

# Bioenergy in South America: Directions and Challenges for Biofuels

Shirley Carla Chamby Espejo<sup>1</sup>, Glenda Rodrigues de Sousa Gaio<sup>2</sup>, Caroline da Costa Silva Gonçalves<sup>3</sup>, Andréia Cristina Furtado<sup>4</sup>

<sup>1,2,4</sup>Latin American Institute of Technology, Infrastructure and Territory, Federal University of Latin American Integration (UNILA), Brazil

<sup>3</sup>Latin American Institute of Life and Nature Sciences, Federal University of Latin American Integration (UNILA), Brazil

Received: 16 Sep 2021,

Received in revised form: 15 Oct 2021,

Accepted: 22 Oct 2021,

Available online: 29 Oct 2021

©2021 The Author(s). Published by AI Publication. This is an open access article under the CC BY license (<https://creativecommons.org/licenses/by/4.0/>).

**Keywords— Bioenergy, Biofuels, Challenges, Policy, South America**

**Abstract**—Biofuels have become a global interest for many private and public investors, since, in several European countries, bioenergy is considered a part of the energy matrix. However, South America is entering the same path, promoting, and applying policies to produce liquid and gaseous biofuels, so that they are developed in a more environmentally friendly way, have a social impact, and are economically sustainable. It could represent a strategic opportunity for the development of the entire southern continent's energy matrix, in addition to the fact that biofuels can be an ally in the fight against climate change and stimulate economic development, reducing rural poverty and promoting more integrated and efficient agricultural systems. This work aims to demonstrate the existence of bioenergy in South America, its state of the art in the countries, updated information, production, use of biofuels, and showing the policies applied throughout these years, to provide an information base.

## I. INTRODUCTION

In the middle of the 20th century, the actions adopted against climate change began to be a fundamental focus regarding the environment and energy stability. Various factors influenced the reduction of our natural resources, being that over the last few years, their consumption has increased exponentially. The growth of the population, the industrial expansion, and the massive use of technology began to be a concern worldwide due to the depletion of oil reserves, natural resources and added environmental deterioration, which motivated to seek new ideas in the production of renewable energy, as well as public policies that promote its use [1]. Since then, solar energy, hydro energy, and bioenergy from biofuels have been viewed as viable renewable sources and are better known in South America, demonstrating an exponential increase in the use of new energy sources [2].

Bioenergy presents itself as a feasible route for the future of energy consumption because it involves the use of biological materials for energy purposes, converting them into thermal energy, electricity, and transportation fuels through different processes. Therefore, there are many established bioenergy pathways technically proven, so that the systems are commercially available [2,3].

Latin America has become one of the most propitious and tending regions for agricultural exploitation due to the usable spaces for said activity. In addition, the region has a favorable climate and soils with the necessary properties for it. Considering this context, Latin America is a potential exporter of biofuels [4].

The discussion on biofuels focuses on the techno-scientific aspects of energy sources production, aiming to reform social-political aspects, generating employment and improving economic income, conserving ecosystems, and

reducing environmental pollution, factors that influence decision-making in every country, especially in South America. The scale production of biofuels requires a socio-ecological response that is not economically efficient [5].

Biofuels come from biomass (i.e., sugar cane, wood, agricultural waste, and urban waste), using methods and processes such as hydrolysis, fermentation, gasification, synthesis gas, and rapid pyrolysis to obtain diesel, ethanol, butanol, methanol, dimethyl ether, biogas and other chemical products. Traditionally, biomass is used for cooking and heating. However, in recent years, this has decreased due to efforts to reduce fuel inefficiency and improve access to clean sources, given the negative effects on the local air and other associated impacts [4].

On the other hand, modern bioenergy is making it possible to provide a cleaner and more efficient fuel for the transportation industry. Sustainable energy has become the interest of governments around the world, because, if used correctly, it can be an ally in the fight against hunger and stimulate the economic development of countries, promoting agricultural systems and reducing poverty [5]. The progress and development of renewable energy technologies have been achieved thanks to the efficiency of government policies. Thus, these types of actions continue to be an important factor in overcoming economic, technical, and institutional barriers.

The bioeconomy provides competitive advantages and opportunities to achieve sustainable development objectives, the great benefit for South America is its ecosystem, a large part of the economy is subject to agriculture. Considering the information discussed here, this paper aims to present a panoramic view of biofuels in South America, while being aware of the local development problems and the biofuel market, as well as the internal policies and goals established by each country.

## II. STATE OF THE ART

The development of the global biofuel markets since the beginning of the 20th century prompted public policies for the production and use of this type of renewable energy, but, before promoting and motivating countries, these policies were established through a combination of events, including the use of biofuels. Therefore, they were established with the goal of helping energy security, reducing the greenhouse effect and reusing agricultural residues [6].

The oil market is an important component when it comes to biofuel, as it is the most widely used non-renewable liquid fuel, due to its competitiveness, which can influence the price of biofuels. The United States of

America (USA) is one of the countries that imports oil and understands that one of the main points on the international energy agenda is the economic instability of oil; however, it is one of the first countries to seek and promote investment and research in clean energy technologies and alternative fuel production [7].

The United States Energy Independence and Security Act of 2007 (EISA Act) defined the Renewable Fuels Standard (RFS2) program. This law established mandatory standards until 2022, which dictate that fuels must achieve at least 20% to 50% reduction of the greenhouse effect, as well as the integration of biodiesel and cellulose into the standard fuel production. Additionally, the Environmental Protection Agency (EPA) establishes annual minimum quantities for the four types of biofuels required [5].

The global production of biofuels grew exponentially and is seen as an opportunity for developing and emerging countries, being an alternative to guarantee internal consumption, mitigate the effects of greenhouse gases, as well as satisfy energy demand [8]. First-generation biofuels are made from sugar, starch, and vegetable oil; these materials biologically produce ethanol, propanol, and butanol by the action of sugar, starches or cellulose, although there is a conjecture that they cannot produce enough biofuel without threatening food supply and biodiversity. On the other hand, second-generation biofuels are produced from non-food crops, including food crop wastes. Things such as agricultural residues, wood sawdust, and used oil are inedible products of non-food crops [9]. The third generation focuses on more experimental processes where the products are extracted from algae. However, it has not been carried out on a commercial scale.

