



## A Look to the Biogas Generation from Organic Wastes in Colombia

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### ABSTRACT

In line with the goals of the Paris Agreement and the guidelines of Conpes 3874 of 2016, Colombia has adopted different strategies to optimize the use of biomass as an energy source and the management of materials in urban centers, establishing short and long term goals that convene actors towards the innovation of traditional models to turn them into circulars, proposing promotion mechanisms to be developed as enablers of the circular economy, among which is the production of biogas from different economic sectors. This document shows the current situation of biogas in Colombia, its participation in the national electricity sector, as well as the existing potential for its application and diversification of the existing energy matrix.

**Keywords:** Environmental Pollution, Energy Policy, Alternative Fuels, Biogas, Renewable Energy, Anaerobic Digestion

**JEL Classifications:** Q16, Q42, Q47, Q48.

### 1. INTRODUCTION

The energy crisis that the planet has been experiencing for some decades has promoted the development of new alternatives that allow energy generation without causing a high impact on the environment. Therefore, currently, industries and academic research centers are betting on the study of non-conventional sources of energy (NCSEs), whence they seek to take advantage of clean sources and process waste to obtain maximum utility and thus reduce the use of natural resources. A clear example of this is biogas, whose versatility allows it to be used for heat, electricity, lighting and mechanical power generation processes (ONU, 2017; Raboni and Urbini, 2014).

This mixture composed mainly of methane and carbon dioxide, arises as a solution when the oil was not able to lead the energy needs of growing countries, promoting an effective management

of various materials, such as animal manure, agricultural and food waste, which, when placed in the anaerobic fermentation, supply energy to towns and industries and in turn provide a waste fertilizer for use in crops (MINENERGÍA et al., 2011; UNAL, TECSOL, 2018).

This energy source is an emerging technology within the NCSEs, because currently worldwide, the use of hydropower is prioritized as a fundamental pillar for the change to a greener energy matrix, followed by wind energy, while the use of biomass for energy production only means a percentage of about 7.9%, where biogas only covers a section twice lower than the use of solid biomass in this total (Cámara de Comercio, 2016; Cámara de Comercio, 2017). However, over time this energy has acquired importance because of its usefulness as a fuel for transport networks in housing developments as well as for the transformation into electricity, so that several governments perceive it as a solution to the future

shortage of gas sources, converting it through purification into biomethane or renewable natural gas (Japan for Sustainability, 2018; Agrositio, 2019; SEAT, 2019).

Europe is the world's leading continent in biomass energy production (WBA, 2019). Biogas and biofuels represent 12% of gross inland consumption of biomass and renewable municipal waste used for energy purposes is 7% (Biomass Magazine, 2016). A total of 18,202 biogas plants are in operation with a total installed electrical capacity of 11,082 MW; Germany is the leading country with 61.80% of the total installed and operating plants on the European continent, followed by Italy with 9.3% and France with 4.17% (EBA, 2019). The main sources of raw materials used for the production of this biofuel in these countries come from the agricultural sector (38%), wastewater (28%), landfills (22%), among others (Köttner, 2019).

In Germany in particular, 41.4% of biogas production takes place due to the use of animal excrements, 51.2% due to energy crops and the remaining 7.5% due to municipal and industrial waste (WBA, 2014).

Thus, Europe produces 49.8% of the world's biogas, followed by Asia with 31.9%, America with 16.7% and the rest of the world with 1.6% (WBA, 2014).

In Latin America, Brazil is the country that has shown the most progress in biogas production and its applications are mostly aimed at cogeneration projects UNAL, TECSOL, 2018. They have 40 plants with a total installed capacity of 190.219 MW, being the main raw materials municipal solid waste, followed by agroindustrial and animal waste (ANEEL, 2020).

Colombia, on the other hand, has the biomass and the climate conditions for the development and operation of this technology. However, its growth has been gradually slow, compared to other latinoamericans countries. Thus, a coordinated work of the different institutions such as the academia, the private and public productive sectors is required, in such a way that this initiative is promoted, taking advantage of the existing potential, which would allow to be at the forefront of the sustainable development goals UNAL, TECSOL, 2018.

This study presents an overview of the current situation of biogas in Colombia, its participation in the energy matrix, the main projects operating under this technology, the progress in terms of energy policies, as well as a forecast of the development of this alternative at the national level.

## 2. BIOGAS PRODUCTION AND COLOMBIAN ELECTRICAL SYSTEM

Colombia has gradually made a commitment to the production of first-generation liquid biofuels, and has begun to promote the development of projects that encourage the use of organic waste for energy generation through biogas production (UPME, 2015).

