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INITIAL CAPACITY OF BIOENERGETIC PRODUCTION FOR THE RECYCLING OF PLASTICS IN CABINDA, ANGOLA

CAPACIDAD INICIAL DE PRODUCCIÓN DE BIOENERGÉTICOS PARA EL RECICLADO DE PLÁSTICOS EN CABINDA, ANGOLA

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ABSTRACT

In this paper, the study of the possibilities of the efficient use of forest residuals as raw materials, for the production of bioenergetics that guarantees the operations of a plant for the recycling of plastic residuals is exposed. In the study, a conceptual model and the procedures for the assimilation of technologies of bioenergetic production, reported in previous works, is validated (Muto et al., 2016). Due to their significance, it is considered the uncertainty to the future changes with emphasis to the growth of the demand of capacities of prosecution of urban solid wastes (USW) and the readiness of the raw material. Suitable values of initial investment capabilities are determined for a first step forward so that a second stage investor that increases capabilities must be run at 6 years for initial investment executed capabilities. The first investment will recover in 2.8 years.

Key words: bioenergetics, initial investments, technology assimilation, uncertainty, plastic.

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RESUMEN

En el presente trabajo, se expone el estudio de las posibilidades de que mediante el aprovechamiento eficiente de los residuos forestales como materia prima, para producción de bioenergéticos que garantice las operaciones de una planta de reciclaje de residuos de plásticos. En el estudio se valida un modelo conceptual y los procedimientos para la asimilación de tecnologías de producción de bioenergéticos reportados en trabajos anteriores (Muto et al., 2016). Por su importancia se considera la incertidumbre a los cambios futuros con énfasis al crecimiento de la demanda de capacidades de procesamiento de residuos sólidos urbanos (RSU) y a la disponibilidad de la materia prima. Valores adecuados de capacidades inversionistas iníciales se determinan para una primera etapa con visión de que una segunda etapa inversionista para incrementar capacidades se debe ejecutar a los 6 años de ejecutada la inversión para capacidades iniciales. La primera inversión se recupera a los 2,8 años.

Palabras claves: bioenergéticos, inversiones iníciales, asimilación de tecnologías, incertidumbre, plásticos.

1. INTRODUCTION

Undoubtedly there is a need to enhance the energy matrix with renewable energy sources to which new technologies will be required, so that in studying alternative assimilation of technologies for recycling of Urban Solid Waste (USW), which will require increasingly energy carriers, it is necessary to study the potential use of bioenergy for these processes of recycling of USW.

It is a feature of the process of recycling of USW that each waste has specific technologies that differently requires some form of energy. So, for example, the recycling process of paper requires electricity and steam due to the characteristics of the industrial processes, González (1982). The plastic recycling requires energy in the form of electricity, Grancho (2015) and aluminum requires the energy in the form of direct heat for melting Sambovo, (2015). Therefore, for energy assurance, through bioenergetics of each type of USW, a specific study is required, that considers the technology and logistics to ensure a stable supply of energy sources to the industrial process in which it is invested.

One aspect of great importance, it is also, that to be the source of supply of biomass energy will be a problem of uncertainty in the availability of biomass for attaining bioenergetic productions. In addition, this is combined with uncertainty regarding the demand for recycling capacity, so as it is known, the development itself implies that it increases, due to growth in consumption habits, the total volumes of USW and within them each of the types of waste. These problems of uncertainty lead to that the investors’ processes must evaluate the alternative of investing in productive capacities in excess with reference to the first years of operation, in order to achieve the necessary production capacity when production capacity increases by increased levels of the different components of the USW. Rudd and Watson (1968) raised this problem and later it was considered in the existing problem in the availability of biomass when used as raw material (Oquendo et al., 2016). The application of these concepts have been included in a specific procedure for the study of the supply chain (Muto et al., 2016) which determines the initial investor ability to solve the problem of recycling of USW and energy insurance.

In the specific case of plastic recycling, under the current conditions of Cabinda, it is needed to determine the capabilities to install for the production of electricity.

2. MATERIALS Y METHODS

For the execution of this work, a conceptual model and appropriate procedures for the assimilation of technologies substantiated to the effect was employed (Muto et al., 2016). In the context of a country of the so- called third world, regarding the cost, time used and functional operations, for whose implementation requires a set of actions to process all the information and solve problems arising from the uncertainty of technology (Ley, 2006).

