International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Review Article)

Bioenergy: Paradoxes and dilemmas of a promising energy alternative

Olga Lucía Castillo Ospina *

Colectivo Futuro Presente, Civil Society Organization, Colombia.

International Journal of Science and Research Archive, 2024, 12(01), 2845–2856

Publication history: Received on 11 May 2024; revised on 18 June 2024; accepted on 21 June 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.12.1.1131

Abstract

The energy production that still moves the world comes in the vast majority from fossil sources. However, according to renewable energy main institutions reports, the sources from which this renewable energy is being generated are hydropower with the highest percentage by far, 41.2%, followed by solar 31.2%, wind 26.4%, bioenergy 4.5%, geothermal 0.4%, and tidal with a minimum percentage of 0.02 %. Therefore, bioenergy is located as another of the promising renewable energies, but still with a very low percentage.

As biomass is the main source of bioenergy, it is the renewable energy source with the greatest variety of inputs, for example, biogas from landfill or thermal processes, solid biofuels from wood, municipal waste, and crops or animal waste, and liquid biofuels from conventional and advanced bio gasoline and biodiesel, among others.

The purpose of this paper is to explore and analyze the uses of biomass in some Latin American countries, offering a general reflection on this region, and to expand on the various faces of energy injustice suffered by a series of communities, and also the advances that the bioenergy sources could offer; therefore, the structure of this chapter is as follows: first, some general information and facts related to one of its inputs -the steadily growing problem of human waste production- are exposed. Then, a brief description of bioenergy advances in some Latin America countries is offered, to close with the identification of some challenges to be addressed within the domain of bioenergy and with some conclusions.

Keywords: Bioenergy; Waste; Energy justice; Bioenergy in Latin America

1. Introduction

The energy production that still moves the world comes in the vast majority from fossil sources, since coal (35.4%), natural gas (22.7%), nuclear energy (9.5%), other minor fossil sources (0.9%) and hydropower (14.9%), which totals 83.1% versus just 14.4% of renewable energies, produced a total of 29,165.2 TW/hour of electricity in 2022 [1].

Some environmental arguments still do not allow hydropower to be placed indisputably among renewable energies. "There are several types of hydroelectric facilities, but all are powered by the kinetic energy of flowing water as it moves downstream. Turbines and generators capture and convert that energy into electricity, which is then fed into the electrical grid. The water itself is not reduced or used up in the process, and because it is an endless, constantly recharging system, hydropower is defined as a renewable energy by the Environmental Protection Agency. But it's not considered renewable by everyone. It comes with some 'pretty significant environmental baggage', says John Seebach, senior director of federal river management with the conservation group American Rivers. 'The reluctance to call hydropower a renewable energy is based on the impact of dams on fisheries and water flows.' Several large dams block migrating fish from reaching their spawning grounds. Dam reservoirs impact flows, temperatures and silt loads of rivers and streams. Over the years, these factors have drastically reduced fish populations" (Cournoyer, 2013: 1)].

* Corresponding author: Olga Lucía Castillo Ospina

But, if even knowing the objections about it, we include it in the calculations as the International Renewable Energy Agency (IRENA) does, we have that the installed capacity of renewable energies, that is, the maximum net generation capacity, reached a global total of 3,381,758 MW at the end of 2022, that is, 291,774 MW more than in 2021. Of this total, Asia has practically half, 48%, Europe 21%, North America 14%, South America 8%, Eurasia 4 %, Central America and the Caribbean 2%, Africa 2%, Oceania 2%, and the Middle East 1% (own calculations based on IRENA, 2023 - Mexico was placing in Central America).

In addition to the objections already mentioned about hydropower, it is important to remember that the data that IRENA offers differentiates between hydropower that is produced in mixed plants, that is, those in which the production process requires the consumption of fossil energy and those in which it does not, which adds one more argument against considering all hydropower production as renewable energy.]. And the sources from which this renewable energy was generated are hydropower with the highest percentage by far, 41.2%, followed by solar 31.2%, wind 26.4%, bioenergy 4.5%, geothermal 0.4%, and tidal with a minimum percentage of 0.02 % [2]. Whether or not hydropower is included as renewable energy, bioenergy is located as another of the promising renewable energies, but still with a very low percentage.

As biomass is the main source of bioenergy, it is the renewable energy source with the greatest variety of inputs, for example, biogas from landfill or thermal processes, solid biofuels from wood, municipal waste, and crops or animal waste, and liquid biofuels from conventional and advanced bio gasoline and biodiesel, among others.

Since the purpose of this chapter is to explore and analyze the uses of biomass in some Latin American countries, offering a general reflection on this region, and to expand on the various faces of energy injustice suffered by a series of communities, but also the advances that the bioenergy sources could offer, this structure of this chapter is as follows: first, some general information and facts related to one of its inputs -the steadily growing problem of human waste production- are exposed. Then, a brief description of bioenergy advances in some Latin America countries is offered, to close with the identification of some challenges to be addressed within the domain of bioenergy and with some conclusions.

2. Materials and Methods

2.1. Biomass and Bioenergy

Bioenergy refers to the use of biomass to generate thermal and electrical energy specifically; biomass, its input, unlike all the renewable energy sources mentioned so far, has a series of characteristics that substantially differentiate it from the others. For example, unlike water, sun, and wind, which are the main input that nature directly offers for water, solar and wind energy respectively, bioenergy has among its main inputs not one, but a great variety of elements. which, in addition, are mostly produced and/or transformed by humans; according to the type of biomass, its main categories are: forest biomass (e.g. forests, and wood residues and waste), agricultural biomass (e.g. energy crops, and agricultural residues and waste), livestock biomass (e.g. animal waste), industrial biomass, (liquid biofuel scraps and waste, and organic scraps and waste) and domestic waste (organic scraps and waste, wood, paper, agricultural, livestock, edible fats and oils and human waste, among others).