According to the studies carried out by the Mining and Energy Planning Unit (UPME, in Spanish) (UPME, 2011), it is estimated that in the agricultural sector about 331,000 TJ are produced annually in waste that could be used for energy. While in the livestock sector is estimated to generate about 117,000 TJ per year in the form of cattle, swine, chicken manure and poultry that could be used in conjunction with agricultural waste for biogas production, while in the centers of supply, marketplaces and collection of pruning in the country's major cities are generated about 410 TJ annually.

Therefore, the implementation of biorefineries through the concept of integral use of biomass, its products and by-products, currently allows, in addition to oils or food, to produce one or several energy carriers such as biofuels, biocoal, pellets, biogas or synthesis gas. This type of productive project contributes to rural development and has been the starting point for a series of positive externalities in social and economic terms for rural areas.

Currently, there are some biogas plants operating in the country, such as the one in the Bogotá Botanical Garden (Jardín Botánico de Bogotá, 2017), (MÖBIUS, 2017), the San Fernando wastewater treatment plant and La Pradera landfill in Medellín (SCS Engineers, 2007), EPM, 2017). Also at the Guayabal landfill, the Cúcuta sanitation company built a plant to generate electricity from biogas generated from solid waste. After cleaning, the gas has the capacity to generate about 2 MW of electricity that is used for self-consumption. Promoenergía SAS specializes in providing technical services for the energy sector in Colombia and has promoted the Biobolsa System, which is a pre-fabricated anaerobic tubular biodigester designed for small and medium sized agricultural producers (Promoenergía, 2019). This system converts livestock waste into biogas and biofertilizer for domestic use. In addition, there are some initiatives such as Energreencol, which has 20 plants in operation, making the technology to generate renewable energy available to livestock farmers, industries, municipalities and associations with animals that want to use their waste. Also in Nariño, at the International Cleaner Production Center Lope, the National Learning Service (SENA, in Spanish) has installed the first biogas plant in the area. The plant was donated by the German company Ökobit and has been installed here since there are an estimated 7,500 head of cattle in the area (SENA, 2015).

Since the Colombian government began to fiscally support the generation of renewable energy through the UPME, the country's agricultural industry has discovered the use of renewable energy. Such is the case of Huevos Kikes, Colombia's largest egg producer, which invests in biogás (Huevos Kikes, 2017). In its production process, Huevos Kikes generates a large volume of chicken manure and service water, with which the 800 kW biogas plant can be operated without the need to purchase other substrates.

Finally, with respect to the pig sector in Colombia, the National Fund for Pork Producers, Porkcolombia has encouraged and disseminated the small projects that have taken place for the production of biogas from the use of swine manure as the main substrate. In different municipalities of Tolima, tubular digesters

have been implemented in full cycle production systems, where the generation is being used for heating piglets and/or cooking food. Likewise, in Antioquia an academic prototype of a UASB bioreactor will be installed in order to evaluate and compare both the biogas and the effluent produced in this second generation reaction system with a first generation system (tubular type). The work of this entity has been supported by a number of trainings regarding the implementation, commissioning and benefits of this technology at a national level (Porkcolombia, 2017).

92.35% of the national electrical energy is dispatched in a centralized manner to the entire country, that is, it is produced in large plants from where it must be transported to distribution centers and finally to its final destination (homes or industry) (XM, 2020). The net effective generation capacity up to the first quarter of 2020 for this type of production is 16,188 MW, mostly from hydroelectric plants, followed by thermal plants using conventional sources such as ACPM, coal, fuel oil, gas and Jet-A1 in smaller proportions (PARATEC XM, 2020; ACOLGEN, 2020).