The application of procedures have had as methodological axis the establishment of the different elements that affect decision-making, including the national demand perspective, the price forecasts, the balance of demand and capacity per year, the technology study, consumption of raw materials and sources of supply, investment costs, annual production cost, size and location of the plant. It has been an essential aspect in the consideration of uncertainty to future changes, (Rudd and Watson, 1968).

3. RESULTS AND DISCUSSION

According to the procedure followed, presented and based on (Muto et al., 2016), we follow the next steps:

3.1. Step 1. Determination of product demands and raw materials availability.

In Table 1, the demand for plastic processing existing among Cabinda's USW is presented.

Table 1. Presence of aluminum in Cabinda's USW. Source: Own elaboration (2016)

	Year			
USW	0	5	10	15
Plastic (t/year)	2 920	3 282.63	3 660.63	4 026.82

Table 2 shows the demand for electricity to process this plastic in urban solid waste (USW).

Table 2. Energy demand for plastics. Source: Own elaboration (2016)

	Year			
Bioenergetics	0	5	10	15
Electricity (Kwh/year)	108 000	121 597.79	135 590.85	149 141.83

In Table 3, the demand for raw materials for the production of bioenergetic according to the conversion factors for forest biomass is presented.

Table 3. Demand for raw materials. Source: Own elaboration (2016)

	Year			
Raw Material	**0**	**5**	**10**	**15**
Demand of forest biomass (t/year)	164 896	395 132	966 994	1 434 339.2

3.1.1. Availability of raw materials

Quantification and characterization of biomass energy that exists around a given location is the starting point for any project using biomass as raw material. In this study, aside from knowing the different types of biomass energy, production systems associated with biomass energy are characterized by the diversity of exploitable resources. Undoubtedly, this significantly increases the complexity of the analysis because each project requires specific studies (availability, extraction, transportation and distribution) to determine their viability.

The residual biomass, which can be used for energy purposes, is characterized by its diversity in terms of their origin and characteristics. Therefore, when making territorial studies, this diversity is a very large number of possible alternatives in terms of availability, extraction, logistics and biomass consumption, which significantly increases the complexity of them. This complexity is associated with a high degree of uncertainty due to the multiple uses and interactions between each other and the biomass market itself. That is, depending on the evolution of prices will be more or less profitable to extract biomass from the forest. A first approach to the territory reveals that the main sources of biomass in the province of Cabinda are the forests and agricultural crops. On the one hand, the province of Cabinda has the most productive forest ecosystems throughout Angola because of its orographic layout and weather.

However, despite this potential availability, the reality is that most of this material is immobilized and available in the forest. The absence of technical instruments of forest management, the fragmented structure of the property, the difficult accessibility of land for use or the characteristics of biomasic resource (impurities, moisture, heterogeneity) that have hampered mobilization of forest resources.

3.1.2. Growth dynamics of the forest

According to the Institute of Management of Public Forests (IDF, 2013), Maiombe's forest with its 300.000 hectares approximately, grows an average of $4x10^6$ tons yearly in natural biomass or its equivalent to 4.400.000 m^3 yearly. However, the biomass considered useful for wood production in market value, that is, taking out the natural biomass, is the corresponding part to those species whose utilization is unknown yet and the forest exploring wastes (branches, defective wood, stocks, etc) is approximately 1x10 Kg/ yearly, equivalent to 100.000 m³ of wood. The forest growth rate is 0.3 m^3/ hectares yearly for the type I forest and for the type X forest is 0,5 m^3/ha/ yearly.

Table 4. Growth dynamics of the forest. Source: Own elaboration (2016)

Type of forest	***Growth dynamics***	***Growth in order***
Forest type I	10 m^3/hect43.100.000 hectares	431.000 m^3 /year
Forest type II	10 m^3/hect188.000 hectares	1 880.000 m^3 / year

Forest type X	15 m^3/hect21.000 hectares	315.000 m^3/ year
Total		626 000 m^3/year

Wastes generated in the forest can reach values of 30 to 35% of the volume of wood for industrial purposes and this value, 5% of the volume is intended for traditional energy purposes. In terms of volume, we obtain values of 494 m^3/ha with 369 trees and 442.2 m^3/ha with 365 trees, which leads us to consider that the forest is highly productive.

