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CASE STUDY OF LITHUANIA: INVESTIGATION OF GHG EMISSIONS REDUCTION FROM MUNICIPAL SOLID WASTE MANAGEMENT PRACTICES

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Abstract. This upcoming article will present a comprehensive case study conducted in Lithuania, focusing on the reduction of greenhouse gas (GHG) emissions through innovative municipal solid waste management practices. The research methodically analyze various waste management strategies implemented across Lithuania and their effectiveness in lowering GHG emissions. A significant portion of the study will be devoted to exploring the policy implications of the findings. It will propose actionable recommendations for policymakers, aimed at enhancing the efficacy of waste management systems in reducing environmental footprints. The outcome of this research is a set of data-driven insights that can inform future waste management policies.

Keywords: waste management, sustainability, decarbonization, GHG emissions, municipal waste.

1. Introduction

Daily human activities significantly contribute to global warming through the release of greenhouse gases (GHGs). An average individual generates approximately 0.74 kilograms of waste daily, as per World Bank data (Kaza, 2018), with a third of this waste being improperly managed, posing environmental risks. This mismanagement contributes to over 3.3 billion tonnes of CO_2 equivalent emissions worldwide. Projections indicate a potential doubling of waste production, underscoring the urgency of adopting effective waste management strategies. These strategies prioritize waste prevention, reuse, recycling, and recovery before resorting to landfill disposal, the latter being a significant source of methane emissions, accounting for about 11% of global and 50% of waste sector-specific methane emissions (Kaza et al., 2018).

The waste management sector plays a pivotal role in the emission of GHGs, with activities ranging from collection to disposal contributing to atmospheric carbon levels. GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), are significant in climate change, highlighting the sector's impact on global warming. Addressing the escalating waste volumes necessitates a shift towards decarbonizing waste management practices.

Decarbonization refers to strategies aimed at reducing or eliminating carbon emissions across various sectors, from transportation to waste disposal. Within the waste management sector, decarbonization is viewed as a critical component of climate change mitigation efforts. By adopting and implementing effective decarbonization measures, the sector can significantly reduce its carbon footprint and environmental impact, offering a viable approach to mitigating GHG emissions associated with waste (Morseletto, 2020).

2. Introduction to Lithuania's waste management

As it can be observed from the Figure 1, The annual production of municipal waste in Lithuania has exhibited a relatively constant figure, approximately 1.3 million tonnes, since 2016, with a recorded amount of 1.35 million tonnes in 2020.

Notably, the per capita waste generation has observed a gradual escalation from 444 kilograms per

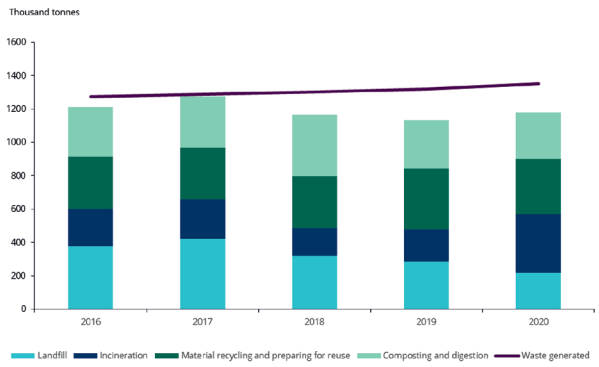

Figure 1. Municipal waste generation and treatment in Lithuania between 2016 and 2020, in thousand tonnes (EEA, 2022)

capita in 2016 to 483 kilograms per capita by 2020. This increment, however, remains below the estimated European Union average of 505 kilograms per capita (European Environmental Agency [EEA], 2022). In a strategic move to diminish its dependency on landfill disposal, Lithuania has significantly expanded its capacity for processing mixed municipal waste. This expansion includes the enhancement of both Mechanical Biological Treatment (MBT) facilities and the adoption of waste-to-energy incineration methods. The operational commencement of two additional waste incineration plants in 2020 markedly augmented the nation's incineration capacity from 255,000 tonnes annually to 615,000 tonnes, as reported by the Ministry of Environment in 2021. As a result, the proportion of waste consigned to landfills decreased from 29.8% in 2016 to 16.3% in 2020, with a corresponding rise in incineration to 25.9% (Valstybės kontrolės tarnyba, 2023).

