Energy Sustainability in Islands: Waste Management in the Archipelago Fernando de Noronha, Pernambuco (Brazil)

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Abstract

The increase in population and the acceleration in the pattern of consumption cause a greater generation of solid waste. Among these residues, the urban solid waste that comes from human activities in cities and human settlements is significant. If these are not disposed of correctly, they can cause environmental impacts such as contamination of water, soil and atmosphere. In addition, many municipal solid wastes is toxic to living things. Alternatives to better management are fundamental to raising the environmental quality of ecosystems and the survival of the human species on the planet. Aiming to study a favorable sustainable use of the waste, this article made an analysis about the energy potential of these, advantages and limitations of the process. The research analyzed four types of thermochemical processes and estimated the efficiency of each relative to the gravimetric typology produced by the local population and visitors of the Fernando de Noronha archipelago. Incineration is the least efficient technique, while plasma gasification is the most recommended. When analyzing the cost-benefit of the processes, the conventional gasification is the most indicated, having the capacity to supply about 17.5% of the local residences. Thus, the implementation of thermo-chemical plants may be an alternative to waste management, reducing the economic costs and operational risks of the current process, thereby minimizing potential negative environmental impacts and reducing the population's dependence on other less sustainable sources of electric energy.

Keywords: *Energy reuse, Energy generation, Environmental management.*

I. INTRODUCTION

There is a direct link between increased solid waste generation and urbanization, changing individuals' lifestyles, and the economic, social, cultural and political development of nations (THAKARE; NANDI, 2015). These factors cause social and environmental impacts due to the absence of adequate management, affecting human health and the environment (ANTHRAPER et al., 2018; WANG et al., 2018). For the industrial sector, this process is also true. Reducing manufacturing waste generates increased productivity of industries, reducing costs and increasing value added to products and processes, improving socio-environmental sustainability (KARTHIKADEVI, 2014). Effective and efficient control of the materials can significantly reduce waste generation, due to a variety of inventory reasons including obsolescence, spoilage and losing products (REDDY; SREEMAN, 2016).

The negative changes of these discarded materials in nature are still more problematic in islands, where management, management, disposal and cost are limiting factors for an implementation of more sustainable technologies (ESTAY-OSSANDON; MENA-NIETO, 2018). Technologies is sustainable when does not yield hazardous waste and is appropriate for several scales of production (SWAMINATHAN; NAGARATHINAM, 2016).(Size 10 & Normal)An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

According to Fernandes and Pinho (2017), the insular environments have specific biotic and abiotic characteristics, limitation of natural resources, particular composition of ecosystems, with ecological vulnerabilities even more evident, being influenced by the anthropic actions, mainly. In this perspective, the management of these presents some limitations aiming at the establishment of sustainable processes due to the limited geographic space, the absence of efficient recycling and of projects that work with the transformation of solid waste into new raw materials (CAMILLERI-FENECH et al., 2018).

Environmentally friendly and sustainable waste management in islands, archipelagos and small island states requires strategic planning in dematerialization, reduction of volume generated and adequate final disposal (FULDAUER et al., 2019). According to the authors, the management of waste in a sustainable way in these areas is still incipient because of the underdeveloped infrastructure until the lack of technical staff, being visible the environmental degradation caused by this. The system of Green Supply Chain Management (GSCM) is a way to itenhances eco-friendly product to the predictable supply chains by comprising performances like green processes, green plan, green industrial production, recycled products and waste management (REDDY; SREEMAN, 2016).

Faced with this problem, actions are required to increase the efficiency and effectiveness of the collection, transportation, treatment and final disposal phases of solid waste, as well as the adoption of new technologies to reduce their generation and volume (BERTICELLI, PANDOLFO, KORF, 2017). The technologies applied for the treatment of waste need to be financially sustainable, socially adequate, legally acceptable, technically feasible and environmentally friendly (ADENIRAN; NUBI; ADELOPO, 2017).

