Bioeconomy
New Framework for Sustainable Growth in Latin America

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ACADEMIC EDITORS

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Responsibility is the burden of freedom:
Act so that the effects of your action are compatible
with the permanence of genuine human life.
Hans Jonas

Foreword

Bioeconomy is a strategy based on the more efficient use of biological resources, technologies, and processes to provide goods and services demanded by our societies. It is rapidly evolving towards a broad vision for sustainable development which is not only about using new knowledge and technologies converging and empowering each other to offer unthinkable, but recently possible new options, but moreover a total change in the role of biological resources in the structuring of economies and the search for social welfare. Lately, it has been introduced as a feasible way to face the emerging demands for production and consumption patterns more aligned with the Sustainable Development Goals (SDGs) synthesized in the 2030 Agenda.

For countries in Latin America and the Caribbean, these trends represent a new, powerful opportunity. The region is not only a great producer of sustainable biomass, but also has important developments in its scientific-technological capacities, industrial infrastructure and bioenergy generation—in which it has become one of the main actors in international markets—. Strategically, this represents the possibility of giving a different approach to a discussion that has been going on for a number of years now, namely, agriculture *vs.* industry as the basis for various development strategies. The old sectoral "limits" have become vague and irrelevant, resulting in new value chains and ways of using natural resources, beyond the restrictions imposed by the so-called "resource curse."

We have begun to travel the road in this direction and, in recent years, the vision of bioeconomy has been incorporated into many strategic discussions at the regional level, but more importantly, the initiatives designed from the perspective of bioeconomy in specific productive sectors multiply day by day in a process that clearly confirms the potential of the ideas behind them.

This work summarizes the main features of these processes presenting specific cases that could be considered emblematic for the opportunities they entail. The analyses presented are part of a series of regional projects implemented with the support of the European Commission, in which I participated from different perspectives: first, as a representative of the Inter-American Institute for Cooperation on Agriculture (IICA) in Uruguay and Brazil, and then, since 2018, as

Director General of the Institution. As a representative in Uruguay in 2007, I hosted a meeting of the bi-regional ALCUE-Food project, where Latin American and European experts identified and discussed the opportunities that bioeconomy could offer for countries in the region. This would become the basis of the ALCUE-KBBE project, in which twelve Latin American and European countries participated and was implemented between 2011 and 2014.

ALCUE-KBBE was aimed to establish the foundations for a strategic partnership between the EC and the Latin American and Caribbean region to facilitate collaboration and coordination of research and innovation in knowledge-based bioeconomy, including agriculture, fishery, forestry, food and related biotechnologies, in which the IICA was an active participant. As part of its activities in 2012, and as a representative in Brazil, we again hosted the first regional meeting to identify R&D priorities for the development of bioeconomy in Latin America and the Caribbean. This project represented a regional milestone in the discussion of the value of bioeconomy, not only for the development of agriculture in the countries of the Americas, but also as a priority central point for its cooperation with European programs. Then, this was substantiated by bioeconomy becoming one of the work areas of the Joint Initiative on Research and Innovation (JIRI) in the framework of the Heads of State and Governments Summits involving countries in Latin America and the Caribbean and the European Community.

These experiences have been determining factors for me as IICA's Director General to decide to present, as part of the new Medium-Term Plan (2018-2022) approved by the Executive Committee of the Inter-American Board of Agriculture in July 2018, the Bioeconomy and Productive Development Program, which comprehensively supports the efforts of countries in the region in pursuit of developing their bioeconomies. In this context, it is my honor to submit the contents of this work for your consideration.

MANUEL OTERO
Director General
Inter-American Institute for Cooperation on Agriculture - IICA

Introduction

Guy Henry,* Elizabeth Hodson de Jaramillo,** Rafael Aramendis,***
Eduardo Trigo **** and Sara Rankin*****

After the Green Revolution, countries in Latin America opted for development models that boosted economic growth based on natural resources and import substitution. This scheme was weak due to the reduced value addition and diversification it received from the industry, and the consideration that natural resources are limited and indispensable for its sustainability. Many countries were trapped in the market of commodities, subject to the fluctuation of their availability and prices. As a result of this situation, the concept of *bioeconomy* emerged as a socioeconomic model that reduces fossil resource dependence and promotes the production and intensive use of knowledge of biological resources, processes and principles, for the sustainable supply of goods and services in all economic sectors (bioenergy, agriculture and bio-inputs, food, fiber, health products, industrial products and bioplastics), while decisively contributing to human welfare and to decarbonize the economy to comply with global environmental agreements for sustainability.

This concept recognizes the fundamental role of scientific and technological knowledge as the driving force to redefine the relationships among agriculture, biomass, and industry. Using this approach, processes based on biomass as a raw material are circular and sustainable: Waste production is reduced to a minimum and new products and services are created in multiple sectors. This makes it possible to address the challenges of a region comprehensively and coherently and, at the same time, create new sources of equitable economic and social growth, from a territorial perspective. The primary objective of bioeconomy is to reduce the use of

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non-renewable fossil energy and replace it with renewable resources in a context of environmental, social and economic sustainability by producing, processing and consuming biological materials and minimizing polluting waste (Henry, Hodson, Aramendis, Trigo, & Rankin, 2017).

> Bioeconomy proposes an economic model in which the production of goods and services is based on the efficient and sustainable use of biological resources (genes, bacterial, plant and animal biomass) and natural resources (such as soil and water), as well as the use of waste generated in their processing, thus reducing the use of fossil energy and contributing to the overall objective of decarbonizing the economy.

Bioeconomy is a response to four emerging and converging global challenges: (i) increased world population (nine trillion people by 2050); (ii) increased global demand for biomass (at least 60 % above current rates), worsening the scarcity of natural resources; (iii) growing evidence that the era of oil and cheap energy is about to end; and (iv) concerns about climate change. This shows that continuing with the same development model is not an option and that bioeconomy will be an essential tool to meet the United Nations Sustainable Development Goals (SDGs).

This new economic model differs from others in that it incorporates knowledge into the definition of new alternatives and productive paths in order to migrate from the unsustainable fossil oil economy to the biomass economy and move from the use of non-renewable sources to renewable schemes and processes that could be called *photosynthesis in real time*. This puts greenhouse gas (GHG) emissions and sequestration at the same geological time and not separated by millions of years as in the case of oil. Current knowledge of biological processes and the ability to intervene and manipulate them according to specific interests or objectives allows, on the one hand, to propose solutions and, on the other, to create opportunities (products, processes or services) and, thus—with the application of scientific advances—open little-known, but very promising innovative fields. It is no longer about traditional value addition, but about the emergence of new value chains or networks that take advantage of cascade technologies to optimize processes in multiple products, while generating circularity and, therefore increase sustainability. Summarizing, bioeconomy is based on the transition from fossil fuel dependence to a situation in which agriculture not only contributes to food safety, but also to the production of biomass as a renewable raw material for industry, energy generation, and other uses.

The core elements of bioeconomy are biological resources, processes and principles, as well as all technologies (conventional and modern) associated with their knowledge, development, processing or regeneration (Rodríguez, Mondaini & Hitschfeld, 2017). Bio-based strategies change established balances regarding access patterns, use of resources, and distribution of benefits, to promote increased productivity and competitiveness of products in the economy of a given territory. It is necessary that the community has a better understanding with a clear decision-making process, in order to identify and manage advantages and disadvantages emerging between old and new activities, between different ranges of application, and between the short and long term. A key strategy is to strengthen training at all levels and to promote entrepreneurial skills, as well as communication and decision-making processes. It is also crucial to foster the coordination of institutional actions under principles of competitiveness, equity, sustainability, multisectoriality and decentralization.

Therefore, the implementation of bioeconomy requires a platform of key actors, in which the productive sector continuously interacts with ministries and public agencies, academia and civil society. The successful transition to bioeconomy in a given territory, will require intense endeavors in the development of human resources and better mechanisms for inclusive and equitable social participation. Bio-based processes require not only a solid technological basis and reordering of the base of scientific skills for innovation and development, but also that producers and industrialists are capable to manage new processes (innovation), generally much more knowledge-intensive than conventional approaches.

Bioeconomy has gained momentum worldwide and is a reality in many developed countries such as Germany, France, Finland, the Netherlands, Russia and Japan. At the beginning of 2018, nearly fifty countries included defined bioeconomy policies or strategies in their development plans, and subregional strategies have already been established (German Bioeconomy Council, 2018). Approaches are aligned with the SDGs in search of internal economic growth, environmental protection, competitiveness, and employment to promote social inclusion. In the European Union, for example, this model has created employment for around 22 million people in the agro-food, chemical, biotechnological, forestry and energy industries, with an annual turnover of around two quintillion euros (€2×10^{18}).

Bioeconomic Reflections on the Agricultural Sector*
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Our political and productive culture in the agricultural sector remains primarily short-term, an expensive survival formula that jeopardizes our agricultural economy in the long run.

