

PRACTICES FOR PRODUCING ENERGY FROM BIOGAS IN LANDFILLS: A COMPARATIVE STUDY BETWEEN COMPANIES IN ITALY AND ROMANIA

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Abstract. The waste landfill sector contributes annually to climate change through its greenhouse gas emissions, particularly methane. To reduce emissions from this sector, an effective and sustainable solution is to use the biogas emitted by these landfills to produce energy. Due to its benefits and growing interest, the topic has been adopted in global literature but has received little attention in Romania. Thus, this article presents a comparative analysis of biogas utilization practices between Italy and Romania. The analysis aimed to study the practices adopted by companies operating landfills in the two countries, identify the main differences between them, and formulate recommendations for improving the practices of companies in Romania. The study highlights the fact that, at the current time, there are no functional systems in Romania that can use biogas from municipal solid waste landfills to produce energy. One of the reasons for this is the low efficiency of the waste management system, mainly due to the lack of an adequate selective collection and transport system, which affects sorting and recycling processes. The results highlight the need to increase ambition, study more efficient technologies and systems, and make the necessary investments in this sector. These will contribute to multiple benefits in the future, such as reducing greenhouse gas emissions and the overall impact on the environment, producing green energy that can successfully replace fossil fuels, with a positive economic and social impact.

Keywords: waste, landfill, energy, biogas, emissions.

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INTRODUCTION

Solid waste landfills are a major source of greenhouse gas emissions. This is due to the main components of biogas: methane (CH₄), carbon dioxide (CO₂), hydrogen sulfide (H₂S), and hydrogen (H₂) [1]. Methane is one of the most potent greenhouse gases, as over a 100-year period, the emission of 1 kg of CH₄ is equivalent to the emission of 25 kg of CO₂ [2]. It is estimated that 30% of global methane emissions are generated by solid waste landfills [3]. According to the latest EU inventory of greenhouse gas emissions, the waste sector recorded emissions of

approximately 101 Mt of CH₄ in CO₂eq in 2020, most of which came from solid waste disposal (80%), followed by domestic and industrial wastewater treatment and disposal (15%) and biological treatment of solid waste (4%) [4].

Biogas is the gas emitted into the atmosphere from landfills and is the result of the anaerobic decomposition of organic substances found in waste. A sustainable solution is to produce energy from biogas to limit the negative impact of emissions from solid waste landfills. Energy recovery involves the application of various processes, such as combustion, gasification, and anaerobic digestion to convert waste into electricity, heat, or fuel [5]. Due to its dual positive impact (emission reduction, green energy production), the use of biogas, or more specifically methane from biogas, for producing electricity and/or heat has been addressed in literature, with numerous studies and analyses available. However, the subject of energy production from landfill biogas in Romania has been treated very little. Moreover, regarding municipal solid waste management, the available data show that there is currently no national case study in Romania that attests to the technical performance of waste management operations for this key waste stream [6]. Thus, the main purpose of this study is to analyze, in relation to other European Union countries, the performance in producing energy from landfill biogas of municipal solid waste landfill management companies in Romania.

Italy is one of the countries with high energy production and efficient technologies for recovering biogas from landfills. In 2021, electricity production from Italy's biogas plants was 8124.2 GWhel, with 77.2% of production concentrated in Emilia Romagna, Veneto, Lombardy, and Piedmont. The main sources of biogas for energy production came from agricultural and forestry activities (69.5%), 15.9% from animal manure, and 14.6% from waste and sludge [7]. Thus, to carry out this analysis, biogas utilization technologies for energy production from landfills used by companies in Italy and Romania were compared. This comparative analysis consisted of studying the best-known and most efficient ways of using landfill biogas in both countries, identifying the main differences between the two, and finally, based on these, offering recommendations. The results of this study are expected to highlight a high level of inefficiency in the use of biogas for energy production by companies in Romania. According to available data, Romania has a low rate of composting and anaerobic digestion because it does not have sufficient capacity for the separate collection and proper treatment of biological waste [8]. Therefore, this paper is addressed to representatives of companies operating in the field of landfills to identify sustainable solutions for using the biogas emitted by landfills for energy production.

