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To cite this article: W Reyes-Calle and J.W. Grimaldo-Guerrero 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **844** 012010

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Drivers of Biomass Power Generation Technologies: Adoption in Colombia

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Abstract. The share of non-conventional renewable energies in Colombia represents less than 4% of electricity generation; the government aims to increase the net installed electricity generation capacity to over 10% by 2028. A structural analysis was carried out for decision-making: international experiences was used to identify Social, Environmental, Technical and Economic indicators and with the MICMAC method, the key variables were identified to define improvement strategies. This research determined the driver elements that will allow Colombia to effectively include biomass as an electrical energy source.

1. Introduction

The essential need for energy supply has aroused global interest in having alternative energy sources [1, 2], mainly to replace fossil fuels due to the objective of reducing the emissions of greenhouse gases [3, 4] and the gradual depletion of oil reserves in the world [5]. Renewable energies are presented as an alternative for electrical and thermal energy sources [6]; to achieve these goals there needs to be an increase in projects that use these resources [7] and technological migration in the net installed electricity generation capacity (NIEGC) needs to be carried out [8, 9].

As a government plan, countries mainly encourage projects that use energy such as biomass, solar energy and wind energy [10, 11, 12]. Colombia aims to increase its share of Non-Conventional Renewable Energies (NCRE) in NIEGC to over 10% by 2028 [13]. Currently, this share represents less than 4% of electricity generation [14].

The government of Colombia has not developed projects with NCRE sources on a large scale [15, 16], its NIEGC is based on hydroelectric power (67.3%) and fossil-fuel power (27.1%) [17, 18]. Due to the climatic fluctuations suffered by the country, caused by the El Niño-Southern Oscillation (ENSO), the design of the NIEGC has led to energy crises, specifically in the years 1992 and 2015 [19, 20]; As a solution to the latest crisis, the law 1715 was proposed [21] as a fundamental pillar to create an incentive to renewable energy projects.

Biomass is used as an energy substitute for coal and gas in fossil-fuel power plants [22], in which technological adaptations have been made to use them for direct burning [23], lowering the acquisition costs of fossil fuels [24]. Among the international practices for the diversification and promotion of the use of biomass the following initiatives stand out: Japan proposed the concept of combustible garbage which achieved to promote the recycling and the use of all waste material [25]. The United States suffered an increase in the volume of produced garbage and in the consumption of electric energy due to the accelerated population and economic growth [26], as an alternative it was decided to generate



electricity and heat with urban biomass, which achieved the reduction of volume in landfills [27]. Sweden created laws to protect its forests and to use recycled materials to generate biodiesel; currently 20% of the fuel used for public transport is biodiesel [28].

Colombia should face changes for the inclusion of biomass energy due to its high potential [29]; Biomass power generation would be able to provide public electricity service to the populations of Non-Interconnected Zones (ZNI) [30, 31, 32] – the major part of these zones are located in remote areas. In spite of the efforts made by the Colombian government, no progress has been made and no large projects that influence the NIEGC have been launched, since the projects that were carried out were mostly projects for self-consumption and in most cases with capacities not exceeding 1MW [33]. In order to achieve this goal, it is necessary to carry out a restructuring that allows strengthening the system by means of the lessons learned from countries that have achieved technological migration.

This research presents a review of the strategies employed by some countries in America, Europe and Asia to produce electricity with the use of biomass in order to establish key factor using the MICMAC method. The results allow identifying current barriers and initiatives for the development of strategies to improve the incorporation and growth of technologies for the use of biomass in Colombia.

2. Methodology

The design of this research is oriented to analyse the characteristics applied for the development and use of biomass from a conceptual and methodological dimension, identifying best practices based on international experiences. The research is organized in the following three phases, namely:

2.1. Identification phase

A review of relevant sources, mainly documentation and regulations from certain governments of Europe, Asia and America, is used to promote the technological inclusion of biomass as an energy source for the production of electricity. The indicators and criteria that were identified for the incorporation of the power generation technology will be the basis for the formulation of key variables, which will make it possible to identify drivers.

2.2. Analytical phase

International experience shows the lack of initiatives and the inexperience about these processes in Colombia. The measures taken by other countries will help to create concepts and procedures for the development of a pertinent strategic vision to attain the objective that is pursued by the government. The Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) method is used with the established variables; the results will present a conflict zone where the key elements for the promotion of technologies for the generation of electric power with biomass will be located.

2.3. Propositional phase

The analysis of the key elements will allow the design of medium – and long – term planning proposals in the electricity market. The results are a tool to evaluate the different factors according to their degree of relevance and to determine guidelines for the management and adoption of energy policies.

3. Results

3.1. Identification of factors for the implementation of biomass generation technologies

The European Union (EU) guidelines of 2017 were identified [34], these guidelines establish the goal of reducing the emission of greenhouse gases by 20%, increasing the use of renewable energies in the EU to 20% and improving energy efficiency by 20%; this commitment was set up due to the dependence on fossil fuels and the importing countries as well as to promote mitigation of related environmental problems [35]. Agents such as industries, governments and academia have developed alternatives to encourage the achievement of the goals; these alternatives are legal proposals to promote the use of biomass, the inclusion of generators in the grid, an increase of self-generation [36, 37] and an adaptation

of technologies in existing plants to use biomass [38]. A relationship between social and economic growth and the initiatives of renewable energy generation projects, especially with biomass has been identified in populations far away from the national electricity grid [39].

