POTENTIAL OF THE BIOECONOMY TO TRANSFORM FOOD SYSTEMS

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Foreword

This paper sets out to offer a reflection and analysis for global and regional audiences that can influence the strengthening and transformation of food systems in Latin America and the Caribbean (LAC), such as national and regional governments, international cooperation organizations, development agencies, multilateral banks and donors, among others.

This material is part of the process of dialogues and construction of action proposals led by the Inter- American Institute for Cooperation on Agriculture (IICA) in the region, in preparation for the Food Systems Summit to be held this year.

This paper has received valuable contributions from various individuals and organizations at different stages in its development. We would like to thank the collaborators for contributing their time and knowledge to this paper.

The writing of the present paper was coordinated by Hugo Chavarría (IICA), with the participation of Eduardo Trigo (IICA), Carl Pray (Rutgers, The State University of New Jersey), Stuart J. Smyth (University of Saskatchewan), Agustín Torroba (IICA), Justus Wesseler (Wageningen University & Research), David Zilberman (University of California at Berkeley), Juan F. Martínez (IICA Consultant).

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Introduction

The present paper sets out to identify, analyze and visibilize the role that the bioeconomy could play in strengthening and transforming food systems, particularly in LAC. To fulfill the goals proposed, the material is made up of the following three major areas:

1. Bioeconomy: concepts and contributions to sustainable development goals (SDGs).
2. Contributions of the bioeconomy to transforming food systems.
3. The pending issues in the agenda to drive the transformative role of the bioeconomy in food systems in LAC.

The first section analyzes the concept of bioeconomy, its drivers and its relationship with other sustainable development approaches; it also covers bioeconomy's contributions to the SDGs of the 2030 Agenda.

The second section—the most extensive in the paper—stresses the potential of bioeconomy to increase efficiency, add value and sustainability in food system processes, transform rural territories, promote better use of resources, improve nutrition and health, and increase environmental sustainability and resilience in the face of climatic and other events.

The paper concludes with a third section analyzing the pending challenges, tasks and agenda in terms of bioeconomy, so that LAC can fully tap into the transformative potential of bioeconomy in food systems in the region.

3

Bioeconomy: concepts and contributions to SDGs

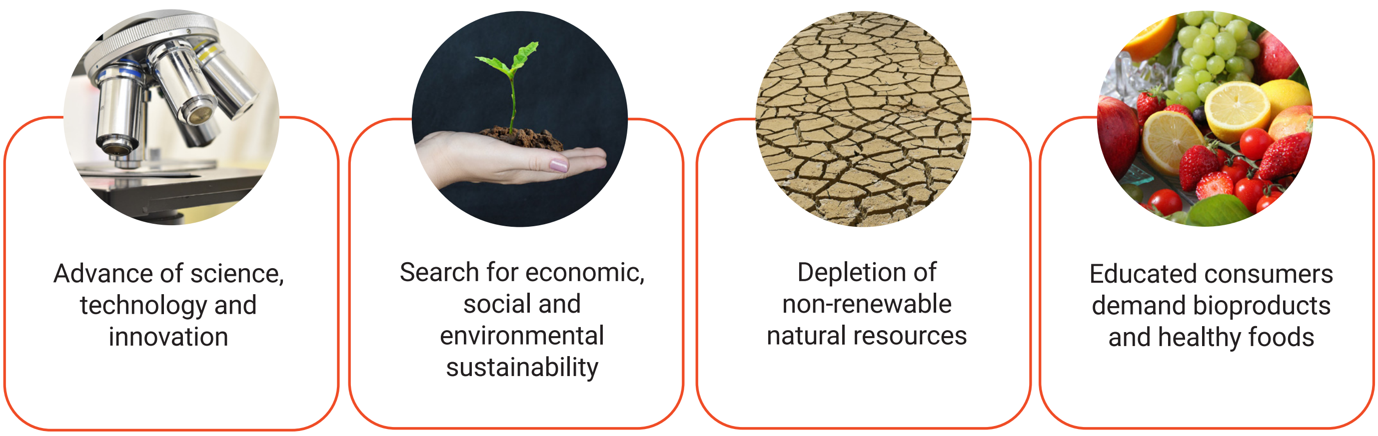
This section analyzes the concept of the bioeconomy, and its relationship with other economic approaches (circular economy and green economies) and with the SDGs of the 2030 agenda.

Conceptual aspects of the bioeconomy

The most widely recognized definition of bioeconomy was proposed at the 2018 World Bioeconomy Summit: the bioeconomy is the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy (IACGB 2020.)

As a sustainable development approach, the concept of bioeconomy emerges in the context of the current era, promoted by diverse factors such as those shown in figure one.

FIGURE 1. MAIN DRIVERS OF THE BIOECONOMY



The bioeconomy concept is also promoted by other scientific-technological variables proposed by Krüger et al. (2020), Torres-Giner et al. (2020) and van Dijk et al. (2021). These variables are:

- Advances in research and development in the field of biological engineering and sciences.
- Technologies of the fourth industrial revolution.
- The science and technology of materials (e.g., nanotechnology) and
- Digitalization (e.g., information and communication technologies (ICTs) and the Internet of Things (IoT.))

All the above elements are drivers to harness primary and residual biomass (agricultural and food waste), not only to increase recycling and shorten supply chains, but also as an alternative raw material to produce fuels/energy, chemical substances, bioplastics and pharmaceutical products, among many others (Usmani et al. 2021). It is hoped that future bioeconomy innovations, such as synthetic biology, nitrogen fixation crops, nanofertilizers, etc. (Herrero et al. 2020) will generate greater positive impacts on sustainability (Biber-Freudenberger et al. 2020.)

The bioeconomy presents similarities and differences with other concepts that are also considered sustainable development approaches, such as the circular economy and the green economy (D'Amato et al. 2017.)

TABLE 1. SIMILARITIES AND DIFFERENCES BETWEEN BIOECONOMY AND OTHER SUSTAINABLE DEVELOPMENT APPROACHES

VARIABLE	BIOECONOMY	CIRCULAR ECONOMY	GREEN ECONOMY
Reduction of greenhouse gases (GHG)	●	●	●
Efficient energy use	●	●	●
Efficient material use	●	●	●
Conservation of natural resources	●	●	●
Responsible consumption	●	●	●
Social inclusion	●	●	●
Scientific and technological approach	●		
Innovation and transformation (productive structures)	●		

Regarding the differences indicated in Table 1, the scientific and technological approach of the bioeconomy allows a deep knowledge of natural resources, ecosystems and the services that these provide. Furthermore, the capacity to innovate and transform makes it possible to influence productive structures, which includes the use of knowledge for processing and the creation of cascading value - added chains (which aim for the greatest possible value.) These potentialities for development can be expressed in:

- Generation of better jobs, income and new integrated production.
- Greater food security.
- Environmental sustainability and mitigation—adaptation to climate change.
- Improvements in the competitiveness of agriculture and rural territories.