This article consists of the following sections: the literature review section will present studies on energy production from landfill biogas, and an overview of the situation in Romania regarding municipal waste landfill management. The methodology used in the comparative analysis of landfill gas energy production practices in Italy and Romania will be detailed below. Following the study, the main differences observed between the two countries' approaches will be presented, and a series of recommendations for increasing efficiency in Romania will be proposed.

LITERATURE REVIEW

According to data provided by the International Renewable Energy Agency, global electricity production from municipal waste in 2019 was 68,506 TWh. Europe had a production of 24,285 TWh, representing 35.45% of global electricity production from municipal waste, of which Germany accounted for 8.48% (5.8 TWh), the United Kingdom for 5.55% (3.8 TWh), and Italy for 3.46% (2.4 TWh) [9]. An average of 1.5 billion tons of waste is deposited in municipal solid waste landfills each year, which generally have a methane generation rate of 75 billion Nm³. Thus, for each ton of waste, approximately 0.78 MW of electricity can be generated, i.e., 6,500-10,000 MWh of electricity per year [5]. Developing countries generally have higher rates of municipal solid waste. Research conducted by Cudjoe, Han, & Nandiwardhana [10] in China highlighted that the electricity generation potential of anaerobic digestion is higher, ranging from 636 GWh to 33.61 TWh, and leads to a 92.7% reduction in global warming potential, while gas-to-energy conversion ranged from 521 to 23.45 TWh and leads to a lower reduction of 71.5% [10]. The theoretical estimates of Gerardo Collaguaz et. al [11] regarding the use of internal combustion engines to produce electricity from biogas emitted by a municipal waste landfill in Bihor County with a methane concentration of 55% and a flow rate between 150 and 290 m³/h show an approximate production of 400 kWe, totaling between 40 and 76 MWh of electricity produced, respectively [11].

An analysis of municipal solid waste management systems based on technical (assessment of technical resource use), economic (economic viability and sustainability of circular practices), and sustainability (performance in environmental, financial, and social sustainability) of municipal solid waste management in 27 European countries carried out between 2017 and 2021 highlights superior performance in the Netherlands, Slovenia, France, Italy, Germany, and Sweden [12]. Regarding the technical indicators established (%) for recycled, incinerated, and landfilled waste, Romania is considered to be the least performing Member State in the European Union in terms of

municipal solid waste management, with a significant amount of waste ending up in landfills [6]. Romania has also seen a decline in technical and sustainability aspects and is among the worst-performing countries in economic and sustainability aspects [12]. Romania has a low recycling rate of 12% in 2022, significantly below the EU-27 average. The waste disposal rate was 74% in 2022. The current estimated capacity for composting or digesting separately collected bio-waste could only treat about 27% of the amount generated (estimated at about 1.7 million tons) [8].

Table 1: Italy and Romania waste management data in relation to the European level from 2020 (2018-2022)

	2018		2019		2020		2021		2022	
	RO	IT	RO	IT	RO	IT	RO	IT	RO	IT
Waste generated	2.37	13.52	2.41	13.32	2.40	12.43	2.42	12.28	2.51	12.47
Waste treatment	2.27	12.61	2.27	12.52	2.23	11.49	2.28	11.39	2.41	11.55
Disposal - incineration and recovery - energy recovery	0.41	9.87	0.43	10.03	0.48	9.12	0.54	9.13	0.73	9.09
Disposal - landfill and other	7.36	11.66	7.45	11.36	7.57	10.70	8.34	10.75	8.11	9.86
Recovery - energy recovery	0.42	9.75	0.44	9.92	0.49	9.02	0.55	8.95	0.68	8.93
Recycling	0.57	14.49	0.59	14.52	0.58	13.08	0.55	12.77	0.63	13.51
Recycling - material	0.62	13.19	0.57	13.51	0.45	11.49	0.53	11.16	0.61	12.06
Recycling - composting and digestion	0.48	16.81	0.61	16.33	0.82	15.92	0.59	15.44	0.67	15.93

Source: Eurostat, [13]