The current landfill waste mainly consists of MBT residuals, following the 2013 prohibition against the landfilling of untreated waste. Concurrently, the period observed a modest increase in material recycling rates and a significant flow in the quantities of waste composted and digested, primarily driven by MBT-derived outputs classified as composted or digested, according to Eurostat data from 2021 (EEA, 2021).

In the years 2018, 2019, and 2020, the volumes of treated municipal waste were consistently lower than the generated amounts. This discrepancy is attributed to mass losses inherent in the MBT process, as well as the temporary storage of combustible MBT outputs. A notable decline in the treatment rate in 2019 was linked to the increased temporary storage of refuse-derived fuel (RDF), which could not be processed due to the incineration facilities operating at maximum capacity, as indicated by the Lithuanian Environmental Protection Agency in 2019 (European Environmental Agency, 2023). However, this backlog is anticipated to be addressed with the inception of the two new incineration plants in 2021, as stated by the Environmental Protection Agency of Lithuania in 2020 (Valstybės kontrolės tarnyba, 2023).

An improvement in the accessibility of municipal waste collection services has been observed, with coverage expanding from 94% of the population in 2010 to 99% by 2019, demonstrating a significant reduction in the number of individuals not served by waste collection services. This data, provided by the Environmental Protection Agency of Lithuania and Eurostat in 2020 and 2017 respectively, underscores a comprehensive enhancement in waste management infrastructure (Eurostat, 2020).

3. Green House Gas emissions from waste management

GHG emissions from the waste sector can be primarily attributed to a reduction in greenhouse gas (GHG) emissions resulting from the disposal of solid waste, specifically through a decline in landfilling practices. Landfilling refers to the act of depositing waste onto land or into designated areas. One significant contributor to GHG emissions in landfills is the organic portion of the waste, which generates methane emissions. In Lithuania most of the landfills are used for construction and the waste, that are no longer available for recycling or the waste that are left after the treatment. There are only 11 working landfills in Lithuania (Valstybės kontrolės tarnyba, 2023). Although comparing the waste sector with other biggest contributors, the reduction in GHG emissions is not so significant; the waste sector managed to reduce its emissions by 35% over 30 years (EEA, 2023a).

In the Lithuanian waste sector, there has been a pronounced diminution in greenhouse gas emissions (GHGEs), achieving a 1.9-fold decrease from 1.689 million tonnes of CO_2 equivalent to 894 kt CO_2 eq. This trend is associated with demographic decline, enhancements in waste management infrastructure, and elevated environmental consciousness. Methane emissions, predominantly originating from landfill biodegradable waste and wastewater processes, represented 25% of the total methane output in 2021. Additionally, the sector was responsible for 2% of the aggregate nitrous oxide emissions, arising from wastewater treatment, composting, and waste incineration activities. Notably, the fraction of municipal waste directed to landfills has significantly reduced, facilitated by the deployment of mechanical-biological treatment facilities, implementation of deposit-return schemes for disposable packages, and increased societal awareness, ending in a 46% reduction in landfill GHGEs from 1990 to 2021. Enhanced sewage collection and wastewater treatment efficacy have concurrently improved sludge quality and tripled the reduction of

GHGEs from these activities over the examined period (Konstantinavičiūtė, 2021).

In the Figure 2 it can be seen the current trends in GHG emissions from waste sector. In 2019, land disposal of solid waste and sewage sludge was identified as the predominant source of greenhouse gas (GHG) emissions within the waste sector, accounting for approximately 69.6% of its total GHG output. The trend in GHG emissions from these sources initially saw a slight increase from 1990 to 2003, followed by a decline attributed to the reduction in waste disposal volumes, enhanced landfill gas extraction, and the anaerobic digestion of sewage sludge. A notable surge in emissions between 2000 and 2003 was primarily due to the disposal of significant quantities of organic waste from sugar production, which subsequently decreased as this waste began being repurposed for agricultural use by producers. Post-2010, following the development of regional waste management systems and the introduction of Mechanical Biological Treatment (MBT) facilities in 2016, GHG emissions from biological waste treatment, including composting and anaerobic digestion, rose significantly, reaching 15.1% of the sector's total emissions by 2019 (Konstantinavičiūtė, 2021).