This productive, commercial and social potential of the bioeconomy (particularly in rural areas) has already been shown and analyzed in various studies around the world. For example, the bioeconomy generated over 2.47 million direct jobs in Argentina in 2017 (Coremberg, 2019) and in Colombia it is expected to generate 2.5 million new jobs in the bioeconomy sectors with the recently launched national strategy (Government of Colombia 2020.)

Bioeconomy contributions to SDGs

Given the opportunities that the bioeconomy offers, the policies and instruments that promote it would make it possible to support the smart specialization of agricultural and rural territories, as well as meeting the challenges of the SDGs of the 2030 Agenda. This would diminish local inequalities and boost the generation of opportunities with a territorial focus based on a sustainability approach.

The use of SDG indicators in monitoring and evaluating the bioeconomy have shown connections between this and the 2030 Agenda for sustainable development (Calicioglu et al. 2021). In an analysis of national bioeconomy strategies, different SDGs relevant to the bioeconomy were identified, for example:

- The bio-based economy can play a fundamental role in the decarbonization of the planet (SDG 13: climate action), in the production of agricultural bioinputs and healthy foods and in the sustainable intensification of agricultural production (SDG 2: zero hunger, SDG 3: health and wellbeing and SDG 15: life of terrestrial ecosystems.)
- In addition, closing production cycles through the use of biomass waste improves sustainable production indicators (SDG 12: responsible production and consumption and SDG 11: sustainable cities and communities.)
- Another contribution of this new paradigm is the design of biomaterials and the generation of different types of bioenergy (SDG 9: industry, innovation and infrastructure and SDG 7: access to affordable, reliable, sustainable and modern energy), which help to generate new jobs (SDG 8: decent work and economic growth) and promote SDG 17 to boost international cooperation partnerships and agreements in science and technology (S&T.)

- The bioeconomy approach as a development model that enables the fulfillment of SDGs related to food security and nutrition, health and wellbeing, clean water and sanitation, Baumol et al. 1982, is analyzed in table two.

TABLE 2. POTENTIAL CONTRIBUTIONS OF THE BIOECONOMY TO SDGS

POTENTIAL CONTRIBUTION	SDGS CONTRIBUTED TO
Productive models that harness science and technology to use biological resources in a sustainable and efficient manner to locally produce substitutes for petrochemical products (e.g., bioenergies, biofertilizers and bioplastics) or meet demand from new consumers (e.g., functional foods or biocosmetics.)	**SDG 2:** zero hunger. **SDG 3:** health and wellbeing. **SDG 7:** affordable and clean energy. **SDG 9:** industry, innovation and infrastructure. **SDG 13:** climate action.
Use of productive practices that contribute to sustainability and environmental resilience while adding productivity and efficiency.	**SDG 13:** climate action. **SDG 15:** life of terrestrial ecosystems.
Circular economy production systems, by means of the productive use of biomass waste derived from production and consumption processes.	**SDG 11:** sustainable cities and communities. **SDG 12:** responsible production and consumption.
Development of products, processes and systems through the reproduction of processes and systems observed in nature.	**SDG 9:** industry, innovation and infrastructure. **SDG 14:** underwater life. **SDG 15:** life of terrestrial ecosystems.
Bioremediation to tackle environmental contamination problems (e.g. the recovery of degraded or contaminated soils and the treatment of water for human consumption and waste.)	**SDG 6:** clean water and sanitation. **SDG 15:** life of terrestrial ecosystems.
Increase in the economic density of rural territories, from new industrialization processes and the local use of biomass to generate energy, bioproducts and bioservices.	**SDG 7:** affordable and clean energy. **SDG 8:** decent work and economic growth.

Source: Chavarría et al. 2020.

It is important to clarify that: a) not all SDG benefits are exclusively attributable to the bioeconomy, as many other economic, social and environmental areas are also concurrent to the purposes of the SDGs and b) some conditioning factors (economic/financial, institutional capacity and human resources capacity, regulations and laws) will enable the benefits of the bioeconomy to have a positive impact on SDGs.

4

Bioeconomy contributions to transforming food systems

This section describes the contributions and potentialities of the bioeconomy to increase efficiency, add value and sustainability in food system processes, while transforming rural territories, promoting better use of resources, improving nutrition and health, and increasing environmental sustainability and resilience to climatic and other events.

Sustainable food systems

A sustainable food system is one that guarantees food security and nutrition for all people without putting at risk the economic, social and environmental foundations of future generations (FAO n.d.)

FIGURE 2. THE SUSTAINABLE FOOD SYSTEM

Source: Compiled based on FAO (n.d.)

It is increasingly necessary to move toward more sustainable and equitable food systems. This transformation entails providing healthy and nutritious foods and, at the same time, generating opportunities for subsistence and reducing negative impacts on the environment and natural resources (von Braun et al. 2020).

Action tracks to transform food systems

In line with the transformation toward more sustainable and equitable food systems, the UN Food Systems Summit established five action tracks (5ATs) (Table 3) that seek to guide the global discussion and serve as the basis for the participatory construction of proposals.

TABLE 3. ACTION TRACKS FOR TRANSFORMING FOOD SYSTEMS

ACTION TRACK		PROPOSAL
	**Action track 1** Ensure access to healthy and nutritious food for all	End hunger and all forms of malnutrition, reduce the incidence of non-communicable diseases, enabling all people to be nourished and healthy.
	**Action track 2** Shift to sustainable consumption patterns	Build consumer demand for sustainably produced food, strengthen local value chains, improve nutrition, and promote the reuse and recycling of food resources, especially among the most vulnerable.
	**Action track 3** Boost nature-positive production	Optimize environmental resource use in food production, processing and distribution, thereby reducing biodiversity loss, pollution, water use, soil degradation and greenhouse gas emissions.
	**Action track 4** Advance equitable livelihoods	Contribute to eradicating poverty by promoting full and productive employment and decent work for all actors along the food value chain, reducing risks for the world's poorest, enabling entrepreneurship and addressing the inequitable access to resources and distribution of value.