The potential of biofuels depends on the demand for fossil fuels that are required in transport (gasoline, CNG, LPG, and diesel), in addition to the technological possibility of the engines when admitting mixtures with such fuels [10].

The European Union, in a political framework, established the cooperation of biofuels between countries in the 2009 Renewable Energy Directive (RED), which decrees those renewable fuels, including liquids, must be increased to 10% of the total used as transportation fuel by 2020, which requires fuel producers to gradually reduce environmental pollution [11].

In 2019, the global production of liquid biofuels had a raise of 5% to 161 billion liters, which is equivalent to 4 EJ [12]. This is due to the increase of investments in renewable energy over the years. The Table 1 below shows the leading countries in renewable energy production and capacity.

Table 1: Leading countries in renewable energy by production and capacity

	1	2	3	4
Hydroelectric capacity	Brazil	China	Lao <sup>1</sup>	Bhutan
Solar water heating capacity	China	Turkey	India	Brazil
Ethanol production	United States	Brazil	China	India
Biodiesel production	Indonesia	United States	Brazil	Germany

The leading producer is the United States, with a 41% share, despite the production drops in both ethanol and biodiesel. The producer with 26% was Brazil and, further back, Indonesia with 4.5% followed by China, 2.9%, and Germany, 2.8%. It is worth highlighting the participation of Brazil as the only country in South America that competes in the leadership of renewable energy investment.

Bioethanol is the most widely used liquid biofuel from corn, cane sugar, and other crops. Moreover, biodiesel is also commonly produced from vegetable oils and fats, including waste such as used cooking oil [13]. Both bioethanol and biodiesel form large groups of liquid biofuels nowadays.

By the end of 2019, at least 70 countries had conventional biofuel policies, while at least 9 countries already had some form of advanced biofuels or policy incentive programs before this year, and at least 24 countries had the goal of advancing biofuels, in addition to setting a collective objective of 70% renewable electricity by 2030 [10,14].

In Brazil, Sweden, and the United States, millions of vehicles on the road accept a blend of up to 85% of ethanol/gasoline [15]. Flexible fuel vehicles run on gasohol mixed with gasoline and anhydrous ethanol with E100 hydrated ethanol.

The use of biogas to generate electricity and heat increased at the end of 2019, some 132,000 biodigesters are in operation around the world [16]. In China, there are more than 100,000 units, followed by Europe, with around 18,000, and the United States, with 2,200 sites in all 50 states producing biogas [17].

The production of biofuels in South America is led by Brazil, Argentina, and Colombia, according to a study published by the Economic Commission for Latin America and the Caribbean (ECLAC) [5]. The Fig. 1 shows the biofuels available in each country from bioethanol, biodiesel, and biogas.



Fig 1: Biofuels in South America

In most of South America, there is a great acceptance of biofuels, although some countries are still exploring the subject, while others have been developing it for years, which is the case of Brazil, a country that developed technology, research, and internal policies to obtain an alternative liquid fuel, and it turned out to be the example for neighboring countries [18].

The regulations and decrees in recent years are important because the political, environmental, and social interest that are committed to the fight against climate change is observed. Table 2 shows the most important regulations in each country.

Table 2: Biofuel laws and regulations in South America

Country	Laws and Normatives
---------	---------------------

<sup>1</sup> Laos PDR, LAOS People's Democratic Republic.

Argentina	Resolution 554/10	Ratifies Addendum to the Biodiesel Supply Agreement for its mixture with fossil fuels in national territory.	Chile	Law 20.257	Introduces modified actions to the General Law of Electric Services regarding the generation of energy with non-conventional renewable energy sources.
	Biofuel Law 26,093	Approves project to obtain bioethanol from corn and sorghum in the country.		Law 5.238-08	Bill that creates the National Fund for Research and Development of Biofuels.
Bolivia	Law 3207	Biofuel Incentives, September 2005, which establishes a series of incentives for the incorporation of biodiesel in the country's production as an additive in the use of fuel in the national territory.	Ecuador	The Executive Decree 2332,	The Biofuels Consultative Council of the Presidency of the Republic creates, with this decree, the National Biofuels Council with the mission of: "defining and approving plans, programs and projects related to the production, management and commercialization of biofuels", according to Article 3, as well as the responsibility of: "establishing policies and preferential support mechanisms for the agricultural and agro-industrial sectors, especially small producers, and will regulate the price of the biofuel in question"
	Law 1098	Regulatory framework that allows the production, storage, transport, marketing and mixing of additives of vegetable origin, in order to gradually replace the import of additive inputs and diesel oil, safeguarding food and energy security with sovereignty.		December 2nd, 2004,	which was created.
Brazil	Law N° 737 de 1938	Imposed almost at the beginning of the 20th century, this law made the addition of alcohol to gasoline mandatory.	Paraguay	Law N° 2.748	Promotion of Biofuels, which declares its production, the raw materials for its manufacture, and its use throughout the national territory of national interest.
	Law N° 8.723 de 1993	The obligatory nature of the mixture of anhydrous alcohol and gasoline.		The Paraguayan Norm (La Norma Paraguaya) NP 16.018.05	It was prepared by the Technical Committee for Standardization (CTN) 16 - Fuels, formed by representatives of public institutions, private companies, consumer associations, and universities, in order to establish the requirements and test methods for pure Biodiesel (B100) that It is used in Diesel engines.
	Law 11.097 de 2005, que	Introduces biodiesel into the Brazilian energy matrix, reforms laws 9478 of 1997; 9847 of 1999 and 10636 of 2002.		Law N° 1.002, 2008	Law for the Promotion, Investment and Generation of Electricity with the Use of Renewable Energies.
	Law 11.116 de 2005	Establishes the special registry of producer or importer of biodiesel in the federal revenue secretariat of the finance ministry; modifies laws 10451 of 2002 and partially law 11,097 of 2005	Peru	Law N° 28054, August 7th, 2003	It establishes the general framework to promote the development of the biofuels market on the basis of free competition and free access to economic activity.
Colombia	Law 939 del 2004	Stimulates the production and commercialization of biofuels for use in diesel engines.			
	Decree 2629, f 2007	Expands the mandatory mix of biofuels to 10% as of 2010 and establishes that new vehicles must be capable of consuming a mix of at least 20%.			

