Analysis of Mozambique's Public Policies in the sugar-energy sector

Análise das Políticas Públicas de Moçambique no sector sucroenergético

Análisis de las Políticas Públicas de Mozambique en el sector azucarero-energético

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Abstract
A concerted effort has been underway to identify novel solutions that will supplant the use of fossil fuels, the combustion of which has been identified as a primary contributor to greenhouse gas emissions. The objective of this paper is to analyze Mozambican public policies regarding the dissemination of the sugar cane sector and its contribution to the national energy matrix. The analysis revealed that the prominent sugar companies, namely Maragra, Xinavane, Chemba, Marromeu, and Mafambisse, collectively produced 2,737,556 tons of sugar cane during the 2019/2020 harvest season, cultivated across an expanse of 47,351 hectares. Regarding sugarcane production, the country possesses the capacity to yield 766,516 tons of bagasse, which has the potential to generate approximately 331,135 megawatt-hours (MWh) per annum. This would be sufficient to supply 689,864 inhabitants per hour. However, the prevailing public policies in Mozambique's energy sector currently do not mandate the sale or supply of surplus energy produced by industries to the national electricity grid.
Keywords: Public Policies; Energy matrix; Sugarcane.

Resumo
Tem havido uma busca vigorosa de novas soluções para substituir os combustíveis fósseis, que são a principal fonte de emissões de gases de efeito estufa. O objetivo deste trabalho é analisar as políticas públicas implementadas em Moçambique com o objetivo de disseminar o setor de cana-de-açúcar e avaliar sua contribuição para a matriz energética nacional. As cinco empresas açucareiras Maragra, Xinavane, Chemba, Marromeu e Mafambisse produziram coletivamente 2.737.556 toneladas de cana-de-açúcar na safra 2019/2020, cultivadas em uma área total de 47.351 hectares. Com relação à produção de cana-de-açúcar, o país tem a capacidade de produzir 766.516 toneladas de bagaço, o que poderia gerar aproximadamente 331.135 MWh por ano. Isso seria suficiente para abastecer 689.864 habitantes por hora. No entanto, as políticas públicas atualmente em vigor no setor de energia em Moçambique não preveem a venda ou o fornecimento de energia excedente produzida pelas indústrias para a rede nacional de eletricidade.
Palavras-chave: Políticas Públicas; Matriz energética; Cana-de-açúcar.

Resumen
Se han buscado con ahínco soluciones novedosas para suplantar a los combustibles fósiles, que son una de las principales fuentes de emisión de gases de efecto invernadero. El objetivo de este trabajo es analizar las políticas públicas aplicadas en Mozambique con el fin de difundir el sector de la caña de azúcar y evaluar su contribución a la matriz energética nacional. Las cinco empresas azucareras Maragra, Xinavane, Chemba, Marromeu y Mafambisse produjeron colectivamente 2.737.556 toneladas de caña de azúcar durante la zafra 2019/2020, cultivadas en una

superficie total de 47.351 hectáreas. En cuanto a la producción de caña de azúcar, el país tiene capacidad para producir 766.516 toneladas de bagazo, que podrían generar aproximadamente 331.135 MWh al año. Esto sería suficiente para abastecer a 689.864 habitantes por hora. Sin embargo, las políticas públicas actualmente en vigor en el sector energético de Mozambique no prevén la venta o el suministro de los excedentes de energía producidos por las industrias a la red eléctrica nacional.
Palabras clave: Políticas Públicas; Matriz energética; Caña de azúcar.

1. Introduction

Saccharum officinarum L., commonly referred to as sugarcane, is a tropical plant characterized by a slender, *cylindrical* stem and broad leaves that can reach heights up t*o six meters.* Its *cultiva*tion is predominantly concentrated *in tropical and subtropical* regions, *and* it *is* extensively utilized to produce sugar and ethanol *(Guerra et al., 2020). Brazil is the* global leader in *sugarcane* production, while *South Africa* is *the 13th largest producer on the African continent (Ruggeri & Corsi 2019; Mnisi & Dlamini 2012).*

From an economic perspective, *sugarcane* demonstrates notable versatility. Beyond its primary function of *produc*ing *sugar and ethanol*, its derivatives find application in manufacture of distilled beverages, animal feed, and a variety of by-products utilized biofuels, biofertilizers, paper, and energy sources (*Guerra et al., 2020).* The strategic integration of sugar-energy sector into the comprehensive utilization of sugarcane biomass has emerged as a pivotal alternative, particularly from environmental and energy perspectives. This integration contributes to the transition to renewable sources and the promotion of sustainable waste management practices.