As an essential technology applied to sustainable grid, renewable energy integration plays a significant role on carbon emission (SWAMINATHAN; NAGARATHINAM, 2016). The potential of electricity generation through thermochemical routes is widely discussed in the contemporary scientific community as a technological alternative to replace the energy matrix in some localities (RODRÍGUEZ-MONROY; MÁRMOL-ACITORES; NILSSON-CIFUENTES, 2018; AHMED et al., 2018; BISHT; THAKUT, 2019; GARCÍA-VELÁSQUEZ; CARDONA, 2019; LI et al., 2019; SANTOS et al., 2019). This is a way of reducing the volume of solid waste and disseminating alternative sources of energy. In Brazil, the National Solid Waste Policy encourages the practices and techniques of energy recovery of Urban Solid Waste - USW (BRAZIL, 2010).

Due to the vulnerability of small islands to contamination and pollution by WSU, this work aims to quantify the energy potential of different waste technologies in the Fernando de Noronha archipelago (Brazil). The continuous improvement of eco-efficiency can further ensure the waste minimization and pollution prevention in longer and shorter perspectives (REDDY; SREEMAN, 2016). Efficient planning and management does not only help to decrease solid wastes, but also decrease air emissions such as greenhouse gas emissions (REDDY; SREEMAN, 2016). This work intends to be a reflection on the energy sustainability in insular environments, following the Goals of the Sustainable Development - GSD of the Organization of the United Nations (UN, 2015).

II. SOLID WASTE AS AN ALTERNATIVE ENERGY SOURCE

It´s important to study the thermo-chemical and biochemical technologies in the generation of electrical energy to transform a discarded material into an alternative source of electricity generation for different businesses (DALMO et al., 2019). The economic, social and environmental viability are basic precepts for the implementation of more appropriate and environmentally friendly technologies (KORAI; MAHAR; UQAILI, 2017). According to the authors, in addition to the benefits of more suitable destination for solid waste, the diversification of the energy matrix allows greater security in the availability of this resource.

Several nations are seeking to increase investments in this area, mainly for energy security, treatment and correct disposal of waste, as well as to reduce the negative changes that these can cause in the environment (GAURAV; KHANAM, 2017; LINO, ISMAIL, 2018; LOKAHITA et al. 2019; SANTAGATA et al., 2019). This precept is valid for several sectors, such as the industry that with the help of Lean production method, can provide a high quality product to their customer, by satisfying their requirements, "doing more with fewer resources" (KARTHIKADEVI, 2014). The concept of Lean Management contains comprehensive approaches to waste-free or waste-free design and oriented to the process's substantiality in organizations (WEBER; OBERHAUSEN; PLAPPER, 2015).

According to the Energy Research Company (EPE) (2014, apud OLIVEIRA et al., 2018, p.780), the incineration of USW for the production of electric energy in addition to replacing part of the energy generated from fossil sources contributes to the reduction of greenhouse gas emissions and manure from landfills. Studies demonstrate the benefits of treating USW for energy production, since this stage is after the reduction, reuse and recycling (3Rs) (MAIZE, 2016; LINO; ISMAEL, 2017; LIU; NIE; YUAN, 2019; MINELGAITĖ; LIOBIKIENĖ, 2019).

Researchers find opportunities of power generation from the USW, with the electric potential of landfills approximately 16 GW in Brazil (SANTOS et al., 2018), 3,244,444 kWh or 3,244 MWh, Electrical Power (EPPMSW) of about 40555 kW or 41 MW and Power to Grid of 27 MW in Nigeria (IBIKUNLE et al., 2019), Kingdom of Saudi Arabia was estimated at 671 MW and 319.4 MW (OUDA et al., 2016) and about the power generation from biomass residues, the highest energy potentials to be located in Indonesia (407 TWh), Thailand (194 TWh) and Vietnam (153 TWh) (STICH et al., 2017). The type of treatment used in the generation of energy, having as raw material the solid residues, must be analyzed under the environmental, economic and social spheres, since the environmental impacts can be significant, which configures in the environmental degradation (SANTOS et al. 2019). Incineration, for example, requires strict monitoring and operational control of toxic gas emissions into the atmosphere.

A. Incineration

Incineration based on the restoration of the calorific value of waste through a controlled heat treatment process and its transformation into energy. First, solid waste burned in the primary chamber, which is the direct recipient of the waste. This phase is carried out at elevated temperature, so that the substances present become gases and smaller particles. However, the temperature regulated, ranging from

500 ° C to 900 ° C, so that nitrous oxides do not form and volatilization of large amounts of metals such as lead, cadmium, chromium, mercury and others.