Using data provided by Eurostat on municipal waste by waste management operations and comparing this data for the two countries (Italy and Romania), Table 1 shows that Italy has a significantly higher recycling rate than the European Union average compared to Romania, with an average of 0.58% in Romania and 13.67% in Italy. Waste treatment also has a higher percentage in Italy (11.91%) than in Romania (2.29%), but also a higher production of energy from biogas, 9.31% (Italy) compared to 0.52% in Romania. It can also be seen that the waste generated during the period analysed shows a slight decrease in Italy, from 13.52% to 12.47%, while in Romania, there is an upward trend from 2.37% to 2.51% [13].

METHODOLOGY

This section explains the methods used and the steps taken to conduct this research. The research carried out in this article consists of a comparative analysis based on qualitative criteria regarding the use of biogas from municipal landfills for energy production by companies in Italy and Romania.

The methodology used to carry out comparative analysis is based on three research objectives:

The first objective is to identify effective practices for using biogas from municipal landfills, which are used by companies in Italy and Romania.

The second objective aims to analyse these practices and identify the main differences between the approaches of companies in each country analyzed. The differences are identified based on three selected criteria: the sorting process, the technology used, and energy production.

The third objective consists of formulating recommendations on using landfill biogas for energy production following the comparative study.

This study was made possible by the European Star project, whose main objective was to study sustainability practices in organizations and companies. The analysis was expanded and the data presented in this article was used in the research. For Romania, given the lack of data and clear official reports at the national level, research was conducted using information available on the websites of companies operating municipal waste landfills, the municipalities they serve, and the National Agency for Environment and Protected Areas (ANPM). ANPM regulates activities impacting the environment and manages documents of public interest, such as annual environmental reports, integrated environmental permits, etc. The main results of the analysis will be presented below.

RESULTS AND FURTHER DISCUSSIONS

In both countries, landfill operators are responsible for collecting waste from users, transporting, sorting, recycling, and treating it. Thus, based on qualitative criteria, differences were found in the sorting process, the technologies used, and energy production. All of these are described in more detail below.

ACEA Pinerolese Industriale S.p.A. (API) is a private multi-utility company owned by the 47 municipalities it serves. The 47 municipalities (Consorzio Pinerolo Energia) are in the Piedmont region of northwestern Italy, covering an area of approximately 1,348 km². These municipalities, together with over 150,000 inhabitants and over 70 companies, benefit from water cycle management services, integrated with waste management, anaerobic treatment of organic fractions, and two hydroelectric power plants [14].

In Romania, according to the latest available information, except for Maramureş County, there is at least one municipal waste landfill in each county that complies with the legal provisions. The counties of Brăila, Dâmboviţa, Harghita, Neamţ, Tulcea, and Prahova have two such solid waste landfills, and Constanţa County has three [15]. In Romania, these landfills are owned by the administrative authorities in whose territory they are located and which they serve. Still, most of them are operated by private companies to which the management of waste disposal has been delegated.

The sorting process

In terms of the sorting process, the approaches are very different. In the case of Acea Pinerolse, the entire sorting process has a high standard of performance and automation. The material received consists of organic waste sorted from homes, bars, and restaurants, and is stored in a basin and then transported to a machine (Frisacco) that cuts the garbage bags. The released material is then transported to a screen that separates organic matter from plastics that must be removed, after which it reaches an organic mixer. This machine is protected by an international patent and was designed and built entirely by Acea technicians. It removes any metal, plastic, and inert residues, such as ceramics, helping to homogenize the mass of materials. Ferrous metals are detected and removed using special machines [2; 16].

In Romania, the sorting process has a low standard of performance and automation. It has been found that the majority of companies operating landfills use sorting stations, but there are still landfills where sorting is done manually by company staff. Even landfills with sorting stations are assisted by manual sorting by authorized personnel. The performance of sorting stations can be analyzed in terms of their utilization capacity, which is quite low on average, below 50%. Operating well below the designed capacity of the sorting station is caused by the low level of separate waste collection by the population. Furthermore, even if recyclable waste is collected separately by the population, it ends up in the same collection vehicle and becomes mixed at the sorting station, which leads to a reduction in the amount of recycled material [17].

