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CALCULATION OF ECONOMIC VIABILITY AND ENVIRONMENTAL COSTS OF BIOMASS FROM *DENDÊ* OIL FOR SMALL COMMUNITIES OF BRAZILIAN NORTHEAST REGION

Luiza C. Stecher[1], Rafael R. Pacheco[2] and Gaianê Sabundjian[3]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
luizastecher@usp.br

[2] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
rafaelrade@gmail.com

[3] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
gdjian@ipen.br

ABSTRACT

The current environmental problems caused by human activity has been gaining attention in society, i.e., as it has Influenced in the growth and development of the global economic. The availability of energy resources is central point to economic development and the generation of energy is responsible for a significant portion of the emissions causing the greenhouse effect nowadays. The Brazil, a developing country, still has a large number of people without access to electricity, which affects the quality of life of individuals. In this context, it should think in the sustainable economic development, so the alternative energy sources emerge as an option for power generation. Can highlight biomass as a source in the Brazilian scenario by its wide availability and variety. Therefore, the objective of this work is to estimate the economic viability of the decentralized generation of electricity based on the use of biomass from *dendê* oil in small communities in the Brazilian Northeast considering the environmental costs involved for the source in question. The methodology is based on economic concepts and economic valuation of environmental resources. The biomass from *dendê* oil was adopted in this work by its characteristics and availability in the studied region. The results show that the generation of energy by biomass from *dendê* oil, it will contribute significantly to the sustainable development of the region, already that it will bring gains environmental, social and financial to society.

1. INTRODUCTION

The energy model of most countries is based on the consumption of fossil fuels. The combustion of these fuels for energy production is responsible for the annual addition of more than 5 billion tons of carbon into the atmosphere [1].

The sustainable growth can only be achieved with efficient use of energy resources, development of technology and the use of alternative sources, particularly in developing countries, and should be set according to the carrying capacity of ecosystems, respecting the environmental limits [1,2].

Environmental costs and externalities are increasingly debated by society. According to Mankiw [3] externalities arise "when a person engages in an action that causes impact on the well-being of a third party that does not participate in this action without paying or receiving any compensation for this impact." If the impact generated is adverse is a negative externality and is beneficial positive. You need to identify and value these externalities for these costs or benefits can be internalized in the final price of the good.

So the aim of this study is to calculate the environmental cost in electricity generation phase produced out from *dendê* oil biomass and estimate the economic viability of this source in small communities of northeastern Brazil. To achieve the proposed objective it will be developed equations for the estimative of availability of source and the application of the methodology of the Economic Evaluation of Environmental Resources (*VERA*), where the environmental cost of the analyzed source for generating phase is obtained.

2. BIOMASS FROM *DENDÊ* OIL

Biomass may be classified as any organic substance which can be transformed into mechanical, thermal or electrical energy. It can be considered as an indirect form of solar energy, responsible for photosynthesis, which is the basis for biological processes of plants, producing chemical energy, which will be converted into other forms of energy or energy products. Biomass is considered one of the great alternatives for diversification of energy sources in the country and in the world [4].

All technologies for obtaining electricity from biomass accounts on conversion of raw materials into an intermediate product, which is used to generate mechanical energy that will run the electricity generator [4].

The use of biomass energy has two extremely important factors: its short time renovation potential maintenance of the balance of CO_2, since the gas emitted in the burning process is captured during photosynthesis [5]. According to Moret [6], the use of sustainable biomass in electricity generation brings a positive impact on the environment by reducing emissions, because the net balance of CO_2 is null. Thus, it may be assumed that the use of biomass in electricity generation will generate a positive externality.

Vegetable oils *in natura* are a good alternative of natural origin for the replacement of diesel fuel in non-electrified communities, as long exists the technical possibility to have it burned in diesel generators. [7]

According to Coelho *et al.* [7], some simple changes in the vegetable oil can improve its performance as a fuel, such as *dendê* oil fractionation for the use of the less viscous fraction and the increase in fuel injection pressure. The wear of engines due to the use of *dendê* oil causes an increase between 20-25% in system maintenance costs due to preventive maintenance adequacy for seeking to equate the system lifetime to the lifetime of the system that uses diesel oil. In contrast, the cost of production of *dendê* oil is around half the diesel oil.