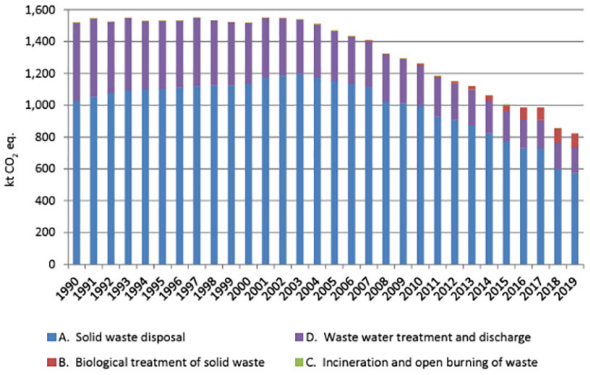

Figure 2. Trend of GHG emissions in waste sector during the period 1990–2019 (Konstantinavičiūtė, 2021)

4. Strategies for GHG emissions reduction in MSW management

Effective waste management is a crucial component of the circular economy, aiming to ensure the safe handling of municipal waste for human health and the environment. This involves reducing waste generation, encouraging the efficient use of secondary materials for recycling or energy production, thereby minimizing the exploitation of natural and other resources and landfilling. The waste hierrarchy is presented in the Figure 3 (European Commission, 2022).

Figure 3. Waste hierarchy (European Commission, 2022)

Policy and regulation play a pivotal role in steering Lithuania's waste management practices towards GHG emissions reduction. The EU's Waste Framework Directive, along with national regulations, has set ambitious targets for recycling and waste reduction, pushing for a transition to a circular economy. Public-private partnerships have been instrumental in achieving these targets, facilitating investments in recycling facilities, waste-to-energy plants, and innovative waste management solutions. These collaborations have enabled the integration of advanced technologies and practices into Lithuania's waste management infrastructure.

The strategic objective of Lithuania's waste prevention and management involves a multifaceted approach aimed at reducing the generation of waste, ensuring the health and environmental safety of waste management practices, and promoting the efficient use of material and energy resources. This strategy prioritizes minimizing the consumption of natural resources and landfill waste disposal while reducing environmental pollution and supplying the industry with local raw materials (Lietuvos Respublikos Vyriausybė, 2021).

The State Waste Prevention and Management Plan for 2021–2027 was developed in line with Lithuania's overarching environmental and sustainable development policies, including the National Progress Plan 2021–2030, the National Sustainable Development Strategy, the National Environmental Protection Strategy, the National Energy and Climate Action Plan for 2021–2030, and the National Climate Change Management Agenda (Lietuvos Respublikos Vyriausybė, 2021). These foundational documents, ratified by various government resolutions and laws, establish the framework for Lithuania's approach to waste management within the context of broader environmental goals, emphasizing circular economy principles and the integration of advanced technologies and innovations. The plan aligns with the National Environmental Policy's (NPP) sixth strategic goal of maintaining high environmental quality and sustainable use of natural resources, protecting biodiversity, mitigating Lithuania's climate impact, and enhancing resilience to climate change effects. It specifically targets reducing waste generation and efficiently

managing waste in accordance with the prioritization of waste management and prevention hierarchies, improving waste sorting at the point of generation, and decreasing the quantity of waste sent to landfills (Valstybės kontrolės tarnyba, 2023).