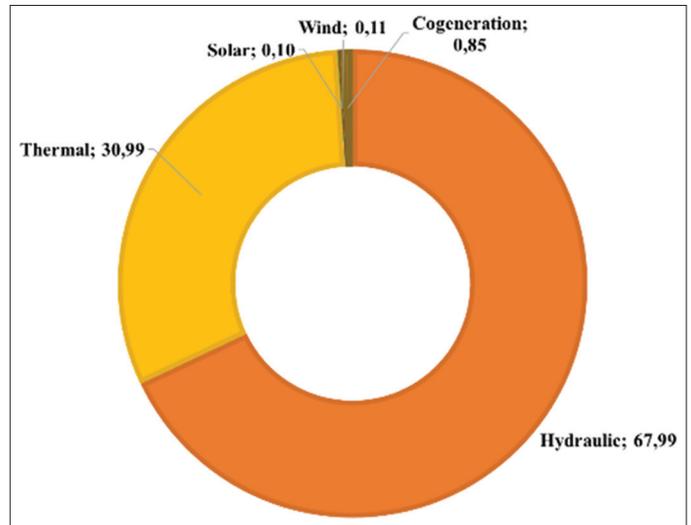
On the other hand, the remaining 7.65% is the result of investment initiatives in the development of new technologies that promote decentralization, such as self-generation, cogeneration, implementation of renewable energies such as wind, solar, biomass, additional hydraulic plants and finally some thermal plants; which together add up to an effective net generation capacity of 1,341.13 MW for the aforementioned period (ACOLGEN, 2020) (PARATEC XM, 2020).

This means that Colombia currently has a total installed capacity for electricity generation of 17,529.13 MW. Figure 1 shows the national energy matrix summarized and without distinction of the conditions of centralization; from which the important participation of renewable energies (69.02%) stands out, due to the contribution of hydroelectric power plants. However, if only the participation of non-conventional energy sources is taken into account, an incipient value is found (1.04%) against the total generated. This last value includes the contribution of biomass, through small biogas plants in self-generation and thermal projects and sugarcane bagasse for cogeneration.

The involvement of non-conventional renewable energy sources is illustrated in the Figura 2. Bagasse from sugar cane is the main actor among the other alternatives for generating energy, from the process of gasification (in addition to the fiber, the kernel and the rachis of the palm); followed by wind and solar radiation. Biogas production from the anaerobic digestion process is reduced to 5.55 MW currently produced by three plants nationwide, which entered the National Interconnected System in 2016.

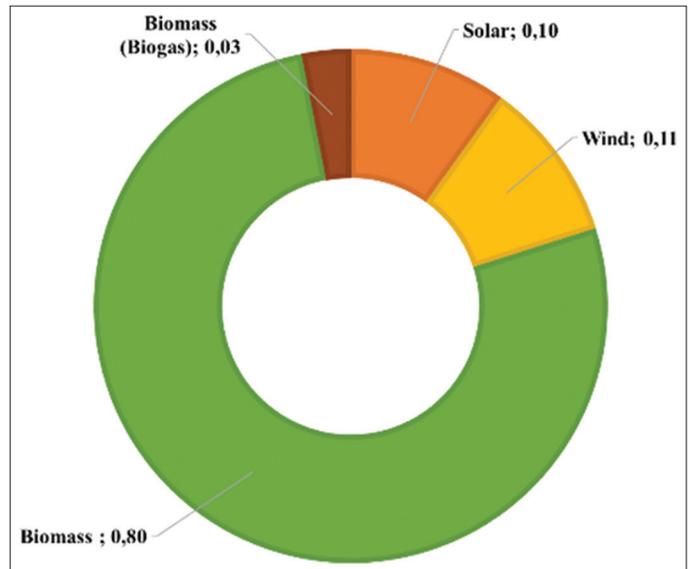
*Biogás Doña Juana S.A.S. E.S.P.* is one of the plants that uses biogas from the decomposition of approximately 6,700 tons of urban solid waste per day from Doña Juana Landfill, located in Bogotá city, to generate electricity. Consolidated in 2009 as a Clean Development Mechanism (MDL in spanish) project contemplated in the Kyoto Protocol, it obtained 4,637,018 emission reduction certificates (ERCs) by 2016 for the burning of the methane produced, making it the project with the largest

**Figure 1:** Colombian energy matrix. Electricity generation capacity 2020



Source: Adapted by the authors based on data from (PARATEC XM, 2020).

**Figure 2:** Contribution of non-conventional energy sources to the Colombian energy matrix 2020



Source: Adapted by the authors based on data from: (PARATEC XM, 2020).

number of certificates issued by the United Nations to date, preventing 800,000 tons of CO<sub>2</sub> from reaching the atmosphere annually. However, towards 2016 they increased their business lines, including the production of electrical energy with a 1.7 MW plant and currently, they have three central plants that add up to a total installed generation capacity of 24.68 MW (Biogás Doña Juana, 2020).