There is hope. In the last decade, models have begun to appear in the Colombian agricultural sector that apply the principles of bioeconomy. One of the most significant is the considerable development of new bioproducts that are beginning to be used not only in those production models labeled as "organic", but also by producers that have been incorporating them in conventional production systems because they are seeing in them a valuable tool to give sustainability sustain their undertakings and to minimize the adverse environmental impacts and negative image of agricultural production in a part of society.

We must closely monitor the developments associated with the bioeconomy strategies of some developed countries to know how to take advantage of them with efforts focused on our own economy, such as creating a competitive supply of local biomass generation leveraging our tropical conditions in which we have comparative advantages to make the most out of the developments of third parties.

*Author's inputs to the Foro Nacional de Bioeconomía, Colombia, 2017. Available at: https://blog.ciat.cgiar.org/es/la-bioeconomia-motor-de-desarrollo-integral-para-colombia/

There is not a single form of bioeconomy, but many that adjust to local conditions and the possibilities of each situation. Bioeconomy is defined very differently around the world and the terminology used also differs, but, in the end, bioeconomy policies encompass innovation and comprehensive sustainability in their social, environmental and economic dimensions, associated with the growth of the economy and employment. According to the approaches and perspectives, a number of terms are used, each with its particular biases, including bioeconomy, bio-based economy, green economy, green growth, circular economy. Aspects common to the various definitions of bioeconomy are its relationship with knowledge and science, technology and innovation, with the application of biotechnologies and reduced fossil fuel dependence, as well as the added value of the products and the concepts of sustainability and eco-efficiency.

The global definition recently adjusted at the 2018 Global Bioeconomy Summit (Global Bioeconomy Summit, 2018) is: "Bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology and innovation, to provide information, products, processes and services across all economic sectors aiming towards a sustainable economy." It is a dynamic and complex social transformation process, which demands a long-term policy perspective. The vision of a sustainable bioeconomy is the *biologization* of the economy with new bio-based processes and industrial products, which implies changes in consumer behavior.

For Latin America and the Caribbean, it is a very relevant approach since it is in a privileged position, given its abundant natural resources (biodiversity, water, land, among others), although it is necessary to strengthen its science, technology and innovation (STI) capacities and to promote technological cooperation. Furthermore, it is necessary to adopt sound public policies and viable strategies to promote the development of bioeconomy in the region, for which joint work among institutions, coordination and governance is crucial. The region shows important developments in different areas (pathways) in Argentina, Brazil, Chile, Colombia, Costa Rica, Peru, Mexico, among other countries. It is clear that each country and each region should establish their own bioeconomic development agenda based on an equation that includes, on the one hand, the territory, its capabilities and vocations, and, on the other, the possibilities and opportunities that technology provides, considering a cross-sectional main point: the training of human resources capable of leading the transformation.

For the above reasons, this book provides examples of different approaches and some experiences of Latin American countries that are moving towards the construction of a national strategy specifically dedicated to bioeconomy. For instance, Brazil, with the successful application of bioeconomy focused on obtaining bioenergy and where alternative mechanisms for partnerships are being proposed so that the small farmer is included and benefits from technologies; Colombia, which explores the valuation and use of biodiversity resources as a point of entry into bioeconomy; Chile, with the obtaining of bioproducts; Costa Rica, with examples of value addition in agrifood chains; and Mexico, where spin-offs and start-ups already have products in the market such as biofertilizers and biofungicides in association with multinational companies and where some national companies obtain ethanol from non-conventional sources (cyanobacteria) and others develop, sell and export functional foods, bioplastics and industrial enzymes. It also presents examples of ventures of young researchers from the region with high social and economic potential and a regional analysis associated with the effect of public policies on the promotion of bioeconomy in the region of Latin America and the Caribbean (LAC).

Development of the Oil Palm Agro-Industry in the Framework of Bioeconomy*
Jens Mesa Dishington
President, Fedepalma, Colombia

The palm sector has been a key factor in the development of the biofuels policy, due to the role of palm oil as the main input for biodiesel production. A life cycle analysis study for palm biodiesel in Colombia, commissioned by the Ministry of Mines and Energy, resulted in Colombian palm biodiesel having a potential reduction in GHG of around 83%. The generation of bioproducts that serve as an input for the chemical industry and for pharmaceutical, nutritional and biocosmetic products, as well as the creation of new bio-services such as those related to cellular medicine and stem cells may become the future of this sector.

It was identified that within Colombia's export portfolio oil palm may reach even more potential clusters than oil itself. In order to address these challenges of diversification and value addition, public investment in important topics such as science and technology should be consistent with the strategies that the country wishes to undertake in order to achieve a sustainable economy. While the global average of research and development spending as a percentage of GDP is around 2.1%, Colombia's spending was only 0.2%.

Particularly, the agricultural sector has had to sustain its research and development activities primarily with agricultural para-fiscal contributions and no government resources. It is important to encourage investment in the business sector using economic incentives for innovation initiatives and technological reconversion. Only the sum of the efforts of the productive sector, academia and the state could place Colombia on the path of sustainable growth.

*Author's inputs to the Foro Nacional de Bioeconomía, Colombia, 2017. Available at: https://blog.ciat.cgiar.org/es/la-bioeconomia-motor-de-desarrollo-integral-para-colombia/

The discussion in our region is just beginning and it is opportune to mention the emerging issues raised around the world. At the recent Global Bioeconomy Summit(April 2018), topics relevant to research agendas and policies were defined, mainly focused on the close relationship between bioeconomy and climate change management and adaptation; effects on health; digitization and converging technologies (bio, nano, computing); communication and public confidence in transformative sciences and technologies; interdisciplinary education and training at all levels; biodiversity as a resource and basis of bioeconomy; marine and ocean bioeconomy; innovative sources of financing; and bioeconomy in cities. Recommendations include the establishment of international mechanisms for knowledge coordination and exchange, with actors in the forum, as well as the participation of United Nations organizations in sustainable development, biodiversity and innovation fora, particularly in the Paris Agreement on Climate Change (Global Bioeconomy Summit, 2018).

Productive Pathways of Bioeconomy for LAC Identified in the ALCUE-KBBE (Knowledge Based Bio-Economy) Project*

Some "productive pathways" have been identified that lead to producing more with less and reducing the environmental impact, although the processes are maturing, as the authors point out:

1. **Leveraging biodiversity resources** covers all scenarios where the distinctive feature is value addition through innovative transformation, market development for products, use of functional traits, development of new local products, etc.
2. **Eco-intensification** is related to agricultural practices aimed at reducing the environmental impact of agricultural activities without sacrificing current levels of production/productivity (minimum tillage, bio-inputs, precision agriculture).
3. **Biotechnology applications** (products and processes), including tissue culture, marker-assisted selection (in crops and animals), genetically modified seeds, molecular diagnosis, improved animal reproduction through molecular techniques, modified enzymes, microorganisms and yeasts, etc. This extends both to the management of natural resources and to food, fibers, and chemical industries and energy supply.
4. **Ecosystem services** include processes through which the environment provides resources used by humans such as air, water, food, and materials. Given the special nature of the relationship and interaction between natural resources and social and economic activities in the bioeconomy approach, an ecosystem perspective is a fundamental component of any sustainable bioeconomy strategy.
5. **Value chain efficiency** includes activities that (i) reduce waste losses at any level and (ii) aim at the development of the links with markets needed for innovative bioproducts.
6. **Biorefineries and bioproducts** refer to the bioenergy sector and processes focusing on the substitution of fossil fuel as an industrial input; for example, ethanol, biodiesel, biogas plants, as well as different activities of green chemistry.

* Eduardo J. Trigo, Guy Henry, et al. Bioeconomy Working Paper No. 2013-01. Towards bioeconomy development in Latin America and the Caribbean. ALCUE-KBBE Project.

In the context of LAC, the initial steps to bolster bioeconomy took place in 2008, in Buenos Aires, in a bi-regional workshop between the European Union and Latin America as the final event of a project in the framework of European Commission Program 6 (ALCUE-Food). There, proposals and studies were formulated and built, aiming to involve actors from different fields around the construction of the nascent bioeconomy model in the region. The European Commission has been strongly supporting activities with a bi-regional approach, such as the ALCUE-KBBE Project

(Knowledge Based Bio-Economy 2011-2014), and the Latin America, Caribbean and European Union Network on Research and Innovation (ALCUE-NET), 2014-2017. In these activities, potential, opportunities, capacities, ongoing experiences, specific policies and conditions for the development of bioeconomy both in the region and in the countries have been analyzed and discussed, allowing to set research agendas and proposals on the subject (Hodson de Jaramillo, 2014). The results constitute a significant assessment of the situation, limitations and opportunities of the region, in addition to its base of natural resources, policies and research and development capacity, and lists of ongoing projects relevant to the implementation of bioeconomy; and allow to propose a list of pathways or routes and good practices.