Biomass energy has been identified as a significant source of renewable energy, currently contributing approximately 10% to global primary energy demands. It is a prominent solution for reducing greenhouse gas emissions and promoting sustainable development, as it is derived from organic materials that are easily obtained and replaceable, such as plants and crops (Perea-Moreno, Samerón-Manzano & Perea-Moreno, 2019; Ellabban et al., 2014). Biomass energy boasts a high degree of versatility, as it can be converted into heat, electricity, and biofuels to meet a wide range of energy needs. It is noteworthy to note that biomass resources are abundant in nature, with global production estimated at approximately 100 billion tons per year (Ellabban et al., 2014).

Over the past decade, global energy generation from biomass has increased from 132 TWh in 2000 to 589 TWh in 2019. This trend is projected to continue, with an estimated 1,168 TWh of biomass-derived energy expected by 2030 (IEA, 2020). A substantial portion of this augmentation can be ascribed to the worldwide escalation in sugarcane cultivation, a development that, in addition to addressing food security concerns regarding, contributes to the sustainable economic growth of the producing countries.

Brazil, India, and Cuba are notable examples of countries that have utilized sugarcane waste to diversify their energy matrix, with a particular emphasis on meeting the needs of rural areas. This approach offers two key benefits: it reduces greenhouse gas (GHG) emissions in the sugarcane sector (MNRE, 2020; Carpio & Souza, 2020; Gutiérrez et al., 2017; Moonmoon, 2021), and it enhances rural area access to energy.

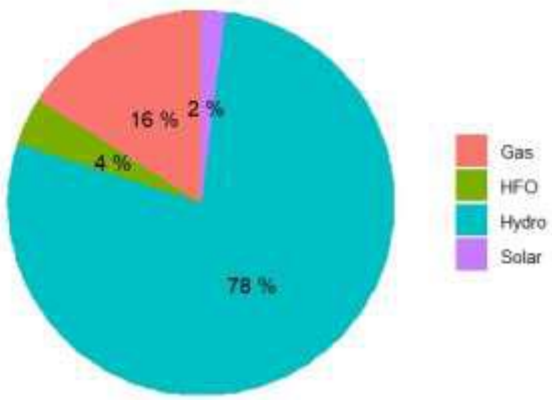
Sugarcane bagasse (Saccharum officinarum) is an agricultural residue that is produced during the processing of sugarcane. Its utilization in diverse applications has been demonstrated to be effective, and it has been incorporated into the energy matrix with the objective of contributing to the reduction of greenhouse gases (GHGs), as outlined in Sustainable Development Goals 2030.

Sugarcane bagasse is extensively employed for cogeneration of electricity using renewable heat around the globe. A comprehensive analysis by To et al. (2018) has estimated the global annual potential for electricity generated by sugarcane bagasse cogeneration is estimated to be approximately 135,029 GWh.

Sugarcane bagasse has been demonstrated to yield bioethanol and xylitol at levels of up to 0,2 g/g and 0,4 g/g respectively (Ajala et al., 2021).

Consequently, the population lacks access to electricity and clean energy for cooking food, which has adverse effects on health and the environment, including deforestation. Despite the considerable energy potential, ranging from non-renewable to renewable sources, only 17% of the population in Mozambique has access to electricity (MOÇAMBIQUE, 2009). With the rise in sugar cane production, cogeneration emerges as a promising avenue for enhancing electricity access in rural regions. However, the absence of initiatives to adopt flex-fuel crs and the limited prospects of ethanol production hinder the potential of this approach. Figure 1 illustrates the installed capacity of energy in Mozambique, which is distributed among hydroelectric, HFO, gas, and solar sources.

Figure 1 - Installed capacity in Mozambique.



Source: Authors.