The gas phase generated in the primary camera routed to a secondary chamber where the gas mixture is burned at a higher temperature. The final gases, after the second combustion, are cooled with heat recovery and then treated. The solid part remaining after the entire process ranges from 4% to 10% by volume of the parent material. This is sterilized and rendered inert (CASTRO 2015, apud PRATES et al., 2019). According to Klinghoffer and Castaldi (2013), as quoted by Dalmo et al. (2019), incineration plants can generate from 0.3 to 0.7 MWh of electricity per ton of waste, varying according to the size of the plant and the heating value of the waste.

According to Machado (2015), several countries currently use incineration as an alternative source for the final disposal and energy utilization of USW. However, it is not widespread in Brazil. The average capacity of the plants that use this thermochemical process is 1500t / day of USW; being the largest facility found in China, with capacity to process 3000t / day. The incineration process must be directly connected to a system which has advanced technology for cleaning the gases before they are released into the atmosphere. In Brazil, because many of the facilities do not present this technology, there is environmental contamination due to high emissions, and many incinerators have been uninstalled over time (FERREIRA, 2015).

B. Pyrolysis

Pyrolysis is a physicochemical process consisting of the thermal degradation of solid waste in the absence of oxygen. This technology has a pretreatment of residues, with the separation of glass, metals and inert materials (MOYA et al., 2017). According to Chen et al. (2014), quoted by Garcia and Mendonça (2018), this technique uses a reactor that presents temperature control, which needs to maintain the temperature between 300°C and 800°C. It consists of a set of complex chemical reactions accompanied by processes of heat transfer and mass. The heterogeneous composition of the fractions produced and the possible interactions between them make the process even more complex (MAZZONETTO, 2016).

The pyrolysis method begins with the thermal decomposition of the material at 300 ° C with reduced or oxygen-free oxygen inside the heated chambers. Then the temperature increases to 800 ° C in a non-reactive atmosphere. The final products of the process are solid waste rich in carbon (coal), condensable organic gases and vapors (KINUNNEM et al., 2014). According to Alessandro et al. (2013 apud MOYA, 2017), among the advantages of pyrolysis are: the fact that the equipment is easy to install; does less harm to the environment compared to incineration; all wastes are used to produce different bio-products; and the gases produced can be used in different energy applications such as engines, boilers, fuel cells, turbines and heat pumps.

According to Garcia and Mendonça (2018), this is the technology most used for the energy conversion of the USW in the world. Even so, the pyrolysis is the most incipient of the technologies, still needing several studies, mainly in the evaluation of the characteristics of the bio-oil obtained. In Brazil, the companies Atteris and Delta Bravo use the pyrolysis process for waste disposal, generation and commercialization of pyrolysis products. At the global level, companies like Metso and Global Green International develop works with pyrolysis of various wastes (ROCHA, 2016).

C. Conventional Gasification

Solid urban waste is a source of biomass and used for the production of renewable energy, and substitutes for fossil fuels are possible. The process of thermal degradation of solid waste is gasification, which has developed over the last three decades (ARENA, 2012). This occurs at temperatures between 500°C and 1300°C and has syngas synthesis gas (ROCHA, 2016). According to the State Foundation for the Environment (FEAM, 2013), cited by SILVA, 2017, syngas consists mainly of carbon monoxide, hydrogen, and in smaller amounts of carbon dioxide, light hydrocarbons, methane, nitrogen and Water. The syngas identified as a potential source of renewable energy, and used for the production of chemical inputs and other gases (SAMIRAN et al., 2015). Their properties vary according to the biomass used and the operating conditions of the reactor (ROCHA, 2016).

The advantage of gasification in relation to incineration is due to the possibility of treating and cleaning the gas produced prior to its combustion, removing polluting substances and thus presenting lower emissions (CHEN et al., 2015; SILVA, 2017). According to Okamura (2014), this thermochemical process can occur in two ways, direct and indirect. In direct gasification, the entire procedure occurs in a single reactor, where exothermic oxidation also occurs. In this type of gasified, air or oxygen generally used as oxidizing agents; and all necessary heat to the methodology is produced inside the reactor (VITASARI et al., 2011).