It is also important to note that gaseous emissions generated by the use of *dendê* oil are within the parameters found in diesel engines. However, *dendê* oil does not have sulfur, and emissions from biomass balance is zero [7].

3. BRAZILIAN NORTHEAST REGION

The Brazilian electric power supply model is based on the generation of large amounts of power connected to the grid, a model economically not viable model for sparsely populated regions. The electrification of these regions is based on insulated systems with diesel generators. Diesel oil is the main energy source used in non-electrified communities [7], which is why this will be the source to be considered as a basis for comparison of environmental cost analysis.

Lack of access to electricity directly reflects the living conditions of populations. The nine states that make up the northeast region of Brazil are in the last places in the national ranking, Alagoas being the worst state in number of HDI in the country [8].

For this work we developed a database with all municipalities in the Northeast region of the country, with a population between 1,000 and 10,000 analyzing the number of inhabitants, population density, land area, Municipal Human Development Index (IDHM) 2000 and the estimated number of families with an average of 5 people in the city. The table was developed from data obtained from the IBGE [9] and the United Nations Development Programme [10]. The results for three cities of every state of Brazil's northeast region will be demonstrated, one being the least populous, other being the most populous and a third with the population in the middle between the extremes.

4. METHODOLOGY FOR THE CALCULATION OF ENVIRONMENTAL COSTS

4.1. *VERA* Methodology

For better utilization of environmental resources, it is important to do a proper economic evaluation of environmental goods and services.

The economic value of the environment is originated all of its attributes that may or may not be associated with its use. The VERA is determined using value (VU); composed of direct use value (SUVs), indirect use value (VUI) and option value (VO); and non-use value (UNV) representing the existence value of the asset (VE) [11]. Motta [11] defines the VERA according to equation (1):

$$VERA = (VUD + VUI + VO) + VE \tag{1}$$

In cases where the environmental effects are localized or specific, they may be measured by their directly impact [2].

In this work an analysis of avoided costs considering the substitution of the electricity-diesel generator by generators run by *dendê* oil will be placed. Initially it will be described emissions of greenhouse gases in the environment originated from diesel generators to produce electricity and those values will be converted to monetary values and compared with the values obtained for the studied source. The environmental cost obtained for the analyzed source is subtracted from the value found for the environmental cost of diesel. If the value generated is negative the impact of this alternative source is beneficial, positive externality. If the impact is adverse, negative externality. From the insertion of the values of these externalities in the equations, the evaluation of the economic viability of the studied source will be studied.

4.2. Greenhouse Gas Emissions Analysis (GHG)

Alvim et al. [12] evaluated the greenhouse gas emissions (GHG) emissions in equivalent tonnes of CO_2 per energy unit (MWh) of various energy sources. Emissions of CO_2 (carbon dioxide), CH_4 (methane), NMVOCs (volatile organic compounds except methane), CO (monoxide carbon) and N_2O (nitrous oxide) are converted into CO_2 equivalents following the criteria adopted by the Global Warming Potential (GWP). The criterion considers the conversion of the emission of a pulse of 1 kg of a compound to the emission of a pulse of 1 kg of the reference gas, CO_2 in the case of GWP [16]. Table 1 shows the emissions in gCO_2eq / kWh_{el}, equivalent to tCO_2eq / GWh_{el} related to electricity generation phase estimated for some energy sources.

Table 1: Emissions related to electricity generation phase [12]

Energy Source	Total Emission in Generation Step (gCO_2eq/kWh_{El})
Diesel Oil	755
Fuel Oil	725
Coal	1262
Natural Gas	465
Nuclear	0,8
Wind Power	5,4
Photovoltaic	0

4.2.1. The Clean Development Mechanism (CDM) and its Contribution to the analyze of the environmental costs

The Clean Development Mechanism (CDM) allows earning international funds from projects that can contribute to the reduction of environmental impacts caused by the greenhouse effect and consists of certification of emission reduction projects and carbon sequestration for developing countries and selling these certificates to developed countries in order to achieve these emissions reductions targets. Developing countries that implement the CDM will issue emissions reduction certificates (CER) and these certificates will be used by developed countries in meeting their targets for reducing greenhouse gas emissions agreed under the Kyoto Protocol [13]. For each metric unit of carbon reduced through the project through the CDM, it will be credited a carbon credit (CER) to be sold [14]. Carbon unit is calculated as previously described in the GWP methodology.