Mozambique has considerable potential for biomass energy production, reaching up to 6.7 EJ/year. However, this requires the adoption of sustainable agricultural practices. Such a measure could reduce the dependence of 70% of the population on the use of firewood and charcoal, whose estimated consumption is 22 million tons/year, that is not transformed into electricity. This represents a significant threat to deforestation (Cuvilas et al., 2010). To ensure the economic and environmentally sustainable use of sugarcane waste in each location, it is essential to implement public policies that encourage this practice. In the context of the global transition towards renewable energy sources, the sugar-energy sector can play a pivotal role. This paper aims to analyze Mozambican public policies in the dissemination of the sugar cane sector and its contribution to the national energy matrix.

2. Material and Method

The methodology of the present study is that of documentary research from direct and indirect sources and of a qualitative and quantitative nature (Pereira et al., 2018). Mozambique is a country located on the east coast of the African continent and has an area of 801,537 km². It is divided into 11 provinces, with the province of Maputo City containing the country's capital, Maputo City (INE 2017). The country is bordered to the north by Tanzania, to the northwest by Malawi and Zambia, to the west by Zimbabwe, South Africa, and Swaziland; to the south-by-South Africa, and to the east by the Indian Ocean, known as the Mozambique Channel. The climate in Mozambique is tropical humid, characterized by two seasons: the hot rainy season (October to March) and the cold dry season (April to September). The relative humidity is relatively high, with temperatures varying between 20°C in the south and 26°C in the north of the country. Currently, Mozambique has five sugar plants, namely Maragra and Xinavane in Maputo province/southern zone, and Chemba, Marromeu and Mafambisse in Sofala province/central zone. Table 1 shows the overall production capacity in hectares of land and tons of sugar cane.

Table 1 - Area farmed and quantity of sugar cane produced.

Province	Production area (ha)	Sugarcane (t)
Sofala	18 767	665 000
Maputo	28 584	2 072 556
Total	47351	2.737556

Source: Authors.

The average composition of sugarcane is 12.5 to 13% fiber, 70% water, and 17 to 17.5% soluble solids (Brix). Brix is comprised of sugars (glucose, fructose, and sucrose) and non-sugars (ash, salts, proteins, etc.). According to the literature, it is estimated that 1 ton of sugarcane produces 0.27 to 0.30 tons of bagasse at the end of juice extraction. Each ton of bagasse produces 2 tons of steam in water tube boilers, which is the initial point for the energy cogeneration process. The steam produced is directed to a turbogenerator plant where it will feed turbines coupled to electricity generators. The generation of 0.2 MWh of electricity from one ton of steam is possible in modern systems or high-performance technologies utilizing multi-stage turbines in greenfield plants. This equates to the electricity required by a city of 10,000 inhabitants.

2.1 Legal Framework for the Energy Sector in Mozambique

The legal framework for the energy sector in Mozambique comprises three instruments that provide an overview of the government's policies and strategies surrounding this sector.

a) Energy Strategy - which was approved by Resolution No. 24/2000 of October 3 by the Council of Ministers, serves as a guiding instrument for the country's energy policy (Moçambique, 2000).

b) Biofuels Policy and Strategy (PEB) - was approved by Resolution No. 22/2009 of May 21 as a legal instrument in biofuels, guiding production, consumption, and marketing in Mozambique (Moçambique, 2009). Subsequently, to guarantee the applicability of this public policy, two additional instruments were approved. The Interministerial Biofuels Commission (CIB), established by Presidential Decree No. 7/2011 of July 26, is responsible for coordinating, supervising, monitoring, and evaluating the implementation of the PEB (Mataveia, 2013). Additionally, the Regulation of Biofuels and Their Mixtures, approved by Decree No. 58/2011 of November 11, regulates the production, processing, and marketing of biofuels (Mataveia, 2013).

c) New and Renewable Energy Development Policy (PDENR) - which was approved by Resolution No. 62/2009 of October 14, seeks to promote the use of renewable energy in Mozambique (Moçambique, 2009).

3. Results and Discussion

Table 2 presents the calculation of the balance of electricity production from bagasse in relation to the total area of sugar cane production in Mozambique. The estimated yield of bagasse from the 2,737,556 tons of sugar cane produced in an area of 47,351 hectares is 766,516 tons, which produces 1,655,674 tons of steam. The ratio of one megawatt-hour (MWh) to five tons of steam indicates that the quantity of steam produced can generate approximately 331,135 MWh per year. This equates to 69.0 MWh of energy per hour. Accordingly, given that 1 MWh is sufficient to supply 10,000 inhabitants, the potential for bagasse to generate electricity in Mozambique is estimated to be sufficient to supply electricity to 689,864 inhabitants per hour.