Technologies used

In the case of the Italian company Acea Pinerolese, the leading technology used in biogas recovery is the biodigester, as can be seen in Figure 1. This technology has a high biogas recovery rate. Anaerobic biodigestion involves natural fermentation in the absence of oxygen in digesters (2,600 m³ tanks) at a temperature of 55°C. After approximately two weeks of maturation, the organic waste is converted into methane-rich biogas, and the digestate is converted into digested sludge. The biogas extracted from the biodigesters is temporarily stored in a 3,300 m³ gasometer, where biogas from the landfill and the wastewater treatment plant are also collected [2; 16]. Thus, biogas recovery has a high rate both due to the technology, using the biodigester, and due to the recovery of multiple sources of biogas production.



Figure 1: Stages of the process of using biogas from solid waste in Acea Pinerolese

Source: Taken from the presentation given by the representative of Acea Pinerolese at the workshop organized on July 10, 2025, at SAA - School of Management as part of the STAR project.

Depending on the degree of modernisation and efficiency, landfills in Romania generally operate sorting stations, composting stations, transfer platforms, landfill leachate treatment plants and mechanical-biological treatment plants. Mechanical-biological treatment is considered a smart technology that meets the "Best available techniques" standard imposed by the European Union. However, this technology has a low biogas recovery rate. Research also shows that less than a third of landfills currently use this technology, with plans to build such a system in at least four more counties.

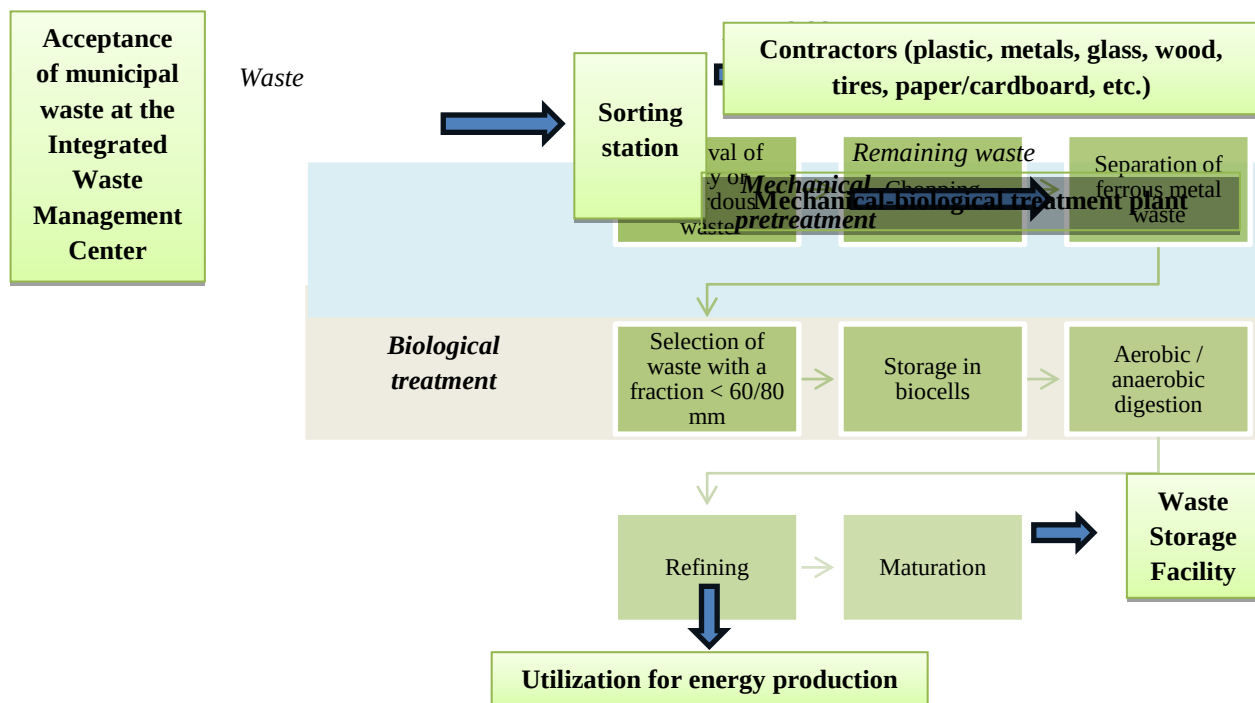


Figure 2: Stages of the waste disposal process in municipal landfills in Romania

Source: Diagram created according to (Miclăușu Camelia, 2024) [18]

