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Scoping aspects in the evaluation of plasma gasification technology for energy production from Municipal Solid Waste

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Abstract

In Cartagena, the management of municipal solid waste (MSW) faces significant challenges due to rapid population growth and unplanned urban expansion. Plasma gasification has been considered as a sustainable and cost-effective waste-to-energy technology. In this article, we scoped essential aspects for evaluation of plasma gasification technology that could treat Municipal Solid Waste and produce energy in Cartagena and this short communication is informative for project engineers as well as energy engineers, plant operators, and cost analysts.

Keywords: Municipal Solid Waste (MSW); Plasma Gasification; Environment; Green Energy

1. Introduction

In recent years, interest has recently been growing in waste destruction and disposal due to the vast amount of produced municipal solid waste (MSW) and the overcapacity landfills disposal. Municipalities are seeking alternatives for treating MSW and another residues in an economically, feasible, and environmentally friendly manner [[1]]. Plasma gasification has been investigated and applied for the conversion of waste to renewable energy for several decades. Several reports have indicated that plasma gasification has potential on treating waste in a sustainable and cost-effective manner [[2]-[6]].

Destruction of MSW through thermal plasma gasification results to energy production in the form of synthetic gas and reduces the risk from pathogens from land spreading, as plasma heating destroys all pathogens [[7]]. Besides synthetic gas, vitrified slag is produced from the inorganic part of MSW, which consists of a mixture of liquid and solid fractions. In this regard, the application of slag in road construction emerges as one of the most attractive options in terms of environmental impact. However, the mass and energy balance analyses reported to date for the life cycle of plasma gasification systems often lack a basis for comparison due to the varying accounting systems and boundaries used [[8]]. Many studies on energy balance have focused on specific types of waste, particular plasma systems, different waste management strategies, and specific utilization options for syngas.

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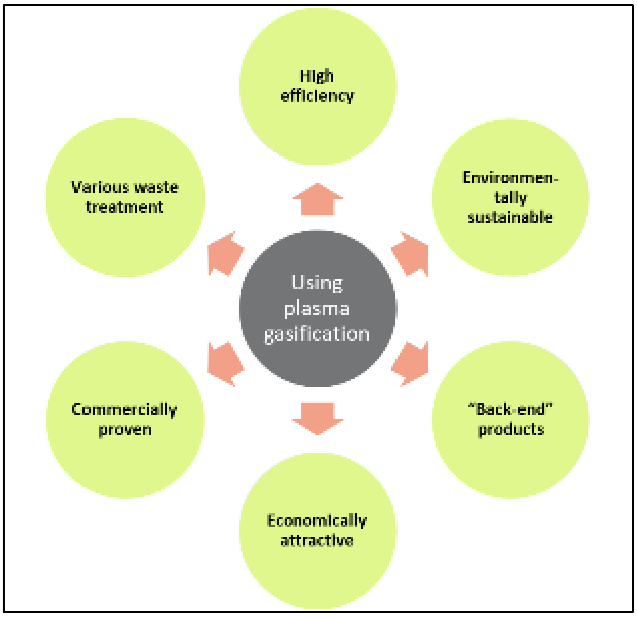

Figure 1 Beneficial use of plasma gasification technology

In this context, the implementation of advanced technologies such as plasma gasification could offer a viable solution for transforming MSW into renewable energy and other useful by-products, such as vitrified slag [[2]]. This technology would not only help reduce reliance on landfills but would also contribute to the generation of clean energy and the mitigation of public health issues associated with improper waste disposal. However, for its successful implementation, it is necessary to conduct technical and economic feasibility studies, as well as to ensure institutional support and active community participation [[9],[10]].

This communication aims to briefly summarize essential factors for the application of plasma gasification technology in Cartagena for green energy generation from MSW. This article may revive the waste-to-energy vision in an eco-sustainable manner for the case of Cartagena city.

2. Essential factors

2.1. Potential in Cartagena, Colombia

In Cartagena, the management of municipal solid waste (MSW) faces significant challenges due to rapid population growth and unplanned urban expansion. According to the Integrated Solid Waste Management Plan (PGIRS) of Cartagena, the city generates approximately 1,500 tons of waste per day, of which only a minimal and limited percentage is recycled or reused, while the remainder ends up in landfills such as Pasacaballos [[11]]. This situation has not only led to the saturation of these sites but has also caused negative environmental impacts, including soil contamination, greenhouse gas emissions, and the proliferation of disease vectors.

Furthermore, the lack of adequate infrastructure and effective source separation programs has hindered the implementation of sustainable waste management strategies. Although there are some local initiatives to promote recycling and waste reduction, these have not been sufficient to counteract the growing volume of waste. Based on a previous study [[12]], Cartagena urgently requires innovative technologies and more robust public policies to improve waste management efficiency and reduce its environmental impact. Treatment of municipal waste in in the region of Cartagena, Colombia has been regarded a challenge for the local authorities as MSW are mainly disposed in landfills. For the selection of the location for a plasma gasification plant in Cartagena topographical, societal and ecological aspects need to be considered.