When made with air, a poor gas produced, with a calorific value between 950 and 1600 kcal/Nm³. When using oxygen, it results in a gas of better quality and a higher calorific value, between 2400 and 4300 kcal/Nm³ (FERREIRA, 2015). Indirect gasification is when the process does not occur with the aid of an oxidizing agent, necessitating an external energy source. The most commonly used gasification agent in this case is water vapor, as it is easily produced and increases the amount of hydrogen in the fuel gas produced (SINGH et al., 2011; FERREIRA 2015).

D. Plasma Gasification

Plasma is denominated as the fourth state of matter, presenting good electrical conductivity and high viscosity (SUN et al., 2013; SILVA, 2017). The American scientist Irving Langmuir, in 1929, used the term plasma in physics to designate a partially ionized gas (FERREIRA, 2015). He claims that this material consists of a mixture of electrons and positive ions and decomposes compounds efficiently, producing emissions much less than incinerators. In this treatment process, the USW go into the system through "lock hopper" chambers, which present heated air to favor the combustion of these residues.

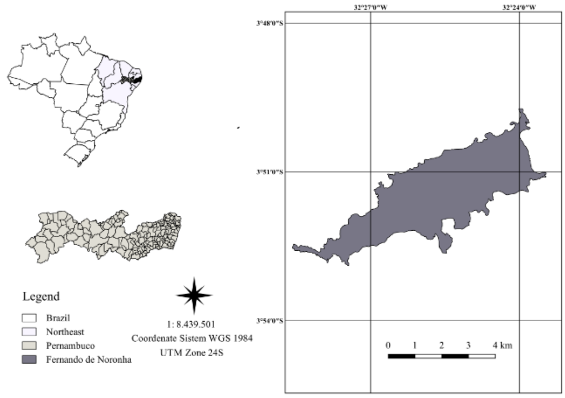
After the burning of the residues, they are converted into combustible gas and this gas is treated by the plasma flame, being decomposed in a vertical furnace called "shaft" (FEAM, 2010; FERREIRA 2015). As final product occurs to the formation of gases derived from the organic compounds and the vitrification of the inorganic fraction. These gases are mostly hydrogen and carbon monoxide, which move the turbines coupled to the reactor, producing energy (CASTRO, 2015).Plasma technology has some advantages over other methods. Its high temperature reduces to 99% the volume of the solid residues and vetrifica the inorganic residues, transforming them into products similar to minerals of high hardness. However, this technique also has its drawbacks. Due to the high temperatures (around 15 ° C) and to be a delicate process, the electricity consumption and the cost of implantation are high (SILVA, 2017).

III. METHODOLOGY

A. Characterization of the Study Area

The archipelago of Fernando de Noronha (Figure 1) has the title of Natural Patrimony of Humanity by the United Nations Organization (UNESCO, 2001). It is located at 4º below the Equator, at latitude 3°54 'S and longitude 32°25' W, 545 km from Recife, State of Pernambuco, Brazil. The emergence of the archipelago occurred due to volcanic activity. This is part of an alignment of submarine mountains distributed along a strip with East-West direction, which extends from the Atlantic Dorsal to the Brazilian Continental Shelf. The climate is tropical, Aw (Köppen-Geiger) (BECK et al., 2018) and has an annual average rainfall of 1,351 mm, since this environment is close to the equator, having two well defined dry and rainy seasons. The average temperature is 26.7°C (IBAMA, 2005).

Figure 1. Geographic location of the Fernando de Noronha Archipelago, State of Pernambuco (Brazil)



This island environment internationally recognized for having natural landscapes and paradisiacal beaches, consisting of 21 islands, islets and cliffs occupying an area of approximately 26 km², of which 17 km² correspond to the main island, which inhabited only. In this limited area, 3,021 people are permanently present (IBGE, 2018, MMA, 2017). In addition, 92,000 tourists visited Noronha in 2017 (ATDEFN, 2018). The economy of the place focused on providing service, especially in tourist activities. Gross domestic product per capita was US $ 11,943.86, being the 5th largest in the State of Pernambuco (IBGE, 2016).

From the point of view of geopolitical management, the archipelago has two Conservation Units - Federal UC, the Fernando de Noronha National Marine Park - Panamar/FN and the Environmental Protection Area - EPA. Panamar is an Integral Protection Area, its main objective being to preserve nature, with only indirect use of natural resources admitted, with restricted access. Created by Presidential Decree nº 96,693 (BRAZIL, 1988), Parnamar aims to preserve marine and terrestrial ecosystems, fauna, flora and other natural resources, providing controlled opportunities for visitation, leisure, environmental education and scientific research.