Forest wastes are wood, charcoal, sawdust, twigs and leaves from the tree pruning. Such waste have features 100% natural, they have high density of charring fire, it is a solid organic material, and easily absorbs water (Muto et al., 2014). Although the volume of waste generated in agricultural production is very high (hundreds of millions of tons annually) a relatively small part would be profitable today to power because of the lack of appropriate technology/costs of collection and transport. There are, however, several studies analyzing the potential of many agricultural residues for the production of biofuels, considering aspects of logistics and current use (if they are already normally removed from the field (Muto et al., 2016).

For energy production, forest resources can be utilized, i.e. biomass from forestry practices of cleaning, sanitary pruning and the remains of wood that can be used, branches and bark, tops and stumps or roots. Forest residues have the advantage of constant availability. This property makes biomass renewable energy easier to manage, allowing us to create a reserve of energy for times when other sources are not available.

Table 5 shows the amounts of forest biomass by the zones of location and distance from the town of Cabinda where necessarily will be located the plant of plastic recycling and the processing facility from forest waste to electric power, by development strategy defined by the government of Cabinda. In Table 6, the distances between the different areas are presented.

Table 5. Location of the availability of forest biomass in the province of Cabinda. Source: Own elaboration (2016)

Zone Nº	***Tons of available biomass***
Zone 1 (Belize)	247 748.96
Zone 2 (Buco -Zau)	346 169.78
Zone 3 (Cacongo)	33 666.71
Zone 4 (Cabinda)	33 666.71
Total	661 252.17

Table 6. Distances between zones in Kilometers

	Zone 1 (Belize) Km	***Zone 2 (Buco-Zau) Km***	***Zone 3 (Cacongo) Km***	***Zone 4 (Cabinda) Km***
Zone 1 (Belize)	0	40	116	162
Zone 2 (Buco -Zau)	40	0	76	120
Zone 3 (Cacongo)	116	76	0	46
Zone 4 (Cabinda)	162	120	46	0

3.2. Step 2: Surveillance on available and emerging technologies.

Interior and exterior relevant information on technological trends is periodically monitored.

The current socioeconomic scenario is marked by the globalization of markets, mainly caused by the substantial improvement of communications and transport, in which has greatly influenced the development of Information Technology and Communications (ITC) allowing the exchange of knowledge at any time globally.

In the case study, it was consulted a variety of detected sources which shows that the types of documents to monitor is very broad: from scientific and technological information (Patents, scientific articles, standards, etc.) to information relating to news, events, courses, supply and demand for technology, research projects, also carried out semi-automatically. According to this search, it was selected the technology proposed in Figure 1.

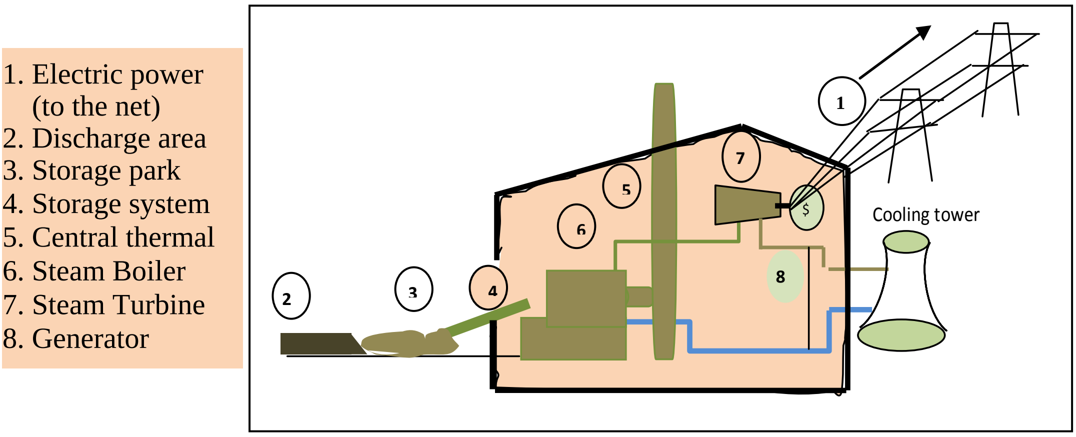

Figure 1. Technological scheme of production of electricity using forest biomass
Source: Montero (2005)

The main equipment used for combustion of forest residual biomass are steam boiler and the steam turbine (e.g. of a small plant).