	**Action track 5** Build resilience to vulnerabilities, shocks and stress	Ensure the continued functionality of sustainable food systems in areas that are prone to conflict or natural disasters. The action track will also promote global action to protect food supplies from the impacts of pandemics.

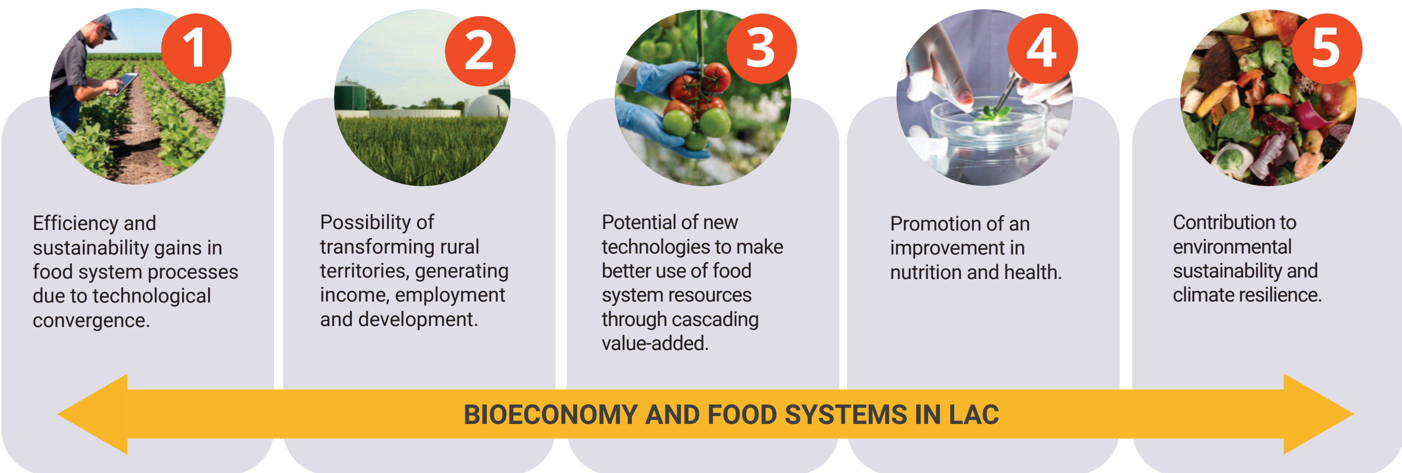
Source: Compiled by author based on UN (n.d.)

As table three shows, the bioeconomy has enormous potential to contribute to every one of the action tracks to transform food systems. These possibilities are covered in the following section.

Potential of the bioeconomy to transform food systems in LAC

In the case of LAC, the potential of the bioeconomy to support the transformation of food systems are based on the biological wealth of the region, the productive, industrial and commercial structure, technical and scientific capacities and the socioeconomic conditions of rural territories. From these elements, figure 3 shows the main potentialities of the bioeconomy to transform food systems in LAC.

FIGURE 3. POTENTIALITIES OF THE BIOECONOMY TO TRANSFORM FOOD SYSTEMS IN LAC[1]



Source: Compiled by author.

1. It is important to bear in mind the fundamental role that scientific and technological knowledge plays in advancing the implementation of the bioeconomy as a development model for the region's food systems, for which the following actions are available: a) develop different models for working with natural resources and associated knowledge; b) design and apply new forms to increase, strengthen, maximize and promote scientific and technological knowledge around these resources; and c) find consensus between the two visions, since they are not mutually exclusive.

The following sub-headings explore further the scope of the potentialities of the bioeconomy to transform food systems in LAC, and the connection with the action tracks explained in the previous section.

1. Efficiency and sustainability gains in food system processes due to technological convergence[2]

Historically, agriculture in LAC has driven internal development and today it leads international markets. However, the productive and commercial structure of agriculture in the region has been based on agricultural commodities, without harnessing a large part of the biomass generated. In 2019, agrifood exports from LAC—by value—behaved as follows (ITC 2021):

- 45% were primary agricultural products (chapters 06, 07, 08, 09, 10, and 12 of the HS).
- 21% were primary products from livestock (chapters 01, 02, 03, 04, and 05 of the HS).
- Only 34% of agrifood exports had any level of added value (chapters 11 and from 15 to 24 of the HS) (ITC 2021).

KEY AGRICULTURE DATA IN LAC

- In 2019 agriculture contributed 4.7% of GDP and 14% of jobs in the region (World Bank 2021).
- In 2019 agriculture had a 14.3% share of the export value of agrifood products globally (WTO 2021).
- LAC ranked first in the export of tropical fruits, coffee, roots and tubers, oilseeds, cereals and meats, among others (WTO 2021).

Undoubtedly, the use of new science and technology to add value to biological resources leads to more profitable and sustainable markets. Cingiz et al. (2021) show the connections between different sectors of the bioeconomy and estimate that these contribute between 30% and 50% to the total added value of the bioeconomy. This can be observed in indicators such as:

- Agricultural commodities (oilseeds, flours and vegetable oil, sugar, cereals), which are the fundamental basis of agrifood exports from LAC, grew at annual rates below 4.45% in the last decade (Betancur et al. 2018).
- Biofuels, bioplastics and biofertilizers (bio-based sectors with greater added value) grew at an annual rate of 25%, 20% and 14% respectively in the last five years (Betancur et al. 2018).

2. Contributes to action tracks 1, 3 and 5.

It is a priority to reduce the large gaps and inequalities in agricultural yields present not only among LAC countries, but also within the countries themselves. To do so requires combining scientific and technological knowledge from diverse fields such as biology, the technologies of the fourth industrial revolution and engineering, among others, to reposition the role played by biological resources and improve capacity to understand and take full advantage of the opportunities that these offer.

The rise in S&T knowledge increases efficiency and production, which highlights the intrinsic potential value of natural and biological processes (IACGB 2020.) Impacts of S&T include (Lokko et al. 2018, Malyska et al. 2018, Akutse et al. 2020):

- Increase in the productivity of biomass (including waste and residues) and development of new bioproducts with high added value such as nutraceuticals, bioenergy and other biological materials used by the cosmetic, pharmaceutical and chemical industries, among others.
- Generation of a range of new services and a greater value in biodiversity, such as integrated pest management based on new biological fertilizers and pesticides.