The APA is a Sustainable Use Area. This objective is to reconcile nature conservation with the sustainable use of natural resources (BRASIL, 2000, Art. 7). In addition, because it is an isolated environment of the continent, it has unique characteristics, such as endemic species, and this environment is suitable for experimenting with various hypotheses of environmental management. Created by State Decree No. 13,553 (PERNAMBUCO, 1989), the APA / FN aims to protect ecosystems, reconciling human occupation with raising environmental quality, allowing the direct use of natural resources, conditioned to the management plan. It is a Sustainable Use Conservation Unit. In this way, access is restricted, monitored by the competent environmental agencies, to achieve the objectives of the APA (MMA, 2017).

B. Bibliographic Survey

At the first moment of the research, a bibliographic survey was conducted to identify general information on "solid waste generation", "energy production through solid waste" and "solid waste management" in scientific articles, books, institutional websites , theses and dissertations, to understand and analyze the methods of estimation of their generation in certain areas, as well as the current technologies to transform these materials, in which they would be discarded in the environment, in an energy source. This method allows researchers greater scientific development and maturity in the area of knowledge, as well as identifying research trends (YOO; JANG, 2019).

C. Estimate of Solid Waste Generation

Data collected on the tourist flow of each month, as well as the average permanence of this floating population, the management reports and activities of the Territorial Autonomy of the State District of Fernando de Noronha - ATDEFN between the years of 2014 and 2017. The migratory control of visitors who landed at the Governador Carlos Wilson Campos Airport during the analyzed period, monthly. These official documents followed the guidance of the State Government of Pernambuco, so that the public management obtain and document the results on the practices and actions that take place in the archipelago (ATDEFN, 2017). Therefore, all the activities that take place in this insular environment are objectives of the annual balance, consolidating in Noronha a concept of intelligent, sensitive and sustainable city.

Determined the population estimate present on the island by data from the Brazilian Institute of Geography and Statistics - IBGE, in the Automatic Recovery System - SIDRA. This system allows the user to access various data, involving the population, health, education, Gross Domestic Product - GDP, the characteristics of the national territory, besides making population estimates. There is a direct relationship between number of people that go to a locality and available territorial area with numbers of fixed people and visitors, especially when in an island area (YOU; YANG; FU, 2018).

Brazilian Association of Public Wastes and Special Wastes - ABRELPE launches, annually, the Solid Waste Panorama in Brazil. This provides the per capita generation of solid waste per individual. The documents published by this association have information on the solid waste management of the country, the regions and the Brazilian states. These orient public policies for the sector, in the structuring of selective collection, in the treatment technologies and in the reduction of the final volume generated from it (ABRELPE, 2017). Also, a country needs to have the historical evolution on solid waste, to allow an efficient diagnosis on generation and composition. In this perspective, from the values of tourist flow, average permanence and solid waste generation per capita determined the total waste generated by tourists (Equation 1) in the period between 2014 and 2017.

$$Et = Ft * T * GP \ (1)$$

Et = Estimated generation of solid waste from tourists (kg)
Ft = Tourist flow (number of inhabitants)
T = Average length of stay (days)
GP = Generation per capita solid waste (kg / inhab / day)

Also determined the total of residues generated by the residents of Fernando de Noronha (Equation 2).

$$Ei = Pl * P * GP \ (2)$$

Ei = Estimation of the generation of solid wastes from the islets (kg)
Pl = Local population (number of inhabitants)
P = Monthly stay (days)
GP = Generation per capita solid waste (kg / inhab / day)

For the calculation of the total generation of solid waste generated (Equation 3) in the archipelago, he used the simple summation formula.

$$ET = Et + Ei \ (3)$$

ET = Estimated total waste generation (kg)

D. Alternative Energy Production Using Different Thermal Technologies

From the estimated amount of USW produced per year by the entire population of the Archipelago and by the tourists, the conversion was made to know the amount of electric power capable of being produced from them.. Using the conversion rate determined by Young (2010) for pyrolysis, conventional gasification and plasma gasification, and the average of incineration conversion quoted by Klinghoffer and Castaldi (2013) (Table 1), calculated the amount of electric energy in kWh per year for the most commonly used types of thermochemical processes. From these values, comparative analyzes were carried out with Fernando de Noronha energy consumption.