A description of the equipment for direct combustion of biomass is done:

- *Steam boiler*: biomass is burned directly to obtain hot gases and thermal energy generation (by exchanging heat of the combustion gases with water), and / or electricity (superheating the water until steam).
- *Steam Turbine:* driven by pressurized steam and its rotor are moved and transmit the rotation to the generator.
- *Generator*: its rotor as move generates electricity.
- *Cooling tower*: In laden, it cools the water for steam condensation.

Therefore, according to the desired application of combustion and magnitude in energy efficiency (power of the system of energy generation), there are various scales by which technology diverges in configuration and magnitude. For the analysis of combustion technology, they have distinguished three scales according to the installed power.

- Small-scale (5-500 kW): Ranging from domestic homes up to boilers to supply hot water or heat to residential and community levels.

- Medium scale (500 kW 5 MW): Includes boilers for residential supply, buildings and / or small districts, depending on the installed power. The energy produced is thermally and / or electrically, depending on the equipment installed. For higher powers 1MW, there are usually installed gas turbines or steam for electricity generation. The supply of biomass from forests involves a regional scope.
- Large-scale (> 5MW): These are plants aimed at generating electricity, which can supply thermal energy to cover the heat demand of the territory (hotels, restaurants, industrial estates).

3.3. Step 3: Alternative diagnosis of the availability of raw material

This is another step that is recommended when the raw material is insufficient or is not compatible with existing technologies in the market, which is not the case.

3.4. Step 4. Scaling technology

In this step, due to their specialized nature we seek alliances with third parties and in this case in particular with universities or research centers.

In the same, we create a group of specialists responsible for the development, design, selection and making of the assembly of the power plant, according to the type of raw material and the materials to produce.

Requirements should be taken into account such as operational flexibility and productive capacity. The technology decides which design should contribute to lower costs for production, so these plants should be well conceived from the beginning in order to prevent pollution and generation of carbon dioxide.

3.5. Step 5: Planning of alternatives of chain supply

The procedure developed for this step includes as a first requirement the planning of the logistics supply of raw materials that has been recommended in previous work (Muto et al., 2016).

The actual behavior for this case study outlined below:

The situation corresponding to the majority of existing farms today is that the remains extended are scattered over the plot. One aspect of crucial importance in optimizing the collection of the remains is the integration of operations of this residual biomass concentration in the conventional use of forestry. Once the material is concentrated, the major limitation affecting the handling of residual forest biomass is the low bulk density, difficult and expensive transport. Therefore, harvesting technologies are based either on trituration in compression chips or waste to form high-density units. Regardless of the methods used for timber extraction biomass, there are currently three technology options for extracting forest residues. The logistics system includes the collection, transport, storage, handling and pretreatment of biomass energy, i.e. all activities between the points of origin of the plant biomass to generate electricity.

The logistics system is in the case study, because there is a variety of types of energy biomass with very diverse backgrounds, the accessibility of biomass will be different depending on the topography and infrastructure of the site and the features that must supply. Thus, it can be a direct route from the mountain or field to the plant that includes the collection, pre-treatment, storage, and transshipment in certain possible points. A description of each of the stages is the following:

3.5.1. Stage 1: Cutting and extraction zone

Cutting and extraction: the first phase will take place in the forest or on the mountain and involve the cutting and extraction. By cutting, it means forest or agricultural operation where the wood or plant is obtained and the residue is generated, after the cuts will proceed to the extraction or removal of material to accessible places for the teams that made the crushing. For operations related to extraction, mobile machinery must be adapted to the specific conditions of each type of crop or specific use and there are usually: a) tractors with the respective attachment; b) Hydraulic Sarmentador of one or two boxes; c) Autoloaders; d) packing machines.