Uruguay	Law 17.567, October 1st, 2002	Declares the national interest in the production throughout the country, of alternative, renewable fuels and replace them with petroleum derivatives, made with national material of animal or vegetable origin.
	Law 18.195, November 2007	The regulation of the production, commercialization and use of agro-fuels corresponding to the categories that are defined. Its main articles are: - Promotion of the production of agro-fuels with national raw materials. - incorporation goals
Venezuela	-	-

In the rest of the world, the development of biofuel markets is comparatively smaller, depending on political support and price trends, which generates a mixed perspective in different countries. Table 3 shows the world production of liquid biofuels for the years 2018 and 2019.

Table 3: World production of the main biofuels in recent years

Fuel	2018/ billion liters	2019/ billion liters
Bioethanol production (annual)	111	112
FAME Biodiesel Production (annual)	41	47
HVO Biodiesel Production (annual)	6	6,5

Bioethanol represented around 59% of biofuel production in terms of energy, FAME biodiesel 35%, and hydrotreated oils (HVO) / Hydroprocessed fatty acids (HEFA) 6%. Other biofuels included biomethane and a range of advanced biofuels [19].

A. Bioethanol production in South America

Biofuel production in Brazil, for example, arose almost from the automotive industry in the 19th century. Since the 1930s, bioethanol has become a common component of gasoline and since 1975 it has been blended with gasoline [19]. According to the ANP (2019), approximately 45% of the energy and 18% of the two fuels consumed in Brazil come from renewable energy sources. In 2018, Brazil produced approximately 33 million liters of bioethanol, used as the only fuel in Flex vehicles (hydrated) and mixed with gasoline (anhydrous) [20].

The constant variations in the oil market caused technological advances in the automotive sector during the 2000s, because of the Flex-fuel engines, which changed the dynamics of the market, the support of the state drove the growth of investment in the production of bioethanol. The latest policies to maintain the price of gasoline and the elevation of the anhydrous mixture of common gasoline from 25% to 27% in 2015 represent a relief for domestic markets, as the increase in gasoline will determine the consumption of biofuels. Brazil is expected to raise its ethanol production and consumption in the coming years, due to the RenovaBio program, which proposes the reduction of the intensity of emissions from the transportation sector [21].

Bioethanol in Colombia is the product of public policies for rural, environmental, and energy development that have been working in recent years, which contributes to the generation of new jobs and the diversification of the energy sources. Thanks to government policies and private sector investment worth 900 million dollars in 7 distilleries, Colombia is the third-largest bioethanol-producing country in Latin America after Brazil and Argentina [22]. Since 2005, the use of liquid biofuels has been implemented to reduce gasoline emissions with the mixture of 10% fuel alcohol and 90% gasoline of fossil origin in the south of the country (E10 oxygenated gasoline) [23–25].

Peru, for its part, produces ethanol from different types of honey through yeast fermentation, in addition to mixing gasoline to increase octane and reduce greenhouse gas emissions, Peru still does not extract ethanol from sugar cane. However, there is extensive experience in the production of pharmaceutical alcohol, rectified alcohol, rum, and huarapo. Currently, there are projects to serve the national (Petroperú) and international market (the United States and Japan) [26]. Some agro-industrial companies on the coast have been implemented to supply ethanol to the international market due to the demand for the product.

Argentina, in turn, obtains bioethanol through the biomass fermentation process, which can be mixed with naphtha in variable quantities in its pure state as an alternative or in the manufacture of methyl tert-butyl ether. Currently, the production is from molasses, a by-product of sugar, sugar cane juice with 72% and 28% of cereals, mainly corn [27]. In 2018, the installed capacity was 950 thousand tons per year, almost 64% was saved in greenhouse effect emissions, the highest concentration of bioethanol production plants is due to the northeast of Argentina [28].

In Paraguay, corn and sorghum are used as raw material for the production of bioethanol, both, for anhydrous alcohol (99.5 GL) and hydrated alcohol (96 GL).

Furthermore, as a by-product of the industrial process of crude corn oil and dry distillation, residues are obtained, and soluble substances are used as an animal feed base [29].

While Uruguay produces bioethanol from sweet sorghum, sugar beet, sugar cane, and from starches such as sorghum grain, corn, wheat, barley, cassava, the National Administration of Fuels, Alcohol and Portland (ANCAP), a Uruguayan public company in charge of the exploitation and management of the national alcohol and fuel monopoly, receives anhydrous ethanol from the ALUR SA production plant in Paysandú, a company responsible for the production of bioethanol, biodiesel, animal feed, energy, and sugar, in addition to being in charge of the distribution and mixes with gasoline in the percentages mandated by law [26,30].

In Ecuador, gasoline contains a derivative of sugar cane (ethanol) called, by the country, Ecopais mixed by Petroecuador, with a composition of 95% pre-mixed gasoline and 5% bioethanol. However, they intend to advance with the Inen-935 normative, which establishes gasoline for combustion engines [26,31].

Chile does not produce ethanol commercially yet. However, research centers and universities carry out various investigations to make the process viable. In addition, the lignocellulosic consortium BIOENERCEL S.A. seeks to take advantage of forest biomass to produce bioethanol [32,33].