Using a geomembrane system, they produce biogas with an average concentration of 52.5% vol. of methane, 38.1% vol. of carbon dioxide and 42 ppmV of hydrogen sulfide, among other trace gases. By 2011 and 2012 they reached a production peak of slightly more than 13,000 Nm<sup>3</sup>/h, which could only be

approached in 2015 with 12,000 Nm<sup>3</sup>/h. In general, the flow of biogas is considerably variable over time and as a consequence the generation of energy is also (Figura 3). From the beginning of the operation until June 2019, a total of 11,089.572 kWh had been sold, for a biogas flow variation between 6,000 Nm<sup>3</sup>/h and 8,000 Nm<sup>3</sup>/h in that period (UAESP, 2019; Biogás Doña Juana, 2020).

There are currently two plants in the palm-growing sector that are investing in their production processes in Colombia, with the aim of increasing self-generation of energy and thus reducing dependence on fossil fuels and the grid (Portafolio, 2015). Thus, Manuelita Aceites y Energía of the Manuelita group, in 2013 implemented an energy efficiency system based on the capture and use of biogas from the industrial waste treatment plant (effluents from the extraction of oil from the fruit of the palm) for the generation of clean energy in the department of Meta. This resulted in a reduction of 80,000 tons of CO<sub>2</sub> per year (Manuelita, 2018).

This biogas plant consists of two lagoons that allow the capture of up to 5 million cubic meters of methane per year, which is used to generate electricity in the biodiesel plant and the extraction plant (1.4 MW), as well as to produce steam in the biodiesel plant and high pressure steam (65 bar), used to generate electrical or mechanical energy (Portafolio, 2014).

As of March 2016, the company began selling the surplus from the biogas plant, contributing to the mitigation of the shortage in the energy supply at the national level due to the El Niño phenomenon (Manuelita, 2016). In 2017 and 2018, it generated energy surpluses of 2,180 MWh (including contributions from the rest of the biomass), providing energy to nearly 1,196 colombian households. In total they have an installed capacity of 5 MW for biogas and biomass (Manuelita, 2018).

This initiative was joined by the C.I. Tequendama plant of the Daabon group, located between Aracataca and Fundación (Magdalena), with a MDL Project (Heraldo, 2013), which use the waste water from the oil extraction process for the production

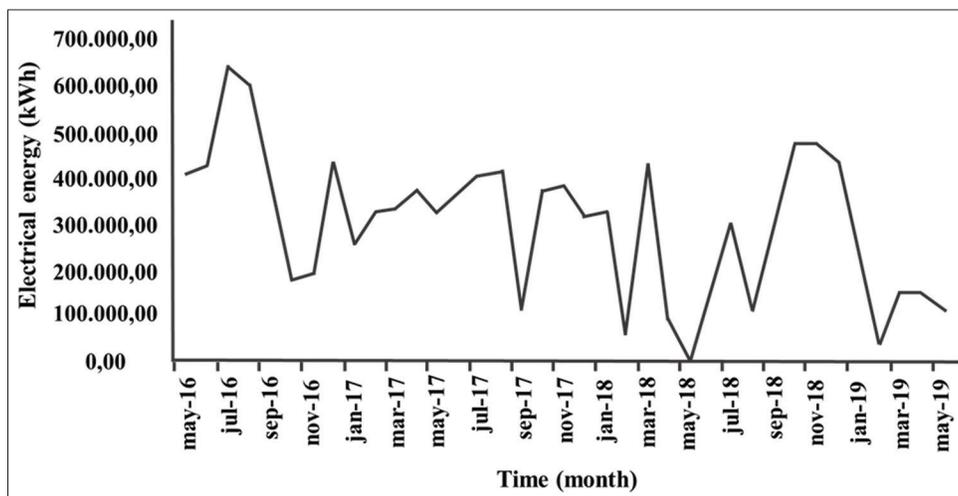
of biogas, which manages to generate 3.5 MW of electricity, of which one is consumed and 2.5 MW/day is left for sale to the grid. The water resulting from the anaerobic digestion is taken to the palm plantations to irrigate 70 ac. and the sludge obtained from this process is used to fertilize plantations (Portafolio, 2015; DAABON, 2016; Fedebiocombustibles, 2016).