Figure 1 presents the identified elements from international experiences that were used to improve the implementation of technologies for the generation of energy with biomass; these elements are classified into four (4) groups according to their nature: Social, Environmental, Economic and Technical. Indicators belonging to the social group are identified as characteristics that benefit the individual and improve their quality of life; the environmental factors deal with the effects on the environment like the reduced pollution and improvements in air quality; the technical elements show the benefits in the NIEGC through technological advances; the economic ones establish movements of the market for the creation of new projects.

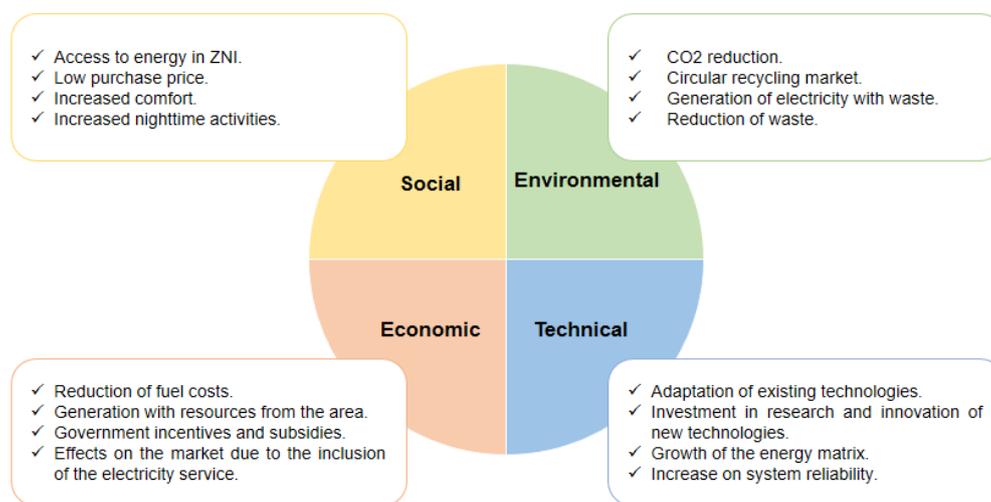


Figure 1. Indicators and criteria for the use of biomass. Sources: [40, 41, 42, 43, 44, 45, 46]

Figure 1 presents the groups of indicators and criteria that allowed obtaining an adequate management for the use of biomass and to benefit the different agents of the market, mainly the final users; these variables will promote the growth of biomass use in Colombia.

Table 1. Variables identified to improve the use of biomass in Colombia.

Code	Causal	Remark
V01	Energy use in urban, forest, agricultural and animal wastes	Garbage can be used as fuel in the generation of electric energy. [40, 44, 43]
V02	Lack of a garbage sorting system	Absence of a system structured by the government, in which it specifies how it should be recycled and in which it provides tools for doing so. [45]
V03	Energy model for the sale of energy and preferential tariffs according to the generation technology	It is seen as an incentive for private companies to generate energy with renewable sources and sell it to neighbouring communities. [28]
V04	Costs of acquiring technologies to generate energy with biomass	Currently, biomass energy is expensive because of the costs of technological investments. This is why many countries choose to adapt the existing technology.

V05	Lack of incentives for the implementation of new technologies	Colombia does not have incentives or initiatives from the government to acquire technologies or adapt existing thermal plants that do not work.
V06	Generation in non-interconnected zones	Biomass is a type of energy widely used for generation in non-interconnected areas, according to international experience. [42]
V07	Saturation of sanitary landfills	Saturation leads to the opening of a new sanitary landfills. Through the recycling and energetic use of the waste, this problem is reduced.
V08	Gas emissions from waste	The emission of gases into the atmosphere is reduced compared to fossil-fuel power plants. The environmental impact is lower. [26]
V09	Lack of awareness of recycling	Lack of training to classify and recycle the different type of garbage of the communities. [41]
V10	hydroelectric power and fossil-fuel power generation	Colombia depends mainly on these two energy sources. This has diminished the reliability in some moments of history. Biomass is an energy source that can be included in the NIEGC to provide versatility for the system. [18]
V11	Industrial sector initiatives	Agreements with industries concerning the generation and distribution of electric energy to neighbouring communities with their waste. [44]

3.2. MICMAC Method for the identification of key variables

Using the variables in table 1, the MICMAC method is applied to identify the interactions between them, and to determine the driving power and dependence of each of the variables. Table 2 presents the results of the cross-impact matrix.