The process and analysis of the experiences and dynamics of bioeconomy in the European Union also led to reflections and questions related to the context of LAC and the main challenges for the implementation of the bioeconomy-based development model such as: (i) How important is (and can be) bioeconomy for LAC? What would be the economic value of bioeconomy for a country, region or sector?; (ii) What is the potential value of bio-based sectors?; (iii) What are the main success factors and what are the limitations for bio-based companies?: and (iv) How do public policies affect the development of bioeconomy? The development of sustainable models that benefit small farmers or industrial processes that make efficient use of water resources were also considered, and as a primary interest for all countries in LAC, the utilization and recovery of residual biomass for, on the one hand, reducing pollution and, on the other, obtaining value-added products, including renewable energy, soil fertilization, feed or diverse bioproducts.

For the entire LAC region, the shift towards an economy based on biomass replacing fossil fuels clearly represents a significant change in conventional socioeconomic, agricultural, energy and technological systems. Bioeconomy leverages innovations in life sciences and bioindustries to achieve sustainable ecological and social growth, as well as employment creation based on this sustainable utilization of biological resources. For the bioeconomic approach to become the driving force of transformation towards sustainability in a circular economy context, a more systematic, intersectorial and international approach is vital, with public policies decidedly supporting this model.

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Bioeconomy in Argentina: Scope, Current Situation, and Sustainable Development Opportunities

Eduardo Trigo,* Marcelo Regúnaga,** Ramiro Costa,*** Ariel Coremberg****

Introduction

The bioeconomy, understood as a set of sectors using biological processes and resources to obtain goods and services, is a concept that has been establishing as a development alternative for an economy that, globally, should face the double challenge of meeting the food, fiber and energy demands of a population that will be exceeding ten billion by the end of the 21st century, while reversing, or at least minimizing, the adverse effects on the environment and natural resources that are generating the current patterns of economic organization.

For Argentina, the bioeconomy represents a particularly relevant option because it is applicable to areas of strength, such as biomass availability and scientific-technological capacities; and to the long history of private institutions related to the agro-industrial sector. It also enhances some basic aspects of the country's know-how: its character as a large and very efficient biomass producer, which is widely recognized nationally and internationally. There is a broad consensus that the ceilings of biomass production and productivity levels in Argentina may increase significantly in the coming years. Simultaneously, advancing the consolidation of an effective and efficient bioeconomy would allow implementing a more balanced territorial development strategy than the existing one, given the location-specific advantages of industries tapping multiple biomass sources in the relevant regions.

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These strengths have already come through in several successful developments that allow asserting that the bioeconomy model is underway in Argentina. The emergence and growth of Argentine biotechnology companies, the massive use of genetically modified organisms (GMO), the wide dissemination of environmentally friendly production strategies, biofuel production, and the use of some of its co-products in regional production development and biomaterial and bioenergy production alternatives are clear examples of this process and the benefits that a comprehensive bioeconomy development strategy may bring to the country.

This chapter presents the main conceptual bioeconomy strategies; describes the opportunity it provides to implement long-term development in Argentina; reviews the country's particular conditions as a biomass producer and scientific-technological support; points out some relevant ongoing experiences in Argentina; estimates the size of Argentine bioeconomy; and reflects on the challenges that the country will face in the transition towards a bioeconomy-based economic and social development strategy, raising some questions that will need to be tackled in its implementation.

The bioeconomy concept

The world is at a very particular moment, both because of the problems it is confronting and because of the emerging opportunities of new technologies. The need to anticipate and respond to the demands that population growth and the global economy will generate in the coming decades, together with the increasing restrictions on the availability of resources necessary to cope with these demands sustainably, categorically emphasizes that business as usual is a scenario that can hardly be maintained for long (Gerland et al., 2014).

In the last two decades, both internationally and nationally, the bioeconomy has been certainly identified as a desirable development strategy. Regardless of the approach —the use of biomass or the part of knowledge—, the common thread is the role of innovation (technology, logistics, business and markets) that aims to improve solar energy collection and its transformation into other sources of energy, products and services, in order to influence the environmental impact of production, distribution and consumption activities, and to promote more efficient and sustainable use of natural resources in general.

Current economic development depends mainly on the use of fossil resources to obtain energy, chemicals, and other industrial inputs. These resources represent photosynthesis processes of millions of years ago, whose exploitation made modern engineering and chemistry possible, but are also recognized as one of the main drivers of climate change that is affecting humanity (Haggett, Nájar, & Ramazzini, 1998). Furthermore, the bioeconomy is based on a concept that can be called *real-time photosynthesis*, in which the use of natural biomass as the main source of energy and carbon puts carbon emission and sequestration at the same geological age and, therefore, considerably improves the environmental impact of the economic activities involved.

Biotechnology is the main component of a set of knowledge and technologies that makes the bioeconomy the reality of our time, but it is not the only technological platform concerned. Other technologies facilitate data collection on a large scale and complement new biological technologies for much more effective agriculture in terms of land use and environmental impact. Nanotechnology also supports these processes in a convergence manner in which breakthroughs in one field boosts those of the others (National Research Council, 2014).

Biomass-knowledge-innovation interactions, as well as the implicit environmental "circularity", make it possible to introduce the bioeconomy as an important instrument to rise to the interrelated challenges of food security, resource depletion and climate change at present, and, at the same time, enable sustainable economic growth through new bioproduct-based activities and value chains.

New opportunities for the sustainable economic development of Argentina

The international context creates the need to promote a less fossil resource-dependent society that makes better and more efficient use of renewable natural resources—quite different from what we do today. This means a new economic scenario of comparative advantages, sectors, countries and relative competitiveness, which requires new policies and institutions to contain and guide the behavior of actors in the economy in order to optimize existing opportunities and minimize the costs of transition to new conditions.

The possibilities for Argentina in the framework of the bioeconomy should be considered based on the fact that most sectors or market segments comprising it, are new, recent and, therefore, not yet established, and where entry barriers are not fully defined, so there are extraordinary benefits for those who penetrate these new markets. The current scenario for Argentina unfolded by the bioeconomy seems to be vastly different from the one it experienced at the beginning of the last century, with the country's insertion in international markets as a commodities supplier. At the time, and as part of the economic processes resulting from the Industrial Revolution and the emergence of oil (exploration), Argentina integrated into the world through so-called short value chains, of which local agriculture was part by providing raw materials with limited value-added services (financial, local and international transport) or processing (food and fiber), except in a few sectors oriented to the domestic market.

This system helped the nascent republic attract immigrants and capitals to primary production, and to grow. It was soon argued that this alternative would not be enough to absorb a growing urban population. Thus, the agriculture-industry conflict arose as two opposed sectors, without evident feedback between them. Since then, a long pendulum type cycle between *agricultural development* —seen as a "traditional" sector without the capacity to create sufficient employment that had to be commercially neglected and unprotected— and *industrial development* —conceived as "progress"— began. This has been a prevailing perspective for many decades in which priority was given to import substitution as a development strategy.

A bioeconomy vision allows for rethinking the links between agriculture and industry, beyond traditional points of view. *Biologization* of the economy is a growth strategy that crosses all sectors and in which interactions expand, to include a much more complex and strategic set of input-output and intersectoral relations. Modern and competitive industrial development based on biomass and knowledge implies a careful analysis of intersectoral synergies and the search for complementary development alternatives, i.e., a new paradigm for the economic and social development of Argentina based on the creation of genuine competitiveness.

The confluence of factors that define the current way of life (increased demand, climate change, natural resource constraints, beginning of the end of the oil era), coupled with the emergence of biotechnology as an instrument to take better advantage of biological processes, are opening a rearrangement cycle that puts the focus back on the ability to efficiently produce and process biomass.

The challenge for Argentina is not to make the same past mistake of antagonistic intersectoral views, but utilize the new cycle more systemically, advance in the opportunities to integrate agriculture (main source of biomass production, not only in the Humid Pampas) and new industrial bodies, based on the use of biomass to produce bioenergies and bioproducts; and engage in global processes —global bioeconomy— with finished or, at least, intermediate goods resulting from biomass processing. A brief review of what is happening with bioeconomy development around the world reveals that there are three types of situations (Kircher, 2012):

Those with wide availability of natural resources for biomass production and, at the same time, a well-developed and mature industrial, science and technology base (United States, Canada and Russia).

- Those with a well-developed industrial and scientific-technological base but lacking own biomass production of global relevance (the majority of European countries).

- Those with ample actual or potential biomass production and relatively developed scientific-technological systems, but with deficiencies in their industrial capacities (Brazil, Argentina, Malaysia, Colombia and Mexico).
- Argentina is part of this last group in which, clearly, the chance arises from its condition as a large biomass producer (current and potential, both in volume and diversity). The strategic challenge is how to build, on this basis and the existing scientific-technological capacities, the industrial development paths to effectively leverage this potential.

The main areas of insertion are energy and food. The latter has the double opportunity to ensure that the country's productive potential —today conservatively estimated as close to or greater than 50 % of current volumes, achievable within a decade— becomes a reality, so that it remains a strategic component of global food security, while exploiting cascade technologies. These, as in the case of hydrocarbons, produce large product families (food, bioenergy, biomaterials, inputs for industry, etc.) in order to add value to a wide variety of industries, adapt production to the new food demands of increasingly urban populations with specific form, time and space requirements, and be conducive to better environmental performance of products and production processes, incorporating the concept of *circular economy*.