Bolivia produces first-generation bioethanol from sugarcane bagasse to produce fuel with 60% ethanol, of which other types of alcohol can be obtained, in addition to sorghum with a minimal contribution [34]. In 2017, the ANH (National Hydrocarbons Agency), through the hydrocarbons ministry, approved Law 1098, where it commits to using a mixture of anhydrous ethanol and gasoline of 8 to 12% in 2020 [33].

#### B. Biodiesel production in South America

In Brazil, biodiesel production has increased by 11% in 2019, reaching 5,900 million liters [35]. It is the second biggest producer of biodiesel in the world, according to data from the ANP 2018 [36]. Industries in the country respond positively to the increase in mandatory blends, being that, in 2014, it was a 6% blend, and, in 2018, it reached 10%, increasing production by 56.4%. The Brazilian production of biodiesel happens mostly in the South and Center West regions of the country, and it is mainly constituted of multinational companies that act in various segments of the agro-industrial business, from production to marketing [37,38].

Biodiesel in Colombia is produced from vegetable oils of palm, sunflower, soybean, and rapeseed, among others, besides fats and tallow of animal origin. There are 12 companies that supply 67 palm nuclei located in the Central, Eastern, and Southwestern areas of the country [10]. In addition, Colombia is one of the first countries to export biodiesel. In June 2020, it exported 4 million liters to Germany from the Manuelita plant located in the department of Meta, complying with the biofuel quality standards of EN14214, which describes the requirements and test methods for DMARDs [26,39].

Peru takes a step forward in the production of biodiesel by obtaining an alliance with PETROPERU and the Amazon region of palm growers, where they commit to offering crude palm oil, according to their condition and the standards required for the production of B100, which will have the technological support of the Heaven Petroleum Operators (HPO) company, regarding the raw material production process and the production of low sulfur fuel [40].

According to the Foundation for the Promotion of Exports of Palm Oil and its Derivatives of National Origin (Fedepal), Ecuador produces biodiesel from palm oil and its derivatives, due to the surplus production of this vegetable. Ecuador's Decree 3103 establishes that diesel must be mixed with vegetable biofuels, from 5% to 10% [41].

Argentina's production is based exclusively in soybean cultivation as raw material with the transesterification method, a chemical process that combines oil with alcohol. Since 2007, it has emerged as a sector with better performance, strengthening the productive development of the country. In the following years, there was an increase in its production of Biodiesel, with 803,640 m<sup>3</sup> in 2015 and, in 2016, with 910,891 m<sup>3</sup>. Besides these years, a change in the reference values could be noted; for example, in 2017, it reached 1,105,107 m<sup>3</sup> and, in 2019, 2,147,270 m<sup>3</sup> were produced. However, in 2020, the production decreased to 1,120,759 m<sup>3</sup>, almost half of what was previously registered, is due to various factors, but mainly because of the tragedy of the COVID-19 virus.

Uruguay obtains biodiesel from soybean, rapeseed-canola, sunflower, turnip, camelina, brassica (also known as Ethiopian or white mustard), spurge or castor oils, with soybean and rapeseed-canola being the most used. The company in charge of manufacturing is ALUR S.A., which receives trucks from the Arena plant or by pipeline from the Capurro plant, both use conventional technology (homogeneous basic transesterification). The company is certified by the international body of the European

standard International Sustainability and Carbon Certification (ISCC) [19,20].

The biodiesel production in Chile is very low, according to the records by the Chilean College of Agronomists, which indicate that it does not exceed 150 thousand liters per month, its installed capacity for production is less than 3 million liters per year [42].

Bolivia is committed to the production of biodiesel from soybeans since 2019. In an agreement with private and public companies, a pilot plant of the Tropical Agricultural Research Center (CIAT) was installed to obtain biofuel from crude soybean oil, and they experiment with Cusi, macoror, pinion, and sunflower to generate technical information and knowledge about these processes [43,44].

### C. Biogas production in South America

The expansion of biogas in several countries for electricity generation includes places such as the continent of Africa, India, Latin America, and the Middle East [45] Mexico produces open biogas through poultry waste in the state of Jalisco. The first biogas plant in Brazil uses pig manure in addition to the waste from 18 large pens to run 240 kW motor generators [46].

One of the leading countries in biogas production is Brazil, which began with the oil crisis in 1979, but, as of 1982, the Energy Mobilization Program - PME was launched, which encourages the installation of biodigesters in rural areas. The federal RenovaBio program was instituted to be a National Biofuels policy as annual national decarbonization goals for the fuel sector, encouraging its manufacture, which resulted in future policies that support the generation of renewable energy with biogas and biomethane [17].

Colombia, in recent years, has developed small projects regarding the use of biogas through biodigesters. There are two plants that generate 3MW from biogas for their own consumption and, according to the data collected, Colombia has 62 small plans [47].

Argentina, however, has grown enormously in relation to its technological development, increasing the number of digester plants, improving the quality and diversity of raw materials, as well as the number of service providers. In 2020, the ministry of sustainable development promoted and bought biodigesters that will be installed in different institutions, such as agricultural technical schools. The project finances the incorporation of specialists in the field of energy and biogas [48].

Since the decree of incentives for renewable energies in Peru, the installation of biodigesters at the national level

has increased, but there is a lack of coordination to optimize their development.

Ecuador began to produce biogas from urban solid waste. This project is executed through the agreement of the Metropolitan Public Company for Comprehensive Solid Waste Management (EMGIRS EP) and the company GasGreen S.A., as a strategic alliance to benefit the environment [31,49].

Chile developed biogas projects at different scales for different energy uses. Until 2015, they generated a total of 43 MW that came from waste from dairy farms, landfills, and sewage sludge. There are also biogas projects led by the food and agricultural industry with the aim of generating electrical or thermal energy to replace fossil fuels [50].

