [7]. The output diagrams of the Afvalzorg model, adjusted for the conditions of the landfill Meglenci, are presented in Figure 3 and Figure 4, where it is assumed that the peak of the produced and captured methane will be in 2055, after the closure of the landfill. Parameters corresponding to the climatic conditions in the region of the landfill Meglenci have been adopted, and also the percentage representations of the waste components in the Southwestern region of North Macedonia have been entered.

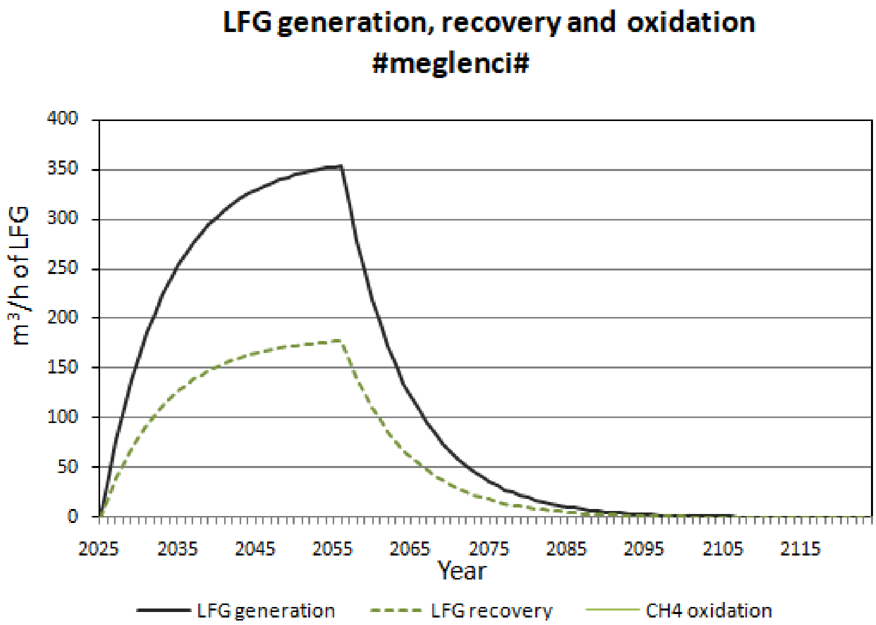

Figure 3: Afvalzorg model volume flow for landfill gas production and recovery (no oxidation)

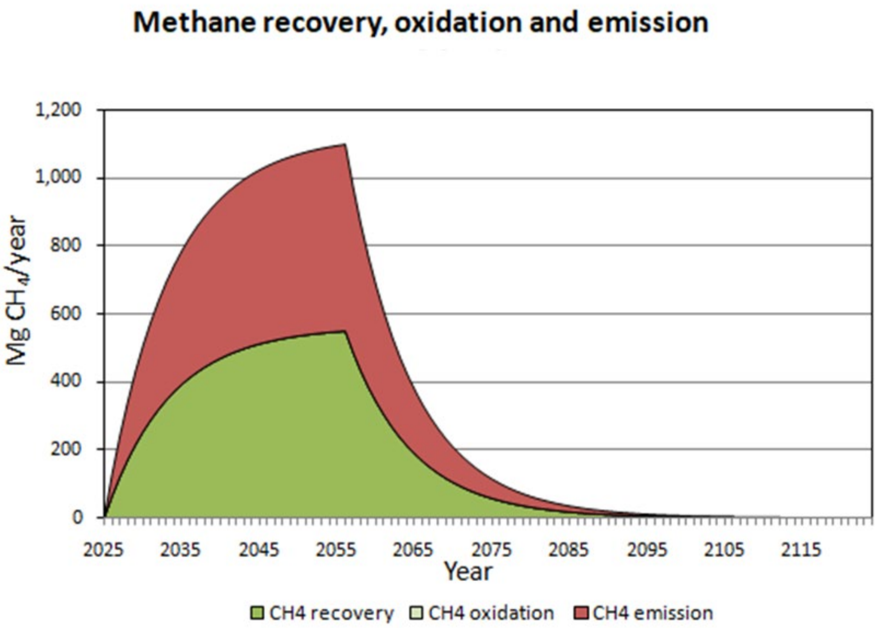

Figure 4: Afvalzorg model mass flow for methane emission and recovery (no oxidation)

During the researches, field measurements were also made at specific landfills for which an estimation was made for the production and extraction of landfill gas according to Afvalzorg's model, showing that the average actual extraction for the 14 LFG plants was only 39.6% of the extraction estimated in the model, [11].

4. Landfill gas utilization systems

LFG utilization plants typically consist of an extraction system and an exploitation system [11]. The simplest system is by capturing LFG through vertical gas pipes and using it for energy purposes. The gas engine-generator unit can produce electricity or represent a combined plant for obtaining heat and electricity.

