Transition to Recycling vs. Energy Recovery in Municipal Solid Waste Management: Evaluating the Speed of GHG Emission Reduction

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Introduction

Technological advancements have shifted consumption patterns, leading to increased municipal solid waste (MSW) generation and a move towards a circular economy, emphasizing resource reduction, maximized product usage, and sustainability in design (Van Caneghem et al., 2019). Despite Europe's progress in adopting circular economy principles, global waste management practices lag, with a significant reliance on landfilling due to its cost efficiency (Kaza et al., 2018). However, landfilling is associated with significant greenhouse gas (GHG) emissions along with other pollution (Siddiqua et al., 2022), while urgent reduction of GHG emissions is required to mitigate climate change (IPCC, 2022). Alternatives to landfilling, such as recycling and waste-to-energy (WTE) (here WTE is used to refer specifically to incineration of MSW with energy recovery), commonly offer less environmental impact and contribute to reducing greenhouse gas emissions by limiting the need for non-renewable materials and providing alternative energy sources (Malinauskaite et al., 2017). However, the transition to alternatives requires significant investments in recycling and WTE infrastructure and active involvement of waste producers in case of recycling (Hu et al., 2022). Considering the necessity to reduce GHG emission drastically in a couple of decades and the time needed for such transitions to come to effect, this study aimed to determine if WTE could be a faster solution for mitigating GHG emissions in MSW management compared to recycling. To achieve this, the study assessed the speed of transition from landfilling to WTE and recycling in countries that performed in landfill diversion well in the past and calculated GHG emission reduction over the transitional period in selected cases.

Methodology

MSW statistics of 13 countries (Lithuania, Latvia, Slovenia, Slovakia, Croatia, Ireland, Austria, Norway, United Kingdom, Finland, Poland, Italy, and China) that performed well in the transition from landfilling of MSW to recycling and/or WTE in a short period of time were analyzed. The *speed of transition* was quantitatively assessed using mathematical equations that consider the percentage changes in waste incineration, recycling, and landfilling relative to the period of time in which the shift from landfilling to recycling or WTE happened (transition period). Calculated indices allow to evaluate and compare the progress each country has made in shifting towards more environmentally friendly waste management practices. To estimate the reduction of environmental impact that was brought by diverting MSW from landfills, Life Cycle Assessment (LCA) was conducted for here selected cases - Finland, Poland, and Italy - due to data limitations. The LCA followed ISO 14040 and ISO 14044 and was done using LCA for Experts (former GaBi) software and Ecoinvent database to model GHG emissions. The functional unit was set at one ton of MSW. System boundary included activities starting from sorting of collected recyclables and ending at waste treatment, while expanding the system to account for avoided production of materials and energy. The LCA model included recycling of plastics, paper, glass, metals and biowaste, assuming specific separation rates and substitution ratios to estimate environmental benefits of recycling of different waste fractions. Data on MSW composition and amounts of separately collected fractions of MSW were country-specific, collected from national statistics and other literature. Due to limited data on waste composition, the LCA model was simplified by assuming that PET recycling can represent recycling of all collected plastic waste and recycling of steel can represent recycling of all collected metals. Lastly, to compare selected cases with regard to the speed of reducing emissions in MSW management, the change in GHG emissions over the transition period was divided by the duration of transition period.

Results and Discussion

The *speed of transition* indices that were calculated for 13 countries showed that Ireland, Norway, and Finland had a rapid shift from landfilling to WTE. Meanwhile, Lithuania, Slovenia, Slovakia, Latvia, and Italy demonstrated the swiftest transition to recycling. LCA results, coupled with consideration of time needed to reduce the emissions (Table 1), show that among Finland, Italy, and Poland, Finland was a standout performer in terms of reducing GHG emissions. Finland demonstrated a significant reduction in GHG emissions in MSW management mostly by adopting MSW incineration and the highest emission reduction rate (-42 $kgCO_2$-eq/(ton MSW treated×year)). Poland followed, having a moderate GHG emission reduction rate, and presenting a balanced case where both recycling and WTE were developed to divert waste from landfill. Italy was observed to prioritize recycling and appeared to reduce GHG emissions the least. Italy's slower transition to WTE can be highlighted as one of the reasons for its position behind Finland and Poland in terms of it speed in GHG emission reduction over the transition period. These findings suggest that developing WTE technology can be a faster way to reduce GHG emissions from MSW management practices. Variations in operational efficiencies and other factors related to application of WTE technology in each specific case may affect the environmental benefit of shifting from landfill to WTE.

Table 1. GHG emissions reduction rate in Poland, Italy, and Finland transitioned from landfilling to recycling and/or WTE in MSW management.

Country	**Italy**	**Poland**	**Finland**
Transition period	2012 to 2020	2010 to 2020	2010 to 2020
GHG emission reduction over the transition period [$kgCO_2$-eq/ton MSW treated]	from -100 to -277	from 270 to -51	from -79 to -500
GHG emission reduction rate [$kgCO_2$-eq/(ton MSW treated×year)**]**	-22	-32	-42

Conclusion

The results of the study indicated that MSW management system in Finland was the most effective in GHG reduction to its swift WTE implementation. In Poland, a notable progress was made while pursuing the development of both recycling and WTE moderately. Italy's focus on recycling made it the slowest in GHG emission reduction rates. These findings can support the hypothesis that implementation of WTE is a faster solution in reducing GHG emissions in such countries where landfilling has a major share of MSW management. The influence of operational efficiencies and other parameters of WTE and other waste treatment processes on LCA results will be further evaluated using uncertainty analysis to verify the reliability of the findings.

References

Hu, J., Chen, H., Zhou, P., & Guo, P. (2022). Optimal subsidy level for waste-to-energy investment considering flexibility and uncertainty. Energy Economics, 108, 105894. https://doi.org/10.1016/J.ENECO.2022.105894

International Organization for Standardization, 2006. Environmental management - Life cycle assessment - Principles and framework. ISO 14040:2006. Geneva: ISO.

IPCC. (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change . Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926

Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowski, P., Thorne, R. J., Colón, J., Ponsá, S., Al-Mansour, F., Anguilano, L., Krzyżyńska, R., López, I. C., A.Vlasopoulos, & Spencer, N. (2017). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. Energy, 141, 2013–2044. https://doi.org/10.1016/J.ENERGY.2017.11.128

Siddiqua, A., Hahladakis, J. N., & Al-Attiya, W. A. K. A. (2022). An overview of the environmental pollution and health effects associated with waste landfilling and open dumping. Environmental Science and Pollution Research 2022 29:39, 29(39), 58514–58536. https://doi.org/10.1007/S11356-022-21578-Z

Van Caneghem, J., Van Acker, K., De Greef, J., Wauters, G., & Vandecasteele, C. (2019). Waste-to-energy is compatible and complementary with recycling in the circular economy. Clean Technologies and Environmental Policy, 21(5), 925–939. https://doi.org/10.1007/S10098-019-01686-0/METRICS

Kaza, S., Yao, L. C., Bhada-Tata, P., Van Woerden, F. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development. Washington, DC: World Bank. http://hdl.handle.net/10986/30317