### 3. POLICY FOR PROMOTION OF BIOGAS GENERATION IN COLOMBIA

In Colombia, national policies for the energy sector are managed by different actors whose synergy allows the generation, transmission, commercialization and distribution of electricity. The Ministry of Mines and Energy is the entity in charge of directing this policy regarding mining, hydrocarbons and energy infrastructure, while the Mining and Energy Planning Unit (UPME in spanish) issues and monitors the National Energy Plan and the Electricity Sector Expansion Plan. The Energy and Gas Regulation Commission (CREG in spanish) regulates the provision of public services, while the Superintendence of Public Domiciliary Services (SSPD in spanish) monitors and controls. For its part, the National Dispatch Center (CND in spanish), intervenes with the planning, supervision and control of the national electricity network and the National Operations Council (CON in spanish), establishes the technical standards to ensure that the integrated operation of the National Interconnected System is safe and reliable. Finally, the Advisory Commission for Coordination and Monitoring of the Energy Situation in the Country (CACSE in spanish) coordinates the different government entities in such a way as to achieve coverage of national electricity demand and XM operates and manages the market (Castillo et al., 2015; Cabello et al., 2019; XM, 2018).

Despite the low percentage of biogas participation at the national level, Colombian government has been developing specific regulations aimed at the use of waste for its production, supported by the initiatives of public service providers in the country, such as Gas Natural S.A. E.S.P. in Bogotá D.C. and EPM in Medellín, which established the precedent for the issuance of document

Figura 3: Electricity generation in Doña Juana plant (kWh)



Source: Adapted by the authors based on data from: (UAESP, 2019).

CREG-056 of May 22, 2009 (CREG, 2009a), through which an analysis is made of biogas situation, for this period of time, at the national and international level and the possible uses that could be given to in the country, considering injection into the National Transport System or isolated or dedicated networks. From this document, the relevance of defining regulations closely applicable to biogas was identified, for which agents, users and the Superintendence of Public Home Services were involved through Resolution 066 of May 26, 2009 (CREG, 2009b) adopting rules applicable to domestic public service of combustible gas with biogas.

In 2014, the country manifests once again its regulatory development in energy terms, since the issuance of Law No. 1715 of May 13, 2014 (Congreso de la República de Colombia, 2014), which regulates the integration of non-conventional renewable energies into the national energy system. This establishes in article 37 that, the use of local energy sources, mainly renewable, will be supported to attend to energy needs different from electricity generation; being biogas a non-conventional renewable energy source capable of favouring energy solutions of combustible gas and electricity using the same production technology, allowing the development of more efficient projects for the benefit of the users.

Towards 2016, Colombia understands that resolution CREG 135 of 2012 conditions the beginning of the provision of fuel gas service with biogas to the implementation of quality and safety measures, so it was considered necessary to adopt rules to regulate the provision of public service at home with this energy source, through Resolution No. 087 of June 13, 2016 (CREG, 2016a), which in turn led to Document CREG-151 of 2016 (CREG, 2016b) where the comments of the previous consultation were given to companies such as Pro-Organica, TGI S.A. E.S.P, EPM, Ecopetrol, Fedepalma, UPME, Naturgas, among others, which shows the growth of interest in the subject and the degree of relevance it was acquiring at a national level. Finally, the rules applicable to domestic public service of fuel gas with biogas and biomethane were adopted through Resolution No. 240 of December 06, 2016 (CREG, 2016c).

At the end of 2018, the national government, together with the ministries, Colciencias and SENA, launched the National Strategy for the Circular Economy (Gobierno de Colombia, 2018), ranking as the first country in Latin America to present new opportunities for the sustainable development of the territory and the productive chains. With this, a new economic development is sought that includes the continuous valorization of resources, the closing of material, water and energy cycles, new business models and industrial symbiosis to optimize efficiency in the production and consumption of materials and reduce carbon and water footprints.

Within the lines of action of this strategy, the optimization and use of biomass is considered, as well as the sources and use of energy, where biogas enters to play an important role as a contribution to the fulfillment of the established indicators, like the increase of pilot projects of energy generation with biomass, increase in the percentage of energy generation from residual biomass and the

development of a portfolio of tools and instruments to incorporate energy generation from biomass in the tariff system.