Strategic waste prevention and management objectives up to 2027 encompass:

- Waste Prevention: Avoiding waste generation and reducing the amount of waste and harmful substances in materials and products by encouraging the choice of reusable items, promoting repair and maintenance services, combating littering, ensuring food waste prevention, and fostering eco-friendly design and business models that incorporate waste prevention.
- Preparation for Reuse: Separating waste at the source for potential reuse or recycling and increasing public environmental awareness and responsibility in waste sorting.
- Recycling and Reuse: Enhancing the recycling process and the use of secondary materials.
- Alternative Waste Utilization: Employing non-recyclable waste to reduce environmental and health risks, and minimizing the amount of waste used for energy production.
- Waste Disposal: Safely disposing of unavoidable waste without harming public health or the environment, including the safe disposal of asbestos waste.

The plan also aims to strengthen the waste prevention and management control system by improving data collection and processing on waste generation and management, tightening control over the activities of product and packaging manufacturers and importers, and enhancing the qualifications of environmental protection control system employees.

Measures to achieve the strategic waste management goals and tasks by 2027 are detailed in the plan's annexes, along with criteria for evaluating the plan's implementation (Valstybės kontrolės tarnyba, 2023).

Other countries has similar, but efficient ways for waste sector decarbonization. For example, Norden Countries as Denmark, Finland, Iceland, Norway and Sweeden has reduced their GHG emissions from waste management sector significantly – by 8 million tonnes of CO_2e, corresponding to a 59% emissions reduction in the sector (Nordic Council of Ministers, 2023). The way to achieve this result were the ban for the landfills, mandatory waste separation – plastics, metals, paper, as well as organic waste. The main accelerator for waste sector decarbonizarion in Nordic countries were waste-to-energy technologies, such as incineration with energy recovery, are utilized to convert non-recyclable waste into heat and electricity, reducing the reliance on fossil fuels for energy generation.

Another example is "Pay as you throw" programm in South Korea, that was implemented in 1995 (Wang et al., 2023). Under this system, households and businesses are charged based on the amount of waste they generate, incentivizing waste reduction and recycling. South Korea's pay-as-you-throw program has been successful in reducing waste generation, increasing recycling rates, and promoting sustainable consumption patterns.

Recommendations

1. According to the other countries examples it is recommended to apply organic waste collection system in all municipalities.
2. Promotion of public awareness and education plays a crucial role in waste reduction and recycling practices, more campaigns would help to increase awareness.

5. Conclusions

1. The waste hierarchy principles–emphasizing prevention, reuse, recycling, and recovery–are central to Lithuania's waste management strategy.
2. The deposit-return system for beverage containers notably improved recycling rates and public participation in sustainable waste management practices.
3. Lithuania's innovative approach to managing non-recyclable waste through waste-to-energy technologies contributes to waste reduction and energy production.
4. The adoption of new technologies and innovative waste management solutions is crucial for addressing the evolving challenges of waste generation and management.

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LIETUVOS ATVEJO ANALIZĖ – ŠESD IŠMETAMŲJŲ DUJŲ MAŽINIMO IŠ MIŠRIŲ KOMUNALINIŲ ATLIEKŲ SEKTORIAUS VERTINIMAS

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Santrauka. Šiame straipsnyje pristatytas tyrimas apie situaciją Lietuvoje, daugiausia dėmesio skiriant šiltnamio efektą sukeliančių dujų (ŠESD) emisijų mažinimui taikant inovatyvias komunalinių atliekų tvarkymo praktikas. Tyrimo metu analizuojamos įvairios visoje Lietuvoje įgyvendinamos atliekų tvarkymo strategijos ir jų efektyvumas mažinant ŠESD emisijas. Dėmesys skiriamas pažangiems technologiniams metodams ir politikos sistemoms, atitinkančioms aplinkos tvarumo tikslus, integruoti. Straipsnyje pasiūlytos įgyvendinamos rekomendacijos, kuriomis siekiama padidinti atliekų tvarkymo sistemų veiksmingumą mažinant ekologinį pėdsaką. Šio tyrimo rezultatas – tai duomenimis pagrįstų įžvalgų rinkinys, galintis padėti formuoti būsimą atliekų tvarkymo politiką.

Reikšminiai žodžiai: atliekos, emisijos, tvarumas, žiedišku-mas, komunalinės atliekos.