As to energy, in addition to conventional biofuels (ethanol or biodiesel), the opportunity points to the implicit circularity in the bioeconomy and the possibility of turning current costs (disposition of biological waste from industry and urban solid waste) into energy inputs, which not only contribute positively to the country's energy balance, but also represent a source of industrial competitiveness by reducing local energy costs (Golden, & Hanfield, 2014).

Advantages derived from the wide availability of biomass by Argentina are by no means small. Biomass is not a homogeneous category and there are significant differences in the location, energy density and transportability of different types. Also, due to its physical characteristics (essentially large volume) and its low unit price, in most cases it "travels badly" i.e., long distance transportation for processing is not efficient from an economic point of view. All this should be reflected in the regional (bioeconomy) development strategies to be designed for its use and *in situ* value addition. Implementations in this sector require a close location of the raw material for it to be a source of competitiveness in the regions where it is produced and a good starting point for the development of new value chains with wide territorial coverage. These characteristics highlight the regional dimension of the bioeconomy. In this sense, it does not seem appropriate to speak of an Argentine bioeconomy. On the contrary, a bioeconomy will be built as a reflection of what happens in each biomass producing region and the specific paths chosen in each case to optimize the use of and value addition to their natural resources. The type of industries and value chains that are to be promoted to achieve their integral use should consider agroecological conditions (biomass supply), physical and institutional infrastructure, and existing or potential research and development (R&D) capacities (own or network-wise).

Biomass production and scientific-technological capacities as a platform to develop a bioeconomy in Argentina

Biomass production in Argentina

Biomass production as a source of renewable energy

Argentina has very favorable ecological conditions to produce the main sources of biomass that can be employed to obtain various types of bioenergies: woodfuels and agrofuels. In addition, urban waste, which can also be used for bioenergy production, is available.

The main sources of direct biomass supply are native forests and forest plantations, as well as forest and sylvicultural waste, biomass of byproducts from sawmill, cotton, rice, peanut, sugar, herb industries, etc. The quantification of biomass production in Argentina as a source of renewable energy shows that the country's sustainable production from native forests and forest plantations is approximately 193 million tons of dry matter, of which about 143 million tons (equivalent to 42,900 ktoe[1]/year) are physically accessible and potentially available for energy use. To these resources can be added three million tons of woody biomass from sawmill byproducts and the pruning of permanent woody crops, providing a total of 146 million tons of potentially available resources of forest and fruit tree pruning origin. Of this total, it is estimated that 124 million tons (equivalent to 37,200 ktoe/year) come from potentially commercial sources, to which can be added about three million tons if another potentially available non-woody biomass coming from byproducts of sugar, rice, peanut and other agroindustry, is included. It can be affirmed that there is huge potential for unused biomass production, which is available for energy use in the country.

1 Kilotons of oil equivalent.

Agricultural crop production that can be sourced for food or agrofuels

- *Agricultural crops* that can be used for biofuel production. These include sugar and starchy, oilseed and other energy crops. 2010/11 cycle productions of the main crops in Argentina that can be potential sources of biofuel supply are listed in Table 1.
- *Agricultural byproducts* obtained from primary production, such as corn, wheat, soy and other stubble. Three main crops were considered in terms of production volume: soy, corn and wheat. From the 2010/11 grain production, the total biomass produced as stubble was calculated. Out of this, the available volume was estimated (50 % of the total obtained) because it is understood that the rest should remain in the system to be incorporated into the soil and achieve a sustainable cycle, as summarized in Table 1. It is estimated that the total numbers in the table are in the order of 90 % of total grains produced.
- *Animal byproducts* obtained from livestock production, such as manure, chicken bedding, etc. Table 1 shows an estimate of the total annual manure generated by the main livestock activities in medium and large business establishments.
  Another biodiesel production alternative is tallow. Although the national meat industry is large and has a high potential tallow supply, the price of fat, compared to that of soy, is uncompetitive, so this option is not included. Neither were other byproducts obtained from the industrial processing of agricultural raw materials considered because no industries have been found to produce relevant quantities of other byproducts identified as possible raw material for obtaining biofuels, beyond grains and other products already mentioned.
- Urban solid waste. According to the National Observatory of Urban Solid Waste, the provinces of Buenos Aires, the Autonomous City of Buenos Aires, Córdoba and Santa Fe produce 8.2 million tons of urban solid waste (USW) per year. It is estimated that 50 % of USW is organic, resulting in some 4.1 million tons/year of potentially usable waste for energy generation.

Table 1. Potential supply of various sources of biomass in Argentina, 2011*

Sources of biomass for alternative purposes	Unit	Physical volume
1. Woodfuels	Millions of tons of dry base	146.00
2. Agrofood or agrofuels		
Sugar-starch		
Sugarcane	Millions of tons of wet base cane	19.81
Corn	Millions of tons of grain	23.01
Sorghum	Millions of tons of grain	4.46
Oilseeds		
Soy	Millions of tons of grain	48.89
Sunflower	Millions of tons of grain	3.67
Peanut	Millions of tons of grain	0.70
Other (flax, rape)	Millions of tons of grain	0.06
Agricultural byproducts, stubble available	Millions of tons of dry matter	24.44
Animal byproducts, manure available		
Meat cattle	Millions of tons	10.49
Milk cattle	Millions of tons	5.86
Pigs	Millions of tons	2.24
Poultry	Millions of tons	0.13
3. Urban solid waste	Millions of tons of urban solid waste	4.10

Note. Total amounts to 294 million tons, but a line with such total physical volume was not included because it corresponds to non-homogeneous products.
Source: Trigo et al. (2012) and Ministry of Science, Technology and Productive Innovation.

Biotechnology capacities of the Argentine scientific-technological system

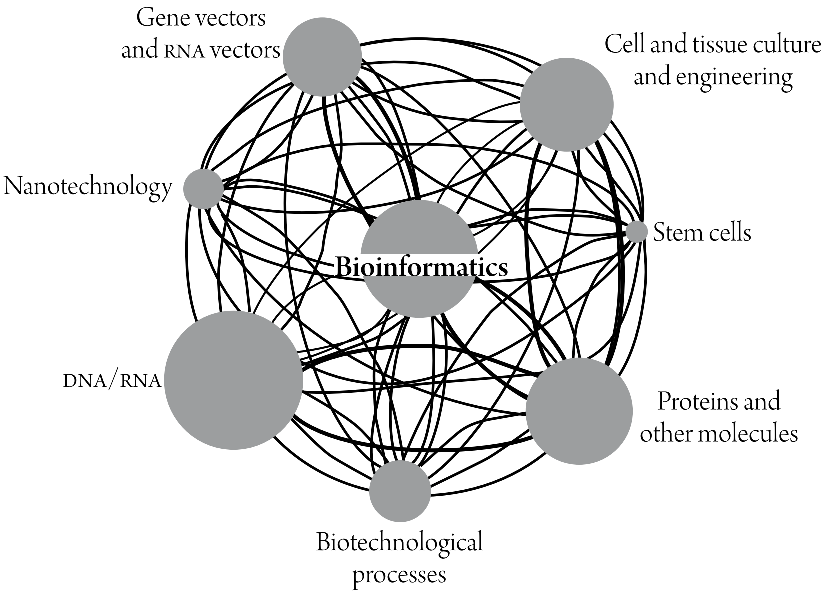
To actively participate in the opportunity offered by bioeconomy, it is not enough to have abundant sources of biomass. It is also necessary to have a human resource structure and a research and development infrastructure, particularly in the field of biotechnology. While it is not the only sector of science and technology involved in the promotion of bioeconomy, it is perhaps the most gravitational in strategic terms. This involves a set of strongly science-based and interdisciplinary technologies, which require huge investments in research, development and innovation (R&D&I) and qualified human resources, both in the public sector and in companies, as well as sophisticated equipment in R&D centers, not limited to research laboratories, but also in relation to the components of scaling up to the commercial stages. Argentina has a valuable precedent: a base of highly qualified human resources in basic sciences (biology, chemistry, etc.), medical sciences and engineering, which are already assisting in the formation of research teams in a broad spectrum of areas of biotechnology.

Various government institutions have designed and implemented policies and programs to support and finance biotechnology. As a result of this political priority, the scientific sector has improved substantially in the last two decades, through increased resources allocated to the programs of the Ministry of Science, Technology and Productive Innovation (MINCYT) and the National Council of Scientific and Technical Research (CONICET), as well as to national universities. In addition, the resources of the Fund for Scientific and Technological Research (FONCYT) and the Argentine Technological Fund (FONTAR), which have been internationally funded (Inter-American Development Bank [IDB] and World Bank), and those from international cooperation, particularly the Biotecsur Project co-financed by the European Union and the Southern Common Market (MERCOSUR), have been quite relevant. For these reasons, the biotechnology capacities of the Argentine scientific-technological system are quite important, mainly the biotechnology research groups at national universities (43 %), Conicet centers (40 %), groups of science and technology agencies (such as the National Institute of Agricultural Technology [INTA] and the National Institute of Industrial Technology [INTI]), non-profit organizations (14 %), and r&d groups in hospitals (3 %).