When the use of LFG for energy purposes is not economically viable, the gas should be burned in a flare. Incineration is done for environmental reasons, in order to reduce methane emissions and their contribution to the greenhouse effect. Combustion also reduces unpleasant odors and the risk of fire and explosion.

Figure 5 shows the types of landfill gas utilization systems in the world by 2023 [12]. The largest part refers to plants for the production of electricity, direct use is made by burning and obtaining thermal energy in boilers, while RNG (Renewable natural gas) systems improve the quality of landfill gas to that of natural gas and it is transported in gas pipelines. RNG plants have the smallest application in the world, but have seen significant growth in recent years.

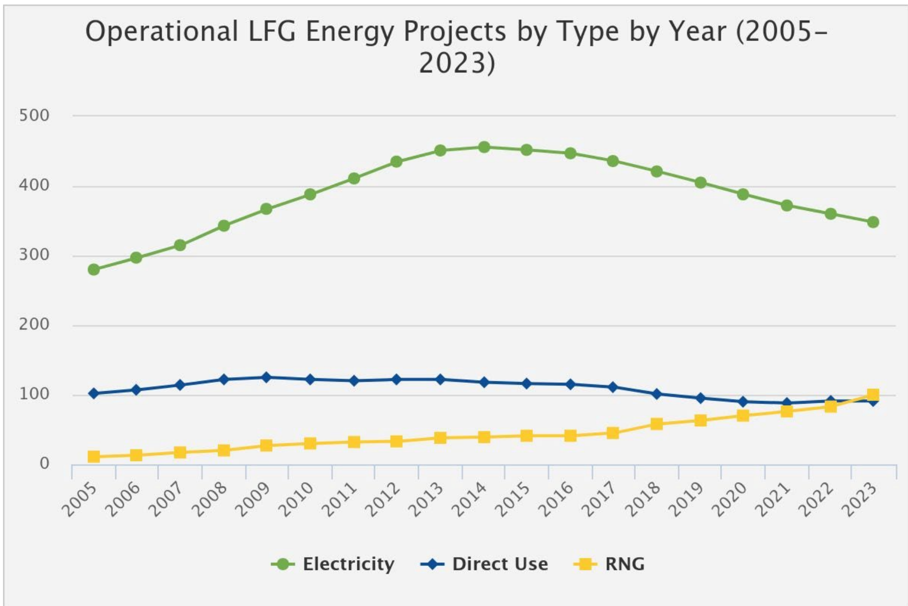

Figure 5: Statistics from the EPA (Environmental Protection Agency) on types of landfill gas systems

5. Economic analysis

To estimate the economic benefits of energy production from landfill gas, a mathematical model is used where investment, operational and maintenance costs are included. Indicators are also used that show specific investment costs related to equipment for capturing LFG of different quality, adjusting the system to implement the legislation, *etc*. In addition, with such research, the benefits resulting from the difference in the preferential tariffs and the costs of electricity production have been estimated, [13]. From Figure 6 it can be seen that the specific costs are lower in case of higher landfill gas quality and lower installed capacity of the power plant. The optimum of specific costs is located between an installed power of 0.2 MWe and 0.6 MWe [13]. Landfill gas quality is presented in three scenarios (10 MJ/m^3, 13 MJ/m^3, 18 MJ/m^3) depending on the quality and stage of waste decomposition.

