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The Socioeconomic Feasibility for Production of Briquettes from Agroforestry Waste: A case study in the City of Chókwè

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ABSTRACT

The current production of charcoal is one of the leading causes of deforestation in Mozambique. Given this situation, renewable energies are seen as an alternative to reduce the pressure that forests have been suffering. The main aim of this study was to evaluate the socioeconomic feasibility of deploying a briquette factory to be fed by agroforestry residues in the city of Chókwè. The study was conducted based on three possible scenarios of the briquettes machine energy use - Scenario 1 with total dependence on the national power grid; Scenario 2 with an On-grid system; and Scenario 3 with an Off-grid system. Therefore, a study was carried out to quantify the leading indicators of the economic viability of projects, such as the Net Present Value (NPV), Payback, and Internal Rate of Return (IRR). Additionally, a sensitivity analysis of NPV was also carried out considering the Scenario 2 of energy consumption. The results show that producing briquettes from agroforestry waste could be a legitimate alternative to minimize the deforestation rate. The proposed scenarios are economically feasible and present an estimated time of capital recovery of around three years with the IRR around 40%. The social assessment revealed that 98% of the people in the city of Chókwè are unaware of the existence of charcoal briquette, but they are willing to use it.

Keywords: Renewable energies; Agroforestry residues; Briquettes; Economic viability.

RESUMO

A produção actual de carvão vegetal é um dos principais factores do desmatamento em Moçambique. Com isso, observa-se nas energias renováveis como uma alternativa para a redução da pressão que as florestas vêm sofrendo, aliados a reutilização de resíduos agrícolas para fins energéticos. O objetivo deste trabalho foi de avaliar a viabilidade socioeconômica da instalação de uma fábrica de produção de briquetes a base de resíduos agroflorestais na cidade de Chókwè. O estudo foi conduzido baseando em 3 possíveis cenários de uso de energia da briquitadeira, Cenário 1 com dependência total da rede nacional de energia, Cenário 2 um sistema On grid e Cenário 3 com um sistema Off grid. Portanto, foi realizado um estudo para quantificar os principais indicadores de viabilidade econômica de projetos, como o Valor Presente Líquido (VPL), Payback e Taxa Interna de Retorno (TIR). Adicionalmente foi feita uma análise de sensibilidade do VPL considerando o Cenário 2 de consumo de energia. O levantamento da parte social do projecto foi feito com vista a perceber o nível de aceitabilidade dos briquetes de resíduos agroflorestais pela comunidade. Resultados mostram que os cenários propostos são economicamente viáveis e apresenta um tempo de recuperação de capital aproximadamente a três anos e com a TIR que ronda nos 40%. A avaliação social mostrou que 98% da população de Chókwè não tem conhecimento sobre a existência dos briquetes, mas estariam dispostos a utilizar essa nova forma de combustível.

Palavras-chave: Energias renováveis; Resíduos agroflorestais; Produção de briquetes; Viabilidade econômica.

INTRODUÇÃO

In Mozambique, forest resources have been intensively used for energy purposes. It is estimated that 80% of the energy consumed is obtained from the forest, and 98% of the forest products obtained annually are destined to produce firewood and charcoal (Falcão, 2013). Despite tremendous forestry potential, Mozambique faces enormous challenges in managing these resources, partly due to the high demand of the forestry industry and the fact that about 85% of energy needs are met by biomass energy (Zolho, 2010). However, the excessive consumption of forest resources for energy generation has put significant pressure on forests, which is consequently one major contributor to climate change in the country.

Renewable energies bring numerous advantages to the environment since they are less polluting, inexhaustible, accessible, and low-cost. Hence, its socio-economic insertion and the possibility of replacing fossil fuels in some applications make it ideal for minimizing part of the environmental problems that the world faces (Fortes *et al,* 2020). Due to its geographical location and geological conditions, Mozambique has a wide range of renewable and non-renewable energy resources, which can generate favourable conditions to satisfy local and regional energy needs. Holding a total renewable energy potential in the country of 23,026 GW (Giga Watt) with 2 GW of biomass (wood, ethanol, and biodiesel) indicates Mozambique's inherent gain (Aler, 2017). Despite this, the country has emerged in energy poverty, where more than two-thirds of the population does not have access to the national energy network, thereby remaining dependent on solar panels and biomass (Fortes *et al,* 2020).