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Gaps in agricultural yields between countries (FAO 2020):

- Coffee: between 0.2 and 1.9 t/ha
- Rice: between 0.9 and 8.6 t/ha
- Sugarcane: between 20 and 129 t/ha
- Corn:between0.8 and 11.9 t/ha
- Wheat: between 5 and 15 t/ha

In family farming, yields may represent less than 50% of commercial agriculture yields (ECLAC et al. 2014).

The impact of these trends is greater because in interacting with each other the different disciplines (biology, biotechnology, chemistry, nanotechnology, data science, ICTs, engineering, reproduction, health and others) promote progress of each specific field (MIT 2005, Park 2017). Through this technological convergence, the bioeconomy influences the improvement of productivity and sustainability of biological resources through:

- The development of plant and animal varieties resistant to diseases and pests.
- Developments in the knowledge of soils and their microbiology, which provide alternatives in the efficient use of inputs from precision agriculture.

In parallel, the technological convergence between ICTs and digitalization contributes to a renewed and modernized vision of food systems, added value chains and international trade.

ITCs and digitalization have the potential to increase the efficiency and sustainability of agricultural and food supply chains and the new forms of biomass industrialization. In all cases, the use of these technologies (figure 4) must be ethical.

FIGURE 4. EXAMPLES OF NEW TECHNOLOGICAL APPLICATIONS OF AGRICULTURE

Big data: manages large volumes of data from various sources to establish predictive analyses that enable more accurate decision-making in the field.

Block chain: enables the operation of traceability systems for agricultural and food products over different agricultural value chains and makes it possible to properly monitor the use of residue and waste.

Artificial intelligence: makes it possible to monitor soils and crops and generate algorithms of information processes and learning models.

Remote sensors: capture crop information via air, satellite or land overtime.

Geolocalization: via remote sensors, determines variable layers of information from a given area or terrain (GPS, SIG).

Robotics: enables the automation of agricultural tasks and processes; also develops and applies autonomous equipment for certain agricultural activities.

Internet of things: Collects weather, environmental and agricultural information and sends it to processing and data analysis systems to support decision-making in the field.

Source: Compiled by author based on Aramendis et al. (2018).

Regardless of the type of technology adopted and the purposes for which it is adopted, this is a process that occurs in stages and which is conditioned by multiple factors, where agricultural producers' digital skills and educational level and the type of agriculture and form of insertion in the markets play a fundamental role. Some relevant examples of commercial applications of these technologies in LAC are the following (Aramendis and Rodríguez 2021):

- **EIWA** (Argentina): Uses digital platforms for the selection of open field phenotypes that cover the complete cycle of breeding, development and marketing.
- **SPACE AG** (Perú): Combines data captured by drones and satellite images and creates digital maps of different crop areas.
- **I CROP** (Brazil): Uses software linked to meteorological networks, remote sensors and irrigation monitors to optimize water use and energy costs.
- **AIMIRIN** (Brazil): Develops artificial intelligence for the simulation, control and automation of combustion processes from sugarcane bagasse for electrical energy.
- **AGREE MARKET** (Argentina): Global trading platform for basic agricultural products that allow users to buy or sell on their mobile device or computer.

It is clear that the region is heading toward a precision, digital and intelligent agriculture which, along with other technologies, should increase the value and efficiency of Agrifood chains.

2. Possibility of transforming rural territories to generate income, employment and development[3]

One of the key questions regarding the potential of the bioeconomy to transform food systems in LAC comes from the implications of moving from value chains based on fossil resources to bio-based chains.

3. Contribuye con las vías de acción 4 y 5.

TABLE 4. FEATURES OF FOSSIL-BASED VALUE CHAINS AND BIO-BASED VALUE CHAINS

FOSSIL-BASED VALUE CHAINS	BIO-BASED VALUE CHAINS
• Fossil raw materials are relatively homogenous. • Raw materials are extracted in large volumes from a few highly productive deposits located in limited areas. • The raw material is transformed into materials for the energy, chemical and construction sectors, through large-scale industrial infrastructures and logistics.	• Biological carbon (biomass) comes from a highly decentralized context of broad territorial coverage, due to the diverse nature of agriculture, livestock, fishing and forest production period. • Due to its large volumes, its limited useful life and its low energy and carbon density, it is not economical to transport biomass long distances before processing it. • The unsuitability of transporting biomass requires that biorefineries be organized in a decentralized fashion, in places close to the areas where raw materials are produced. • Biorefineries do not require the large scale that refineries of fossil resources demand.

Source: Compiled by author.

These characteristics of the bio-based value chains promote an increase in the economic "density" of rural territories, which in turn generates a significant transformation in the rural environment and greater integration in the local economy.

Firstly, bio-based value chains contribute new activities—biorefineries and other industrial and logistic infrastructures—to the rural economic context, which adds local value and diversifies sources of income and available job opportunities. The greater economic density generates more opportunities for the rural territories of LAC, highly impacted by situations of low income, unemployment, informality (76% of those employed), poverty (45%, two or three times that of urban rates) and exclusion.

The use of biomass in new industries increases economic opportunities, both for agricultural sectors and for non-agricultural sectors in the region (they generate 58% of the income of rural territories) (ILO 2020).

Greater economic density facilitates the integration of small producers in the region into the developments resulting from local markets and gives them opportunities for inclusion in new bioeconomic clusters.

Likewise, this density could retain the rural youth in their place of origin.

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- LAC concentrates 50% of jobs generated by the biofuels sector in the world. Brazil leads the way, employing over 832,000 people (Torroba 2020b).
- In LAC, the rural sector concentrates over 30.9 million young people aged 15 to 29. Of these, 9.6 million work in the agricultural sector.

A second strategic component of the bioeconomy as a transformative element of food systems in LAC can be found in the implications of a greater local availability of energy at competitive prices to attract other economic activities, aside from those of the bio-based value chain themselves. In this sense, there are many experiences of how rural electrification in the past has triggered local development processes (Riva 2020).

There are precedents of local production of bioenergies in various countries of LAC that have visibilized the development of other productive activities, such as access to communications (internet) and greater quality of life provided by electric energy (Regúnaga et al. 2019). Bioenergies could reduce costs through the decentralization of expensive energy grids (a continuous obstacle for many rural areas, particularly in poorer countries.) They could also improve environmental performance through a more integral use of residual biomass (Tamburini et al. 2020).