Depending on its use, direct or indirect, bioenergy can be classified into: traditional bioenergy that comes directly from wood biomass (such as firewood or charcoal) and manure; biofuels from energy crops, such as some food crops (e.g. wheat, sugar cane, corn and oil palm) and non-food crops such as Jatropha, used mainly for means of transportation; and bioenergy that comes indirectly from by-products and organic waste and from agricultural and forestry waste (e.g. stubble and sawdust).

Biomass is also part of the set of renewable energies because the amount of CO2 released into the air during the combustion process of wood and all inputs of plant origin is equivalent to that absorbed by the plant during its growth. Hence, bioenergy is the largest source of renewable energy globally, although despite its enormous potential it currently represents a very low percentage in both installed capacity (4.5% of the global total in 2022), as well as in electricity production (7.8% of the global total in 2021) in most regions of the world. In terms of geographic regions, the distribution of bioenergy infrastructure and production at a global level is currently quite unequal (Table 1):

Among the factors that have contributed to its low development is the enormous difficulty of obtaining timely and complete statistical data, both at the national and local level, due to the high levels of informality of many of its processes, which in turn makes it difficult to create of public awareness around the problem of waste and garbage, among several others associated with it [3].

Table 1 Bioenergy: Installed Capacity and Electricity Production (Regions of the world 2022 and 2021 - % of the global total)

World Regions	Installed capacity (MW) %, 2022	Electricity production (GWh) %, 2021
Africa	1	1
Asia	43	38
Eurasia	2	1
Europe	28	35
North America	10	11
Oceania	1	1
Middle East	0,1	0,1
Central America & Caribbean	2	2
South America	14	12

Source: own calculations based on IRENA, 2023

However, there are reasons to have greater expectations that bioenergy will supply large amounts of CO2 neutral energy for the future: "i) the use of low carbon intensity fuels for planes, ships, and other forms of transportation; ii) replacing natural gas in dedicated applications with renewable biomethane to provide heating and electricity; and iii) by offering clean cooking solutions to 2.6 billion people who, as of 2021, still lacked them" (IEA, 2023a: 18).

3. Results and Discussion

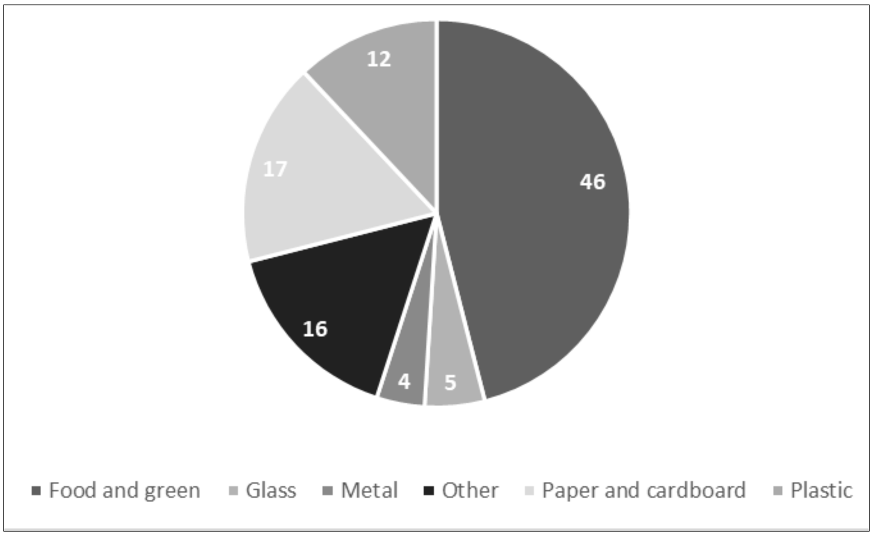
Given that one of the inputs to bioenergy is the garbage we produce, it is important to remember that the world generates 2.01 billion tons of municipal solid waste annually; to have a better idea of this amount, if all this waste was put on trucks, they would go around the world 24 times, and these calculations do not count waste that is not managed by municipalities.

This stunning amount of waste is partly because 99% of the stuff we buy is trashed within 6 months [4]. Worldwide, waste generated per person per day averages 0.74 kilogram but ranges widely from 0.11 to 4.54 kilograms [5]; for example, the United States are the largest producers of garbage per capita, producing approximately 12% of global garbage, although its inhabitants are only the 4% of the world's population; the largest amount of such garbage comes from household and business waste [6].

The regions with the highest waste growth are sub-Saharan Africa, North Africa, South Asia, and the Middle East, where more than 50% of waste is dumped; although Latin America is not yet one of the major producers, we produce 541 tons of garbage daily, that is, on average, each inhabitant produces 1.04 kilos of garbage per day.

In addition to the quantity, the variety of garbage we produce is such that there is no consensus around the types of garbage that exist; in fact, today a list of 47 different types of garbage is offered, several of them with subcategories. However, to facilitate the design of policies for its management, as well as the daily separation of waste by people, various institutions have created systems that group garbage into large categories, one of the best known being the one that separates electronic, glass, metal, paper, plastic, and organic waste [7].