Hence, with the massive pressure that forests have suffered in recent years, the demand for fuel material (firewood and charcoal) has generated major environmental and climatic problems. The district of Chókwè, a region offering great potential for agricultural production, has generated large amounts of waste, which can cause serious environmental issues such as flooding, transmitting diseases, and increasing respiratory problems from burning.

In view of risk reduction, there is a need to reuse these wastes competently. Using biomass for conversion into energy ends (briquettes) is one alternative for minimising agricultural waste. Within this context, alternative energy sources, particularly biomass in the form of briquettes, appear in the scene as an offer of clean energy. The transformation of biomass into briquettes vouches for the reduction of polluting gases emitted during the burning process, the increase in density, and the concentration of its energy content so that the burning potential is improved (Esteves, 2014).

As stated, Mozambique has excellent potential for the use of bioenergy, especially agroforestry biomass. The district of Chókwè is one of the great generators of agricultural products, with large outputs. For example, in 2012, this district produced more than 34,165 tons/year of agricultural products (corn, cassava, and rice) (PEDD, 2012), and which significant portion of this output was converted into waste. Faced with this reality, efforts have been made to reuse waste from various agricultural activities for energy, and one such method is the compaction of plant biomass through the briquetting process, casting forward to the burning of briquettes for energy production as an alternative to forest wood (Paula, 2010). Briquetting is a technological alternative for better use of biomass residues, consisting of a process of compaction of fine or crushed material and utilising high pressure to increase the temperature to affect the process that causes plastification of lignin.

The lignin substance acts as a particle binder during compaction (Moritz, 2017). In addition to lignin, proteins, starches, fats, and soluble carbohydrates are also natural biomass adhesives (Tavares, 2013). Thus, the briquetting process can be carried out manually or industrially (the latter being more profitable). However, to analyse these factors - productivity and profit gains - it is fundamental to use data and appropriate financial evaluation criteria for the characteristics of this project (Dessbesell, 2014).

Filippetto (2008) states that to assess the economic viability of a briquette factory plant, several aspects must be considered, such as the price of the fuel for which the briquette will be substituted, production cost, value, and characteristics of the raw material, as well as its transport. The complexity of the plant significantly influences costs and, therefore, must be evaluated in terms of the expected production volume. Possible investment decisions in the briquette business can be made by evaluating the results obtained by applying investment analysis tools.

According to Pilão & Hummel (2003), the classical methods of investment analysis, objects of financial engineering, come to help and propose a form of the ordering of thought regarding the choice of investing in an enterprise. Therefore, it is possible to choose the action that best meets the expectations of an organization. Nevertheless, the study of the economic viability of a briquette production facility is entirely related to the availability of raw material, the quality of that material, and transport, among other factors that ensure the economic and sustainable balance of the project. This study intends to evaluate the financial viability of the production of briquettes from agroforestry residues in the consumer market to bring new socio-economic and environmental solutions.

MATERIAL AND METHODS

The study was carried out in the district of Chókwè, province of Gaza, Mozambique. Three possible scenarios were simulated based on the energy source, since the use of energy is considered one of the main factors for both the operation and production line of the enterprise. The first system was imposed using energy supplied by EDM (Electricidade de Moçambique), the second with partial dependence on the electricity grid (On-grid), and the third opted for the use of a solar system without reliance on the electricity grid (Off-grid).

Economic analysis

The economic analysis was carried out by estimating production, implementation, machinery and equipment costs, raw material, and energy costs. The project's primary objective is to supply at least 30% of the cooking energy matrix of the population of the city of Chókwè, producing energy from residues that are not considered reusable. The study of economic viability is a sequence of procedures in which the beginning of the market studies allows to identify the essential elements for the analysis of the project. According to Lorenzet (2013), the scarcity of resources in the face of unlimited needs makes each investment seek to improve and better adapt its use to a single asset and constantly evaluates the interest in its implementation.