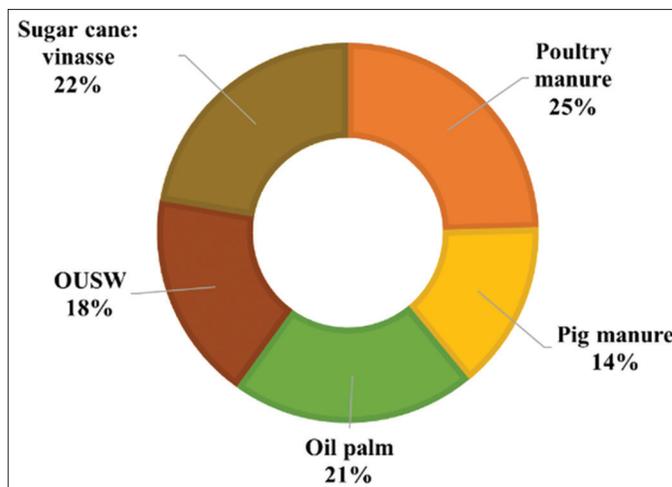
#### 4. FORECASTS OF BIOGAS GENERATION FROM ORGANIC WASTES IN COLOMBIA

Despite the various projects taking place in the country today, Colombia still has considerable energy availability in the variety of residual biomass generated by each productive sector. Figure 4 summarizes the types of prioritized biomasses under technical, environmental and socioeconomic criteria for biogas production in Colombia. These are not necessarily the ones with the largest energy supply, but those that present the greatest possibility of development and incorporation into the national energy matrix. The contribution of the livestock sector stands out with 39% (poultry and pork), followed by the industrial sector through distilleries (22%), the livestock sector with 21% and finally the urban sector with the disposal of Organic Urban Solid Waste (OUSW), which together add up to an energy available of 14.670 TJ/year as biogás (UNAL, TECSOL, 2018).

Based on this potential, the cities or departments that have the greatest variety of these biomasses and therefore the greatest opportunity to take advantage of them are in the same order of priority: Santander and Antioquia, Valle del Cauca, Meta and Bogotá. This means an opportunity for the development of co-digestion, given the benefits that this represents in terms of increased yields in biogas production.

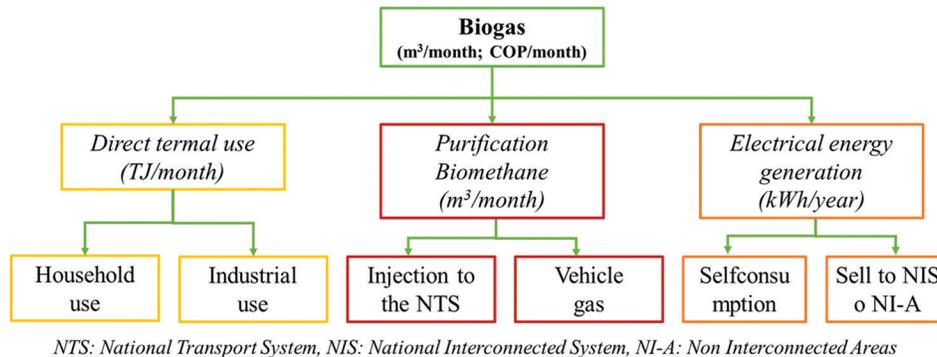
Thus, there is still a wide variety of applications of biogas generated from waste availability in Colombia. As can be seen in Figure 5, there are three major possibilities for the use of this biofuel, two of which are being implemented in existing projects (thermal use and electricity generation) on a small and medium scale, thus leaving the window open for the implementation of the third option as a biomethane, whose scenario is related to the forecasts of depletion of national natural gas reserves in the medium term (UNAL, 2019).

Figure 4: Energy potential of biogas from waste biomasses in Colombia



Source: Adapted by the authors based on data from: (UNAL, TECSOL, 2018).

**Figure 5:** Alternatives for the use of biogas in Colombia



Source: Adapted by the authors based on data from: (UNAL, TECSOL, 2018).

Based on the UPME’s forecasts for the period 2017-2031, it is considered that the additional capacity in the energy matrix from biomass could vary between 145.78 MW and 153.8 MW. In any study scenario, this contribution remains lower than that provided by other non-conventional energies such as wind or solar (UPME, 2017).

### 5. CONCLUSIONS

In spite of having a minimal development in the implementation of the technology that allows the production of biogas from anaerobic digestion, in comparison with other countries, Colombia has high impact projects that today contribute to the fulfillment of its sustainable development and circular economy indicators. The participation of the livestock, urban and industrial sectors is noteworthy, through small-scale projects, which take advantage of the excrement waste produced by the poultry, pig and cattle sectors, the wastewater from treatment plants and urban solid waste, mostly established in the country’s Andean region.

However, it also has larger scale projects, which contribute 5.5 MW to the national energy matrix, from biogas generated from two plants of the palm growing guild and one for the use of organic urban waste.

These initiatives have been possible thanks to the existing regulation, which recognizes biogas as an important non-conventional alternative for the country’s energy development.

There is still a long way to go, in which the intervention of the different sectors committed to social responsibility and the National Strategic Plan for the Circular Economy is important, from companies, government, academic entities and interested associations.