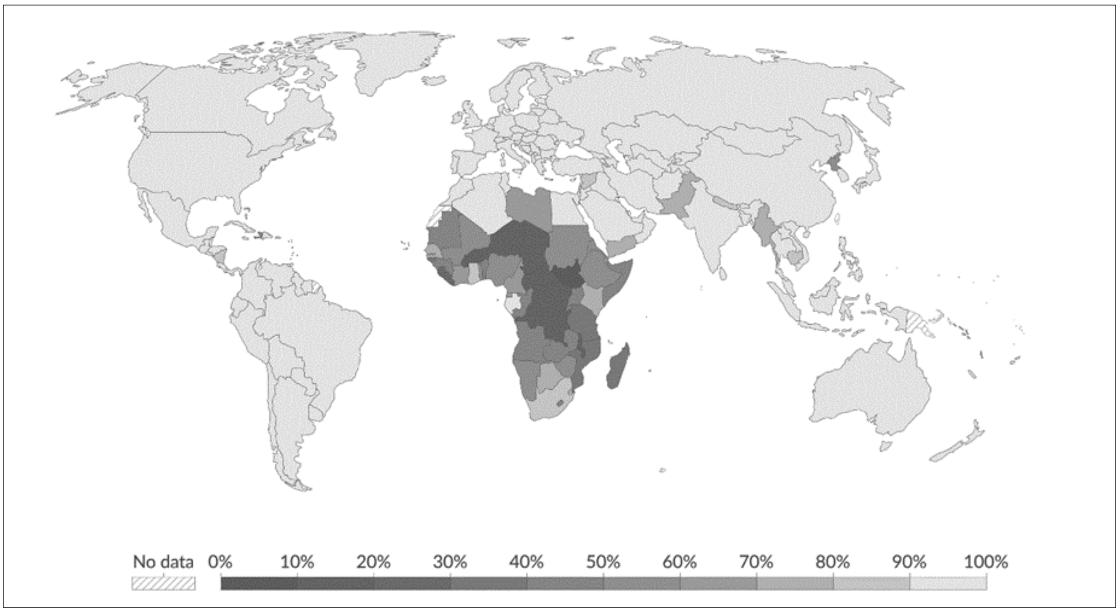
And this is one of the faces of socio-economic injustice, since it is still terribly paradoxical that almost half of the garbage produced globally is organic waste, in which fruits and vegetables are the most prevalent items, since currently 10% of the global population lacks enough food to meet daily nutritional requirements [8]. In Latin America this percentage is higher, because of the 541 tons produced daily, 145 end up in open-air landfills, 11% being plastic, recycling on average only 10%, while a huge 50% is organic waste, especially food [9].



Source: Based on calculations of Kaza et al., 2018

Figure 1 Waste types produced globally (2018)

Another paradox, this time in the field of energy injustice, is that Africa, the continent with the Sub-Saharan region, which is the most vulnerable in terms of multidimensional poverty in the world today, occupies first place in food waste, with 153 kilograms per person/year; they are followed by North America with 135 kilograms, Oceania 127 kilograms, Latin America and the Caribbean 116 kilograms, Asia 114 kilograms and Europe 103 kilograms [10]. In the case of Africa, one of the determining factors is precisely the lack of access to electrical energy or constant electrical energy, which would allow access to drinking water to clean foodstuffs, the use of clean cooking mechanisms to process them, as well as the use of refrigerators or refrigerators to preserve them. The data in the following map are revealing evidence (Fig. 2).



Source: [10]

Figure 2 Global access to electricity (2020 - %)

While the United States is also the country that throws away the most food per capita in the world (139 kilograms per person/year in 2019), Mexico is the country that wastes the most food in Latin America with a very close figure of 137 kilograms. They are followed by Nicaragua (123 kilograms), and which again responds to the paradox of being the country that occupies second place of extreme poverty in Latin America, after Guatemala [11]; although Brazil is the country that wastes the least organic waste per capita, it still throws away 103 kilograms per person/year, while ranking seventh among the most populated countries in the world [12].

The humanitarian tragedy of informal waste prickers in garbage landfills is another face of the existing socio-economic injustice; they generally live there or go there every day looking for food for themselves and their families, for their animals and pets, and for materials that can be reused in any way. It is very difficult to collect reliable data about them, precisely due to the level of informality of their living and working conditions. However, Colombia is the Latin American country that stands out in this sense, since by constitutional mandate in 2012 the first census was carried out in the country's capital, Bogotá, in warehouses or recycling collection centers. Although it is known that there is still an underestimation of the figures, in 2012, 13,984 waste pickers were registered (69% men and 31% women), and the annual registration of new recyclers showed 25,163 in 2022 [13]; Brazil also has some progress in this regard [14].

The vast quantities of organic waste constitute one of the largest environmental pollutants, due to the generation of leachates, odors, the proliferation of insects and the emission of greenhouse gases, mainly methane, contributing greatly to the global warming. And although organic waste is the largest percentage of the total garbage produced, it is the one with the fewest adequate management mechanisms.

An additional dilemma in the use of waste and scraps is the fact that, although it is imperative that human societies reduce the vast quantities already mentioned, at the same time we must improve technology to be able to use it in larger quantities and more efficiently to produce renewable energy. This means that we must reach a balance point, but it is currently unknown what that could be. However, one estimate states that "Up to 50% of bioenergy demand in 2050 could be met by biomass residues" (IEA, 2023a: 68). An example of this situation is the initially Norwegian business known colloquially as "trash to cash"; because its inhabitants do not produce enough waste and garbage for the installed bioenergy production capacity of this country, they import garbage from other countries and without revealing detailed information it is stated that profits increase because "As a rule we generate about 50% of our income from the fee we receive to take the waste and about 50% from the sale of the energy we create" [15].

Another ethical and environmental paradox of a global nature is derived from this market: "As developed countries couldn't handle their high waste production rate, they sold it to poorer countries as a means for them to improve their economies. These emerging countries are the ones that [supposedly] will sort, treat, dispose, and recycle the waste accordingly (…) EU countries' exported waste increased to 33 million tons in 2021; that is an increase of 74% since 2004. Also, the import of waste from countries outside of the EU countries by EU countries increased by 11%. The 27 member states of the European Union export waste to over ten countries" [16]. For now, none of these ten countries are in Latin America.