Table 2 - Balance of electricity production from bagasse.

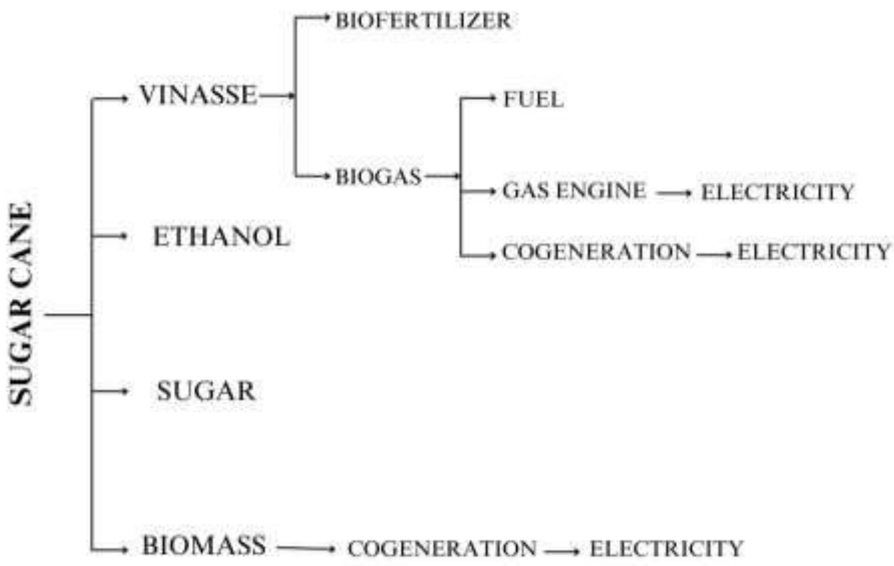
BALANCE OF ELECTRICITY PRODUCTION FROM BAGASSE		
Data	Unit	Volumes
SUGAR CANE	t	2.737.556
Harvest time	days	200
AREA	ha	47.351
FIBER	%	12,5
BRIX	%	17,5
HUMIDITY	%	70
Purity	%	85
POL (sucrose)	%	14,88
BIOMASS PRODUCTION		
Bagasse production	tbag/tc	0,28
Bagasse	t	766.516
Moisture Bagasse	%	51
Brix Bagasse	%	2,3
Pol Bagasse	%	1,8
Steam pressure	Kgf/cm²	67
Temperature	°C	520
Thermal efficiency	tvh/tbh	2,16
Steam production	ton vapor	1.655.674
ENERGY GENERATION - COGENERATION (1 MWh / 5 Ton steam)		
Steam generation Year	MWh	331.135
Steam generation Day	MWh	1655,7

Source: Authors.

Should the expansion of sugar cane production in Mozambique continue in accordance with government projections, the output of bagasse and, consequently, bioenergy will increase in proportion, thereby underscoring the necessity for significant investment in the sugar-energy sector. The sugar plants in Mozambique currently utilize bagasse to cogenerate the electricity that powers the mills themselves during peak production. The remaining portion is made available to communities situated in the vicinity of the facilities.

Investing in the sector is the best way to expand the market and generate revenue for the plants through other products. Ethanol is the perfect solution for flex-fuel cars or as an addition to gasoline to increase the octane rating. It is the only fuel that can help us achieve our universal objective of using fuels with lower GHG emissions.

Figure 2 - Production possibilities from sugar cane.



Source: Authors.

The production of ethanol generates a waste product, called vinasse. This by-product is commonly employed for fertigation of sugarcane plantations. However, there are significant opportunities to enhance its utilization. A biodigestion system enables the generation of biogas, a gaseous mixture composed mainly of methane and carbon dioxide. Natural gas is a fuel that can be readily substituted for various other fuels, primarily oil derivatives, in furnaces, dryers, boilers, and thermoelectric or cogeneration plants. This has a positive impact on mitigating climate change, as this fuel is of sustainable origin (Souza & Macedo, 2010).