Mechanical-biological treatment comprises three stages: mechanical pre-treatment, biological treatment, and refining and maturation (Figure 2). Before entering the mechanical pre-treatment hall, non-compliant waste recorded at the sorting station is unloaded, as well as other categories of biodegradable waste received, including mixed municipal waste. From there, it is transported to the mechanical treatment plant inside the hall. The waste enters the shredder, but not before an operator checks the waste mass and removes any bulky or hazardous waste. The waste is then loaded into a rotating sieve for preselection by size. The belt that transports the waste from the shredder to the sieve is equipped with a magnet to separate ferrous metal waste. Waste smaller than the sieve holes is transported to biocells where biological treatment takes place. Waste larger than the sieve holes is stored in a container and partially recovered for energy through co-incineration, while the rest is stored in the non-hazardous waste landfill [18].

Biological treatment consists of composting (accelerated decomposition) in biocells, closed enclosures covered with semi-permeable foil, designed to limit odor emissions. Biological treatment can be both aerobic and anaerobic, which is a process of decomposition and transformation of solid organic substances by microorganisms (bacteria, fungi) into a stable material, with the formation of CO₂, water, and humic substances. Each biocell is equipped with a ventilation and deodorization system that extracts possible emissions. The system is equipped with a biofilter to neutralize emissions, which are then released into the atmosphere [19]. After biological treatment, the material reaches a mobile sieve for refining the remaining waste (plastic, non-biodegradable organic materials, etc.). The waste that passes through the sieve is deposited in piles for maturation, and the remaining material is sent directly to the landfill or used for energy recovery. Once stabilized, the compost obtained in this way is transported to the landfill and used as cover material [18]. The biogas emitted by the landfill is collected using a system consisting of a network of pipes connected to a suction-compression station (booster station), which ensures that the pressure in the storage cells is lower than outside and, as a result, the gas does not escape uncontrollably into the atmosphere. The landfill gas extraction and collection system also significantly reduces greenhouse gas emissions and improves air quality. Controlled neutralization of landfill gas can be achieved either through a high-temperature controlled combustion plant or through its higher utilization in an electricity and/or heat production plant [20].

Analyses of several alternatives for increasing the efficiency of municipal landfills show that, in order to achieve recycling targets, separate collection of bio-waste and emission capture rates, capacities are needed that can manage/treat the entire amount of separately collected bio-waste. To reduce the quantities of biodegradable waste sent to landfills and achieve the proposed target, this quantity must be treated in anaerobic digestion plants. Treatment in anaerobic digestion plants ensures a reduction in the amount of waste sent to landfill compared to treatment in mechanical-biological treatment plants. This would result in a lower quality biostabilised compost for which recovery solutions would have to be found or which would have to be landfilled [21].

Renewable energy production from landfill biogas

In the case of Acea Pinerolese, the rate of energy production from biogas and emission reduction is very high. In 2020, in line with the Italian strategy for the production of biofuels for transport, including liquid or gaseous fuels such as biodiesel and biomethane from biomass, the Acea Pinerolese plant underwent an upgrade. Until 2020, all biogas was used to fuel three cogeneration units with a total power of > 3 MW to produce electricity and heat. In contrast, the current configuration produces biomethane with a nominal output flow of up to 800 Sm³/h [22].