Another balance that is difficult to achieve is present to the extent that the production of bioenergy based on agriculture and plant material is, simultaneously, a consumer and supplier, not only of energy, but of Greenhouse Gases; although the release of CO2 resulting from the combustion of plant material is compensated by what the plant absorbed during its growth, other energy-consuming factors intervene, for example: the crop in question, who grows it, fertilizers and other inputs, agricultural machinery and the fossil fuels to operate it, among several others. The use of these inputs is even greater if it is industrialized agriculture and this relationship becomes even more complex, since agriculture is in turn one of the sectors that suffers the greatest impacts due to global warming.

3.1. Bioenergy in Latin America

In terms of access to electrical energy, Argentina, Chile, Costa Rica, Cuba, Ecuador, Mexico, Paraguay and Uruguay are the Latin American countries that in 2021 declared having 100% coverage. Nicaragua is the country in the region with the largest number of inhabitants without access, 13.7%, and it is also the country with the largest amount of population without access to this service in rural areas (Table 2), which, without a doubt and as in Africa, affects their food waste.

To the extent that people do not have access to electrical energy, the intensive, direct and polluting use, for human and planetary health, of certain types of biomass (such as firewood, treated wood waste, manure and garbage, including plastic, among others), becomes inevitable to cover their basic needs for heating and cooking food. Hence the relationship between the direct use of biomass and poverty is undeniable, because not having access to energy is undoubtedly a fundamental obstacle to overcoming the state of poverty, generating the vicious circle of remaining below the poverty lines because they cannot access electric energy service and since they cannot access electric energy, they remain below the poverty lines.

But another paradox is present, this time with a hopeful side, which is part of the dynamics of bioenergy: as bioenergy offers the possibility of obtaining biofuels and these come from what are now called 'energy crops', a series of rural communities, currently without access to energy, are participating as producers of sustainable bioenergy, breaking the aforementioned vicious circle. Among the energy crops are sugar cane, beets, corn, and herbaceous energy plants; some inputs to produce biofuels are wood, charcoal, agricultural waste and derived products, forest residues and manure, among others. It is a paradox, because it is also necessary to find a balance point, which for now is not known where it is, so that these crops do not have negative impacts on water use, land pollution and do not contribute to the displacement of crops of human and animal foods, among other valid criticisms.

Table 2 Lack of access to electricity in Latin American countries (2021 - %)

Rank	Countries	National (%)	Rank	Countries	Rural (%)
1	Nicaragua	13.7	1	Nicaragua	33.7
2	Honduras	5.9	2	Peru	16.4
3	Panama	4.7	3	Panama	14.4*
4	Peru	4.4	4	Honduras	14.3
5	Guatemala	2.1	5	El Salvador	5.9
6	El Salvador	2.1	6	Dominican Rep.	5.2
7	Dominican Rep.	1.9	7	Bolivia	4.9
8	Bolivia	1.4	8	Brazil	2.7
9	Brazil	0.5	9	Guatemala	1.9
10	Venezuela, RB	0.012	10	Venezuela, RB	0.1
11	Colombia	0.001	11	Colombia	0.005

Source: Own calculations based on World Bank, 2023b & ; (*) 2020 Data

Turning to its own production of primary energy per capita, Venezuela ranked first in 2021 with 82.7TJ, followed by Colombia with 79.7TJ and Argentina with 69.6TJ. When calculating the per capita production of only fossil fuels, for the same year, these three countries maintained their places, while their own production of renewable energies placed Paraguay, Uruguay and Brazil in the first three positions respectively (Table 3).

In this table it can also be observed that consistent with the fact that Nicaragua, Honduras and Panama are the countries with the lowest electricity coverage in the region in 2021, they are also the countries with the lowest production of primary energy and fossil energy. On the other hand, only six countries have exceeded both the primary energy production per capita of the region's total (54.3 TJ), the production of fossil energy (39.1 TJ) and the production of renewable energy (15.2 TJ), which shows important future challenges.

Some contrasts stand out, such as that of Paraguay, which, although ranked first as a producer of renewable energy in Latin America in 2021, is the only one in the region that only produced hydropower and bioenergy; all the others, however, also produced energy from solar, wind and/or other renewable sources. Guatemala and Nicaragua also stand out because, as already said, although they occupy the first places with extreme poverty in Latin America, they also occupy position 4 and 8 respectively in renewable energy production per capita; in this regard it is important to remind that accessing the production and consumption of renewable energies implies not only political and citizen will, but also important financial and technological investments, among other factors.

The analysis of bioenergy production data in Latin America shows that Brazil is by far the largest producer of energy from biomass and waste, as it produced 63.3% of all production in Latin America in 2021 (Table 4) and in fact it is among the five countries in the world with the highest production of renewable energy [20].

This table also shows that when the calculation is made per capita, Uruguay, Guatemala and Paraguay occupy the first three positions and precede Brazil, producing 27.9%, 23.6%, 19.6 and 18.1% respectively, of the total Latin American bioenergy production. Table 4 also offers the percentage that corresponds to the bioenergy production of each country, over the total of other renewable energies; Cuba is surprising due to the high concentration of its renewable energies in the use of biomass and garbage and, in addition to Guatemala, the first places are also occupied by countries not mentioned until now such as Bolivia and the Dominican Republic.