Return Period (Payback)

The payback is the period between the initial investment and the moment when the accumulated net income equals the value of that investment (Franck *et al*., 2010). That is, the prepayment time of the asset or loan, that is, the period it takes to recover the asset or the time it takes for the investment to reset its accumulated flow (Motta *et al*., 2009). According to Junior (2012) the payback can be defined by:

$$Payback = \frac{Investment\ value}{Cash\ flow}$$

Internal Rate of Return

The IRR is the discount rate that sets the NPV to zero. This rate makes future cash inflows equal to the project's initial disbursement. According to Silva (2020), the IRR can be defined by:

$$\sum_{j=0}^{n} R_j(1+TIR)^{-j} = \sum_{j=0}^{n} C_j(1+TIR)^{-j}$$

Where: Rj = revenues in the period j considered; Cj = Revenue costs in the period j considered; n = project duration in years or in number of time periods; i = annual interest rate, expressed as a decimal.

Net Present Value

The NPV, which represents the project's return to the entrepreneur, is obtained by the difference between the decapitalized value for year zero of the expenses and the expected revenues for each period defined in the project's duration horizon. NPV can be expressed by the formula (Moritz, 2017):

$$VPL = \sum_{j=0}^{n} \frac{R_j - C_j}{(1+i)^j}$$

Where: NPV = net present value; Rj = revenue in period j; Cj = Revenue costs in period j; n = project duration in years or number of time periods; i = annual interest rate, in decimal form.

After calculating the NPV, a sensitivity analysis was performed, modifying the variables (price, raw material, and discount rate) to observe which ones would most influence the NPV. Sensitivity analysis is a study of hypotheses or assumptions, which makes it possible to observe the sensitivity of a given factor when it is subjected to changes in its variables.

Social analysis

Data collection for the social analysis took place in seven neighbourhoods of Chókwè. The data collection was based on a survey (indirect method) with open and closed questions that contained 20 questions. Information was sought on the use of fuels from wood for domestic energy purposes and on knowledge about briquettes. The survey was divided into two parts, where the first part was directed to the household, and the second part was directed to the sellers of charcoal and firewood.

The sampling that was used for the study is of the random type where the entire population has the same probability of being selected. The sampling unit is the household. The sample size to be used in the present study was determined using the formula proposed by Malate (2015) expressed as follows:

$$n = \frac{Z^2 \times N \times {\sigma_p}^2}{(N-1) \times e^2 + Z^2 \times {\sigma_p}^2}$$

Where: n = Minimum number of samples; Z2= 1.96 standard variable at 95% confidence level; N = Population size; $e2$= Acceptable error (precision) =0.5; $\sigma p2$=Population standard deviation

RESULTS AND DISCUSSION

Economic Feasibility Analysis

Table 1 presents the estimated Payback, Net Present Value (NPV), and Internal Rate of Return (IRR), corresponding to the three scenarios of briquette production using three energy systems in 10 years.

Table 1. Estimates of the 3 scenarios across the financial analysis criteria

Financial criteria	**Scenario 1**	**Scenario 2**	**Scenario 3**
Payback (anos)	2,2	2,6	3,2
VPL (Mt)	7, 865, 515	7, 683, 945	7, 618, 242
TIR (%)	49	40	43

The payback time of the invested capital in the three scenarios was around three years. The scenario with the lowest Payback was the first, in which it can be observed that the payback time of the invested capital is shorter compared to the other two. In their studies, Motta *et al.* (2009) state that Payback is the investment recovery time, that is, the period it takes to recover the initial capital. Lorenzet (2013) claims that the sooner the money is recovered, the better it will be for the investment. However, market trends have continually changed, affecting the economy, so the investor should not wait too long to recover the invested capital. Nevertheless, the Payback calculation has a limitation, as it disregards the time value of money and does not present any objective criteria in determining the payback period, which makes it a risk criterion when analyzed individually.