The most frequent activities are DNA/RNA (86 % of groups), bioinformatics (68 %), cell and tissue culture and engineering (57 %), proteins and other molecules (54 %), gene vectors and RNA vectors (38 %), and biotechnological processes (28 %). Less frequent activities are nanotechnology and stem cell research. Figure 1 shows the complexity of the networks that have been set up, based on the multiple biotechnological techniques simultaneously applied or researched by groups. Generally, there is a high degree of relationship and collaboration among R&D groups for training and information exchange, as well as with science and technology agencies (especially the MINCYT). There is also a high level of cooperation with foreign agencies and institutions (40 % of groups), given the global nature of biotechnology development. There is an interesting critical mass of about 1400 people engaged in biotechnology R&D. Regarding the academic level, it is made up of PhDs (55 %), and the remaining 45 % is made up of bachelor or master degrees. Specialties in exact and natural sciences predominate (63 %), particularly biology and biotechnology.

The second important area is medical sciences (24 %), mainly biochemistry and, to a lesser extent, medicine and pharmacology. Other disciplines are agricultural sciences and fishery (8 %) and engineering and technology (4 %). The main limiting factors for the performance of biotechnology R&D activities are access to equipment and supplies, access to financing, and access to highly qualified human resources.

Figure 1. Networks of biotechnological techniques used by research groups



Note. The size of circles and the width of lines represent relative magnitudes.
Source: Encuesta Nacional de Grupos de Investigación en Biotecnología del MINCYT (2014).

Currently, the main production of r&d groups is in biosciences. However, a significant part of the groups has established relationships with non-profit organizations or entities, which has been highly relevant to the local small- and medium-sized businesses sector. The main activities assessed are R&D project cooperation (39 %), advice, technical assistance and consulting provided by research groups to companies (32 %), joint patents (6 %), information exchange (6 %) and training of human resources at companies (5 %). Some of the main obstacles to greater public-private cooperation include limited demand of companies or non-profit organizations, their lack of knowledge about the activities carried out by R&D groups, groups' lack of awareness of companies' needs, and constraints associated with institution management.

Valuable experiences in Argentine bioeconomy development

The capacities mentioned have already materialized in several achievements, including:

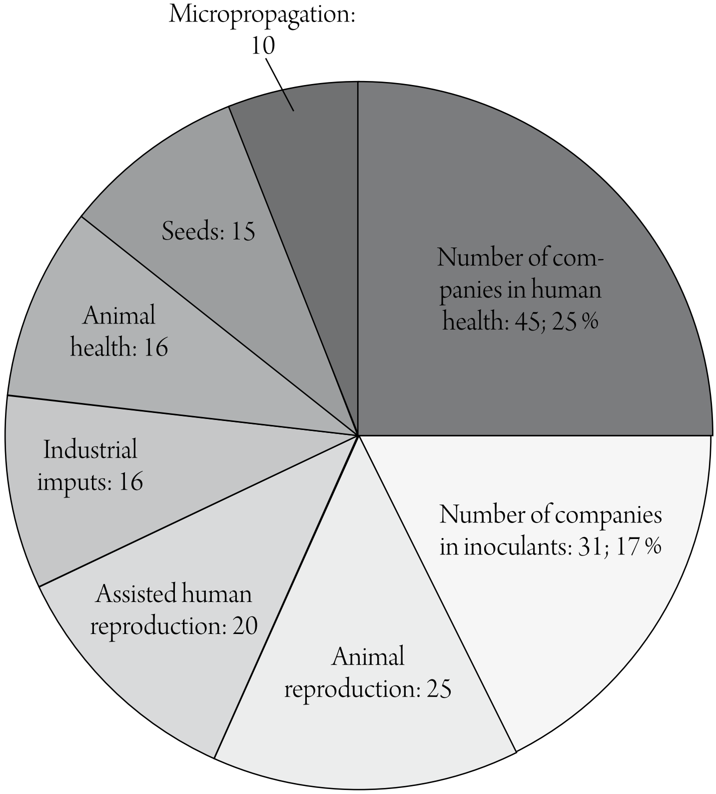
- Development of biotechnology companies in a significant number of sectors.
- Global pioneer in terms of local GMO incorporation and development in grain production and other crops.
- Massive use of environmentally friendly extensive agricultural production systems.
- Dynamism and high potential in the production of vegetable oils, biofuels and biorefinery-derived industrial products.

Development of biotechnology companies

Knowledge-intensive companies, particularly biotechnology ones, are critical to bioeconomy development. Argentina has incipient, but growing small-scale activities within this sector, with a young business structure —a powerful base for future developments if there are promotion policies in place— and a long-term regulatory and macroeconomic stability context. In 2012, some 180 biotechnology companies operated in Argentina (Bisang, 2014). While this is less than the leading countries in this sector, even though it does not substantially differ from the existing ones in Italy (265), Brazil (237) and Israel (233); i.e., Argentina's position is relatively favorable compared to this second group, considering the relevant Gross Domestic Products (GDP) of countries. It is noteworthy that there is a growing presence of Argentine business groups of certain economic importance that will consider substantive business developments in the future based on these technologies. This positioning began more than three decades ago. Towards the 1980s, when the first biotechnological products applied to human health and plant genetics started to appear in the market, Argentina already had some commercial developments using these technologies (microbial enzyme production, micro-propagation, chemical reagents and interferon).

Companies active in 2012 were mainly engaged in the production of seeds, medicines for human use, bioinput development for plant and animal production, vaccines, industrial enzymes, animal reproduction and assisted human fertilization. Figure 2 shows the number of companies in different productive subsectors, identified in 2012. It is estimated that, for 2012, the turnover of biotechnology-related companies (goods and services such as seeds, health and inputs) was in the order of 6600 million dollars, although the turnover of strictly biotechnological activities was about 2100 million dollars.

Figure 2. Number of biotechnology companies in different subsectors



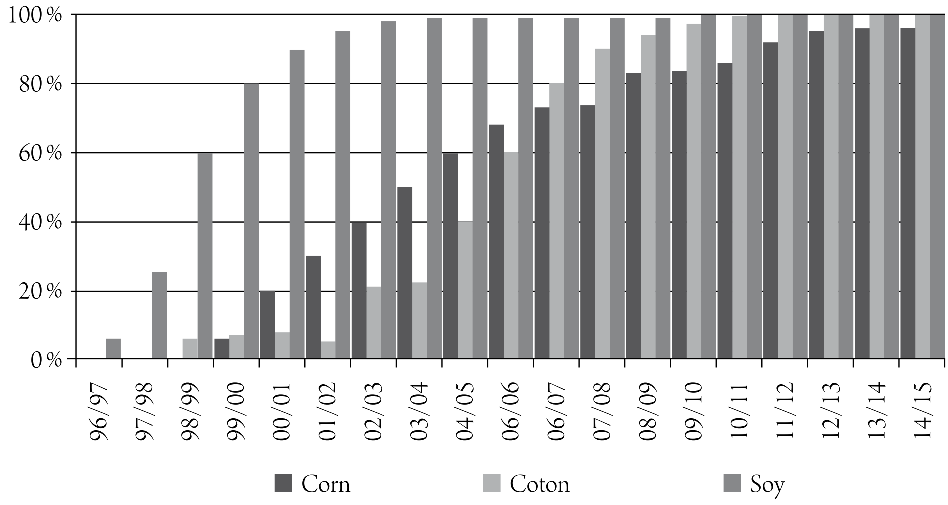
Source: Bisang (2014).

Total human resources employed by companies in biotechnology R&D in 2012 was about 1500. Of this total, 700 professionals were in the seeds sector; 306 in human health; 156 in inoculants, and 125 in animal health. The existence of companies in a wide spectrum of sectors — seeds, micropropagation, bioinputs, health, genetics, human and animal medicines, and industrial inputs (microorganisms and enzymes)— is to be highlighted, given the cross-sectional nature of bioeconomy. From the point of view of strengths and weaknesses, the degree of progress in the seeds sector is a strength, as it allows to anticipate a rapid transfer of scientific advances to biomass production processes. Furthermore, the industrial inputs sector, based on white biotechnology (which uses living organisms or enzymes to obtain degradable products, make changes to improve the efficiency of production processes, and reduce waste associated with industrial production), is perhaps the least developed area, with little local insertion, since most of its activities are for the external market (Bisang, 2014).