It becomes a necessity to train the national human talent, as well as to disseminate the knowledge acquired about these processes, in such a way that the work of the different sectors are merged as a synergy and give rise to more initiatives that allow the use of the existing potential of approximately 14,670 TJ/year as biogas and the favorable climatic conditions of the country.

### 6. ACKNOWLEDGMENTS

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### REFERENCES

ACOLGEN. (2020), Capacidad Instalada en Colombia. Available from: <https://www.acolgen.org.co>.

Agrositio. (2019), Scania Comenzará a Producir Camiones Impulsados a Biogás en Brasil a Partir de 2020. Available from: <https://www.agrositio.com.ar/noticia/206094-scania-comenzara-a-producir-camiones-impulsados-a-biogas-en-brasil-a-partir-de-2020>.

ANEEL. (2020), Matriz de Energía Eléctrica. Available from: <http://www.2.aneel.gov.br/aplicacoes/capacidadebrasil/operacaocapacidadebrasil.cfm>.

Biogás Doña Juana. (2020), Biogas Doña Juana. Available from: <http://www.biogas.com.co/#top>.

Biomass Magazine. (2016), European Biomass Association Releases 2016 Bioenergy Outlook. Available from: <http://www.biomassmagazine.com/articles/13837/european-biomass-association-releases-2016-bioenergy-outlook>.

Cabello, J.J., Morejón, M.B., Gutiérrez, A.S., García, A.P., Ulloa, M.C., Martínez, F.J.R., Rueda-Bayona, J.G. (2019), A look to the electricity generation from non-conventional renewable energy sources in Colombia. *International Journal of Energy Economics and Policy*, 9, 15-25.

Cámara de Comercio. (2016), Normatividad Para Las Energías Renovables en Colombia. Cali: Cámara de Comercio.

Cámara de Comercio. (2017), Centrales Eléctricas en el Mundo a Partir de Biomasa. Cali: Cámara de Comercio.

Castillo, Y., Gutiérrez, M.C., Vanegas-Chamorro, M., Valencia, G., Villicaña, E. (2015), Rol de las fuentes no convencionales de energía en el sector eléctrico colombiano. *Prospectiva*, 13, 39-51.

Congreso de la República de Colombia. (2014), Ley No. 1715. Bogotá, DC: Congreso de la República de Colombia.

CREG. (2009a), Documento CREG 056: Regulación Aplicable al Biogás. Bogotá, DC: CREG.

CREG. (2009b), Resolución No. 066 de 2009. Bogotá, DC: CREG.

CREG. (2012a), Documento 079: Normas Aplicables al Servicio Público Domiciliario de Gas Combustible Con Biogás. Bogotá, DC: CREG.

CREG. (2012b), Resolución No. 135 de 2012. Bogotá, DC: CREG.

CREG. (2016a), Resolución No. 087 de 2016. Bogotá, DC: CREG.

CREG. (2016b), Documento CREG-151. Bogotá, DC: CREG.