For viability studies presented here, it will be considered for the evaluation of externalities and environmental costs, the possibility of selling carbon credits.

According to IPEA [14], the range of variation of prices for emission reduction is very high. This range for the carbon price in the CDM market, through the RECs is between USD 3.00 and USD 7.00. Because of this variation in prices, for this work, the average value will be adopted between the minimum and maximum practiced on the market, or USD 5.00 per ton of CO_2 equivalent.

It is observed that the sale of CER may contribute positively in the viability studies of these sources and may be considered as a credit in the calculation of externalities of the source referenced in this work. So for viability studies presented here, it will be considered for the evaluation of externalities and environmental costs the possibility of selling carbon credits.

5. RESULTS

Initially it is important to distinguish the concepts of financial assessment and economic evaluation, which are distinct within the economics. The financial assessment, developed under the private point of view, compares direct private benefits of a project with its direct monetary costs using financial instruments, synthesizing expected revenues and costs, aiming at higher profitability possible. In economic evaluation, there is a public vision for the formulation of national interest policies, taking into account the analyze of indirect effects and externalities. So, in economic analysis the positive externalities are incorporated into the benefits and the negative to their costs. [15]

The calculations of the energy costs of palm oil biomass were made considering the use of a diesel generator system that would use as fuel vegetable oil *in natura* (*dendê* oil) to generate electricity. Vegetable oils *in natura* are a good alternative of natural origin for the replacement of diesel fuel in non-electrified communities, as long as there is technical possibility to have it burned in diesel generators. [7]

Some simple changes in vegetable oil can improve its performance as a fuel, especially the degumming and neutralization of oils, *dendê* oil fractionation for the use of less viscous fraction and the increase in fuel injection pressure. The increased wear of engines due to the use of *dendê* oil causes an increase between 20-25% in system maintenance costs due to preventive maintenance adequacy and to equate the system lifetime to the life time of the system that uses diesel oil . In contrast, the cost of production of palm oil is around half of the diesel oil. It is also important to note that gaseous emissions generated by the use of *dendê* oil are within the parameters found in diesel engines. However, *dendê* oil does not have sulfur, and emissions from biomass balance is zero [7].

According Blasques *et al*. [16] in systems which use diesel, the generation can be expressed by equation (2) with a loss factor of 1.10 in the network. It is adopted the diesel generation system, since the use of vegetable oils *in natura* conventional diesel generators was proved possible in various experiments. It is possible to do so, however with some specific technical adaptations [7].

$$E_D = k_P \cdot P_L \cdot \Delta t \cdot L \tag{2}$$

Where E_D is the electricity generated by the *dendê* system (kWh); k_P is the network losses factor (1.10); P_L the installed power (kW); Δt is the time in hours and L the load factor (0.275).

To determine the costs of the systems, all calculations will be made considering their lifetime, 20 years [17]. From equation (2), we obtain electricity generated by *dendê* biomass system in a month considering 30 days (E_{DM} = 21,780 kWh / month) and the electricity generated by the *dendê* oil biomass system for 20 years ($E_{D20anos}$ = 5,227,200 kWh/20 years).

From the monthly amount produced by a system it will be determined the number of required Biomass (n_{SD}) for the assistance of each community. Each system will meet a number of families consisting of 5 components (number of inhabitants of the municipality divided by 5) on average 50 kWh/month each. Thus, the value is obtained by dividing the number of families to be assisted by the number of families that each system can meet, which is obtained by dividing the monthly energy for the energy to be provided for each family.

From the determination of the number of systems to be implemented, it is possible to obtain the amount of energy that is actually generated in the city during the lifetime of biomass systems (*dendê* oil) ($E_{EG20anos}$) given the projected number of families. This number is calculated using the equation (3). This data is necessary for the evaluation of externalities.

$$E_{EG20anos} = n_{SD} \cdot E_{D20anos} \tag{3}$$

The total system costs must consider the initial implementation costs (CI) required for the start of power system operation, replacement costs (RC) of the main components of the system because of its service life, operating costs (CO) required to operate the system and is basically considered the cost of fuel and the cost of maintenance (CM) preventive and corrective [16].