Pioneer in mass use and development of genetically modified organisms (GMO) for agricultural production

Argentina is a world leader in the intensive use of transgenics and was a pioneer in its adoption, with an institutional structure for GMO regulation and biosecurity, stressed as an important precedent for Latin America and other developing countries —National Advisory Committee of Agricultural Biotechnology (Conabia), the National Seed Institute (Inase), as well as criteria and requirements, institutional strengthening of INTA in biotechnology, etc.—. After field experimentation and the studies required for commercial release, the marketing of glyphosate-resistant soy was authorized for the 1996/97 cycle. Since then, a large number of transgenic events have been approved for soy, corn and cotton, including stacked events (with several transgenes). The country has 24 years of experience in biosafety and 19 years of experience in the use of transgenic events to produce grains and cotton, as each year more than 20 million hectares are cultivated. This has allowed to achieve significant advances in the efficient use of water and soil, crop management, reduced use of agrochemicals, biological pest control, reduced production costs, increased productivity and reduced soil tillage or non-tillage (Figure 3).

Figure 3. Intensive use of genetically modified organisms in soy, corn and cotton in Argentina (percentage of total cultivated area)



Source: Argenbio (2015). Retrieved from http://www.argenbio.org/adc/uploads/imagenes_doc/planta_stransgenicas/1_Grafico_de_evolucion_de_superficie_cultivada_ogm_en_Arg_en_porcentaje.pdf

Massive use of environmentally friendly production systems (sustainable biomass)

In order to respond to concerns about the gradual deterioration of soils in the Pampa region, the promotion and adoption of a new agricultural paradigm was sought by 1989, initially based on direct seeding for soil conservation, with productive and sustainable agriculture through the rational and smart use of natural resources and technological innovation (sustainable intensification). In Argentina there has been rapid and massive adoption of direct seeding, a system that also includes the use of improved seeds (herbicide-tolerant and insect- and disease-resistant genes), crop rotation, integrated pest control, soil microbiology development, soil structuring and nutrition based on biological inputs complemented by fertilizers, new molecules of agrochemical products, intensive use of information and communication, and more recently, precision agriculture. It is a new agriculture, based on the knowledge provided by the bioeconomy model, including the integration of multiple scientific disciplines (ecology, ecophysiology, genomics, biotechnology, nutrition and protection against biotic and abiotic limitations, information technologies, etc.). Good agricultural practices (GAP) are strategically important because they are the tools to adapt and apply new knowledge to agricultural innovations and a significant contribution to conserving and reducing impact on global warming. Argentina was a pioneer in the creation of a Good Agricultural Practice Network in 2014, comprising of the main public and private institutions in the country and which coordinated institutions' endeavors in training, communication and determination of the scope and measurement of good agricultural practice.

Intense dynamism and high potential in the production of vegetable oils, biofuels and biorefinery-derived products

The cluster of soy, oil and biodiesel production

As mentioned, the supply of raw materials for biodiesel production in Argentina is very high and exceeds local demand, making it the main exporting country of soy oil and cake in the world. More recently, the emergence of the world demand for biodiesel allowed to diversify the purpose of oil production, incorporating this biofuel in the production and export structure of the oilseed chain. This has also led to the production of industrial byproducts in biorefineries. In the last two decades, there has been remarkable growth in the installed capacity for oilseed milling and biodiesel production, for which Argentina has the most modern and largest oil industry in the world and also leads global exports of soy biodiesel. Evolution of the oil processing capacity for biodiesel production in Argentina reached 4.3 million tons of oil per year at the end of 2014, which would allow to supply domestic consumption and the total world trade of biodiesel estimated for 2015. In summary, the soy chain cluster (primary production, grain and oil processing, biodiesel production, export of the complex's products) shows strong international competitiveness, based on production systems, the technology incorporated at all stages, the average size of principal operators, and the location near or at the same ports of export.

In order to calculate the expected evolution of biodiesel production until the end of this decade, various scenarios of evolution of domestic consumption and exports of this product were proposed, and forecasts were made for 2021 in relation to assumptions of high and low levels in demand evolution and Argentine biodiesel production, which are presented in Table 2.

Table 2. Biodiesel production in Argentina (2011 and forecasts for 2021* in millions of tons)

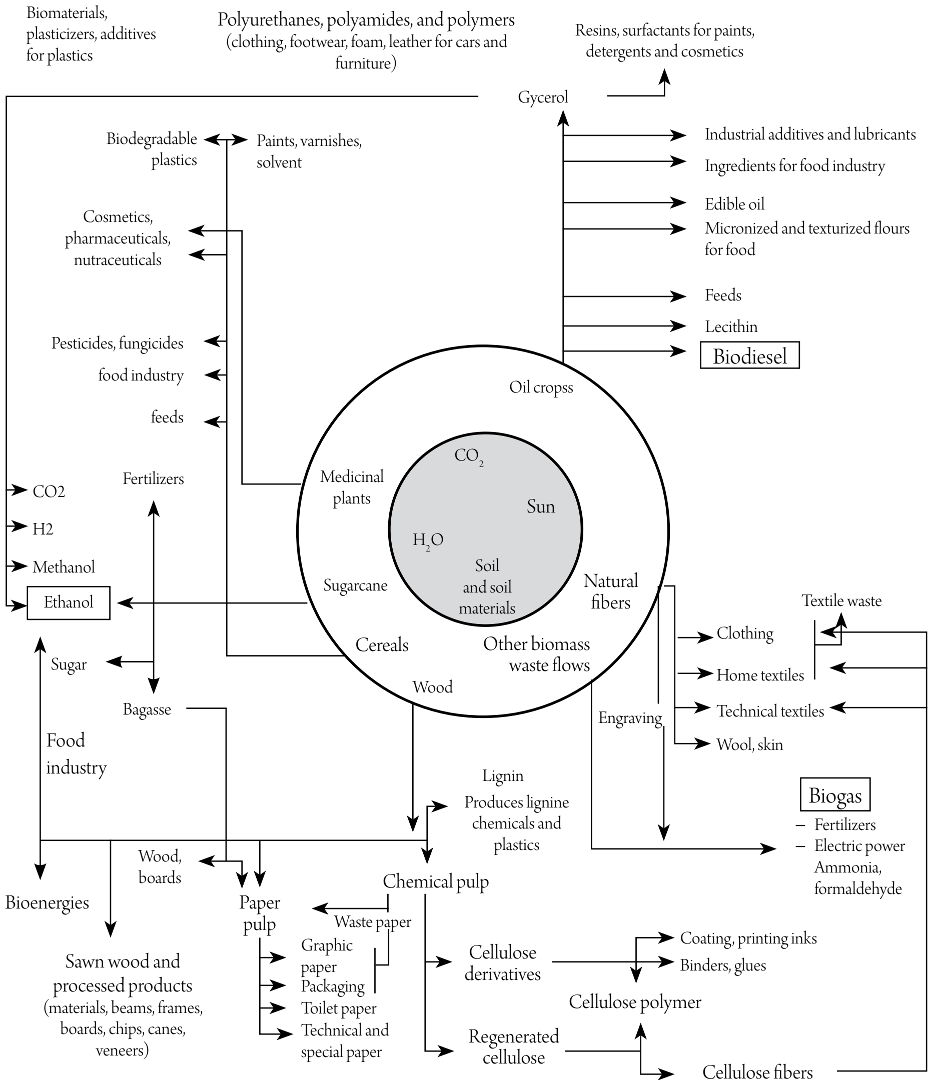
Products	Production 2011	Forecasts 2021	
		Low assumption	High assumption
Biodiesel	2.42	3.92	4.43

* Calculated from the scenarios of evolution of local and international biodiesel demand.
Source: Trigo et al. (2012) and MINCYT.

Potential supply alternatives for industrial products from biorefineries

Due to the great potential of several renewable sources of biomass available in Argentina, it is interesting to outline the development alternatives that can be offered by its processing in biorefineries. Figure 4 shows multiple industrial options based on the processing of the main sources of biomass in Argentina. Industrial bioproducts are extremely valuable alternatives for the local production of inputs for industries that, in many cases, are imported petroleum-derived products.

Figure 4. Alternative industrial uses of biomass in Argentina, 2015



Source: Prepared by the authors.

Other biomaterials and flours that can be produced in the soy chain

In addition to biodiesel and glycerol derivatives, soy milling produces vegetable oils and protein flours that can be used to process into other bioproducts. Vegetable oil gives rise to biodegradable lubricants, surfactants, dyes and various polymers. In addition to fodder for livestock, flour produces protein concentrates, protein isolates and re-fatted, micronized, textured and activated flours. All these products have substantially higher per unit prices than traditional destinations for food and feeds. The enormous current and potential volumes of first soy transformation products could result in far-reaching projects for the industrial making of second and third transformation products, at a scale that would allow for the competitive development of these values added alternatives, in the case of both oil-derived biomaterials and soy flour transformation derivatives.