In the Net Present Value analysis, a positive value was obtained for all scenarios, demonstrating the feasibility of implementing each of the three scenarios. In terms of numbers, the scenario that obtained the highest NPV was the first due to energy costs that are initially lower than the use of a photovoltaic system. Considering this as a long-term project, this initial advantage will become a risk due to the eventual increase in the energy rate over the years. In contrast, this risk does not happen when it comes to use of a solar system. For Lorenzet (2013), one of the premises of the NPV is that it has a value greater than 0 (zero) so that the investment becomes economically viable. However, all that is known so far is that future profitability must exceed initial investments. In turn, Silveira & Lopes (2011) obtained a positive NPV in two scenarios when they studied the increase in the production capacity of the briquetting machine. This result was only possible due to the rise in raw material and energy consumed, which generated greater profits and a positive NPV. According to Figueira *et al*. (2015), the NPV method makes it possible to know the earnings needs of projects in terms of money. The NPV allows the identification of a direct relationship between the investment analysis and the economic environment of a given country.

Gitman (2010) stated that the IRR is considered the most challenging rate to calculate than the NPV, but it is the most used technique for evaluating investments. According to Soldera and Kuhn (2014), the IRR derives directly from the NPV, from the calculation of what the IRR is obtained, and the higher the IRR, the greater the feasibility of carrying out the project under analysis. Brito (2014) studied the evaluation of the implementation of a briquette production company, using the updated cash flow and the invested capital, he obtained an IRR of 37% that exceeded the Minimum Rate of Attractiveness (MRA) of the project and concluded that the project was economically viable based on the IRR found. Figure 1 shows the variation of IRR and NPV in different scenarios.

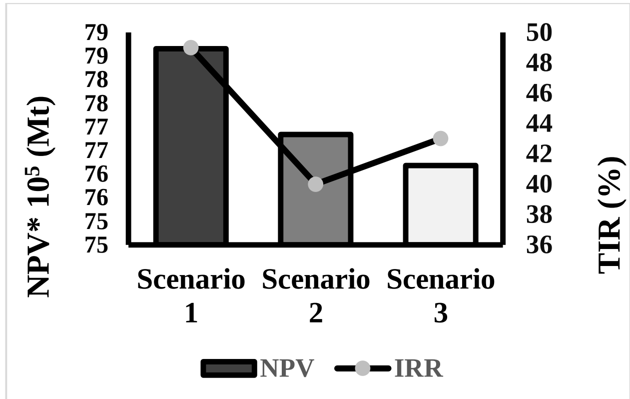


Figure 1. Estimate of NPV and IRR in the three possible scenarios in the implementation of the briquetting machine

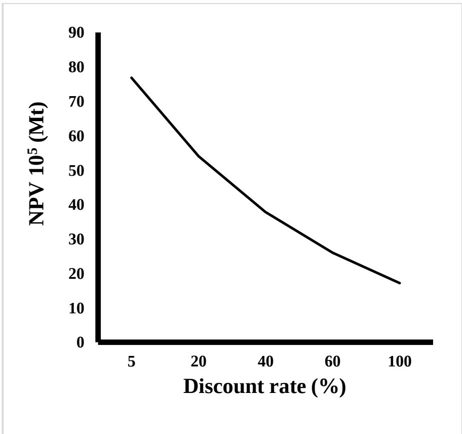
The figure 1 illustrates a stronger positive relationship between NPV and IRR. These results are similar to Silva *et al* (2006), when they studied the technical-economic feasibility of a briquette factory for energy generation. The author analyzed two scenarios with and without the insertion of taxes, obtaining a positive NPV and an IRR of 16.9% higher than the MRA, making an economically viable enterprise. And the second scenario where insertion of taxes had a negative NPV, which made its viability impossible due to the high tax burden in the country. Similarly, this study shows that the most viable scenario for implementing a briquette factory in the city of Chókwè would be the first scenario using energy from EDM. This is represented in a positive Net Present Value, a shorter payback period on invested capital and the internal rate of return is higher than the Minimum rate of attractiveness of 15%.