Table 1. Energy conversion rate of thermochemical processes

Thermochemical processes	Energy conversion rate (KWh / t RSU)
Incineration	500
Pyrolysis	518
Conventional gasification	621
Plasma gasification	740

Source: Adapted from Young (2010); Klinghoffer and Castaldi (2013)

IV. RESULTS AND DISCUSSION

According to Abrelpe (2017), in 2017 the population generated 78.4 million tons of urban solid waste - USW in Brazil. This value shows a growth of 1% in relation to previous years, compared to 2016. In 2015, 79.9 million tons of USW collected, representing an increase of 1.26% to 2014 (ABRELPE, 2015). Approximately 28.2 million tons of solid waste were not collected between 2017 and 2014, a quantity released into the environment in an unsecured and unsustainable way.

Disposing of this material improperly triggers a number of negative environmental impacts on the environment (ABDEL-SHAFY; MANSOUR, 2018). In the Fernando de Noronha archipelago, the number of islanders, tourists and per capita generation of USW increased during the analyzed period (Table 2); the latter being an exception, since there was a reduction in the year 2016. It should be noted that it was the first time, since the National Solid Waste Policy (NSWP), that the sector showed a decrease (ABRELPE, 2016).

Table 2. Number of local population, floating population, and USW per capita generation

Year	Resident population	Tourist population	Generation per capita RSU (kg/inhab/day)
2014	2.884	76.145	0,952
2015	2.930	90.522	0,962
2016	2.974	91.303	0,941
2017	3.016	94.152	0,969

Source: Abrelpe (2014; 2015; 2016; 2017); IBGE (2014; 2015; 2016; 2017)

Faced with limited natural resources and conflicts of land use, monitoring population growth in island environments is necessary to preserve the environment (SALVACION; MAGCALE-MACANDOG, 2015). Estay-Ossandon and Mena-Nieto (2018) have identified that the amount of USW in the Balearic Islands is influenced by the number of individuals, consumption pattern and visitor flow, in which the participation of the Tourist Population is 37.5% Resident in the generation of solid waste.

The zones located in the Environmental Protection Area of the island were changed. The territorial area of the urban land increased by 7.69% of the total territory of the APA between 2005 and 2017, reducing the Wildlife Protection and Conservation Areas, for example. This was due to the growing demand of new residents and tourists in the region (IBAMA, 2005, MMA, 2017). This increase in the number of people visiting or residing in the Archipelago, whether permanently or temporarily, is associated with the increase in USW generation over the years (Table 3).

Table 3. Quantity of municipal solid waste generated by the resident and tourist population of Fernando de Noronha

Year	USW generated by local and floating population (kg)
2014	1,373,395
2015	1,499,979
2016	1,463,959
2017	1,536,131

The amount of solid waste increases over the years. In the year 2016, there was a drop in the generation of these in this island environment. However, 2017 showed the highest increase, with the generation of approximately 1,536,131 kg of this material. The trend of the USW generation is increasing, in view of the increase of residents and tourists in the region. These solid wastes collected and transported to a sorting plant in the Archipelago where there is separation of recyclable, organic and non-recyclable material.

This treatment plant does not have adequate infrastructure, because the amount of material generated is above its operational capacity, and an improvement action in this system is fundamental. After this procedure, all material is separated and shipped back to the mainland (MMA, 2017). From the Port of Recife, the recyclables go to the industries and the remainder to the landfill. The cost of shipping is quite high. Thus, improving solid waste management as well as treatment at the place of origin is important in order to reduce costs and ensure that future generations can also take advantage of the biotic and abiotic characteristics of the ecosystems currently in the Archipelago.

In this sense, the facilities of the plant need improvement, using new technologies of separation and treatment, aiming to respond to the generated volume of solid waste produced on the island. Initiatives to reduce the generation of waste, seeking the dematerialization of processes, as well as standards that alter the gravimetric of waste are essential. This will reduce the cost of transportation of waste to the continent (MMA, 2017). In the field of Public Policies, District Decree 002/2018 (FERNANDO DE NORONHA, 2008) prohibits some types of plastic, which will positively impact the USW management in the Archipelago.