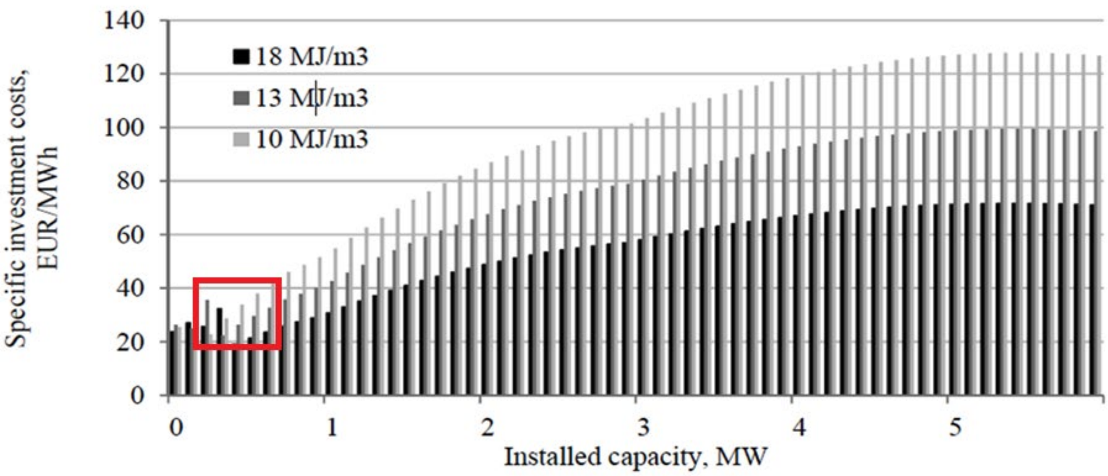

Figure 6: Specific investment costs for electricity generation from landfill gas

6. Solutions for utilization of landfill gas production in Meglenci

If we take into account the results of Figure 3, where in the period of 2035-2055 the landfill generates methane of about 120 m^3/h and if we add the factor 0.396 that indicates the actual utilization of methane extraction, in eq. 1 is obtained:

$$C = Q \cdot LHV_{CH_4} \cdot R \quad (1)$$

where:

$C \approx 0.5\ MW$ is the capacity of the gas engine-generator unit;

$Q = 120\ m^3/h$ is the volume flow delivered by the landfill;

$LHV_{CH_4} = 37.074\ MJ/m^3$ is the lower heating power of methane;

$R = 0.396$ is the utilization factor of methane extraction.

According to the economic framework from 0.2 MWe to 0.6 MWe (Fig. 6), this capacity of the planned plant is justified. According to the obtained results, it can be concluded that the construction of a plant with a gas engine for obtaining electricity from landfill gas at the landfill Meglenci is realistic and justified in the operational period of 2035-2055.

7. Conclusion

The technologies for LFG utilization, the obtained results of the model for estimating the produced and absorbed methane in the landfill Meglenci, as well as the given optimal framework for the costs of the conceptual plant, provide the possibility of building a plant with a gas engine for obtaining electricity energy from landfill gas with an expected capacity of 0.5 MW. Also, the results provide an opportunity for further research related to improving the efficiency of the systems according to the specific conditions of the landfill Meglenci. In case of problems with integrating the plant into the electricity distribution network, an alternative option is to install a gas combustion system in order to prevent methane emissions into the atmosphere.

References

[1] https://app.gdi.mk/download/%D0%A1%D0%BF%D0%B8%D1%81%D0%BE%D0%BA%20%D0%BD%D0%B0%20%D0%BD%D0%B5%D1%81%D1%82%D0%B0%D0%BD%D0%B4%D0%B0%D1%80%D0%B4%D0%BD%D0%B8%20(%D0%B4%D0%B8%D0%B2%D0%B8)%20%D0%B4%D0%B5%D0%BF%D0%BE%D0%BD%D0%B8%D0%B8%20%D0%B2%D0%BE%20%D0%A0%D0%9C.pdf
[2] https://drisla.mk/
[3] Environmental impact assessment study for the investment project "Establishment of an integrated and financially self-sustainable waste management system in the Pelagonian and Southwestern regions", Skopje, 2022;
[4] Strategy for the development of energy in the Republic of North Macedonia until 2040, Skopje, 2019;
[5] Kyoto Protocol to the United Nations Framework Convention on Climate Change, Kyoto, 2005;
[6] Kostovski Z., „Potential for the utilization of solid municipal waste for the production of electricity in the Bitola region“, Master's thesis, University „Kliment Ohridski” Bitola, Bitola, NMK, 2012;
[7] https://www.afvalzorg.com/landfill-gas/lfg-models
[8] Ahmed, S. I., Johari, A., Hashim, H., Mat, R., Lim, J. S., Ngadi, N., Ali, A. (2015). Optimal landfill gas utilization for renewable energy production. Environ. Prog. Sustain. Energy, 34, 289–296, DOI: 10.1002/ep.11964.
[9] Li, S., Yoo, H. K., Macauley, M., Palmer, K., Shih, J.-S. (2015). Assessing the role of renewable energy policies in landfill gas to energy projects. Energy Econ., 49, 687–697. DOI: 10.1016/j.eneco.2015.03.022.
[10] Singh, C. K., Kumar, A., Roy, S. S. (2018). Quantitative analysis of the methane gas emissions from municipal solid waste in India. Sci. Rep., 8, 2913. DOI: 10.1038/s41598-018-21326-9.
[11] Terraza H., Willumsen H., „Guidance Note on Landfill Gas Capture and Utilization“, 2009;
[12] https://www.epa.gov/lmop/switch-renewable-natural-gas
[13] Dace E., Blumberga D., Kuplais G., Optimization of landfill gas use in municipal solid waste landfills in Latvia, International Scientific Conference “Environmental and Climate Technologies – CONECT 2014”, Riga, Latvia, October 14-16, 2014, pp. 293 – 299