In Bolivia, there are agreements with cooperation and organizations that promote research and development in biodigesters to alleviate extreme poverty in some parts of the country. Bolivia offers great energy potential due to its ecological diversity, considering that it is a developing country. Since these agreements started in 2007, 750 biodigesters were installed until 2012, sponsored by the Endev-Bolivia program, in a German technical cooperation. Bolivia shows a middle ground because many biodigester installation ventures are from entrepreneurs and environmental policies or international cooperation [31,51].

Paraguay has promising perspectives for the use of biogas, several studies make this energy sector viable [52]. On the other hand, Venezuela has not yet formalized the start of direct projects with biogas and neither has any incentive for the use of biomass and waste.

### III. METHODOLOGY

Fig. 2 shows the methodology followed by the article.

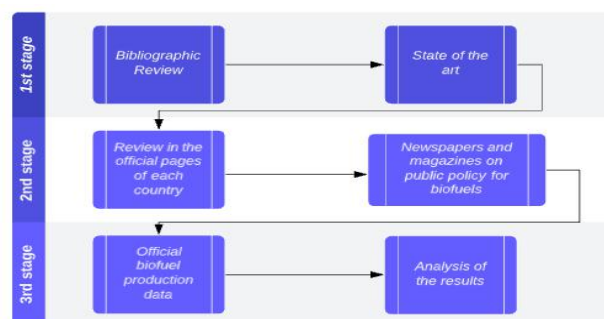


Fig. 2: Methodology used

The methodology used is divided into three stages: the bibliographic review, specific data review, and data evaluation and discussion. In the first stage, a bibliographic review on biofuels focused on the world and

South America is carried out, based on published articles and magazines, as well as the state-of-the-art technology. The second stage consists of the review of specific data in each South American country according to official pages, newspapers, and information found on the web. In the third stage, the data found is evaluated, conducting a discussion of the information found through online searches (Google Scholar).

#### IV. DISCUSSION

Many of the South American countries have implemented public policies for the development of liquid and gaseous biofuels, allowing agriculture in each region, which favors many countries, since the biodiversity in South America makes the development of biofuels from biomass possible.

Moreover, the promotion of new regulations for the use of clean energy helps the development of each country; consequently, many countries have had an increase in energy production, in addition to a larger number of jobs and a clear economic boost in each region. However, some countries, such as Chile and Venezuela are the last to start biofuel projects, regulations, and laws. These measures, despite not developing rapidly, already are an important step in the development of a new sustainable vision.

It should be noted that there are three predominant countries in the production of biofuels, which are Brazil, Argentina, and Colombia. These countries that have, year after year, increased their production in the three types of fuels already mentioned, and this is mostly due to the relationship of the government with investments in the private sector [53]. Brazil is the predominant country in this scenario of production and consumption of biofuels, as a result of its institutional base, solid policies, investment incentives, projects, research and their acceptance by the country, which contributes to overcoming challenges with the participation of biofuels [2]. Table 4 shows the most used fuels in South American countries, in addition to biofuels.

Argentina	Natural Gas Oil Coal Wood	Bioethanol Biodiesel Biogas Biomass
Bolivia	Natural Gas Diesel Gasoline	Bioethanol Bio- diesel Biomasa
Brazil	Natural Gas Petroleum Coal Uranium	Firewood and char- coal Bioethanol Bio- diesel Biogas Biomass
Colombia	Kerosene and jet Gasoline Gas Fuel Oil Charcoal Diesel	Bioethanol Biodiesel Biogas Biomass
Chile	Natural Gas Oil and Coal Derivatives	Bioethanol Biodiesel Biogas Biomass
Ecuador	Natural Gas Petroleum and Coal Derivatives	Bioethanol Biodiesel Biogas Biomass
Paraguay	Firewood Coal Diesel Gasoline	Bioethanol Biodiesel Biogas Biomass
Perú	Gas Natural Petróleo y Derivados Carbón	Bioethanol Biodiesel Biogas Biomass
Uruguay	Oil and Charcoal Deriva- tives	Bioethanol Biodiesel Biogas Biomass
Venezuela	Oil Natural Gas	-

Table 4: Fuels used by each country

Country	Fuels	Biofuels
---------	-------	----------

Ethanol in South America has shown an exponential growth in recent years, increasing its production significantly as well as its technology; in the case of Bolivia, Peru, Uruguay, and Ecuador, the most used raw material in most countries was sugarcane of sugar as first-generation bioethanol. Regarding Bioethanol, the other countries are on the path of growth, as is the situation in Uruguay, Bolivia, Paraguay, Peru, and Chile, which, in recent years, have opted to research the biofuel conversion processes, and investments with private companies to generate biodiesel plants [5,9].

Biogas is a little-explored topic in all of South America. However, Brazil takes the lead in terms of research and investment, and Colombia promoted this biofuel with the private sector. On the other hand, Argentina obtained the collaboration of the government in the purchase of equipment.

The other countries have not yet developed projects in relation to this biofuel, being that most of them were linked to international cooperation funds and executed from NGOs, and, therefore, were small projects. Despite being a new market, it already has a promising future regarding the ways that the agricultural sector can treat waste, solving an environmental problem, and generate energy. However, the main factor that determines the success of the projects is the social implementation strategy, for the rural area biogas can contribute considerably to the quality of life, as it is a fuel that can be used to generate electricity, heating, and cooking utensils. Most small or large-scale projects are based on low-cost Slug biodigesters [54].

Table 5 shows the production of biofuels in South America. This information can be found in official pages of each country, and some data is from important newspapers in the region.