The packing of waste, both agricultural and forest is a very suitable solution to reduce transport costs, preserving the characteristics of biomass and ease its storage. It is considered waste biomass in the form of trunks, branches, stumps, sprouts and sanitary cuts, which have already been killed, processed and debarked in mount, manually or mechanized, moving to short distance. The case study should combine the two systems, manual transports and autoloaders, due to remote access areas; we can also use short-distance transport that allows accumulating the raw material at a point easily accessible.

3.5.2. Stage 2: Biomass Logistic Centre (BLC)

Forest biomass, by its very nature, requires a number of modifications on the raw material with specific machinery so that it meets the requirements of the equipment of the power plant:

- Particle size reduction: is the homogenization and size reduction of biomass energy, use systems chipping, grinding, milling, screening and disintegration.
- Moisture reduction: primarily to reduce transport costs, is achieved by drying. It is the most expensive stage of the previous transformations. There are two forms of drying, the natural and the forced drying.
- Densification or compaction: is to reduce the volume of biomass energy, achieving to minimize the cost of transportation and storage. At the same time degradation by fermentation, is avoided. There are several alternatives such as pelletizing, briquetting and packing.
- Removing unwanted components: is to remove foreign debris, such as metals, plastics, stones. Screening techniques, gravity separation and magnets are applied.
- Storage: taking into account the type of vegetation of Cabinda and characteristics of the raw material is to be used covered warehouses and establish mechanisms for effective monitoring to minimize any risk.

3.5.3. Step 3: Power Plant

After the discharge of the materials with energy target in the central warehouse of the power plant, a prior natural drying to the residue is performed, in order to reduce its moisture content and increase the calorific value, it proceeds the management and weighing battery.

3.5.3.1. Transport

Short distance transportation of solid waste from the mountain to the logistics center is done by: Dingo Autoloader AD6A-24

The long-distance transportation to the center is done by using a rigid trailer truck, road train (rigid truck with trailer) or mobile floor truck mainly used only for the transport of crushing solid waste.

3.5.4. Step 4. Determination of the optimal initial capacity of the plant considering the uncertainty of future changes:

Based on the experience in previous studies, Rudd -Watson (1968) and similar works for the industry of sugar cane developed by (Oquendo and González, 2005), has proposed a procedure shown in (Muto et al., 2016).

This procedure includes two stages; one to study the uncertainty in the demand of the installation production and another for the uncertainty in the availability of raw materials for biofuels. The necessary growth in electricity production has been estimated based on the amounts of plastic to recycle as summarized in Table 2 by considering future changes in Table 1.

The first step of the method includes adjusting an equation of growth in demand for bio-energy and raw material availability Figure 2.

3.5.5. Electricity demand

Simple regression - Energy demand vs. Time

$$Energy\ demand(Kwh/y) = 39569.8 + 23268.4 \cdot Time \quad (1)$$

Adjusted model is show in figure 2.

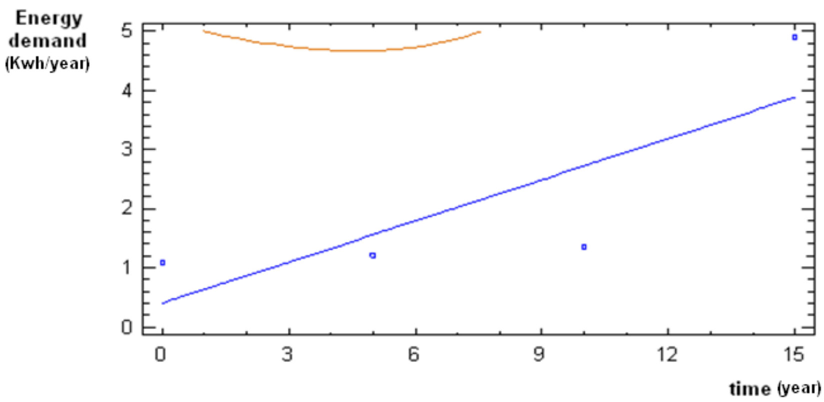

Figure 2. Growth of electricity demand for the recycling of plastic over time.
Source: Own elaboration (2015)

Table 7: Initial capacity considering the demand for electricity. Source: Own elaboration (2016)