An analysis of the public policies of the energy sector in Mozambique reveals that the legislation in place encourages production, processing, and marketing, as well as the coordination, supervision, monitoring, and evaluation of implementation by the government. The primary objectives of the public policies are to stimulate the sustainable production of biofuels based on local energy resources to complement imported fuels, to reduce the country's dependence on imported fossil fuels, and to reduce the weight of the import bill on the national economy. Consequently, the country will diversify its energy matrix, promote rural development through investments in biofuels and support small-scale producers with a view to increasing productivity.

The Biofuels Policy and Strategy (PEB), which was approved by Resolution No. 22/2009 on May 21, aims to promote sustainable development and environmental preservation through national and international participation by means of educational and research institutions. This participation is intended to promote the development of technical capacities and food and nutritional security (Moçambique, 2009). The strategy outlines a baseline study and evaluation of a few dozen crops to produce raw material for biofuels in Mozambique. In the initial phase, nine crops were retained for further evaluation. However, to produce ethanol, sugar cane is included in this group.

Sugarcane is a crop that has the potential to significantly reduce greenhouse gas emissions. This crop is recommended as a raw material for ethanol production in Mozambique due to its high yields, low cost, and the fact that it is not a staple food crop for the population. To coordinate, supervise, monitor, and evaluate the implementation of the PEB, the Interministerial Biofuels Commission (CIB) was created and approved by Presidential Decree No. 7/2011 of July 26. The CIB is responsible for regulating the production, processing, and marketing of biofuels and their mixtures, as outlined in Decree No. 58/2011 of November 11 (Mataveia, 2013).

Finally, Resolution 62/2009 of October 14th approved the New and Renewable Energy Development Policy (PDENR) with the intention of contributing to the country's development in the energy sector. This is done in a context in which globalization requires the adoption of measures conducive to the stability of demand and supply of energy goods and services for the different strata of society. It is evident that renewable energies play a significant role in the global market for primary energy mixes. The policy promotes the use and exploitation of available renewable energy resources with the objective of accelerating access to modern forms of energy. In accordance with the PDENR, the term *new and renewable energy sources* encompass all forms and carriers of primary and secondary energy that depend on and are replenished, directly or indirectly, by solar radiation or the hydrological cycle of the planet Earth, by the force of the gravitational field, ocean currents and thermal capacity, or volcanic activity (Moçambique, 2009).

Mozambique has made considerable strides in its legislative framework with the recent enactment of Law 11/2017 on September 8. This legislation established the Energy Regulatory Authority for the electricity sector, which includes renewable energy sources. In accordance with Article 4 (d) of Law 11/2017, ARENE has been entrusted with the responsibility of regulating the distribution and marketing of all forms of energy.

Nevertheless, it is notable that not all public policies in Mozambique provide for government incentives for energy production and sustainable management of agroforestry waste. The generation of electricity in sugar mills, for instance, is not permitted to be sold within the community or supplied to the national electricity grid due to the absence of appropriate incentives and policies in the legislation. Similarly, there is no commercial production of first- or second-generation ethanol from sugar cane in Mozambique. Nevertheless, several sugar mills produce ethanol for beverages and alcohol as by-products or molasses products.

It is important to note that in addition to sugar production, sugarcane by-products represent a significant economic opportunity. This can result in a reduction in production costs, which in turn will help to increase the sustainability of the sector. Furthermore, the utilization of by-products from sugar production offers a solution to environmental management regarding the disposal of the substantial quantities of waste generated by the sugar production process in Mozambique.

4. Conclusion

The current sugar production in Mozambique has the capacity to produce 766,516 tons of bagasse and generate approximately 331,135 MWh per year, which is sufficient to provide approximately 689,864 inhabitants with electricity per hour. The current public policies pertaining to the Mozambican energy sector do not anticipate the sale or provision of surplus energy produced by industries to the national electricity grid. The lack of political support for the sale of surplus energy represents a significant obstacle to the large-scale implementation of cogeneration. It is therefore evident that the implementation of new public policies designed to promote the growth and consolidation of this sector in the country is necessary to stimulate the production of energy from bagasse and facilitate its expansion to new markets.

Future research should focus on analyzing the regulatory framework required for integrating surplus sugar cane energy into the national grid, as well as identifying challenges and opportunities for stakeholders providing data for the development of sustainable energy policy.

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