Table 5: Biofuel production in South America

Country	Biofuels	Production	Unity
Argentina	Bioethanol (2019)	1.06	Million liters
	Biodiesel (2019)	2.14	Million tons
	Biogas		
Bolivia	Bioethanol (2018)	80	Million liters
	Biodiesel (2018)	3	Million tons
	Biogas	-	-
Brazil	Bioethanol (2019)	35,6	Billion liters
	Biodiesel (2019)	5,9	Billion liters
	Biogas		
Colombia	Bioethanol (2017)	366,75	Million liters
	Biodiesel (2018)	406.12	Thousand Tonnes
	Biogas	-	-
Chile	Bioethanol		
	Biodiesel		
	Biogas		
Ecuador	Bioethanol (2016)	113.5	Million liters
	Biodiesel	-	
	Biogas	-	
Paraguay	Bioethanol (2010)	121.86	Million liters

	Biodiesel (2010)	5.80	Million liters
	Biogas	-	
Peru	Bioethanol (2018)	182	Million liters
	Biodiesel (2018)	154	Million liters
	Biogas		
Uruguay	Bioethanol (2018)	1.79	Million liters
	Biodiesel	5.22	Million liters
	Biogas		
Venezuela	Bioethanol	-	-
	Biodiesel	-	-
	Biogas	-	-

Some data were not found, since many of the countries are venturing into the production of liquid biofuels, because they do not have an established registry. However, there are several data regarding the progress that each country has.

## V. CONCLUSIONS

The environmental repercussions have started a global race in search of new alternatives to maintain the ecological balance. Thus, biofuels appear as an alternative to fuels.

European countries undertook the development of new alternatives to replace fossil fuels, investing and promoting public policies with the exchange of technology, which helps to increase the production of bioethanol, biodiesel, and biogas.

Biofuels offer opportunities to meet the environmental, economic, and social challenges in South America. However, to get to this point, there are important steps that must be taken, considering the exchanges that governments must make.

Despite negative impacts or associated risks, there are more opportunities in rural development growth that governments can explore. Although biofuels are emerging in South America and some countries are in the full development and implementation phase, as the case of Chile and Venezuela, most of them already have industries and a consolidated legal framework for bioethanol and as is shown in Table 4, several countries have significant biofuel production capacity. It must be considered that government policies are key for industrial development and have played an important role in the development of South America, where there was the implementation of public policies on the requirement of mixing alcohol with gasoline ranging from 1 to 10% in several countries.

Furthermore, it is important to consider that energy needs must be followed, and the objectives should be cautious reasonable when regarding the development of the implementation. Most of the countries mix their common gasoline with bioethanol or biodiesel in a percentage of 1-10%, the impulse of the established regulations of each country generated a change in the use of biofuels. In this way of finding the best alternatives, Brazil far surpasses several countries as it has managed to use a B100 car powered exclusively by biofuel.

Boosting and promoting technology transfer and adaptation between countries is a good start for significant development for biofuels.

In the last 10 years, the countries in South America have begun to invest in technologies for their production. Additionally, one of the causes that these projects are carried out is thanks to the national government policies of each country, which fostered the agricultural sector and private companies to invest in new practices, facilitating a business that is not only beneficial for each region but also for the locality, generating employment and income.

#### ACKNOWLEDGEMENTS

The authors are grateful for the support and promotion of research by UNILA (n° 137/2018/PRPPG, n° 087/2019/PRPPG and n° 96/2020/PRPPG), CAPES-DS (n°88887.608662/2021-00), Federal University of Integration in Latin America – UNILA and CAPES-Araucaria Foundation.