Table 3 Total primary, fossil and renewable energy production per capita in Latin American countries (2021 – TJ) *

	Countries	Primary production per cápita		Countries	Fossil production per cápita		Countries	Renewable prod. per cápita
1	Venezuela RB	87.2	1	Venezuela RB	78.4	1	Paraguay	41.4
2	Colombia	79.7	2	Colombia	71.1	2	Uruguay	39.2
3	Argentina	69.5	3	Argentina	62.6	3	Brazil	25.9
4	Ecuador	65.8	4	Ecuador	59.4	4	Guatemala	25.4
5	Brazil	61.4	5	Bolivia PNS	56.2	5	Chile	24.8
6	Bolivia PNS	61.2	6	Mexico	45.2	6	Costa Rica	21.2
7	Mexico	50.8	7	Brazil	35.5	7	El Salvador	13.8
8	Paraguay	41.4	8	Peru	20.3	8	Nicaragua	13.8
9	Uruguay	39.2	9	Cuba	11.0	9	Honduras	11.1
10	Peru	28.1	10	Chile	3.0	10	Panama	10.8
11	Chile	27.9	11	Guatemala	0.9	11	Venezuela RB	8.8
12	Guatemala	26.3	12	Paraguay	0.0	12	Colombia	8.6
13	Costa Rica	21.2	13	Uruguay	0.0	13	Peru	7.8
14	Cuba	16.0	14	Costa Rica	0.0	14	Argentina	6.9
15	El Salvador	13.8	15	El Salvador	0.0	15	Ecuador	6.4
16	Nicaragua	13.8	16	Nicaragua	0.0	16	Mexico	5.7
17	Honduras	11.1	17	Honduras	0.0	17	Cuba	5.0
18	Panama	10.8	18	Panama	0.0	18	Bolivia PNS	5.0
19	Dominican Rep.	4.7	19	Dominican Rep.	0.0	19	Dominican Rep.	4.7
	Total LATAM	54.3		Total LATAM	39.1		Total LATAM	15.2

Source: Own calculations based on IEA, 2023b; (*) Primary energy is understood to be energy sources in their natural state, that is, they have not undergone any type of physical or chemical transformation through human intervention. Among them are fossil sources (oil and coal), and renewable sources (hydraulic, nuclear, wind, solar, geothermal, tidal, and as part of bioenergy, firewood and other vegetable fuels).

Table 4 Bioenergy production over the total of Latin America, per capita and over the total of other renewable energy sources. (2021 – TJ)

	Countries	Bioenergy Prod/Renew LATAM (%)		Countries	Bioenergy Prod. per cápita (TJ)		Countries	Bioenergy Prod/Other Renew (%)
1	Brazil	63.3	1	Uruguay	27.9	1	Cuba	97.6
2	Guatemala	6.6	2	Guatemala	23.6	2	Guatemala	92.7
3	Mexico	5.9	3	Paraguay	19.6	3	Bolivia	77.8
4	Chile	5.4	4	Brazil	18.1	4	Dominican Rep.	75.4
5	Colombia	3.6	5	Chile	17.1	5	Uruguay	71.2
6	Argentina	3.1	6	Nicaragua	9.3	6	Honduras	71.1

7	Peru	2.2	7	Honduras	7.9	7	Brazil	70.0
8	Paraguay	2.1	8	Cuba	4.9	8	Chile	68.8
9	Uruguay	1.6	9	Colombia	4.3	9	Nicaragua	67.2
10	Honduras	1.3	10	Argentina	4.2	10	Argentina	60.6
11	Nicaragua	1.0	11	Peru	4.1	11	Peru	52.3
12	Cuba	0.9	12	Bolivia	3.9	12	Mexico	50.2
13	Bolivia	0.8	13	Costa Rica	3.7	13	Colombia	50.1
14	Dominican Rep.	0.6	14	Dominican Rep.	3.5	14	Paraguay	47.4
15	Ecuador	0.3	15	El Salvador	3.3	15	Panama	27.3
16	El Salvador	0.3	16	Panama	2.9	16	El Salvador	23.8
17	Costa Rica	0.3	17	Mexico	2.8	17	Ecuador	18.6
18	Panama	0.2	18	Ecuador	1.2	18	Costa Rica	17.4
19	Venezuela RB	0.2	19	Venezuela RB	0.4	19	Venezuela RB	4.9
	Total LATAM	100.0		Total LATAM	9.7		Total LATAM	63.8

Source: Own calculations based on [19]

3.2. Some advances in bioenergy in Latin America

Brazil produced 63% of the total bioenergy production in Latin America in 2021 (Table 4), thanks to the fact that, among other factors, in 2018 it began construction of one of the largest biogas plants for electricity generation in the world, which opened in 2020. It has the capacity to supply 62 thousand homes and is fed with vinasse that is processed during the harvest, *cachaça* and other sugar cane by-products processed on a commercial scale at the Bonfim plant located in the same place, in the state of Sao Paulo. Vinasse is the liquid residue produced by the fermentation of must in alcohol distilleries; it is produced in large quantities and has a high organic load and *cachaça* is the residual organic pollutants from raw sugar production and is produced all year round,

The two plants belong to Raízen, which is a corporation made up of Shell (U.S.), and the agro-industrial company Cosan, with Brazilian capital and other minor shareholders, and seeks to produce biogas in the 35 ethanol plants it currently has in Brazil. The production of bioethanol, which comes from its 860,000 hectares cultivated in sugar cane (an area almost the size of Puerto Rico), is marketed in more than 7,300 Shell and Oxxo (another partner) service stations and in airports in Brazil. and Argentina [21].

For its part, seeking to solve the problem of environmental pollution, Cuba achieved a production of 97.6% of bioenergy of its total renewable energies produced in 2021 (Table 4). To produce biogas, a wide variety of waste from agricultural and industrial activity was processed, such as excreta associated with the raising of pigs, poultry and cattle, and organic liquid waste from the food industry, particularly from the meat, dairy, brewing, canning, fishing and sugar industries. The biogas production potential of both agricultural and industrial activities reached 710,095 MWh/year, and of this 63% of the total corresponds to agricultural activities.

