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Bioenergy generation potential from direct combustion and gasification of municipal solid waste in Brazil

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Abstract

In efficient waste separation, intended for material recovery, a residual amount remains, which can be utilized for energy recovery through a thermochemical process. The conversion of waste into energy and recycling are complementary treatment methods in integrated waste management systems that aim to reduce the waste amount disposed in landfills, and the use of inappropriate sites as final destination, cooperating with the reduction of greenhouse gas emissions (GHG). In 2021, Brazil generated 225,348 tons of MSW daily, 60.2% (45 million tons per year) of which was sent to landfills, and the rest - 38 million tons per year (corresponding to 39.8% of the total amount collected) - was sent to inadequate disposal facilities (controlled landfills or dumps).

At the 26th Conference of the Parties-COP26 of the United Nations Framework Convention on Climate Change, held in Scotland, Brazil committed to reducing 50% of GHG emissions levels by 2030, using the year 2005 as a baseline (332 million tons of $CO_{2\text{-eq}}$), increasing the share of sustainable bioenergy in its energy matrix (50% bioenergy). However, some studies conducted in Brazil showed that waste disposal in landfills contributed with 4.4% of GHG emissions in 2019, moreover, it is predicted that by 2030, GHG emissions may increase due to current waste management practices, mainly because of the high proportion of organic waste, paper and cardboard, which generate large amounts of methane when disposed in landfills.

In this sense, a waste management plan can include waste-to-energy (WtE) technologies, which comprise thermochemical treatments such as combustion and gasification because the waste, which cannot be recycled in a technically or economically feasible way, could be used to generate energy as well as provide a substitute for burning fossil fuels. In Brazil

the gasification system (fluidized bed) is marketed for the treatment of refuse derived fuel (RDF), the fluidized bed system (Boa Esperança plant) was projected to treat 56 $t.day^{-1}$ generating 1 MWh of electric energy. The first energy recovery unit (ERU) via combustion in Brazil is under construction, and three additional ERUs are projected to be built in the coming years.

In this context, this paper presents an estimate of the potential for bioenergy electricity from direct combustion (mass burning) and fluidized bed gasification of MSW generated in Brazil, as well as the $CO_{2\text{-}eq}$ emissions avoided by thermal treatment. The analysis was carried out taking into account the goals of the national plan for solid waste in Brazil: recovery of 20% of recyclable material and recovery of 13.5% of the organic fraction (destined for anaerobic digestion and composting) in relation to the total mass of MSW. The study was carried out considering two scenarios: the first scenario estimates the bioenergy potential from waste collection coverage data of 92% (nationwide). The second scenario considers 100% waste collection coverage (elimination of inappropriate final disposal practices). The landfill emissions ($CO_{2\text{-}eq}$) mitigated by thermal treatment of waste via combustion and gasification were estimated according to the "Guidelines for National Greenhouse Gas Inventories" methodology of the Intergovernmental Panel on Climate Change (IPCC) and taking into account the global warming potential for a 100-year period (GWP100) equal to 28 for CH_4 and 1 for CO_2 on a mass basis.

The use of the incineration system was established for municipalities with a population of more than 1 million inhabitants; for municipalities with more than 55 thousand inhabitants the gasification system (fluidized bed) was studied. Regarding to the incineration system, the average lower heating value (LHV) of the MSW was estimated from data available in the literature and considering the average gravimetric composition of the region in which the municipality is located in the country. In relation to the gasification system, it was assumed that the LHV of the syngas resulting from the RDF process at 15% moisture was 1.294 $kcal.\ Nm^{-3}$. The electrical energy conversion efficiency adopted for incineration was 25% and 28% for gasification.

From the energy point of view, MSW thermal treatment plants could contribute an additional 2% of electric energy in the national energy matrix avoiding the emission of millions of tons of $CO_{2\text{-}eq}$ per year. Furthermore, the use of millions of cubic meters of landfills could be avoided. It is concluded that in Brazil, waste-to-energy technologies such as combustion and gasification bring benefits such as reducing the use of

inappropriate waste disposal sites and exploring an energy source that could contribute to the Brazilian energy matrix.

Keywords: Waste-to-Energy; Thermal treatment; RDF