The supply of affordable and stable energy—the absence of which constitutes a critical restriction to improving the efficiency and sustainability of food systems—is offered increasingly by the bioeconomy through options that do not compete with food production (Gabashwediwe et al. 2019). Furthermore, in a gradually more interconnected region, emerging bioeconomy networks (added value, energetic and productive diversification) are a viable strategy to reverse the conditions that feed rural emigration and to make rural areas more competitive for social and economic development (Hartley et al. 2019).

3. Potential of the new technologies to make better use of food system resources through cascading value-added[4]

The first potential includes the new bioeconomy technologies, which increase productivity and food security by making an efficient and friendly use of natural resources. To this are added the components resulting from the integral use of the biomass production described below.

The integral and efficient harnessing of all the biomass production to obtain biomaterials contributes to reducing GHG emissions, and adds cascading value, generates new jobs (and income) and collaborates so that food systems are safer and more productive. As can be observed in Table 5, diverse co-products are generated by the catalytic cracking of the biomass.

TABLE 5. CO-PRODUCTS GENERATED BY CRACKING BIOMASS

Energy biomaterials	Refers to liquid, solid and gas biofuels that—under the term "bioenergies"—represent 10% of the world supply of primary energy (IEA 2019).
Foods for human and animal consumption	Foods allocated for animal and human consumption (protein flours, expeller pressing, bagasse, wet/dry distillers grains with soluble substances, texturized proteins, etc.)
Products with high value-added	There is a broad range of products with high value-added that are processed by the pharmaceutical, alcochemical and oleochemical industries, among others.

Source: Compiled by author.

The efficient and integral catalytic cracking of the biomass leads to the "multi-product" industry (Baumol et al. 1982), where the production of co-products makes

4. Contributes to action tracks 1, 3, 4 and 5.

it possible to diversify, complement and distribute costs and make the system more efficient. In parallel, a safer and more resilient food system is generated, as biofuels constitute a reserve of raw materials that can be used as food in cases of crises or harvest loss and the bioinputs (biological fertilizers) make it possible to reduce the dependence on the market of fossil-based inputs.

Furthermore, due to the stability of demand for raw materials that the industry generates from biofuels (especially in multiannual crops), crop producers in LAC have increased and could further increase their sales channels, which would make it possible to broaden the supply of raw materials involved in the process. At present the proportion of the production of certain crops allocated to biofuels is higher in LAC compared with global percentages.

TABLE 6. PROPORTION OF CROP PRODUCTION ALLOCATED TO BIOFUELS

CROP	GLOBAL PERCENTAGE	LAC PERCENTAGE
CORN	16 %	2 %
SUGARCANE	20 %	43 %
SOYBEAN OIL	19 %	31 %
PALM OIL	16 %	13 %

Source: Compiled based on Torroba (2020a).

The development and strengthening of the biofuels industry may be beneficial to LAC farmers as:

- It is possible to reorient the raw material of crops (particularly multiannual crops) toward this industry when the prices of agricultural commodities are unappealing.
- This industry generates a diversified demand of raw materials, whose possible positive impact on prices may promote improvements in living conditions for farmers in LAC (of which 60 million depend directly on the sector.)
- The diversification of exports of agricultural commodities—through the export of biofuels—reduces the vulnerability of some LAC countries that concentrate their exports on a few primary products (e.g. Argentina.)

The productivity of the biofuels sector—the basis of the integral cracking of the biomass—has improved with time. This can have very positive effects on the rest of the processes of the food system. In Brazil, for example, the cost of producing sugarcane ethanol fell 70% between 1975 and 2010. With the advances of biotechnology, the cost of biofuels and the environmental impact will diminish and added value will increase (Debnath et al. 2019).

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- One case worth highlighting is the development and implementation of mini-distilleries on farms that convert corn into ethanol for biofuels and distillers grain for animal feed. This permits a reduction in transport distances and the subsequent increase in profitability and sustainability of agricultural SMEs. This technology was developed and launched recently in Argentina (Rosenstein 2017).

The use of waste in the integral cracking of the biomass, used in the production of alternative biofuels such as biogas, advanced biofuels, etc., provides greater efficiency in food systems, as it enables the transformation of raw material waste or residue into energy of biological origin.

Aramendis et al. (2019) state that the use of residual biomass[5] in biorefineries may come from different sources such as:

- The agricultural sector (crops, garbage, fruits.)
- The food and nutrition agroindustry.
- The livestock and animal raising industry (waste from meat and dairy industry and animal production.)
- Forest products, byproducts and residues (waste from primary and secondary timber industry, residues and byproducts from the cellulose and paper industry.)
- Sludge from the treatment of domestic and industrial sewage.

Of all the sources mentioned, a wide range of products can be obtained including electricity and heat, energy products (solid, liquid and biogas biofuels), non-energy products (foods, animal feed, fertilizers, bioproducts, bioplastics, bioadhesives, biolubricants, etc.) and biochemical products sold as commodities or building blocks to later be transformed as bioproducts (Aramendis et al. 2019).

5.By way of example, the potential world residue from forestry, agriculture and organic waste is 40 to 170 exajoules per year (EJ/year), with an average estimate of around 100 EJ/yearby 2050 (IPCC 2012). In 2006, the biomass residue generated in Costa Rica had an energy content of 60,354 terajoules, with which it was possible to generate almost 635 MW of electricity in one year (FAO 2013).

4. Promotion of improvements in nutrition and health[6]

The results of the Latin American Study of Nutrition and Health (ELANS), made on the daily consumption of ten food groups in eight countries of LAC, show poor quality diets for the food groups rich in nutrients, which suggests a greater risk of non-communicable diseases in urban areas of LAC in the coming decades. As a result, urgent public health actions must be taken to improve the consumption of critical foods, in order to prevent non-communicable diseases (NCDs) (Kovalskys et al. 2019).

FIGURE 5. RESULTS OF THE STUDY ON DAILY FOOD CONSUMPTION IN EIGHT COUNTRIES OF LAC

35%

of the population consumed the range of optimal foods: vegetables, fruits, nuts and seeds, wholemeal cereals, fish, seafood and yogurt.

7.2%

of the population consumed the amount of fruit and vegetables recommended by the WHO, 400 grams a day.

Less than

15%

of the population covered the range of optimal consumption of vegetables and fruits.

Compiled based on Kovalskys et al. (2019).

Although the LAC region does not have high levels of prevalence of undernourishment, there are still some countries in the region—e.g., Haiti, Venezuela, Nicaragua, Bolivia and Honduras—where over 10% of their population cannot acquire sufficient foods to satisfy their minimum daily dietary energy needs during a period of at least one year (FAO 2018).