#### REFERENCES

- [1] Ullate, P. M. (2016). Biocombustibles y su mercado internacional. Universidad nacional de Rosario Facultad de ciencias economicas y estadísticas.
- [2] Coviello, M. F., Gómez, J. J., Razo, C. & Rodríguez, A. (2008b). Biocombustibles líquidos para transporte en América Latina y el Caribe. Naciones Unidas: CEPAL, 187. [https://repositorio.cepal.org/bitstream/handle/11362/3638/S2008449\\_es.pdf?sequence=1&isAllowed=y%0Ahttp://www.cvt.org/files/Biocombustibles líquidos para transporte en América Latina y el Caribe.pdf](https://repositorio.cepal.org/bitstream/handle/11362/3638/S2008449_es.pdf?sequence=1&isAllowed=y%0Ahttp://www.cvt.org/files/Biocombustibles%20l%C3%ADquidos%20para%20transporte%20en%20Am%C3%A9rica%20Latina%20y%20el%20Caribe.pdf)
- [3] International Renewable Energy Agency. (2018). Renewable capacity statistics 2018 Statistiques de capacité renouvelable 2018 Estadísticas de capacidad renovable 2018. [www.irena.org](http://www.irena.org).
- [4] Coviello, M. F., Gómez, J. J., Razo, C. & Rodríguez, A. (2008b). Biocombustibles líquidos para transporte en América Latina y el Caribe. Naciones Unidas: CEPAL, 187. [https://repositorio.cepal.org/bitstream/handle/11362/3638/S2008449\\_es.pdf?sequence=1&isAllowed=y%0Ahttp://www.cvt.org/files/Biocombustibles líquidos para transporte en América Latina y el Caribe.pdf](https://repositorio.cepal.org/bitstream/handle/11362/3638/S2008449_es.pdf?sequence=1&isAllowed=y%0Ahttp://www.cvt.org/files/Biocombustibles%20l%C3%ADquidos%20para%20transporte%20en%20Am%C3%A9rica%20Latina%20y%20el%20Caribe.pdf)
- [5] Viana Leite, M. A. (2013). La Bioenergía en América Latina y El Caribe. El estado de arte en países seleccionados. In *La Bioenergía en América Latina y el Caribe*. <http://www.fao.org/3/a-as112s.pdf>
- [6] Nakamya, M. & Romstad, E. (2020). Ethanol for an agriculture-based developing economy: A computable general equilibrium assessment for Uganda. *Energy for Sustainable Development*, 59, 160–169. <https://doi.org/10.1016/j.esd.2020.10.003>
- [7] Dufey, A. (2006). Producción y comercio de biocombustibles y desarrollo sustentable: los grandes temas. In Instituto Internacional para el Medio Ambiente y Desarrollo, Londres. [https://books.google.com.br/books?hl=pt-BR&lr=&id=8q85\\_nrOh2gC&oi=fnd&pg=PA1&dq=biocombustibles+no+mundo&ots=f0RezEzw-a&sig=Dt9gYlxhs3iKIdCMWLWBNXN4Lvo#v=onepage&q=biocombustibles no mundo&f=false](https://books.google.com.br/books?hl=pt-BR&lr=&id=8q85_nrOh2gC&oi=fnd&pg=PA1&dq=biocombustibles+no+mundo&ots=f0RezEzw-a&sig=Dt9gYlxhs3iKIdCMWLWBNXN4Lvo#v=onepage&q=biocombustibles%20no%20mundo&f=false).
- [8] FAO. (2008). Efectos de los biocombustibles en el medio ambiente. *Biocombustibles: Perspectivas, Riesgos y Oportunidades*, 63–83.
- [9] Traxco. (2012). Biocombustibles 2G - Biocombustibles de segunda generación. In REDESMA (Issue 19). <https://www.sciencedirect.com/topics/engineering/second-generation-biofuels>.
- [10] OCDE/FAO. (2017). Situación del mercado de biocombustibles. OCDE-FAO Perspectivas Agrícolas 2017-2026. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016PC0767R%2801%29>.
- [11] The European Parliament and Council, Directive on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC (2009), pp. 16–62.
- [12] IEA. (2020). Global EV Outlook 2020 - Análisis - IEA. <https://www.iea.org/reports/global-ev-outlook-2020>
- [13] IEA. (2021). Renewables - Fuels & Technologies - IEA. <https://www.iea.org/fuels-and-technologies/renewables>
- [14] Volcovici, V. (2019). Latin America pledges 70% renewable energy, surpassing EU: Colombia minister. In Reuters. <https://www.reuters.com/article/us-climate-change-un-colombia/latin-america-pledges-70-renewable-energy-surpassing-eu-colombia-minister-idUSKBN1WA26Y>
- [15] IEA. (2020b). Petróleo 2020 - Análisis - IEA. <https://www.iea.org/reports/oil-2020>
- [16] Serna, F., Barrera, L. & Montiel, H. (2011). Impacto Social y Económico en el Uso de Biocombustibles. In *J. Technol. Manag. Innov. (Vol. 6, Issue 1)*. <http://www.jotmi.org>
- [17] Jain, S. (2019). Global Potential of Biogas. [https://www.worldbiogasassociation.org/wp-content/uploads/2019/09/WBA-globalreport-56ppa4\\_digital-Sept-2019.pdf](https://www.worldbiogasassociation.org/wp-content/uploads/2019/09/WBA-globalreport-56ppa4_digital-Sept-2019.pdf)
- [18] Europe, B. (2019). Informe estadístico 2019 – BioenergyEurope. <https://bioenergyeurope.org/article/101-statistical-report-2019.html>
- [19] Callejas, Edmar Salinas, V. G. Q. (2009). Los biocombustibles. *El Cotidiano*, 157, 75–82. <http://www.redalyc.org/articulo.oa?id=32512739009>