- CREG. (2016c), Resolución No. 240 de 2016. Bogotá, DC: CREG.
- DAABON. (2016), Plan Manejo Ambiental. Aracataca, Magdalena: DAABON.
- EBA. (2019), Statistical Report: European Overview. Brussels: EBA.
- EPM. (2017), Gestión Social y Ambiental. Available from: <https://www.2017.sostenibilidadgrupoepm.com.co/gestion-social-y-ambiental/nuestra-gestion/temas-materiales/diversificacion-de-energias-renovables/biogas>.
- Fedebiocombustibles. (2016), Palmicultores Son Capaces de Producir Energía. Available from: [http://www.fedebiocombustibles.com/nota-web-id-2221-titulo-palmicultores\\_son\\_capaces\\_de\\_producir\\_energ%C3%ada.htm](http://www.fedebiocombustibles.com/nota-web-id-2221-titulo-palmicultores_son_capaces_de_producir_energ%C3%ada.htm).
- Gobierno de Colombia. (2018), Estrategia Nacional de Economía Circular. Bogotá, DC: Gobierno de Colombia.
- Heraldo. (2013), Autogeneración Energética Por Biogás, Apuesta de Daabon. Available from: <https://www.elheraldo.co/noticias/agropecuaria/autogeneracion-energetica-por-biogas-apuesta-de-daabon-113053>.
- Huevos Kikes. (2017), Bioenergía Para la Sostenibilidad. Available from: <https://www.huevoskikes.com/noticias/bioenergia-para-la-sostenibilidad>.
- Japan for Sustainability. (2018), Japanese Railway Begins Biogas Production Using Food Waste From Station Buildings. Available from: [https://www.japanfs.org/en/news/archives/news\\_id035992.html](https://www.japanfs.org/en/news/archives/news_id035992.html).
- Jardín Botánico de Bogotá. (2017), UAESP y Jardín Botánico Obtienen Segundo Puesto en Innovación Que Deja Huella. Available from: <http://www.jbb.gov.co/index.php/noticias-del-jardin/item/161-uaesp-y-jardin-botanico-obtienen-segundo-puesto-en-innovacion-que-deja-huella>.
- Köttner, M. (2019), Overview of the Biogas Industry and Introduction to Biogas Technology Content: Outlook On Biomethane. Stuttgart: Universidad del Atlántico.
- Manuelita. (2016), Manuelita Inicia Venta de Energía Eléctrica a Partir de Fuentes Renovables. Available from: <http://www.manuelita.com/manuelita-noticias/manuelita-inicia-venta-energia-electrica-partir-fuentes-renovables/?lang=en>.
- Manuelita. (2018), Informe de Sostenibilidad. Cali: Manuelita.
- MINENERGÍA, PNUD, FAO, GEF. (2011), Manual de Biogás. Santiago de Chile: MINENERGÍA.
- MÖBIUS. (2017), Casos de Éxito. Available from: <http://www.mobius.net.co/casos-de-exito>.
- ONU. (2017), United Nations Framework Convention on Climate Change. Available from: <https://www.unfccc.int/es/news/la-conferencia-de-la-onu-sobre-el-cambio-climatico-2017-busca-aumentar-de-manera-rapida-y-conjunta>.
- PARATEC XM. (2020), Capacidad Efectiva Por Tipo de Generación. Available from: <http://www.paratec.xm.com.co/paratec/sitepages/generacion.aspx?q=capacidad>.
- Porkcolombia. (2017), Boletín Ambiental. Colombia: Porkcolombia.
- Portafolio. (2014), Manuelita Busca Su Sostenibilidad Productiva. Available from: <https://www.portafolio.co/negocios/empresas/manuelita-busca-sostenibilidad-productiva-49220>.
- Portafolio. (2015), Palmicultores Son Capaces de Producir Energía. Available from: <https://www.portafolio.co/economia/finanzas/palmicultores-son-capaces-producir-energia-30820>.
- Promoenergía. (2019), Pequeñas Plantas de Biogás. Available from: <http://www.promoenergia.co/biodigestores/index.html>.
- Raboni, M., Urbini, G. (2014), Production and use of biogas in Europe: A survey of current status and perspectives. *Ambiente and Água: An Interdisciplinary Journal of Applied Science*, 9(2), 191-202.
- SCS Engineers. (2007), Informe de Evaluación Relleno Sanitario La Pradera. Medellín, Colombia: SCS Engineers.
- SEAT. (2019), From the Recucling Bin to Your Fuel Tank. Available from: <https://www.seat.com/company/news/company/seat-turns-organic-waste-into-fuel.html>.
- SENA. (2015), Aliados en la Producción de Biogás. Available from: <http://www.sena.edu.co/es-co/noticias/paginas/noticia.aspx?idnoticia=1093>.
- UAESP. (2019), Informe Mensual de Supervisión y Control. Bogotá, DC: UAESP.
- UNAL, TECSOL. (2018), Estimación del Potencial de Conversión a Biogás de la Biomasa en Colombia y su Aprovechamiento. Bogotá DC: UNAL.
- UNAL. (2019), Colombia Afrontaría Escasez de Gas Natural en 2024. Available from: <https://www.agenciadenoticias.unal.edu.co/detalle/article/colombia-afrontaria-escasez-de-gas-natural-en-2024.html>.
- UPME. (2011), Atlas de Potencias Energético de la Biomasa Residual en Colombia. Bucaramanga (Colombia): Universidad Industrial de Santander, 2011. Bogota: UPME.
- UPME. (2015), Plan Energético Nacional Colombia: Ideario Energético 2050. Bogota: UPME.
- UPME. (2017), Plan de Expansión de Referencia Generación-Transmisión. Bogotá, DC: UPME.
- WBA. (2014), Global Bioenergy Statistics. Europe: WBA.
- WBA. (2019), Global Bioenergy Statistics. Europe: WBA.
- XM. (2018), Overview Colombia Power System and Renewable Integration. Colombia: XM.
- XM. (2020), Qué Hace XM? Available from: <https://www.xm.com.co/corporativo/paginas/nuestra-empresa/video-infografico.aspx>.