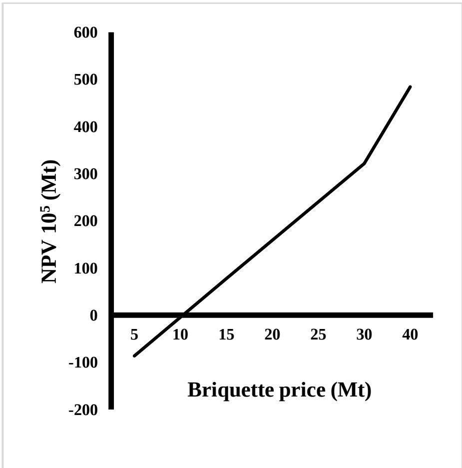
Despite Scenario 1 presenting the highest NPV, a short payback time on invested capital, and an IRR greater than the minimum rate of attractiveness, in consideration of the project's objective, other elements need to be considered. The most viable scenario to be implemented in the city of Chókwè would be the use of an On-grid photovoltaic system (scenario 2) despite having a high initial cost, in the long term, its use would pay off better than another system. According to the GWEC (2016), the expansion of renewable energies contributes to reducing harmful emissions of pollutants, volatile organic compounds, and sulfur dioxide (SO_2). However, the On -grid system has numerous advantages for humans and the environment. The incremental use of solar energy actively contributes to the mitigation of Climate Change by reducing the emission of Greenhouse Gases (GHG) - one of the factors destroying the ozone layer that later culminates in serious damage to the environment.

Franck (2010) demonstrates that installing a biomass briquette industry is a good investment, providing an alternative to reduce deforestation and other environmental benefits such as reuse of organic waste. However, Silva & Souza (2020) have shown that a photovoltaic system, when dimensioned and installed with quality materials, results in a reduction in energy costs and interventions for the maintenance of the system which brings a longer time interval of functionality and the yield of the photovoltaic system itself. Nevertheless, Ribeiro (2020) states that solar energy has high initial costs, but its long-term use compensates for the energy costs of the amount invested as compared to other energy sources. Considering all the factors analyzed, regardless of the high initial cost of acquiring the equipment and observing the country's current energy situation, the best alternative to improve the energy consumption situation of the people in Chókwè is to combine the biomass energy production plant with the use of a solar energy generation system (On-grid) to supply energy for the briquette factory.

Sensitivity analysis of NPV

Sensitivity analysis allows evaluation of NPV changes with profit or risk indicators, such as, discount rates, costs, sales, and other variables. The analysis was carried out considering Scenario 2, as it presents a dual function, and is the best option given the reality of where the project will be implemented. Variables directly linked to the NPV were analyzed: discount rate, raw material price, and price of briquettes (given all three could significantly influence the NPV). In the first graph, we can see the relationship between the NPV and Discount rate, where





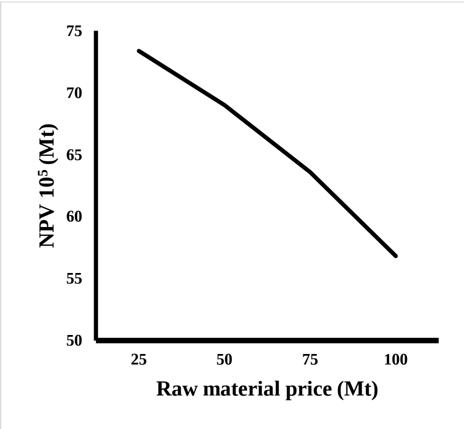


Figura 2. NPV variation in the On grid System as a function of A - Discount rate, B - Briquette price, C - Raw material price.

In the second graph, when the variation of the price of briquettes is applied, it shows that a 5% increase in the respective index provides a significant increase in NPV; but reaches negative values only when prices are lower than 10 Mt. However, the greater the slope of the line, the greater the possibility of variations in the project's economic performance and, therefore, the greater the project risk (Duarte, 2018). The third graph referring to raw material shows that the 25% increase in raw material value influenced the decline in NPV but did not affect its viability in a certain way.

Nevertheless, the sensitivity analysis in this work aimed to identify the variables that most affected the project's economic performance. Duarte (2018), when studying the economic feasibility of implementing a wind system, found that a variable's good behavior improves the project's financial performance. Importantly, the sensitivity analysis of the NPV of the implementation of a solar system with partial use of the electricity grid showed a good performance in all indicators; that is, the implementation of this scenario is economically viable. Thus, it is crucial to analyse the specific factors contributing to the variation of the project profitability.