	Non null Initial demand no on design			***Formulas***
	0.12	***0.15***	***0.18***	***no on design***
Pending	23 268.4	23 268.4	23 268.4	-
Initial Capacity (Kwh/y)	301 906	263 700	237 260	$C^*_i = b_1/i + bo$
First expansion (years)	8.33	6.67	5.56	$\theta = (C^*_i - bo)/b_1$
Capacity expansion (Kwh/y)	193 900	155 120	129 270	$C^* = b_1/i$
Total	495 806	418 245	366 537	$C_t = C^*_i + C^*$

Were:
b_1 = Slope
i = interest rate financier (%)
bo = Coefficient of the equation of the curve
C*i = Optimal initial capacity (kg/day)
θ = time to carry out the first expansion (year)
C* = Capacity to carry out the expansion (kg/day)
Ct = Total Capacity (kg/day)

From this information and applying the methodology proposed in step 5 of the procedure for determing the ability of initial investment, also considering financial uncertainty (Muto et al., 2016) the results for electricity demand obtained are expressed in Tables 7 and 8. In the case of electricity, when it also includes the time performing the first extension.

3.5.6. Biomass Availability

The mathematical expression of the relationship of biomass availability with time is expressed as follows:

$$\text{Biomass availability}(t/y) = 176781 + 59563.1 \cdot \text{Time} \qquad (2)$$

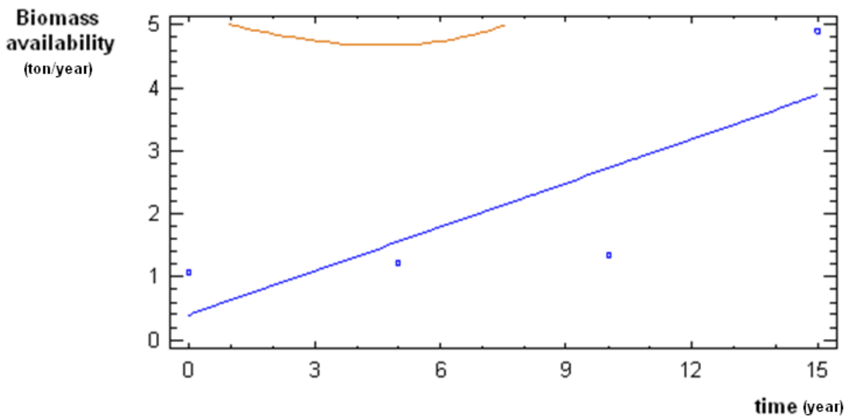

Figure 3. Growth availability of forest residues for electricity for the recycling of plastic with time. Source: Own elaboration (2016)

Table 8. Initial capacity of energy production considering the availability of forest residues. Source: Own elaboration (2016)

	Non null Initial demand no on design			*Formulas*
	0.12	*0.15*	*0.18*	*no on design*
Pending	59 563,1	59 563,1	59 563,1	-
Initial Capacity (Kwh/y)	661 252.17	561 983.33	495 802.11	$C^*_i = b_1/i + bo$
First expansion (years)	8.33	6.67	5.56	$\theta = (C_1 - bo)/b_1$
Expansion Capacity (Kwh/y)	496 359.17	397 087.00	330 906.11	$C^* = b_1/i$
Total	1 157 970.51	959 070.00	826 708.22	$C_t = C^*_i + C^*$

Table 9 summarizes the results of the analysis, it is concluded that the limit of the ability of initial and subsequent investment is given by the actual power demand for plastic recycling since there is full availability of forest residues.

Table 9. Determination of the conditions for initial investment for energy generating installations of forest solid wastes. Source: Own elaboration (2016)

C_1 (i)	*Availability of biomass (t / year)*	*Energy demand (Kwh / year)*	*Requirement of Forest solid waste according to the demand of electric power (t / a)*
$C_{1\ (0.12)}$	661 252.17	301 903.33	431 330
$C_{1(0.15)}$	561 983.33	263 122. 66	375 890
$C_{1(0.18)}$	495 802.17	237 268.88	338 960
$\theta_{1(0.12)}$	8,33	8,33	-
$\theta_{2(0.15)}$	6,66	6,66	-
$\theta_{3(0.18)}$	5.55	5.55	-

The results of Table 9 allow us to understand that the limiting aspect for initial investors' values is the demand of electricity for plastic recycling since there is a large surplus of forest biomass in relation to the demand that is set to ensure energy resources required for this action. Consistent with these results we proceeded to estimate the investor heats of facilities and other economic indicators when the plant is producing at full capacity in the sixth year.