To these challenges is added the socioeconomic impact stemming from inefficient MSW management, as recent studies indicate that landfills consume not only physical space but also municipal economic resources allocated for their maintenance and mitigation of collateral damages, such as contamination of nearby water bodies (e.g., Ciénaga de la Virgen) and conflicts with adjacent communities due to public health impacts [[13]]. The informality in recycling—where the majority of waste pickers work under precarious conditions without access to valorization technologies—

further exacerbates the problem. However, this same informality reveals untapped potential: if formal sorting systems and technologies like plasma gasification were integrated, Cartagena could transform its MSW into a source of clean energy and dignified employment, aligning with national circular economy goals [29].

2.2. Technological aspects

Electricity can be produced using plasma gasification from a wide variety of waste. The technological implementation of plasma gasification is a complex process, involving mainly waste pretreatment, the plasma reactor, flue gas cleaning and energy recovery [[14],[15]]. The scale of installations (capacity of treating of specific amount of MSW ton per day (TPD)) differs and usually a syngas burner/engine system for electricity generation is incorporated.

Technological analysis is based on the quantity and description of the waste (ton of MSW), syngas yield (m^3/ ton MSW), scale of installation (ton per day=TPD) and the end products (slag, metals), factors that are provided by the commercial suppliers [[2],[16],[17]]. Quality and yield of produced syngas are a function of the MSW content and conversion efficiency. Syngas production, cumulative production, and conversion are provided by the supplier.

The net electrical energy for sale shall take into account the energy used by the system which has been removed suppliers [[5],[17]]. It takes into account not only the electrical load of the plasma system, but all the other electrical loads as well. In many situations, the value of the products (electricity, slag, metal) will exceed the operating costs of the plasma system .

2.3. Financial insights

Sustainability of a plant will depend on not only maximizing profits from green power but also on effective management of slag or other funding opportunities. Relevant activities include producing and selling products (i.e. green electricity, slag), transporting MSW to plant, equipment maintenance, operations, and hiring personnel. Different business models can be applied in order to determine the most feasible and profitable scenario for electricity generation [[18]]. After specifying a set of decision variables and constraints, the economic assessment can be conducted. Constraints related to treatment capacity of the plant and slag application can occur during the operation of the installation and need to be considered.

To analyze profitability of the system, net present value (NPV), internal rate of return (IRR) and energetic pay-back time (EPBT) concepts are usually applied as evaluation criteria [[18],[19]]. Variable and fixed operating costs are determined and used in the discounted cash flow analysis to evaluate the viability of such a project. The installation cost can be determined by the necessary operational equipment to be delivered. Total capital investment consists of the total installed costs (total installed equipment cost, warehouse, site development) and indirect costs (proratable costs, field expenses, home office, construction, project contingency) [[18]-[22]] .

Table 1 Basic roles in a plasma gasification power plant. The number of personnel depends on the scale of the installation.

Personnel
Plant Manager
Plant Engineer
Maintenance Supervisor
Lab manager
Administration assistants
Facility workers

Variable operating costs, which include raw materials, waste handling charges, and by-product credits, are incurred only when the process is operating [[23]-[25]]. The cost of consumables can be provided by the suppliers. Fixed operating costs are generally incurred fully whether or not the plant is producing at full capacity. These costs include personnel and various overhead items. The personnel required to operate a PG installation depends on the capacity of the installation and can be guided by the suppliers[[18],[22],[25]].

Once the major three cost areas have been determined - (1) total project investment, (2) variable operating costs, and (3) fixed operating costs - a discounted cash flow analysis can be used to determine the viability of the installation [[18]]. The analysis requires that the discount rate, depreciation method, income tax rates, plant life, and construction start-up duration be specified. The construction time is important to the cash flow analysis because there is generally no income during construction but huge sums of money are being expended [[22],[25]]..

3. Discussion

The sensitivity of the estimated cost and expected revenues from the sale of the off-peak electricity, and process heat co-produced by the conversion of MSW varies, depending on the national markets and prices for energy and industrial materials [[26]-[28]]. At present, little data is available for currently operating installations on how these facilities would be affected by market changes [[27],[28]]. The value of MSW plasma gasification operations is based on a combination of the avoided cost of conventional disposal (via landfill) and the expected revenue form the products taking into account the MSW tipping fees [[2],[26],[26]]. There are several factors that affect the cost and ultimately the profitability of MSW plasma gasification [[29]]:

Figure 2 Critical factors affecting the profitability of a plasma gasification plant.

MSW transporters operate on the profit they generate from disposal fees or by selling the MSW to secondary treatment facilities. This suggests that existing technology/policy drivers and accompanying incentives need to be enhanced.

4. Conclusions

This article briefly scopes essential aspects for the implementation of a plasma gasification power plant treating MSW in Cartagena, Colombia. Plasma gasification has been investigated and applied for the conversion of waste to renewable energy for several decades. Plasma gasification has potential as sustainable technique of treating waste in a sustainable and cost-effective manner. An integrated MSW management process in the municipality of Cartagena using plasma gasification can support the power economy as electricity and heat produced can be supplied in the local network .

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflicts of interest.

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