According to Khalil et al. (2019), the use of waste for the generation of electricity is one of the best options to meet the current demand for energy consumption, used in many developing countries as well as in developed countries. According to Garcia and Mendonça (2018), the main thermal technologies deployed in the world for the conversion of USW into energy generation are incineration, gasification and pyrolysis. Therefore, the energies produced by these three thermochemical processes were determined

(Table 4), dividing gasification into conventional and plasma.

Table 4. Energy calculated by type of thermochemical process according to the amount of USW

Thermo-chemical processes	Year	Production of energy (KWh/t USW)	USW/Year (ton)	MWh/Year
Incineration	2014	500	1,373.395	686.7
	2015	500	1,499.979	749.99
	2016	500	1,463.959	731.08
	2017	500	1,536.131	768.07
Pyrolysis	2014	518	1,373.395	711.42
	2015	518	1,499.979	776.99
	2016	518	1,463.959	758.33
	2017	518	1,536.131	795.72
Conventional gasification	2014	621	1,373.395	852.88
	2015	621	1,499.979	931.49
	2016	621	1,463.959	909.12
	2017	621	1,536.131	953.94
Plasma gasification	2014	740	1,373.395	1,016.31
	2015	740	1,499.979	1,109.98
	2016	740	1,463.959	1,083.33
	2017	740	1,536.131	1,136.74

Among the thermochemical processes analyzed, the least efficient in terms of energy potential was the incineration, while the most efficient was plasma gasification. In a cost-benefit analysis, the conventional gasification process was the most efficient because, according to Mazzonetto and Fialho (2016), it has low energy consumption, inputs and cost of implementation.

In addition, conventional gasification is a sustainable process. The ashes can be used as fertilizer. According to the Energy Company of Pernambuco (CELPE, 2018), in 2017 the Fernando de Noronha Archipelago consumed 17,408 MWh. Of these, approximately 203 MWh consumed by industries, 8,039 MWh for commerce, 148 MWh for rural areas, 1,298 MWh for public power, 2 MWh for illumination and 5,493 MWh for houses.

Comparing the values obtained by Celpe with the values estimated by the thermo-chemical processes in 2017, incineration, pyrolysis, conventional gasification and plasma gasification would respectively supply 14.0%, 14.5%, 17.4% and 20% , 7% of the residences in the Archipelago.

Considering the installation of a conventional gasification plant, since this is the most efficient, or the application of this thermal practice in existing plants, it would be possible to supply electricity to more than 1/6 of Fernando de Noronha's houses. This can be converted into electric power can be transferred with the use of transmission lines, and can also be converted into other forms of energy, such as light, heat and kinetic energy (THIYAGARAJAN, GOKULAVASAN, 2014).

Consequently, the application of these technologies reduces electricity costs, which are high. According to Notton et al. (2019), unlike non-island regions, the islands have no or limited interconnection with large electricity networks. The use of these techniques still contributes to the reduction of environmental impacts resulting from inadequate disposal of USW, due to the difficulties in these environments, such as limited space availability and restricted recycling and resale opportunities (CAMILLERI-FENECH et al., 2017).

V. CONCLUSION

Solid waste generation has been increasing over the years in the Fernando de Noronha Archipelago. There are relation between the growth of the number of residents, the pattern of consumption and the flow of tourists that frequent the island.

The management of these wastes in island environments should be differentiated, mainly because of the cost, the limited space and the presence of fragile ecosystems. Faced with this problem, estimating the generation of waste to adopt technological strategies for energy use is a management tool to reduce the volume generated, as well as reducing transport costs to the continent, in addition to developing a more sustainable city.

Several technologies have been tested, taking into account the cost-effectiveness and sustainability of the site. With this, the technological route that uses the conventional gasification thermochemistry is the most indicated, considering the aspects of value, power generation, cost and area of the enterprise.

From this, it is necessary to encourage the implementation of this technology in the Archipelago, aiming at energy sustainability, one of the precepts for sustainable development. This can be achieved through Public Policies for the energetic beneficiation of waste in the region, considering the difficulty of obtaining this good in the island, in addition to the limitation of natural resources. Finally, diversifying the energy matrix is fundamental to ensuring energy security for all on the island.

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