For a diesel generator set of 100 kW (or 125 kva), the price obtained for a unit in July 2013 is R$ 57,000.00 (C_E). The 105/125 kVA generator set consists of motor Brand CUMMINS TURBO, 6BT5.9-G1 model, with electronic switch, automatic control and digital frame, 2 batteries 12V-150 A/h with cables and terminals, a fuel tank 200 liters and one embedded set of pads vibra-stop [18] [1].

Also need to consider the costs for installing the power house (C_{CF}). The cost of the powerhouse to a system diesel 15 kW of power is R$ 12,000.00 [16]. Taking this as the basis, it is possible to accept a value proportional to the system of 100 kW of power rating of R$ 80,000.00.

[1] Refers to the company Soto Filho: http://www.sotofilhos.com.br/index.html

Thus, the total initial cost of the system (CI) can be obtained at equipment costs of the sum (C_E) and the powerhouse (C_{CF}), as shown in equation (4).

$$CI = C_E + C_{CF} \quad . \tag{4}$$

The replacement cost (CR) for the diesel generator that will operate with palm oil can be considered zero and included in the Maintenance Cost (CM), and there will be replacements of major components in the average life span of the system [16].

According Blasques et al. [16], CM is calculated on the generated energy (equation 2), of R$ 0.272/kWh for diesel oil. As mentioned, the maintenance cost is increased from 20 to 25% when the oil in nature is used in diesel generators. Thus, assuming an average increase of 22.5%, it follows that the maintenance cost will be R$ 0.333/kWh. The Operating Cost (CO) is given by multiplying the fuel consumption value for the oil used. According to Smith *et al*. [17] the use of *dendê* oil in diesel generators is 0.33 liters per kWh generated. The price of *dendê* oil liter can range between R$ 1.80 and R$1.90 [19]. It will be adopted the average value: R$ 1.85.

Thus, one can assume the equation (5) for calculating the total cost of a diesel generator system palm oil (R$) ($CT_D$).

$$CT_D = CI + CR + CO + CM \tag{5}$$

To make the economic viability calculations of systems based on *dendê* oil, some of the components values were updated in case of implementation. For this we used the Citizen Calculator tool, provided by the Central Bank of Brazil [20].

For corrections, it will use the IGP-M. For corrections values between October 2005 and July 2013, the correction rate for the period was 1.5693434 with corresponding percentage of 56.93434%.

All values are updated to July 2013, in order to equate the value of the diesel generator system used in the calculations for *dendê* oil and this way to keep equalized calculations for both biomass used, allowing a fair comparison. Table 2 shows the available prices which were described for the *dendê* oil biomass obtained from the literature, and their values updated in Real (R$). Initial values refer to the dates of publication of the references used in this work.

Table 2: Correction of cost values for *dendê* oil

Item	*Value ref. oct/2005*	*Updated Value jul/2013*
Cost of powerhouse (R$)	80.000,00	125.547,47
Maintenance Cost (R$/kWh)	0,333	0,52

The data for the calculation of a system based on biomass dendê oil described in this item are shown in Table 3.

Table 3: Values of the components of the costs of a system based on *dendê* oil

Item	*Valor*
Cost of conversion equipment (R $)	57.000,00
Cost of power house (R $)	125.547,47
Maintenance Cost (R$/kWh)	0,52
***Dendê* oil cost (R $ / L)**	1,85

From the data on the generation and the cost of the systems, you can get the value of the environmental cost of diesel generator that uses *dendê* oil. For *dendê* oil, these costs will be evaluated from the cost avoided by replacing diesel by *dendê* oil, considering the possibility of selling carbon credits. So *VERA* of the diesel and of the *dendê* oil may be calculated according to the equation (6).

$$VERA = E_{EG20anos} \cdot V_{CER} \cdot EmC_{eq} \tag{6}$$

The value adopted for each carbon credit was USD 5.00 (R$ 2.2779). Emissions of carbon equivalent used are stated in Table 1: 755 gCO2eq / kWh_{el} (0.000755 tCO2eq / kWh_{el}) for diesel. For biomass, is adopted zero emissions, since the literature admits that emissions balance in the use of the source is null.