Alternatives for regional development from corn byproducts

The theoretical potential supply of ethanol from corn processing in Argentina is remarkably high (which could be added that of other similar grains, such as sorghum and other cereals). From the assumption of total utilization of corn production by dry milling, ethanol production could have reached 9300 million liters, and byproducts —distiller's dried grains with soluble (DDGS) and carbon dioxide—, 7.4 million tons each in 2011. The estimates for 2021, assuming the total utilization of corn production for these purposes, would result in the production of 11,700 to 14,000 million liters of ethanol and 9.3 to 11.1 million tons of each byproduct mentioned. The process of investing in corn dry mills producing ethanol and their byproducts has already begun. At the end of 2014, eight plants were operating, with a total installed capacity of over 800,000 cubic meters of ethanol, which would imply about two million tons of corn (as feedstock). The strategic importance of these initiatives, which are mostly located in the interior of the country in areas distant from large urban centers and ports, is not limited to bioethanol production only, but gives rise to regional production models for food (such as dairy and meat), biofuels and bioenergy (from carbon dioxide), and other industrial and small urban center developments.

An estimate of Argentine bioeconomy today

The bioeconomy is not a sector of the economy; it is an industrial strategy that crosses all the economy and includes a great variety of sectors and parts of sectors, traditional and new, which share the concept of the use of biological processes and resources as a central component of their production and service activities (Werny, Coremberg, Costa, Trigo, & Regúnaga, 2015). It proposes a deep transformation in the existing intersectoral relations in the economy, making the concepts *sector* and *value chains* acquire blurry limits, intertwined in an increasingly complex manner, as a result of how the uses of natural resources change; the role of knowledge, capital and work; the creation and collection of externalities; and the distribution of economic benefits from new activities (von Braun, 2013). Traditional value chains lose much of their original meaning with bioeconomy. What can be described as a *value network* emerges, where raw materials are instrumental in different chains, depending on how relationships among demand, technology availability and opportunity costs of resources involved in each particular situation occur.

The industrial strategies of the bioeconomy underline the interrelationships that exist among chains. Instead of looking at an industry, the value chain approach looks at the set of products deriving from a raw material and the fact that raw materials themselves are also substitutable, focusing then on the synergies and how to optimize the interrelationships among chains and the total value created by the system. Within this "network" approach, inefficiencies are highlighted, and opportunities can be identified to improve overall productivity, whether locally, nationally or internationally. In this regard, the potential for recycling and waterfall approaches (cascading) at the processing stage play a determining role in identifying and seizing local value capturing opportunities. The use of waterfall approaches and interrelations among chains are strategic to increase the efficiency of natural resources, provide innovation options and new businesses, and reduce the potential conflict among alternative uses.

This dynamic makes it overly complex to measure the current and potential contribution of bioeconomy to the GDP of countries. Its cross-sectional nature, the type of technological approaches it uses, and the relative newness of bioeconomy in international circles of discussion and implementation of public policies have a hand in the current absence of a standard methodology to know exactly what its share in GDP is and compare it with other economies. Nevertheless, it is possible to advance by defining the products, inputs and activities that will be included as components of bioeconomy. In the case of Argentina, the share of bioeconomy in GDP was estimated from the activities that meet the following criteria:

- Use biomass as an input.
- Incorporate biotechnology as an input.
- All products use biomass and biotechnology as an input.

In other words, the adopted definition of bioeconomy encompasses the production of renewable biological resources and their transformation into food, fodder, bio-based products and bioenergy. It includes agriculture, forestry and fishery, food production and pulp and paper production, as well as parts of the textile, chemical, energy and biotechnology (pharmaceutical) industries. According to these definitions and an estimation methodology prepared specifically for this purpose, Werny et al. (2015) estimated that in 2012 the Argentine bioeconomy represented 15.4 % of GDP. Its value added amounted to approximately US$72,600 million. This share in GDP represents a higher figure than the estimate for agriculture and the agroindustrial sector, as it incorporates other manufacturing sectors. It should be clarified that this estimate does not include the set of machinery and equipment used to make bioproducts, nor the services and logistics emerging from these sectors of economic activity.

Estimated data are summarized in Table 3. It can be noted that the primary sector has the largest share in the total value added of bioeconomy, with 58 % (8.9 % of GDP), and the remaining 42 % corresponds to the manufacturing industry (6.5 % of GDP). Also, not all the industrial value added is created by the manufacturing of agricultural origin (MOA) sectors; they produce 72 % of the total value added in the bioindustry and the manufacturing of industrial origin (MOI) branches represent 28 %.

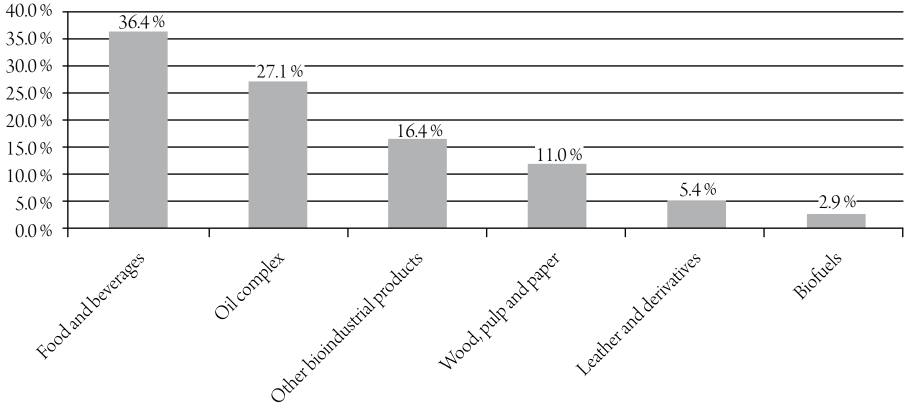
Table 3. Share of sectors comprising bioeconomy in GDP in 2012*

Sector	Bio-value added			Bio-share in GDP (%)
	Millions of Argentine pesos	Millions of US dollars	Share (%)	
Primary bio	191,525	42,086	58	8.9
Bio-manufacturing industry	139,149	30,577	42	6.5
– Manufacturing of agricultural origin	100,300	22,040	30	4.7
– Manufacturing of industrial origin	38,849	8,537	12	1.8
Total bio-sectors	330,639	72,663	100	15.4

Source: Prepared by the authors.

In some fields, it is assumed that biofuels are the entire bioeconomy. However, this work shows that biofuels in Argentina provide only 3 % of the total bioindustry. Biofuels from cereals and oilseeds represent 79.5 % of this subtotal; bioethanol from sugarcane, 12 %; and biogas, the remaining 8.5 %. A considerable percentage of the total bio-industrial value added (97 %) is created outside the biofuels sector. This set of other products and activities is extremely heterogeneous; out of it, 27 industrial activities accumulate 83.7 % of the bio- value added. Adding together the main productive blocks, the primary bioindustrial activity corresponds to food and beverages (36.4 %), followed by the oil complex (27.1 %), other bioindustrial products (16.4 %), the wood, pulp and paper complex (11.9 %), leather and its derivatives (5.4 %), and biofuels (3 %) (Figure 5).

Figure 5. Percentage share of the main subsectors in the value added of bioindustrial activities, 2012*



* Value added at producer prices.
Source: Werny et al. (2015).

Final reflections: Issues to be considered regarding a national strategy to develop the Argentine bioeconomy

The opportunities offered by the bioeconomy to Argentina are momentous and will increase significantly in the coming decades, associated with the expected evolution of the food market and other traditional products, with increased population and income and their impact on the change of diets and food preferences. The expansion will also be encouraged by new demands for industrial goods and services, which emerge strongly given the interest in care for natural resources and the necessary minimization of the effects of economic activity on climate change.

While Argentina has certain weaknesses associated with its degree of industrial development, infrastructure and average competitiveness, it also has advantages based on its wide range of biomass supply, both territorially and in the diversity of its origins. Its strengths in the scientific-technological field and private institutions around the agroindustrial sector are also leverage factors to enhance development strategies.

The available experiences suggest that the bioeconomy not only demands a new knowledge base, but also implies broader changes in the form of social and economic organization and in the behavior of individual economic actors in various aspects, such as investment allocation and production decisions, consumer preferences, etc. It is necessary to contemplate all the features of the policies and regulations that help to promote and guide new processes, as well as to manage the transition costs involved in the transition from the old to the new environmentally friendly and, thus, sustainable economy.

A new bioeconomy-based economic and social development strategy requires an action plan that coordinates the activities of the public sector with a comprehensive view of the dimensions (macroeconomic, tax, commercial, agricultural, industrial, scientific-technological) of public policies and to foster the efforts of the private sector to consolidate the sustained growth in employment and production in a way that is environmentally friendly and advances Argentina's competitive insertion in the global economy.

A relevant factor that has limited Argentine industrial development has been the lack of convergence of investments and access to credit due to the absence of a sound and stable macroeconomy over time, which is a necessary condition to have inflation rates (stay) in line with the world average levels. In this sense, prudent, sustainable and countercyclical tax behavior, as well as its active coordination with the monetary and exchange administration, is a priority to enable tax schemes that stimulate production without neglecting the required resources for the state.

Beyond the general issues mentioned, there is a set of specific themes that need to be addressed explicitly, including society's acceptance and awareness of the advantages and consequences of the new bioeconomy-based development strategy, the new knowledge base needed, human resources, legislation and regulatory frameworks, financing mechanisms, and infrastructure required for an effective transition towards a new way of economic organization.