Especially in infancy, the improvement of the nutritional content of the daily consumption of certain foods has every day and long-term effects. For example, macronutrients (proteins, carbohydrates, fats and fiber) and micronutrients (vitamins, minerals and functional metabolites) can contribute to reducing the risk of

6. Contributes to action tracks 1 and 2.

blindness from vitamin deficiency (Wesseler et al. 2014, Dubock 2014.) Furthermore, the nutrient content of foods—especially a greater availability of minerals —strengthens the immune system and reduces delayed growth (Wesseler et al. 2017). Thus, the bioeconomy can contribute substantially to attaining better nutrition, better health and healthier lifestyles in LAC. This can be achieved via multiple paths as shown in Table 7.

TABLE 7. BIOECONOMY CONTRIBUTIONS TO BETTER NUTRITION

CONTRIBUTION PATH	DESCRIPTION
Application of conventional plant breeding technologies and/or modern biotechnology	These technologies aim to increase the nutritional quantity and quality of foods. Some examples are: increasing protein content in canola, corn, potato, rice and wheat; improving oil and fatty acid content in canola, corn, rice and soy; improving carbohydrates in corn, potato, beetroot and soy; increasing vitamin levels in potato, rice, strawberry and tomato; and increasing the availability of minerals in lettuce, rice, soy, corn and wheat (Newell-McGloughlin 2014).
Adoption of biofortified crops	The adoption of these crops increases the availability of micronutrients (Hefferon 2014).
Diversification of diets	This refers to the variation of the diet such as those based on microalgae and insects that have a high nutritional value due to their content of protein, polyunsaturated fatty acids, bioactive carbohydrates and antioxidants, including pigments such as carotene, chlorophyll and phycobiliproteins (Melgar-Lalanne et al. 2019, Ordoñez-Araque et al. 2021 and Fernández et al. 2021).
New food sources	Development of new food sources based on a newfound appreciation of such foods.

Source: Compiled by author.

Innovations in plant breeding technologies could have a high impact on the transformation of food systems in LAC, as they would contribute to increasing incomes in homes, reduce poverty and increase food and nutritional security (Klümper et al. 2014 and Subramanian et al. 2010).

The shift to genetically modified crops or crops obtained from new plant breeding techniques also improves producers' and consumers' quality of life and health; for example, there is documentation of weed control in genetically modified corn (Gouse et al. 2016), the accumulated reduction in 100 million intoxications by pesticides in genetically modified cotton crop in India (Smyth 2020) and health benefits through the reduction of carcinogenic mycotoxins, such as those found in GM corn (Pellegrino et al. 2018).

As well as offering new food products that improve nutrition and health, the bioeconomy promotes the discovery and appreciation of functional features of local biodiversity (genetics of species and ecosystems.) For example, agroforestry systems with native fruit trees and traditional forest foods can provide the macro- and micronutrients necessary to improve food and nutritional security (Chamberlain et al. 2020).

All these elements are essential for the transformation of food systems in a region that has eight of the world's fifteen most megadiverse countries, 50% of known biodiversity, 16% of seawater resources and 23% of forests in the world (ECLAC et al. 2019). All these processes are accompanied by a growing interest among consumers in natural products, consumption trends that transform food systems and promote new value chains associated with tropical biodiversity and other environments of LAC.

In short, biotechnology innovations in the agriculture and food sectors have the potential to transform the food systems of LAC to attain greater food supply and more nutritional and healthier diets. Furthermore, a greater provision of safe and nutritional foods benefits lifetime health, which contributes to reducing health system costs.

5. Contribution to environmental sustainability and climate resilience[7]

Technologies and investments in the bioeconomy have the potential to bring about substantial environmental gains in food systems, which can contribute with strategies and efforts of the countries of LAC to mitigate climate change and increase their environmental resilience. Some of them are illustrated in figure 6.

FIGURE 6. BIOECONOMIC CONTRIBUTIONS TO ENVIRONMENTAL SUSTAINABILITY AND CLIMATE RESILIENCE

Source: Compiled by author.

7. Contributes to action tracks 3, 4 and 5..

Bioenergies and other bioproducts

It is estimated that global bioenergies generated from biomass could save the equivalent of 1.3 Bt of CO_2 emissions per year, providing 3000 terawatts per hour (TWh) of electricity by 2050 (Zihare et al. 2018). According to the Intergovernmental Panel on Climate Change (IPCC), the good use of bioenergy may significantly reduce GHG emissions in comparison with fossil alternatives.

Within bioenergies, the production of biofuels is one of the industries with the greatest potential from the environmental point of view. Its contribution to the reduction in emissions is based on the whole lifecycle of the product (from the agricultural yields of the crops used to the technologies applied during the primary and industrial production process.)

FIGURE 7. DISTILLERY PLANT

The above has been demonstrated in countries of LAC such as Argentina, where biodiesel produced during the period 2008- 2018 made it possible to save CO_2 emissions equivalent to that generated by 5 million people in one year or which would have been absorbed by 186,000 hectares of forests (INTA 2018).

Similarly, bio-based non-energy products release fewer GHGs in comparison with basic fossil carbon products (Antar et al. 2021). For example, as bioplastics consume less energy during their production than plastics derived from oil, these tend to emit less carbon dioxide in their lifecycle (Yadav et al. 2020).

Integral use of residual biomass

The reduction and harnessing of food waste and residues is another aspect where the bioeconomy offers the possibility to improve the environmental performance of food systems in the region. Annually over 270 million tons of food waste is produced in LAC, enough to satisfy the nutritional needs of 300 million people (Macias et al. 2020).

Due to S&T advances, the region has multiple technologies that make it possible to process residues and use them in the production of new bioproducts (in the food, energy, chemical, pharmaceutical and construction industries.) This has enormous potential to transform food systems in LAC, considering that the residual biomass of the region is represented by 20% of the rice, 12% of the live weight of bovines, 70% of the weight of milk, 70-80% of coffee beans, 66% of sugarcane, 50% of citrus fruits, and 40% of pineapples, among other factors (IICA 2019).

Food waste can be considered a cheap raw material to generate high-added-value products such as biofertilizers, biofuels, biomethane, biogas and chemical substances with value-added (Hassan et al. 2018). These new industries have the potential to contribute to the goals of mitigating climate change and environmental sustainability of commercial activities, as they substitute products of fossil origin that have a high carbon footprint. They also promote the use of inputs (residues) that generated a high amount of carbon dioxide emissions, and contribute to changes in the energy grid.