Furthermore, in the production of biodiesel, priority has been given to the cultivation and establishment of living fences of *Jatropha curcas*, which produces a non-edible oil, with low requirements in terms of soil and which can be planted mixed with various food crops. And as for solid fuels, they come especially from agricultural residues of sugar cane, rice, other minor crops and the forestry sector, among them, firewood for domestic use in cooking food (despite the fact that electricity coverage is 100%) and timber tree plantations for energy purposes [22].

In Guatemala, of the 65 million gallons of bioethanol produced by the five distilleries that currently exist, 80% is exported to be mixed with other fuels, while the remaining 20% is traded in the national market [23]. On the other hand, seeking to promote the use of ethanol in the transportation sector, and to force compliance with the Fuel Alcohol Law, which dictates that gasoline for the transportation sector must have a 1% bioethanol mixture and that it has not been fulfilled, it was announced that from January 1, 2025, the mixture of gasoline with ethanol will be mandatory, although the percentage has yet to be defined [24].

Colombia, Argentina and Peru are the Latin American countries that stand out for the recycling rates of their municipal waste, recycling in 2021, 1.9 million tons, 1 million, and 80,250 tons, respectively [12], while the other countries do not report data. In the case of Colombia, the support from the government to formalize the work of thousands of families who lived from informal recycling is one of the strategies that has contributed to this achievement.

On the other hand, since 2015 Costa Rica has stood out globally for its renewable electricity generation capacity, reaching more than 98% in 2022 [25], although the proportion of installed bioenergy capacity still only reaches 2.6% of the total installed capacity in renewable energies.

In relation to the use of firewood, this is one of the indicators that has usually sought to show one of the faces of the complex relationship between poverty and lack of access to electrical energy. However, it seems that over time this indicator has become distorted in Latin America, since, as data in several countries in the region demonstrate, its use has grown despite broad or complete access to electrical energy; this is the case of Guatemala, Nicaragua, Argentina, Chile and Paraguay [26], although these last three countries have 100% national access to electrical energy.

This fact seems to show that, although governments and institutions guarantee technical access to electrical energy, this does not mean that people can use it, since the cost of the monthly bill is an obstacle. Another minor factor compared to the previous one is cultural, since the benefits of using firewood in traditional cooking or in fireplaces has been revalued.

Table 5 Residential consumption of firewood and charcoal over total bioenergy consumption (1970, 1990 and 2022 – %)

Rank	Countries	1970	Rank	Countries	1990	Rank	Countries	2022
1	Paraguay	96	1	Nicaragua	95	1	Guatemala	90
2	Nicaragua	95	2	Guatemala	94	2	Nicaragua	85
3	El Salvador	95	3	Honduras	92	3	Honduras	78
4	Honduras	95	4	Paraguay	90	4	Paraguay	62
5	Guatemala	94	5	El Salvador	89	5	Peru	55
6	Brazil	88	6	Costa Rica	74	6	Chile	42
7	Ecuador	85	7	Panama	73	7	Dominican Rep.	35
8	Costa Rica	85	8	Colombia	62	8	Uruguay	34
9	Panama	85	9	Uruguay	58	9	Colombia	34
10	Dominican Rep.	79	10	Peru	58	10	Mexico	30
11	Peru	71	11	Chile	56	11	Panama	28
12	Colombia	70	12	Dominican Rep.	56	12	Brazil	27
13	Mexico	62	13	Ecuador	56	13	El Salvador	19
14	Bolivia	58	14	Bolivia	55	14	Costa Rica	13
15	Chile	54	15	Brazil	52	15	Ecuador	0.08
16	Uruguay	51	16	Mexico	41	16	Bolivia	0.07
17	Argentina	13	17	Argentina	0.04	17	Venezuela RB	0.05
18	Cuba	0.03	18	Cuba	0.02	18	Argentina	0.01
19	Venezuela RB	0.01	19	Venezuela RB	0.00	19	Cuba	0.01

Source: OLADE, 2024

Hence, a challenge is to refine the collection of statistical information to determine if the increasing use of firewood is required to cover basic needs due to the costs of electrical energy or if there are other factors. The fact that 32.3% of the United States population states that they are currently sacrificing other basic expenses in order to pay utility bills [27] and that 20 million families are behind on bill payments of electricity [28] or much worse, that the lives of a record number of people in the United Kingdom (the "first world") are at risk this winter because they cannot pay their energy costs [29], validates the considerations presented.

On the other hand, thanks to the residential biomass consumption index, defined as "the relationship between the sum of firewood and charcoal consumption in the residential sector divided by the final consumption of the residential sector" (OLADE, 2023: 47) and calculated by the same organization, the potential of the varied inputs that make up bioenergy in Latin America is revealed. In 1970, Paraguay was the country whose homes had the highest consumption of firewood and charcoal over the final consumption of biomass with 96%, closely followed by four other countries; in fact, of the 19 countries in the region, the residential sector of 16 countries used more than 50% of firewood and charcoal, out of their total biomass consumption (Table 5).

It can also be seen that 20 years later, 15 countries (that is, only one less than in 1970) maintained the same trend of using more than 50% of firewood and charcoal of their total biomass consumption. However, in 2022, the residential sector in only 5 countries used more than 50% of firewood and charcoal of the total biomass used.

One of the urgent challenges is to collect and systematize timely and reliable statistical information that accounts not only for the number of bioenergy units in operation, but also for their characteristics, including the working conditions of the workers who are part of their processes; in this way, their costs, functionality and performance could be evaluated with a view to correcting the identified errors and advancing appropriate technologies.