To remove unwanted gases, increase the methane concentration, and achieve the pressure required for its use, the biogas from digestion is compressed, cooled, washed, and filtered. This is done using multi-stage membranes and processes such as water purification and activated carbon to remove CO₂, H₂S, and other impurities. At the end of these operations, the result is biomethane (proportion > 96% methane), with characteristics similar to natural gas. After treatment, it is used in engines and converted into electricity and heat. The energy is used for local consumption, and the surplus electricity is sold to the national grid, while the surplus heat feeds a district heating network. The digestate is dehydrated and sent to the active composting plant, where it is mixed with previously shredded green waste and subjected to a maturation and refinement treatment [2; 16]. As the biogenic CO₂ separated by the conversion unit is currently released into the atmosphere, the company is evaluating additional vaporization activities [22]. The site is independent of the electricity grid, producing its own needs through cogeneration fuelled by biogas from the landfill, and the total energy produced and consumed on site is approximately 12 MWh of electricity and 17 MWh of heat [23]. In addition, ACEA Pinerolese Energia S.R.L (APE) provides energy sales services to various types of public and private users and is also connected to a local district heating network [14].

In Romanian companies, the rate of biogas energy production and emission reduction is very low, almost non-existent. According to the website of the National Transmission and System Operator (Transelectrica) [24] and the ENTSO-E [25] transparency platform, based on the available information, there are currently no operational units

producing electricity from biogas obtained from waste connected to the national grid [24-25]. The research showed that the Ilfov landfill uses biogas from waste to power its own plant, but none of the landfills studied use biogas to produce energy for delivery to the energy system. Moreover, many of the companies are not only producers of renewable energy but are also energy consumers. Electricity is supplied from the SEN, and there is a generator on site in the event of a power outage [18]. The average amount of energy consumed per ton of waste is approximately 3.5 kWh/ton.

CONCLUSION

The main objectives pursued in this article aimed to identify the practices of using biogas from solid waste landfills in Italy and Romania, analyse them, identify the main differences, and formulate recommendations based on the results obtained. Thus, the research highlighted that, in terms of practices for using biogas from solid waste landfills, Italy has implemented technologies that enable the production of energy from biogas from solid waste landfills, while Romania does not currently use biogas emitted from municipal waste landfills to produce green energy. The analysis of these practices revealed significant differences in terms of sorting efficiency, technologies used, and the amount of energy produced. In terms of sorting, it was found that Romania does not have an efficient collection and/or transport system, an aspect also confirmed by other analyses in this field [6], [8], [12]. In terms of technology, although it is well known that the biodigester technology used in Italy is more efficient than the mechanical-biological treatment used in Romania, companies prefer to implement the latter method, considering it the best available technique (BAT) for waste treatment. Last but not least, in terms of energy production, unlike Italy, where the company covers its own consumption and the surplus electricity is sold to the national grid, in Romania, most companies purchase energy from the national energy grid. Therefore, following the comparative analysis, the following recommendations are made:

- Modernisation and automation of the waste sorting process, but not before improving the efficiency of waste collection and transport. A much more rigorous recycling process is needed so that most of the reusable waste can be recovered, leaving the organic fraction from which biogas is produced. A functional selective transport system must also be ensured.
- Conducting technical and economic analyses on the potential for using biogas in solid waste landfills and feasibility studies on the construction of a system for using biogas from landfills (biodigesters, equipment for removing unwanted gases and increasing methane concentration, electricity and/or heat production units).
- Use all available sources of biogas (wastewater, biogas from biodigesters, and landfills).
- Designing and investing in a biogas recovery system if analyses and studies indicate a high success rate and high revenues.
- Collaboration between companies building such a system and nearby companies that own solid waste landfills, for which the feasibility analysis is not favourable for biogas procurement.

This study is of practical importance as it helps waste disposal companies find better ways to use biogas from the landfills, they operate by providing examples of good practices. However, the article also has a theoretical contribution, presenting a sustainable solution that helps reduce the negative impact on the environment.

This research is relatively limited because it was conducted on a relatively small number of companies, fewer than 50, so the results cannot be generalised. In the future, this research should be extended to a larger number of companies in Italy and Romania in order to identify more sustainable solutions.