Conservation agriculture

Conservation agriculture is based on the fundamental concept of the integrated management of natural resources (water, soil), agroecosystems, biological control, pertinent and adaptable practices, among other elements. One example of this practice is zero tillage.

Some “environmental gains” of the bioeconomy in food systems in LAC are related to the reduction in GHG emissions and savings in the use of chemicals resulting from the application of the technological package, which includes zero tilling and genetic breeding to obtain plant materials with greater capacity for carbon capture and resistance to pests and diseases.

In the 1990s, the incorporation of herbicide-tolerant canola, corn and soybean seeds led to the transition of tens of millions of hectares to zero tilling, reducing the consumption of fossil energy when compared to traditional tilling. Furthermore, the additional incorporation of insect-resistant corn, cotton and soybean reduced the applications of agrochemicals.

Both innovations, the reduction in tilling and decreased use of chemical substances, have benefited the environment significantly with 2.4 billion kilograms fewer of carbon dioxide emissions and 775 million kilograms fewer of active chemical ingredients applied in the world (Brookes et al. 2020). Furthermore, it is estimated that the production and sale of insect resistant crops has diminished the global use of pesticides by 37% (Klümper et al. 2014).

The continuous cultivation of fields without tilling and with coverage crops is increasing the capture and storage of carbon dioxide in soils. This has contributed significantly to the recovery of microbiology and the productive capacity of soils that had deteriorated due to conventional tilling, which have a potential for global warming of between 26% and 31 percent greater than lands with zero tilling (Mangalassery et al. 2014).

Genetically modified crops

In turn, the use of genetically bred crops is driving the production of more sustainable crops within food systems in the region. At present, LAC grows over 80 million hectares with different varieties of improved soy, corn and cotton that not only increase productivity and contribute to improving regional and global food security, but also reduce the consumption of agrochemicals (Chavarría et al. 2019).

FIGURE 8. TRANSGENIC VARIETIES OF GOLDEN RICE

In addition to these traditional crops, LAC has advanced in the research and definition of other modified plant materials such as golden mosaic virus-tolerant beans, PVY-resistant potato, herbicide-tolerant alfalfa with better lignin content, drought-tolerant soy and wheat, herbicide-resistant sugarcane with better energy yield, among various others (Chavarría et al. 2019).

In LAC various studies have evaluated and confirmed the environmental gains of these technologies developed with the bioeconomy vision in food systems in the region. In Colombia, transgenic crops reduced the use of insecticides and herbicides by 26% over a 15-year period. Additionaly, the adoption of GM corn and cotton has permitted the reduction of 8.761 billion kilograms of carbon dioxide that was not released into the atmosphere (Brookes 2020).

Connected to these same advances is the use of new techniques to improve crops, such as editing genes to improve plants' capacity to capture greater amounts of carbon dioxide, which would allow agriculture in LAC to contribute to a greater extent to reducing the impacts of climate change (Ort et al. 2015).

Nature-based solutions

The environmental sustainability of food systems in LAC could benefit enormously if nature-based solutions were harnessed to a greater degree, to respond in a multi-dimensional manner to the problems affecting humans and the environment. As Meza et al. have stated (2019), this approach could use ecological engineering and capture systems engineering, green and blue infrastructure, the ecosystem approach, ecosystem-based mitigation and adaptation, ecosystem services and natural capital to resolve some of the main environmental goals of food systems in LAC.

These include water purification and safe reuse in agriculture, recovering surface and ground waters, the prevention of environmental disasters, adaptation to climate change through agrobiodiversity, the generation of alternative incomes for agricultural producers through environmental services, integrated management of pests and diseases, recovery and remediation of contaminated soils, recovery of degraded lands and pasture and carbon capture and storage. All these are major challenges for a region such as LAC, where over 300 million hectares of land is degraded (IICA 2019).

BOX 1

SYNERGIES RESULTING FROM THE SYSTEMIC BIOECONOMY VISION

The section on the potentialities of the bioeconomy described the different types of contributions the bioeconomy can make to transform food systems. An integral, systemic approach is observed, which leads to synergies between different aspects described above and promotes the generation of clusters in rural territories for economic and social development.

Thus, the bioeconomy proposes a new vision of change and technological convergence as it not only goes into its productive dimensions to increase competitiveness, improve rural income and promote food security, but also promotes all the other dimensions of the food systems: environmental, economic and social.

5

Pending issues in the agenda to drive the transformative role of the bioeconomy in food systems in LAC

This third section analyzes the challenges, tasks and pending bioeconomy issues in the region's agenda, so that LAC may fully leverage the transformation potential of the bioeconomy in food systems.

Pending challenges and tasks

As mentioned on other occasions, the bioeconomy does not bring about the economic social and environmental transformation of food systems per se. Although it has enormous potential to do so, pending challenges and tasks must first be resolved (table 8.)

TABLE 8. PENDING CHALLENGES AND TASKS IN THE BIOECONOMY

CONTEXT	PENDING CHALLENGES AND TASKS
NATIONAL	• Design regulations and standards. • Develop research capacities. • Strengthen support services. • Improve stakeholders' skills. • Establish new networks of bioeconomy value.
REGIONAL	• Regional strategies to raise awareness and persuade. • Regional strategy for skills training. • Coordinate R&D&i among regional agencies. • Manage economic efforts among regional agencies. • Regional R&D&i networks for the bioeconomy. • Regional spaces for sharing experiences. • Fund for regional bioeconomy chains.
INTERNACIONAL	• Investment in R&D&i. • International trade standard. • International funding and cooperation systems.

If pending challenges and tasks are not addressed, the bioeconomy may imply risks and imbalances in the sustainable harnessing of biodiversity, environmental sustainability, competition for soil use, the equitable distribution of benefits, the democratization of knowledge and the inclusion of small-scale agriculture.

National context

It is essential that progress is made in the proper design and implementation of regulations and standards that facilitate the full harnessing of innovations in bioeconomy in the food system and which also ensure that these occur in the context of security and sustainability generated from solid scientific bases.

Regulations must not limit the implementation of opportunities in production, processing, transport and consumption or unnecessarily restrict sustainable growth, employment and resilience. It must be considered that some regulations are necessary to promote the development of the markets of some bioeconomic goods and services (for example, mandatory blend of biofuels for fuel consumption.)