4. Conclusions

To close and as conclusions, some reflections on important and urgent challenges are offered. For example, in addition to the paradoxes and dilemmas already mentioned that are part of the dynamics of bioenergy production, there are some other great challenges such as the complex relationships between energy security and food security, which the war in Ukraine has brought to light; among them, Europe's energy dependence on Russian gas, dependence on Russian and Ukrainian wheat exports from various regions of the world, especially North Africa, and global dependence on the production of inputs for agricultural fertilizers.

Another challenge derives from the fact that "Green energy is the generation of energy from infinite sources that does not produce carbon emissions or negatively impact the environment [while] renewable energy is the generation of energy from infinite sources". Without the approval of several countries and in the midst of the Russia-Ukraine crisis, the European Parliament endorsed in July 2022 that gas and nuclear energy be considered green energies, expanding discussions on what renewable energies are and what they are not.

Another necessary debate, also with broad consequences, is about what can be considered renewable energies versus sustainable energies, which, as already said, also includes hydropower. In this regard, the EU approved in July 2023 a new legislation that prohibits the entry of soy and palm oil derivatives associated with deforestation. This decision was made to diminish carbon emissions and address global warming, because such bio-energy products are renewable, but not sustainable; they are not, because the agricultural practices of such crops currently include the clearing of large areas of forests in countries such as Indonesia, Malaysia and Brazil by companies that also have histories of labor abuse and conflicts with communities. In fact, the WWF in its 2021 report "Stepping Up? the Continuing Impact of Eu Consumption on Nature Worldwide" stated that eight European economies were responsible for 80% of said deforestation between 2005 and 2017, with Germany in first place and other growing countries affected by this decision include Mexico, Argentina and Colombia.

An additional global challenge is the urgency of prioritizing the implementation of the principles of the circular economy; although this would greatly contribute to reducing the amount of garbage, the solution par excellence would be achieved more efficiently if we drastically changed our habits of consumption of goods and services. However, Americans spent a record $222 billion shopping online this holiday season" as was reported by CNN in its newscast on the past January 12, showing that we are still very far from this goal.

Finally, I consider that the greatest paradox in the global energy matrix is that, although the reduction of global energy consumption (fossil and renewable) should be the first action against climate change, the campaigns in this regard are not only timid, but sporadic, to say the least. And they are, because what are considered prosperous economies were founded on high energy consumption, that is, those that produce many goods and services for daily consumption, which quickly end up in huge landfills, at an enormous cost to nature. Consequently, and although the advances in renewable energies and recycling processes are more than welcome, what is inevitably required is a paradigmatic change, a civilizational change, that moves us away from our addiction to unconscious energy consumption.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest to disclose.

References

[1] C. Dickert and S. Parker, What Electricity Sources Power the World?, *Visual Capitalist*, 2023. https://www.visualcapitalist.com/electricity-sources-by-fuel-in-2022/ (accessed Jan. 03, 2024).

[2] IRENA, Renewable Energy Statistics 2023, Abu Dhabi, 2023. Accessed: Jan. 04, 2024. [Online]. Available: www.irena.org

[3] IEA, Bioenergy Review 2023 - How bioenergy contributes to a sustainable future, Paris, 2023. Accessed: Jan. 05, 2024. [Online]. Available: https://www.ieabioenergyreview.org/

[4] The World Counts, World Waste Facts, *A world of waste*, 2024. https://www.theworldcounts.com/challenges/state-of-the-planet/world-waste-facts (accessed Jan. 03, 2024).

[5] S. Kaza, L. Yao, P. Bhada-Tata, and F. Van Woerden, What a Waste 2.0, Washington, D.C., 2018. Accessed: Jan. 03, 2024. [Online]. Available: https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html

[6] A. Pforzheimer and A. Truelove, Trash in America, Santa Barbara, California, 2021. Accessed: Jan. 03, 2024. [Online]. Available: https://frontiergroup.org/resources/trash-america-0/

[7] M. Kalale and B. Musonda, Exploring economic opportunities of the solid waste management policy in Zambia: Case study city of Ndola, *Int. J. Sci. Res. Arch.*, vol. 2024, no. 01, pp. 157–162, 2024, doi: 10.30574/ijsra.2024.11.1.0022.

[8] The World Bank, Prevalence of undernourishment (% of population) | Data, Washington, D.C., 2023. Accessed: Jan. 04, 2024. [Online]. Available: https://data.worldbank.org/indicator/SN.ITK.DEFC.ZS

[9] UN Environment Programme, Waste Management Outlook for Latin America and the Caribbean, Panama City, 2018. Accessed: Jan. 04, 2024. [Online]. Available: https://www.unep.org/ietc/resources/publication/waste-management-outlook-latin-america-and-caribbean

[10] H. Ritchie, P. Rosado, and M. Roser, Access to Energy - Our World in Data, *Our Wolrd in Data*, 2019. https://ourworldindata.org/energy-access (accessed Jan. 04, 2024).

[11] OPHI, Multidimensonal Poverty Index Country Briefing 2022: Nicaragua (Latin America and the Caribbean), Oxford, 2022. Accessed: Jan. 05, 2024. [Online]. Available: https://ophi.org.uk/wp-content/uploads/CB_NIC_2022.pdf

[12] H. Ritchie and E. Mathieu, Waste Management - Our World in Data, *Our Wolrd in Data*, 2024. https://ourworldindata.org/waste-management (accessed Jan. 04, 2024).

[13] F. Parra and J. Vanek, The Collection of Data on Waste Pickers in Colombia, 2012-2022, no. March. W omen in Informal Employment:Globalizing and Organizing (WIEGO), Manchester, p. 19, 2023.