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REFERENCES

- [1] Caetano, B.; Santos, N.; Hanriot, V.; Sandoval, O.; Huebner, R.: Energy conversion of biogas from livestock manure to electricity energy using a Stirling engine. *Energy Conversion and Management*: X. 15. (2022). <https://doi.org/10.1016/j.ecmx.2022.100224>.
- [2] ACEA Pinerolese Industriale S.p.A., POLO ECOLOGICO Energy for the future of the environment, (2017), Polo Ecologico Integrato, aceapinerolese.it, Available from: https://www.aceapinerolese.it/wp-content/uploads/2017/04/POLO_BROCHURE_ENG_2017.pdf, Accessed: 2025-08-08.

- [3] Amponsem, B.; Bensah, E.; Antwi, E.; Ahiekpor, J.; Boahen, B.; Mensah, I.; Narra, S.: Electricity generation from biogas as resource recovery potential from solid waste composition in a mixed-income municipality. *Cleaner Waste Systems*. (2023). 4. <https://doi.org/10.1016/j.clwas.2022.100067>.
- [4] European Environment Agency, Methane emissions in the EU: the key to immediate action on climate change, *eea.europa.eu*, (2022). ISSN: 2467-3196, doi: 10.2800/7532, Available from: <https://www.eea.europa.eu/publications/methane-emissions-in-the-eu>, Accessed: 2025-08-09.
- [5] Yechiel A. & Shevah Y.: Optimization of energy generation using landfill biogas. *Journal of Energy Storage*, 7, (2016). pp. 93-98, Available from: <https://doi.org/10.1016/j.est.2016.05.002>, Accessed: 2025-08-09.
- [6] Gavrilescu, D.; Seto, B.-C. & Teodosiu, C.: Sustainability analysis of packaging waste management systems: A case study in the Romanian context. *Journal of Cleaner Production*. (2023). Vol. 422. 138578. ISSN 0959-6526, <https://doi.org/10.1016/j.jclepro.2023.138578>.
- [7] Giocoli, A.; Carbone, C.; Pierro, N.; Di Florio, G.; Motola, V.; Buffi, M. & Agostini, A.: Advanced biomethane potential from local sources in Italy. *Journal of environmental management*. (2025). Vol. 389. <https://doi.org/10.1016/j.jenvman.2025.126154>.
- [8] European Environment Agency, Waste management country profile with a focus on municipal and packaging waste *Romania*, *eea.europa.eu*, (2025), Available from: <https://www.eea.europa.eu/en/topics/in-depth/waste-and-recycling/municipal-and-packaging-waste-management-country-profiles-2025/ro-municipal-waste-factsheet.pdf/@download/file#:~:text=Until%202022%2C%20Romania%20has%20not%20made%20progress.38%25%20in%202021%2C%20needs%20improvement%20as%20well>, Accessed: 2025-08-08.
- [9] IRENA (2021), Renewable Energy Statistics 2021, The International Renewable Energy Agency, Abu Dhabi. Available from: www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Aug/IRENA_Renewable_Energy_Statistics_2021.pdf, Accessed: 2025-08-09.
- [10] Cudjoe, D.; Han, M. S.; Nandwardhana, A. P.: Electricity generation using biogas from organic fraction of municipal solid waste generated in provinces of China: Techno-economic and environmental impact analysis, *Fuel Processing Technology*, (2020). Vol. 203, Available from: <https://doi.org/10.1016/j.fuproc.2020.106381>.
- [11] Collaguazo G.; Badea A.; Stan C.; Apostol T.; Paraschiv G.; Pásztai Z.: Landfill gas to energy conversion from Oradea municipal waste landfill in Romania. *Environmental Engineering and Management Journal*, (2019). 18 (2), pp. 311-320, Available from: http://www.eemj.icpm.tuiasi.ro/pdfs/vol18/full/no2/5_58_Collaguazo_15.pdf.
- [12] D'Adamo I.; Daraio C.; Di Leo S.; Gastaldi M.; Rossi E. N.: Driving EU sustainability: Promoting the circular economy through municipal waste efficiency, *Sustainable Production and Consumption*, Vol. 50. (2024). pp. 462-474, ISSN 2352-5509, <https://doi.org/10.1016/j.spc.2024.08.022>.
- [13] Eurostat, Municipal waste by waste management operations, (2025), Available from: https://ec.europa.eu/eurostat/databrowser/view/env_wasmun_custom_17875766/default/table, Accessed: 2025-08-09.
- [14] Mutani G.; Santantonio S.; Brunetta G.; Caldarice O.; Demichela M.: An energy community for territorial resilience: Measurement of the risk of an energy supply blackout, *Energy and Buildings*, Vol. 240. (2021). 110906, ISSN 0378-7788, <https://doi.org/10.1016/j.enbuild.2021.110906>.
- [15] Agenția Națională pentru Mediu și Arie Protejate, Lista depozitelor de deseuri municipale conforme cu prevederile legislative – ianuarie 2025, *anpm.ro*, (2025), Available from: <http://www.anpm.ro/documents/12220/2024145/Lista+depozitelor+municipale+conforme+cu+prevederile+legislative+-+actualizat+ianuarie+2025%287%29.xlsx/180b9abe-2237-4589-a62c-47e780210c25>, Accessed: 2025-08-08.
- [16] Acea Pinerolese, AMBIENTE, *aceapinerolese.it*, (2025). Available from: <https://www.aceapinerolese.it/acqua/>, Accessed: 2025-08-08.
- [17] Consiliul Județean Satu Mare, Aviz de mediu, Agenția pentru protecția mediului Satu Mare, *cjsm.ro*, (2021), Available from: <https://www.cjsm.ro/storage/ddr/pjgd/aviz-de-mediu.pdf>, Accessed: 2025-08-10.
- [18] Miclăușu C.: Raport de amplasament pentru “Centrul de management integrat al deșeurilor” com. Galda de jos, extravilan, loc. Galda de jos, jud. Alba, <https://rervest.ro>. (2024), Available from: <https://rervest.ro/anunt-public/>, Accessed: 2025-08-10.
- [19] S.C. Iridex Group Salubritate S.R.L., Raport de amplasament pentru obiectivul: „Centrul de management integrat al deșeurilor Mihai Bravu, județul Tulcea”, (2019), Available from: http://www.anpm.ro/documents/28797/46573580/RAPORT+++DE+++AMPLASAMENT+MIHAI+BRAVU_var+2_020.pdf/a825ea02-04e0-47dd-81d1-79b729cd84bb, Accessed: 2025-08-10.
- [20] Iridex Group, Gestiunea Deșeurilor, *iridex.ro*, (2023), Available from: <https://iridex.ro/gestiunea-deseurilor/>, Accessed: 2025-08-10.