- [20] Ascher, Markus. Federico, Gandugluia. Orlando, V. (2010). Mapeo político institucional y análisis de la competencia entre producción de alimentos y bioenergía. [www.procitropicos.org.br](http://www.procitropicos.org.br)
- [21] Cardenas, S. M. (2019). Estudio de prefactibilidad para el coprocesamiento de aceite de Palma en la refinería de Cartagena. Univeridad Escuela de Administracion Maestria en Administración Medellín.
- [22] Prado Sampaio, M. D. A. (2012). El caso de la producción de etanol en Brasil: ¿un ejemplo para los países de América Latina? Cuadernos de Geografía: Revista Colombiana de Geografía, 21(1), 147–161. <https://doi.org/10.15446/rcdg.v21n1.30698>
- [23] OCDE/FAO. (2020). OCDE/ FAO Perspectivas Agrícolas 2020-2029. OECD. <https://doi.org/10.1787/a0848ac0-es>
- [24] Federación Nacional de Biocombustibles de Colombia. (2015). Federación Nacional de Biocombustibles de Colombia. In Indicadores (Vol. 34, pp. 38–40). <http://www.fedebiocombustibles.com/nota-web-id-2138.htm>
- [25] Arévalo, L. P. Q. M. Y. M. C. J. A. V. M. A. & Suarez, R. Y. A. M. N. A. U. (2015). Evaluación de residuos de papa, yuca y naranja para la producción de etanol en cultivo discontinuo utilizando Saccharomyces cerevisiae. Revista ION, 28(1), 43–53. <https://www.redalyc.org/pdf/3420/342039270005.pdf>
- [26] Gómez, J. M. (2016). Analysis of the variation in the efficiency in the production of biofuels in Latin America. Estudios Gerenciales, 32(139), 120–126. <https://doi.org/10.1016/j.estger.2016.01.001>
- [27] Midagri. (2015). Etanol. <https://www.midagri.gob.pe/portal/objetivos/29-sector-agrario/azucar/249-etanol>
- [28] MINAGRI. (2019). Etanol. <http://minagri.gob.pe/portal/29-sector-agrario/azucar/249-etanol?start=1>
- [29] Inpasa. (2017). Etanol. <https://www.inpasa.com.py/es/productos/etanol>
- [30] ALUR. (2010). ALUR - Misión y Visión. <http://www.alur.com.uy/empresa/que-es-ALUR.php>
- [31] Marti, J. (2019). Experiencias Latino Americanas en la implementación de estrategias para democratizar los biodigestores entre los pequeños y medianos productores agropecuarios. Climate Technology Centre and Network (CTCN)-UNFCCC. Ecuador, 36. [https://www.ctcn.org/system/files/dossier/3b/del\\_1.2\\_biodigestores\\_latinoamerica.pdf](https://www.ctcn.org/system/files/dossier/3b/del_1.2_biodigestores_latinoamerica.pdf)
- [32] ANCAP. (2015). Etanol. <https://www.ancap.com.uy/1591/1/etanol.html>
- [33] Manuel Paneque Celián Román-Figueroa Rodrigo Vázquez-Panizza José Miguel Arriaza Darío Morales Marcela Zulantay, A. & Paneque, M. (2011). Bioenergía en Chile Editado por
- [34] Pacheco, M. (2019). El Gobierno propone incluir más bioetanol en las gasolinas del país | El Comercio. <https://www.elcomercio.com/actualidad/petroleo-bioetanol-gasolinas-derivados-negocios.html>
- [35] DEBER, E. (2018). Bolivia producirá etanol desde mayo y ven ahorro de Bs 400 millones | EL DEBER. [https://eldeber.com.bo/economia/bolivia-producira-etanol-desde-mayo-y-ven-ahorro-de-bs-400-millones\\_107296](https://eldeber.com.bo/economia/bolivia-producira-etanol-desde-mayo-y-ven-ahorro-de-bs-400-millones_107296)
- [36] BnAmericas. (2020). Bolivia incrementará al 12% el porcentaje de mezcla de etanol anhidro en la gasolina - BnAmericas. <https://www.bnamericas.com/es/noticias/bolivia-incrementara-al-12-el-porcentaje-de-mezcla-de-etanol-anhidro-en-la-gasolina>
- [37] Ministério do Meio Ambiente - MMA. (2020). Plano de Dados Abertos: 2021/2022. 28.
- [38] Fallis, A. . (2005). Perspectivas De Los Biocombustibles En La Argentina Y En Brasil. <http://www.inmetro.gov.br/barreirastecnicas/exigenciastecnicas/documentos/arg/biocombustibles.pdf>
- [39] Berry, S. T., Kersley, L., Moen, J. & Denig, W. F. (2013). Creating the Clean Energy Economy. In Annales Geophysicae (Vol. 18, Issue 1). [www.iedconline.org](http://www.iedconline.org)
- [40] PetroPerú. (2020). PetroPerú promueve compra de materia prima nacional para producción de biodiésel. <https://www.petroperu.com.pe/petroperu-promueve-compra-de-materia-prima-nacional-para-produccion-de-biodiesel>
- [41] Lombeyda Miño, B. (2020). Bioeconomía: una alternativa para la conservación. Letras Verdes. Revista Latinoamericana de Estudios Socioambientales, 27(27), 13–30. <https://doi.org/10.17141/letrasverdes.27.2020.3984>
- [42] Ingenieros agronomos. (2019). El Biodiesel en Chile. Patricio Cavieres - Colegio de Ingenieros Agronomos de Chile. <https://ingenierosagronomos.cl/el-biodiesel-en-chile-patricio-cavieres/>
- [43] Revistalideres. (2014). La Fabril llena más tanques con biodiésel | Revista Líderes. <https://www.revistalideres.ec/lideres/fabril-llena-tanques-biodiesel.html>
- [44] Ganaderia, M. de agricultura y pesca. (2019). Bioetanol. [https://www.magyp.gob.ar/sitio/areas/observatorio\\_bioeconomia/indicadores/07/index.php](https://www.magyp.gob.ar/sitio/areas/observatorio_bioeconomia/indicadores/07/index.php)
- [45] Bionergy, I. (2019a). Alemania invierte 5 millones de euros en proyecto de biogás de Ghana | Revista Bioenergy Insight. <https://www.bioenergy-news.com/news/germany-invests-e5-million-in-ghanaian-biogas-project/>
- [46] ASAGA. (2019). ASAGA - Biodiesel en Bolivia. <https://www.asaga.org.ar/index.php/es/noticias/16-noticias/internacionales/295-biodiesel-en-bolivia>
- [47] Bionergy, I. (2019b). Biotech firm opens poultry waste-to-biogas facility in Mexico | Bioenergy Insight Magazine. <https://www.bioenergy-news.com/news/biotech-firm-opens-poultry-waste-to-biogas-facility-in-mexico/>
- [48] Ministério do Meio Ambiente - MMA. (2020). Plano de Dados Abertos: 2021/2022. 28.
- [49] EMGIRS. (2017). Quito genera energía eléctrica con el Biogás de su Basura. <https://www.emgirs.gob.ec/index.php/zentools-2/objetivos-estrategicos/45-travels-3/265-quito-genera-energia-electrica-con-el-biogas-de-su-basura>
- [50] Perez, F. (2015). Biogas Chile: Energía renovable no convencional al alcance de la mano. Revista ElectroIndustria. <http://www.emb.cl/electroindustria/articulo.mvc?xid=2587&>

ni=biogas-en-chile-energia-renovable-no-convencional-al-alcance-de-la-mano

- [51] Herrero, J. M. (2013). Bolivia. Los biodigestores para reducir la pobreza energética e incrementar la producción agropecuaria sustentable. [www.cimne.com](http://www.cimne.com)
- [52] Organización de las Naciones Unidas para la Agricultura y la Alimentación. (2012). El biogás, atractiva fuente de energía renovable para el desarrollo de los pequeños productores agropecuarios en América Latina y el Caribe | FAO. <http://www.fao.org/americas/noticias/ver/es/c/229860/>
- [53] Cepero, L., Savran, V., Blanco, D., Piñón, M. R. D., Suarez, J. & Palacios, A. (2012). Producción de biogás y bioabonos a partir de efluentes de biodigestores Production of biogas and biofertilizers from biodigester effluents. *Pastos y Forrajes*, 35(2), 219–226. [http://scielo.sld.cu/scielo.php?script=sci\\_arttext&pid=S0864-03942012000200009](http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942012000200009)
- [54] Iroaltidis Mota, K., Brito, L., Rodrigues, O., Nívio Batistasantana, ;, Sampaio, G. & Segundo, A. (2017). Produção de biocompostos a partir da biomassa prospecção de patentes no Brasil. *Revista Geintec*, 7(4), 4089–4099. <https://doi.org/10.7198/geintec.v7.i4.817>