The avoided cost to the environment by using the energy generated by palm oil to replace diesel oil is obtained by equation (7) where CE_D is the cost avoided by the use of *dendê* oil.

$$CE_D = VERA_D - VERA_{DIESEL} \tag{7}$$

The total cost of the project using *dendê* oil (CTE_D) is given by equation (8). In this equation, it is set the value of the externality of the energy source in question.

$$CTE_D = n_{SD} \cdot CT_D + CE_D \tag{8}$$

The value generated in kWh for 20 years in a system using palm oil ($V_{kWh(D)}$) is obtained by equation (9).

$$V_{kWh(D)} = \frac{CTE_D}{E_{EG20anos}} \quad (9)$$

Table 4 shows the values obtained for three cities of every state of Brazil's northeast as follows: the least populous, the most populous and one with the population in the middle between the extremes. In the table, you can see the impact of externalities in the total cost of the project beyond the total costs avoided by replacing the system fueled by diesel using *dendê* oil as fuel.

Table 4: Results of the calculations for the use of *dendê* oil

State	City	Generated Energy in 20 years (kWh)	Cost of the project (R$)	Avoided Cost (R$)	Cost of the project considering the externality (R$)
Alagoas	Pindoba	5.227.200	6.091.897,07	44.949,07	6.046.948,00
Alagoas	Palestina	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Alagoas	Maravilha	26.136.000	30.459.485,35	224.745,36	30.234.739,99
Bahia	Catolândia	5.227.200	6.091.897,07	44.949,07	6.046.948,00
Bahia	Cravolândia	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Bahia	Jucuruçu	26.136.000	30.459.485,35	224.745,36	30.234.739,99
Ceará	Guaramiranga	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Ceará	Pacujá	15.681.600	18.275.691,21	134.847,22	18.140.843,99
Ceará	Dep. Irapuan Pinheiro	20.908.800	24.367.588,28	179.796,29	24.187.791,99
Maranhão	Junco do Maranhão	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Maranhão	Nova Colinas	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Maranhão	Fernando Falcão	20.908.800	24.367.588,28	179.796,29	24.187.791,99
Paraíba	São José do Brejo do Cruz	5.227.200	6.091.897,07	44.949,07	6.046.948,00
Paraíba	Vieirópolis	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Paraíba	Juru	26.136.000	30.459.485,35	224.745,36	30.234.739,99
Pernambuco	Fernando de Noronha	5.227.200	6.091.897,07	44.949,07	6.046.948,00
Pernambuco	Calumbi	15.681.600	18.275.691,21	134.847,22	18.140.843,99
Pernambuco	Salgadinho	20.908.800	24.367.588,28	179.796,29	24.187.791,99
Piauí	Miguel Leão	5.227.200	6.091.897,07	44.949,07	6.046.948,00
Piauí	Agricolândia	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Piauí	Beneditinos	26.136.000	30.459.485,35	224.745,36	30.234.739,99
Rio Grande do Norte	Viçosa	5.227.200	6.091.897,07	44.949,07	6.046.948,00
Rio Grande do Norte	Sítio Novo	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Rio Grande do Norte	Luís Gomes	20.908.800	24.367.588,28	179.796,29	24.187.791,99
Sergipe	Amparo de São Francisco	5.227.200	6.091.897,07	44.949,07	6.046.948,00
Sergipe	Feira Nova	10.454.400	12.183.794,14	89.898,14	12.093.896,00
Sergipe	Rosário do Catete	20.908.800	24.367.588,28	179.796,29	24.187.791,99

The cost of the project, per kWh generated, without the internalization of the environmental cost is R$ 1.1654/kWh; the values of externality (cost avoidance) was of R$ 0.0086/kWh, and in the analysis of the cost of the project considering the internalization of externalities per kWh generated the figure is R$ 1.1568/kWh.

6. CONCLUSIONS

In addition to proved social and environmental gains, alternative energy sources also bring financial benefits to the project, since the adoption of these sources enables monetary returns from the sale of carbon credits on the international market.

The avoided costs from the use of alternative *dendê* oil source, replacing the diesel oil as a source for generating electricity enables the insertion of this type of project in the CDM. In this case the avoided costs generated a positive externality that can be turned into CER's to be sold on the international market, enabling the creation of revenue to be reinvested in the project itself.

This shows to the society and to decision makers of energy policies, how much and how the use of fossil fuels are harmful to the whole society and as its replacement by alternative sources for energy generation, such as biomass, in this case *dendê* oil, will only bring benefits, not only economic and environmental, for the whole society.

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