- [21] Avram H.; Bobar H.; Soponar M.; Vintan C., Buruiana C.: Plan județean de gestionare a deșeurilor Constanta, Consiliul județean Constanta, cjc.ro, (2020), Available from: https://www.cjc.ro/dyn_doc/Hotarari/2021/30-PJGD.pdf, Accessed: 2025-08-10.
- [22] Negro V.; Noussan M.; Chiaramonti D.: Alternative options for biogas-to-energy: A comparison of electricity and biomethane generation based on the real operation of a production site, *Applied Energy*, Vol. 377, Part D, (2025), 124687, ISSN 0306-2619, Available from: <https://doi.org/10.1016/j.apenergy.2024.124687>.
- [23] Montoneri E. et. al.: Integrated chemical and biochemical technology to produce biogas with a reduced ammonia content from municipal biowaste. Validating lab-scale research in a real operational environment††Electronic supplementary information (ESI) available, *Environmental Science Advances*, Vol. 1, Issue 5, (2022), pp. 746-768, ISSN 2754-7000, <https://doi.org/10.1039/d2va00068g>.
- [24] Transelectrica, 7. Cerinte privind transparenta informatiilor referitoare la Productie, (2025), Available from: <https://www.transelectrica.ro/ro/web/tel/productie>, Accessed: 2025-08-17.
- [25] ENTSO-E, Installed Capacity per Production Type, (2025), Available from: <https://transparency.entsoe.eu>, Accessed: 2025-08-17.