3.6. Step 5. Optimizing transportation costs of forest biomass for processing USW of Plastics

To determine transportation costs of forest biomass to the plant of power generation considering the different sources of raw materials the problem of minimizing transportation costs is formulated as follows:

Decision variables

B_i - Binary variable indicating whether a processing plant is installed at the location i.

$i = 1 \dots n$

X_{ij} - Number of tons of forest biomass to transport between locations i and j.

$i = 1 \dots n, j = 1 \dots n$

Parameters

L_i - Involved locations. Collection centers of forest biomass and other possible locations to install the processing center. $i = 1 \dots n$

P_i - Production of forest biomass in each location. $i = 1 \dots n$

LD_j - Subset of locations where forest biomass is consumed.

$LD_j \subset L_i, i = 1 \dots n, j = 1 \dots m$

D_{ij} - Distance between locations i and j. $i = 1 \dots n, j = 1 \dots n$

D_j - Demand for forest biomass in each location. $j = 1 \dots m$

C_{palm} - Cost of transporting a ton of forest biomass distance of one kilometer

$f: \mathbb{R} \rightarrow \mathbb{R}$ - Function that indicates how an amount of forest biomass is converted into electrical energy.

Objective function

$$\min Z = C_{forest\,biomass} \left(\sum_{i,j \in L} (X_{ij} D_{ij})\right) \quad (3)$$

Restrictions

In one location you can install a processing plant, but this is not mandatory, this is expressed by the binary variable B_i:

$$B_i \in \{0,1\} \qquad \forall i \in L \quad (4)$$

To limit the total number of processing plants, you must add a restriction:

$$\sum_{i \in L} B_i = 1 \tag{5}$$

The following restriction assures that each location where forest biomass occurs can only send a maximum amount of forest biomass:

$$\sum_{j \in L} (X_{ij}) \leq P_i \qquad \forall i \in L \tag{6}$$

Every place where electricity is consumed must receive a minimum amount of biomass for processing and conversion:

$$\sum_{i \in L} (Y_{ij}) \geq Dem_j \qquad \forall j \in LD \tag{7}$$

Due to the large availability of forest biomass the solution of the problem of transportation is simplified, since the decision is transport residual forest biomass available from the zones, 4 of Cabinda, 3 of Cacongo that are the closest and the necessary rest of the Zone 2 Buco –Zau.

For these conditions, the minimum cost of transportation, to meet the demand that causes the determined initial investment is 4 727.51 USD / year.

3.7. Step 6. Technical, economic and environmental assessment of new technology

To analyze the costs of investment and production costs in line with the proposed methodology and the information available by (Peters and Timmerhauss, 1981) were determined and updated by the current cost index year 2016 forecast as it recommended in the scientific literature (González et al., 2012).

Once the fundamental plant equipment is sized, economic analysis was made, on the basis of calculating the investment cost, production cost, and profit and profitability indicators.

3.8. Determination of the total investment cost and annual output of the processing plant from palm oil into biodiesel

3.8.1. Determination of investment costs

The basic investment studies were referenced to the study by Grancho (2015), accordingly for an installation capacity of 108,000 KWh per year being the results of estimated costs of equipment of 20 191 USD, which along with raw material inputs, allows for a production capacity of 237 268.88 KWh estimate the value of equipment costs and the total cost of the investment with the help of recommendations of (Peters and Timmerhauss, 1981).

$$CFI_{cp_n} = CI_{cp_r} \cdot \left(\frac{cp_n}{cp_r} \right)^{0.6} \tag{8}$$

Being:

CI_{cp_n} : Fixed invested Capital of the new capacity ($)

CI_{cp_r} : Fixed Invested Capital of the reference capacity ($)

cp_n : New Capacity (kg/d)

cp_r : Reference Capacity (kg/d)

Table 10: Components of investment costs for the transformation of forest residuals into electricity, Installed capacity: 237 268.88 KWh **Source:** Own elaboration (2016)