It is also necessary to boost research capacities (financial, human and technological), both in academia and in research centers, to convert the opportunities that the bioeconomy offers into technological and social innovations at the service of the food systems of LAC. Furthermore, it is necessary to strengthen support services (mainly funding) and instruments for the creation and promotion of bioproduct markets, to promote the development of bioindustries and supply chains—based on these innovations—that generate employment, income and economic growth.

BOX 2

SOCIAL INCLUSION, FUNDING AND INNOVATION

For the benefits of the bioeconomy to impact the population and spread through value networks to all stakeholders and sectors in the food system (from the small and medium producer to the members of the consolidated industry), it is necessary to develop fair and equitable associative mechanisms and new funding models.

Cooperatives of small and medium producers—partnered as suppliers in local projects—are proving to be an ideal mechanism to ensure that the benefits of the bioeconomy guarantee social inclusion and local development.

Rodríguez and Aramendis (2019) and Rodríguez et al. (2019) argue that new forms of funding may approach some of the following economic, financial and tax instruments:

- Development of public-private partnerships (PPP) to generate investment funds.
- Combination of financial and non-financial instruments.
- Development of funds to support startups, MSMEs and young entrepreneurs.
- Placement of seed capital to increase work capacity and to develop business capacities.
- Innovation funding platforms.
- Generation of tax instruments (subsidies, exemptions, incentives, etc.)

It is essential to implement research, development and innovation instruments. Aramendis et al. (2018) mention the following as most relevant:

- Generation of business clusters.
- Support for enabling technologies.
- Generation of pilot and demonstration plants that allow society to visibilize and support bioeconomy programs and projects with local and national benefits.

Furthermore, it is essential to strengthen the capacities (technological, organizational and business) of LAC food systems stakeholders (suppliers of inputs, producers, transformers, traders, distributors, consumers, etc.), so that they can harness and convert the transformation opportunities that bioeconomy innovations offer into new business opportunities. This is essential for the participation of youth, women and family farming.

It is necessary to encourage the construction and promotion of bioeconomy value networks in rural territories. At present these are almost non-existent because stakeholders do not work with a network focus, but rather with a chain perspective. Therefore it is essential to connect different stakeholders to promote a more efficient and sustainable harnessing and industrialization of available biomass and biodiversity. For example, it is important to connect coffee hullers that have a large amount of unused waste with producers of biopharmaceuticals, biofertilizers and energy products, who could use this waste as raw material for their processes.

Regional context

In the regional context, the countries of the Americas could join forces to take better advantage of the the opportunities of the bioeconomy.

TABLE 9. PENDING CHALLENGES AND TASKS IN BIOECONOMY AT REGIONAL LEVEL

PENDING CHALLENGES AND TASKS	DESCRIPTION
Regional strategies to raise awareness and persuade	Coordinated efforts to manage knowledge about the opportunities and potential that the bioeconomy offers for the transformation of food systems (focusing on stakeholders in the public sector, academia, the private sector and civil society.)
Regional strategy for skills training	Organizational, business and technological skills training for stakeholders in the food system (mainly agroindustrial producers), so that they can harness the innovations of the bioeconomy and thus increase the efficiency and sustainability of biomass and biodiversity production and industrialization.
Coordinate R&D&i among regional agencies	Coordinate, focus and set priorities in research, development and innovation among different regional agencies involved in bioeconomy development for Latin America (e.g., IICA, IDB, UNESCO, CAF, ECLAC, FONTAGRO, among other organizations.)

Manage economic efforts among regional agencies	Manage economic efforts among regional agencies to leverage projects with regional impact that allow governments and the population to visibilize the advantages and benefits of the bioeconomy in food systems (demonstration projects and pilot projects.
Regional R&D&i networks for the bioeconomy	Promote regional research technology and innovation networks for the bioeconomy (focused on food systems.) Also include strengthening human capital in researchers (academic and scientific) in new sciences and technologies that promote efficiency and sustainability in the production and valuation of biomass and biodiversity.
Regional forums for sharing experiences	Strengthen regional spaces to share good practices and lessons learned in bioeconomy policies, strategies and investments in food systems (Latin American network as precedent.)
Fund for regional bioeconomy chains	Fund for the construction and promotion of regional bioeconomy chains from a public-private consortium in the territories (similar to European projects), with a special emphasis on processes of incubation and acceleration of bioeconomy business proposals in agriculture and rural territories.

International context

Of the many efforts required, one that stands out is international and regional cooperation to promote investment in R&D&i, but it is necessary to significantly increase resources assigned to this at all levels: national, regional and global. Other actions that require supranational efforts are the following:

- International trade standards that enable and promote production, industrialization and sale of bioeconomy products (healthier, greener and with a lower carbon footprint) for the transformation of global food systems.
- An international cooperation and funding system that promotes the generation of conditions that enable bioeconomy chains in the region and which encourages emerging bioindustries.

BOX 3

THE NEED TO BROADEN AND INTENSIFY BIOTECHNOLOGICAL INNOVATIONS

The innovations in biotechnology and bioeconomy required to bring about the transformation of food systems in LAC require major investments in basic and applied research, in training highly qualified professionals and in maintaining a fluid relationship between academia and industry (Zilberman et al. 2013).

The "educational industrial complex" has been essential in establishing biotechnology and information technology sectors throughout the world. In this complex, basic research financed with public funds at universities and other research institutions leads to innovations that are transferred to emerging companies and other private actors multiply them, which allows them to generate and sell these bioproducts.

The educational industrial complex has already given place to the creation of supply chains of new buyer products that are transforming food systems, such as biofuels and oils, fine chemical and pharmaceutical products and foods. Researchers in LAC are leading some of these new enterprises, as well as the exchange between universities and research centers and the private sector.

The success of the educational industrial complex depends on the priorities assigned to R&D and the maintenance of academic excellence and research excellence. In LAC, for example, the high priority assigned to research in the agricultural sector in Brazil has meant that the innovative knowledge generated by the Brazilian agricultural research company (EMBRAPA) was essential in Brazil's emergence as an agricultural power.

The three main obstacles for the development of bioeconomy industries are regulatory uncertainty, high transaction costs and financial limitations for R&D projects that generally require many years until they reach commercial maturity.

The broadening and application of new knowledge require a science-based regulatory environment, that aims to reduce regulatory burdens and accelerates development and the application of new, safe technologies. The appearance of new companies is more likely when there are risk investors and capital markets developed to support emerging industries and when regulatory procedures are streamlined to reduce the cost and time necessary to establish the company definitively.

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