Social Analysis

The consumption of fuel for energy purposes in the City of Chókwè is dictated by the excessive burning of firewood and charcoal due to the high purchase prices of other types of fuel. The figure 3 below shows the type of fuel source most used by the population in the city of Chókwè.

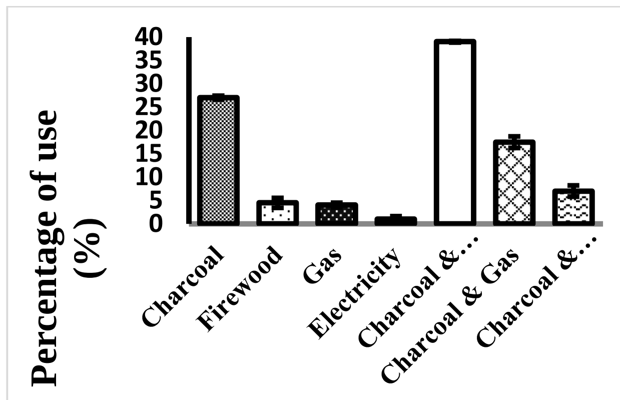


Figure 3: Sources of energy fuel in the city of Chókwè

As shown in figure 3, the most consumed fuel by families in the city of Chókwè is charcoal, with a percentage of 27%. But when combined with other energy sources, in the case of cooking gas, it presents a percentage of 18%. When consumed with another fuel from woody material (firewood), it gives a ratio of 39%. The results obtained in this study agree with the studies by Deus (2014), studying the consumption of wood for domestic energy purposes in the city of Chimoio, where he stated that charcoal was the wood-based fuel most consumed by families.

According to Atanassov *et al.* (2012), several reasons can be suggested for charcoal being the most dominant fuel in all urban areas in Mozambique. This is attributed to cultural factors, as charcoal is widely considered cheaper than other cooking fuel sources, and locals lack awareness of contemporary fuel. However, Nhancale (2008) states that alternative sources to fuels from wood, such as gas and electricity, in urban areas are purchasing power. Due to the high cost of living, most of the population with low incomes in the urban area and almost the entire population in the rural area do not have ready access to gas and electricity. This contributes to the fact that wood-based fuels are the most preferred and accessible.

Similarly with Deus (2014), firewood was the least consumed wood fuel with a percentage of 5%. The reason behind this trend is because it releases a lot of smoke during food preparation; is no longer a common practice in cities, and pollutes the environment where they cook, causing several diseases to children and women who are ordinarily exposed to the smoke caused by firewood.

In general, survey-based studies by Sitoe (2008) showed that 87% of households that use wood fuels (firewood and charcoal) in urban areas use charcoal; whilst the remaining 13% use firewood or a combination of firewood and charcoal. Among the families that use charcoal, some also use electricity, gas, or oil as an alternative energy source. However, the consumption of charcoal is predominantly by low- and medium-income families. This is due to cultural habits, reduced accessibility, and compounded by the lack of consumption of other forms of fuel such as electricity and gas. However, people tend to accept a distinct type of energy fuel if prices conform to the consumer market.

Energy consumption alternatives

As can be seen in Figure 4, regarding the knowledge about briquettes, 90% of interviewees do not know of charcoal briquettes with only 10% having knowledge of this fuel product. Interaction with neighboring countries (such as South Africa) accounts for the knowledge juncture where people are exposed to areas where briquette use is frequent. Concerning the experience in the use of briquettes, only 2% have used or had experience with briquettes, and the remaining 98% are individuals who are uninformed.