[14] M. B. Bouvier and S. Dias, Catadores de materiais recicláveis no Brasil: um perfil estatístico. Women in Informal Employment:Globalizing and Organizing (WIEGO), Managua, p. 12, 2021. Accessed: Jan. 18, 2024. [Online]. Available: www.wiego.org

[15] H. Russell, Trash to cash: Norway leads the way in turning waste into energy, *The Guardian*, Lon, 2013. Accessed: Jan. 12, 2024. [Online]. Available: https://www.theguardian.com/environment/2013/jun/14/norway-waste-energy

[16] J. Okafor, Which Countries Buy Garbage? - The Global Waste Trade, *Trvst*, 2023. https://www.trvst.world/waste-recycling/which-countries-buy-garbage-a-look-at-global-waste-trading/ (accessed Jan. 12, 2024).

[17] World Bank, Access to electricity (% of population), Washington, D.C., 2023. Accessed: Jan. 05, 2024. [Online]. Available: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS

[18] World Bank, Access to electricity, rural (% of rural population), Washington, D.C., 2023. Accessed: Jan. 05, 2024. [Online]. Available: https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS

[19] IEA, Energy Statistics Data Browser, Paris, 2023. Accessed: Jan. 12, 2024. [Online]. Available: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=BRAZIL&fuel=Energy supply&indicator=TESbySource

[20] O. L. Castillo, Who, How and How Far? Renewable Energy Transitions in Industrialized and Emerging Countries, *https://www.intechopen.com/journals/7/articles/147*, vol. 2022, pp. 1–26, Dec. 2022, doi: 10.5772/GEET.10.

[21] Raízen, Raízen Inaugurates Biogas Plant and Strengthens its Renewable Energy Portfolio, 2024. https://www.raizen.com.br/en/press-office/raizen-inaugura-planta-de-biogas-e-consolida-portfolio-de-energias-renovaveis (accessed Jan. 13, 2024).

[22] A. Cuberlo Alonso *et al.*, Atlas de bioenergía - Cuba, La Habana, 2022.

[23] G. Montenegro, El Alcohol guatemalteco que compite en Mercados Mundiales, *Asociación de Combustibles Renovables*, 2023. https://acrguatemala.com/2023/02/14/etanolguatemalacompitemundialmente/ (accessed Jan. 16, 2024).

[24] R. M. Bolaños, Desde el 1 de enero del 2025 será obligatoria la mezcla de etanol con gasolinas, lo que provoca reacciones encontradas, *Prensa Libre*, Managua, 2023. Accessed: Jan. 16, 2024. [Online]. Available: https://www.prensalibre.com/economia/desde-el-1-de-enero-del-2025-sera-obligatoria-la-mezcla-de-etanol-con-gasolinas-lo-que-provoca-reacciones-encontradas/

[25] OLADE, Panorama Energético de Américla Latina y el Caribe 2023, Quito, 2023.

[26] OLADE, Sistema de Información Energética de Latinoamérica y el Caribe (SIE), 2024. https://sielac.olade.org/default.aspx (accessed Jan. 16, 2024).

[27] M. Davies, D. Shepard, and P. Huang, 32.3% Sacrificed Basic Expenses to Pay Energy Bill, *LendingTree*, 2023. https://www.lendingtree.com/personal/energy-bills-study/ (accessed Jan. 18, 2024).

[28] W. Wade and M. Chediak, Can't Pay Utility Bills? 20 Million US Homes Behind on Payments, Facing Shutoffs, *Bloomberg*, 2023. https://www.bloomberg.com/news/articles/2022-08-23/can-t-pay-utility-bills-20-million-us-homes-behind-on-payments-facing-shutoffs (accessed Jan. 18, 2024).

[29] Citizens Advice, Record numbers seek help for energy debt before winter even hits, Citizens Advice warns, 2023. https://www.citizensadvice.org.uk/about-us/about-us1/media/press-releases/record-numbers-seek-help-for-energy-debt-before-winter-even-hits-citizens-advice-warns/ (accessed Jan. 18, 2024).

[30] G. Smoot, Green Energy vs Renewable Energy: What's the Difference?, *Climate Action - Impactful Ninja*. https://impactful.ninja/green-vs-renewable-energy-differences/ (accessed Jan. 15, 2024).

[31] G. Abril, El Parlamento Europeo respalda el sello verde de la UE al gas y energía nuclear, *El País*, Madrid, 2022. Accessed: Jan. 15, 2024. [Online]. Available: https://elpais.com/economia/2022-07-06/el-parlamento-europeo-respalda-el-sello-verde-de-la-ue-al-gas-y-energia-nuclear.html

[32] B. Wedeux and A. Schulmeister-Oldenhove, Stepping Up? the Continuing Impact of Eu Consumption on Nature Worldwide, Gland, 2021. [Online]. Available: https://wwfeu.awsassets.panda.org/downloads/stepping_up___the_continuing_impact_of_eu_consumption_on_nature_worldwide_execsummary.pdf

[33] M. Egan, Americans spent a record $222 billion shopping online this holiday season | CNN Business, CNN Newa, USA, 2024. Accessed: Jan. 12, 2024. [Online]. Available: https://edition.cnn.com/2024/01/04/economy/record-online-shopping-this-holiday-season/index.html

[34] Cournoyer, Governing, *Is hydropower a renewable enrgy or not?*, 2013. https://www.governing.com/archive/gov-hydropower-renewable-energy.html

Authors short Biography

Olga Lucia, Castillo Ospina - Former University Full-Professor and Senior Researcher, currently linked to the Civil Society Organization 'Future-Present Collective' as member and Senior Researcher; sociologist, statistician, and PhD in Development Studies, from a critical perspective and currently working on a) the socio-ecological conflicts of production of energy and the energy transition b) the crisis of democracy and c) the incoherence between the concepts, discourses and practices of "development". Her publications on these and other topics can be found at https://www.researchgate.net/profile/Olga-Castillo-2