Components	*%*	*Cost (U$D)*
Direct Costs =108 677.80		
Indirect costs = 16 301.67 + 0.05 CFI		
CFI= CD + CI = 124 979.47+ 0.05 CFI		

Fixed Invested Capital		131 557.33
Working Capital	8% CFI	10 524.58
Total Invested Capital	CFI+CT	142 081.91

Being; CFI = 124 979.47+ 0.05 CFI, then:
CFI = 124 979.47/0.95 = 131 557.33 USD

For the determination of the total production costs it is necessary to consider all inputs of raw materials and add the transportation costs of Forest Solid Wastes to Power Generation Plant adjacent to the Plastic Recycling Plant.
Adding the minimum cost of Transportation the CTMP is: 4 727.51 USD / year for the production of Energy of forest residues.
C. MP = 527 264.2 + CT = 527 264.2 + 4 727.51 = 531 991.71 USD / year

Estimates of Total Costs of Annual Production should be made for different production capacities to be achieved in the years of operation of the facility, which will gradually grow as the installed capacity of electricity generation is demanded by the demand processing plastic residues.
For the determination of these Total Annual Production costs were selected the percentages of capacity utilization achieved with the different possibilities of electricity demand. Table 11 presents the results of the costs of power generation capacities for 100 percent utilization of the installed capacity of power generation.

Table 11: Cost Components of Power Generation. 100% of design capacity = 237 268.88

Components	***%***	***Cost USD***
1. Manufacturing costs = Direct C. + CF + management costs		
A. Direct costs of production = 549 094.14 + 0.36 CTP		
B. Fixed Charges = (unchanged) 15 786.87 USD		
C. Plant-overhead cost = 0.05 CTP		
II. General expenses = 9 945.73 + 0.00415 CTP		
Total product cost = 0.414 CTP + 574 826.74		

CTP – 0.414 CTP = 574 826.74 = 0.586CTP
CTP =574 826.74 /0.586 = 980 933. USD/year
Cost-effectiveness studies require to determine the economic conditions in the first 10 years of production in which necessarily there have to be a period of under-utilization of installed capacity due to the lack of plastics raw material recycled in the USW which will be covered gradually in the first 5 years. According to this, production levels and annual cost will be as reflected in Table 12.

Table 12. Economic indicators of power generation for Plastics Recycling

Economic Indicator	***Year 0***	***Year 1***	***Year 2***	***Year 3***	***Year 4***	***Year 5 to 10***
% of Utilization	0	55	65	85	85	100
Production cost MUSD	0	525753.1	928 710. 7	772 812.89	772 812.89	980 933
Production KWH/d	0	130497.9	154224.8	201678.6	201678.55	237 268.9
Production KWH/year	0	43064301.7	5089474.76	66553920.84	66553920.84	78298730.4
Production value $/year (0.09 S/kwh)	0	3875787.15	4580475.72	5 989 852.87	5 989 852.87	7046885.73
Profit	0	3350034.06	3651765.03	5 217 039.98	5 217 039.98	6065952.7

From these results it is determined the NPV = 1 532 213.33 USD; IRR = 32 % and pay period = 2.8 years

3.9. Step 7. Incorporation of technology

In this step, according to the results of the economic indicators of the investment proposal is adequate the formal proposal for a draft of implementation of a plant for recycling plastics and electrical energy required for this process using for this forest biomass.

4. CONCLUSIONS

1. The application of a specific procedure is feasible to plan the initial size of an Electric production facility of Forest Biomass in the supply chain process of conversion of biomass into energy carriers.
2. The costs of transportation of forest biomass in the conditions envisaged do not affect the economic feasibility of the project.
3. The initial capacity to be installed to convert forest biomass into electrical energy is not limited by the availability of the raw material, but by the needs of recycling plastics so that future actions should be made to remove that restriction and increase the possibilities for recycling of plastics through appropriate collection and storage of this urban solid waste.
4. The initial capacity to be installed to convert forest biomass into electrical energy is not limited by the availability of the raw material, but by the needs of recycling plastics so that future actions should be made to remove that restriction and increase the possibilities for recycling of plastics through appropriate collection and storage of this urban solid waste.

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