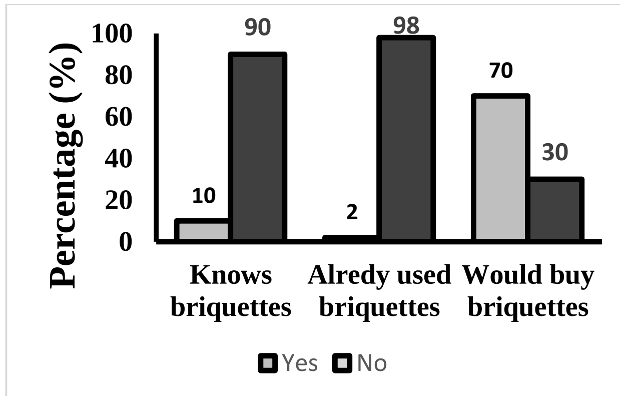


Figure 4. Utilization and Use of Briquettes

When asked about the probability of purchasing briquettes in the national market, 70% of the answers were in the affirmative; with the justification that they would buy it to try, out of curiosity conceding that it has affordable prices; and, because they consider it a good energy material. And the 30% whom responded negatively, claiming not to know where the material came from and still preferring familiar forms of energy fuel.

The results found in this study coincides with Abdala (2019), who studied waste paper's use to produce ecological charcoal in Nampula. For the author, ecological charcoal was accepted by all layers of society (according to the satisfaction survey) since more than half of those surveyed responded positively to the questions posed.

Chiefly, the two points with 100% positive response are related to the ease of burning and rapidity in the emission of thermal heat. Thus, the social acceptance of environmentally friendly charcoal is positive since most people are willing to both try and adopt this type of technology.

CONCLUSIONS

The use and exploitation of renewable energies are currently becoming one of the leading solutions to the problems of deforestation and energy crisis within Mozambique. However, the adventitious uptake of improved technology remains diminished due to the existing unfamiliarity in areas such as Chókwè. The reuse of waste along with its transformation to products such as briquettes to be utilised for energy purposes proves to be a feasible enterprise. Additionally, it provides a solution to the problems of intensive charcoal production from trees, and the major accumulation of agricultural waste (since the country does not have an appropriate system for waste management).

Based on the pre-defined objectives and the observed results, it is concluded that implementing a briquette factory in the City of Chókwè is economically viable. It was observed that there is a large and unexplored consumer market and enough raw material to supply the production of briquettes.

The On-grid Scenario is a better energy system for the briquettes factory. When using the payback parameter, the enterprise showed a quick return on invested capital of around three years. The Net Present Value was positive in the three prospective scenarios, further reinforcing the project's feasibility and demonstrating that briquettes can replace charcoal.

The social analysis was favourable and satisfactorly proving that the residents would accept the introduction of a new product into the consumer market. Also, an enterprise worthy for the generation of jobs and income, which would directly and indirectly affect the constituents, contributing to both quality of life and the economy of the city of Chókwè.

Although the cost of installing a briquette industry is high, its existence in the country is viable. An obstacle is the lack of community information about the benefits of this technology. Yet, it is a socio-economically feasible enterprise conceiving long-term employment and income opportunities for families. With encouragement from agencies linked to the environment, it would be possible to have all-round benefits like a cleaner city, and less pollution of the environment from byproducts of burning and agricultural waste whilst avoiding the devastation of forests to produce firewood by using a new, less problematic energy source.

RECOMMENDATIONS

Based on the observed results, it is recommended:
More in-depth studies on environmental analysis and estimation of the amount of carbon released in a project to collect and understand the information in quantitative terms of carbon emission and thereby predict if it would affect the local environment.

The reuse and valorization of agroforestry residues through the production of briquettes for the generation of energy, which becomes a more efficient form of waste considering that the country does not have an environmentally correct system for waste disposal.

Environmental education and information programs related to Renewable Energies, since 98% of the population of the city of Chókwè is unaware of other energy sources.
Investors are recommended to invest in a project to produce energy from briquettes, considering that the acceptance by the population was satisfactory (prior to topical education); and because it is observed that the production of briquettes is a viable economic and environmental alternative, as it helps to maximize the use of various residues (mainly wood); and project in reducing the impact of the use of native forests in the production of charcoal.

The introduction of other types of waste, such as tree branches proponents of urban pruning, sugarcane bagasse, coconut husks, and peanut husks to deal with large agricultural waste output.

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