Table 2. Cross-impact matrix with the variables in table 1

	V01	V02	V03	V04	V05	V06	V07	V08	V09	V10	V11
V01	0	0	5	0	0	5	4	3	0	2	4
V02	5	0	0	0	0	3	5	4	3	0	3
V03	5	0	0	0	3	5	0	3	0	4	5
V04	5	0	0	0	3	5	0	2	0	2	3
V05	5	0	2	5	0	5	0	3	0	2	3
V06	2	0	5	0	0	0	0	2	0	5	5
V07	4	2	0	0	0	0	0	4	5	0	2
V08	0	0	3	2	4	0	3	0	3	5	0
V09	5	4	0	0	0	4	5	4	0	0	0
V10	0	0	4	0	0	2	0	5	0	0	4
V11	5	0	5	3	5	5	0	4	4	3	0

Table 2 shows the driving power and the dependence of each variable according the cross-impact matrix, the conflict zone contains the variables with high driving power and high dependence. Due to their

ability to influence the other variables, these variables are key elements for the performance of the object of study.

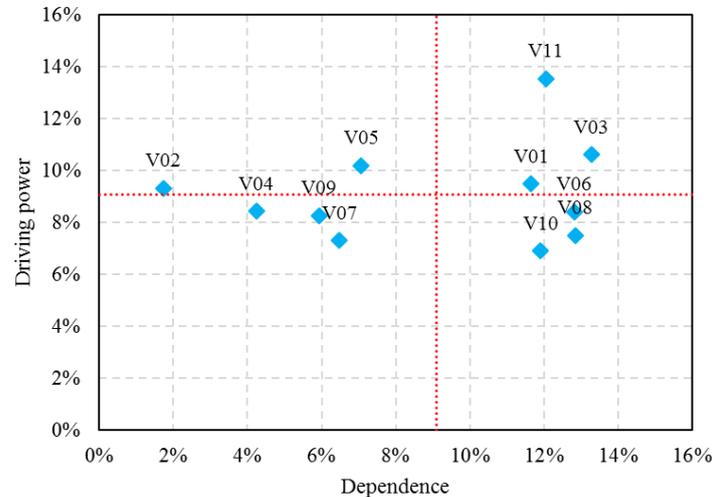


Figure 2. Results obtained from the cross-impact matrix.

The results in figure 2 focus on variables V01 (Energy use in urban, forest, agricultural and animal waste), V03 (Energy model for the sale of energy and preferential tariffs according to the generation technology) and V11 (Industrial sector initiatives) in the conflict zone.

V11 is the second variable with higher dependence and the highest driving power, it indicates the need to encourage the private sector to implement technologies for the generation of energy with biomass and for their integration into the electricity power system, and the possibility to sell the surplus. Variable V03 highlights that the government needs to launch initiatives in order to develop modifications to promote energy that is generated from biomass in the electricity market. V01 indicates that the country does not take advantage of the energy potential of its waste. The results present V02 as a variable with high driving power and low dependence which indicates that actions to promote waste classification are required.

3.3. Suggestions for the improvement of the identified key factors

The results show the lack of a system for the classification of waste, as it is for example employed in Japan [45]. A strict public policy which encourages recycling and stimulates the creation of new projects to generate energy is required to improve the use of waste and its energy potential; countries like Germany, Finland and Brazil have achieved great results by laws [28, 41, 44].

The government's commitment is required to establish duties and preferential tariff relating to the used technology and to provide clarity for the requirements for the sale of surplus electricity. These modifications in the Colombian energy model will encourage private companies that have the potential of generating energy with biomass to implement projects that are beneficial their financial accounts [10]. Colombia's mining and energy planning unit (UPME) estimated the amount of waste Colombia produced [47]. Furthermore, the UPME has a website that shows the technical, economic, financial and environmental viability of projects with biomass [48]. However, the energy department of Colombia should use the key factors (see table 1) in order to achieve the successful inclusion of biomass in the NIEGC of Colombia.

In every urban area, be it large or small, it is necessary to create waste reception centres in order to use the collected waste to power generation plants in the community. The installation of energy plants using biomass as fuel would generate energy and social development in accordance with the objectives set by

the Colombian government. This initiative includes the society and indirectly helps it to be aware of the environmental.

4. Conclusions

The article presented the identification of indicators and criteria in non-interconnected areas that are using biomass. Eleven (11) variables were to promote the growth in biomass use in Colombia were established, the MICMAC method was applied to identify strategic intervention elements and guidelines were provided that allow identifying the key elements identified.

Due to the flexibility of existing technologies and energy in the areas of influence, international experiences present biomass as a reliable alternative for the supply of electricity in areas that are isolated from the electricity grid. This highlights the need for tariff policies to promote the development of projects and to diversify the technologies already implemented.

A garbage classification system is required to optimize the use of waste and to reduce environmental impact. A strict compliance policy is recommended to achieve better results; countries such as Sweden and Japan impose fines to encourage compliance.

The electricity market should provide clarity in the guidelines concerning the sale of surplus electricity produced by companies that are not agents in the electricity sector. Currently the model allows for sale but the lack of knowledge and clarity discourage the participation of the private sector. Currently, Colombia has various means to determine the amount of biomass. However, the UPME should contemplate superior options in order to promote the use of biomass in Colombia, e.g. taxes, subsidies or incentives for the private sector.

For future work, it is recommended to study energy business models to encourage the implementation of projects and conduct a study on the key characteristics of energy models for the sale of energy with biomass.

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