The progress of the bioeconomy in the world is due to the availability of a new knowledge base, which in each case allows to solve the values in the equation of producing "more with less" (the same with less or more with the same) implicit in the concept of bioeconomy. In this regard, some questions that should be explored include: Given the type of available resources and existing capacities, what are the new disciplines and specific research priorities to be promoted? What are the most effective policy instruments to bolster the type of R&D&I activities required, particularly to support networks and consortia composed of multiple actors of networks and value chains? What are the international relationships that should be strengthened and the most effective mechanisms to enter the global knowledge network in priority disciplines from the perspective of Argentine bioeconomy? What instruments and incentives are necessary to advance better coordination between the public and private sectors?

The number and variety of questions for the implementation of the bioeconomy is large, which proves the need to define a roadmap to address and build a comprehensive economic and social development strategy. The opportunities and implications that it may have for the future of Argentina are of paramount importance and can lead to a profound change in the country's progress path, the organization of society and its international insertion, based on the knowledge economy applied to the efficient and sustainable use of natural resources. These constitute one of the highly significant assets to pivot long-term bioeconomy-based development: a knowledge economy that will lead to the creation of high-quality jobs.

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Bioeconomy in Brazil: Overview

Antonio G. Oliveira*

Introduction

In the coming decades, the world will meet several challenges caused by demographic and climate changes that are already perceived. The United Nations Food and Agriculture Organization (FAO) estimates that the world will house some 9.7 billion inhabitants by 2050. This population growth, coupled with continuous urbanization processes, involves an increased demand for energy, water and food in the order of 35, 55 and 70 %, respectively, based on 2005 values.

Given this scenario, Brazil intends to remain at the forefront of the use of renewable energy sources. Currently, it has one of the cleanest energy matrices on the planet: 39 % of the energy consumed in Brazil comes from renewable sources, while the world average is 14 %. Regarding bioenergy, sugarcane products are the most commonly used source since it supplies 16 % of the energy consumed in the country, mainly in the form of ethanol for transport and bagasse for boiler combustion (Empresa de Pesquisa Energética [EPE], 2015a).

Nonetheless, with the commitments that Brazil took on worldwide at the Climate Change Conference (COP-21), for a country of continental dimensions such as Brazil, it is imperative that these matters also meet the need for ecosystem preservation and recovery. The reduction of natural resources and environmental pollution should be priority issues in the new productive strategies. In this context, bioeconomy emerges as a new economic paradigm to contribute to resolving part of global crises.

Public policies and their contribution to biofuels in Brazil

Although Brazil still does not have an exclusive strategy for bioeconomy, it has been implemented through bioenergy in the last 40 years, with aggressive policies to accelerate the development and use of ethanol and biodiesel as fuels (EPE, 2007, 2014, 2015b). The following

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sections highlight the major market demand policies (market pull [MP] and technology push [TP]) applied in Brazil.

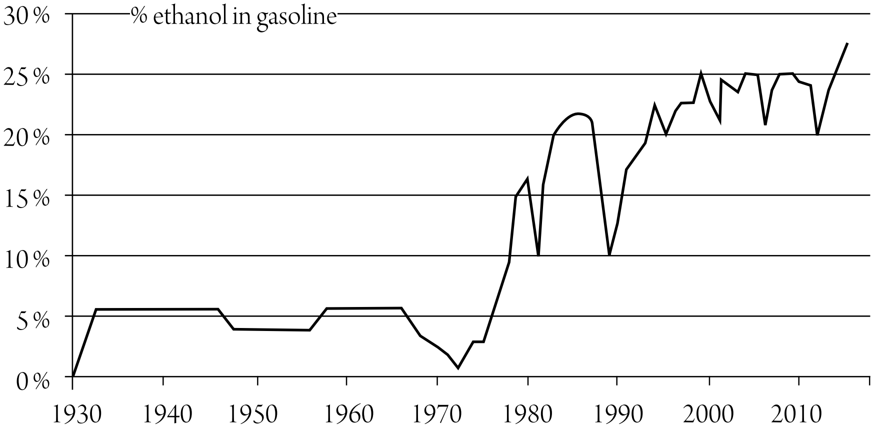
Market demand policies

Pro-Alcohol

Since the 1930s, Brazil has begun to implement the requirement to mix ethanol and gasoline for running cars and motorcycles (Centro de Gestão e Estudos Estratégicos [CGEE], 2015; CGEE-Unicamp, 2009). Ethanol production and use was accelerated when the Brazilian government created the National Alcohol Program (Pro-Alcohol) in 1975 and increased the ethanol-gasoline mixture requirement from 5 to 15 % (Rosillo-Calle & Cortez, 1998). The mandatory use of this mixture is one of the fundamental factors that promoted the ethanol market and related areas.

The minimum and maximum values of the mixture are gradually increasing and, at present, the requirement is a minimum of 18 % (E18) and a maximum of 27 % ethanol (E27) in gasoline (CGEE, 2017). Figure 1 shows how the annual average of ethanol-gasoline mixture is rising. There is an impact on the fleet of light vehicles because today more than 90 % of new cars in Brazil are flex-fuel, i.e., they are capable of running on any amount of ethanol mixed with gasoline or, even, only on ethanol.

Figure 1. Annual average of ethanol-gasoline mixture for vehicles



Source: Taken from Centro de Gestão e Estudos Estratégicos (2017, p. 27).

As a result, the Brazilian ethanol production has increased annually, reaching 28,000 million liters in 2016 and placing the country second in the world ranking of major producers, after the United States (Table 1).

Table 1. Annual ethanol production and production estimate for 2022 (trillion liters)

Country	Feedstock and Fuel	2016	2022 main	2022 acc.	Brief explanation of accelerated case
United States	C ethanol	57.9	60.4	62.0	Higher exports; increased E15 and E85 uptake; integrated technologies to increase output.
Brazil	SC ethanol	28.1	34.5	38.0	Concrete measures to deliver investment in RenovaBio plan; low levels of lost capacity.
European Union	MF ethanol	4.3	5.3	6.6	Roll-out of E10 to new member states; no scalene-down post 2020 in finalised RED update.
China	C ethanol	2.6	3.8	5.0	13th FYP target met, feedstock diversification, measures to simulate investment.
Thailand	MF ethanol	1.2	2.2	2.7	Higher E20 and E85 uptake via fuel infrastructure roll-out; growing cassava feedstock availability.
India	M ethanol	1.1	1.9	3.0	Mitigating inter-state logistical barriers; broadening feedstock base beyond molasses.
Argentina	MF ethanol	0.9	1.2	2.1	Mandate increase to 26%; investment to scale up com etanol capacity; FFV roll-out.
Philippines	SC ethanol	0.2	0.4	0.6	5% mandate achieved; switch from industrial to fuel etanol output; increased cane planting.
Additional fuel etanol production in 2022				10.3	

Notes: C = corn; SC = sugar cane, MF = mixed feedstocks; M = molosses.
Source: International Energy Agency (2017).

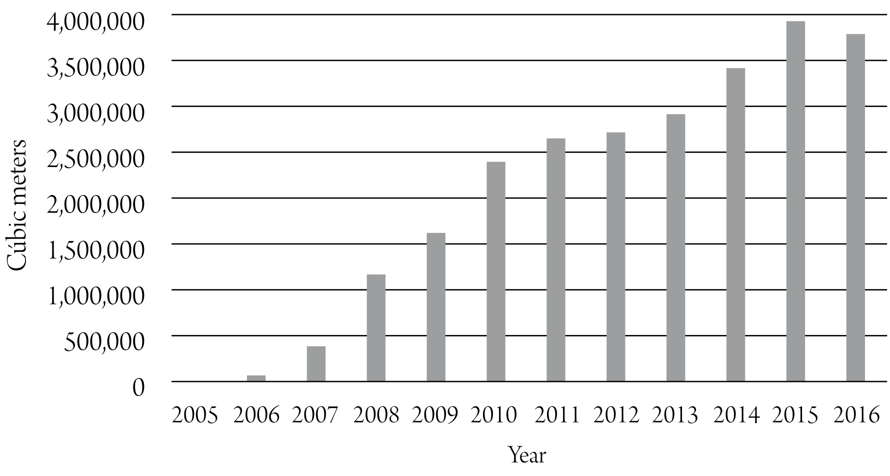
National Biodiesel Production and Use Program (PNPB)

The first records of Brazil's interest in biodiesel date back to the 1920s, when the National Institute of Technology experimented with alternative and renewable fuels; however, only after the oil crisis in the 1970s, the first major government initiative to stimulate biodiesel, called Pro-Aceite (Vegetable Oil Production Plan for Energy Purposes) emerged. The plan had audacious objectives, such as to generate vegetable oil surpluses that made its production costs competitive with oil, and the subsequent goal of mixing 30 % vegetable oil with diesel oil, with the intention of replacing it in the long term. But, with the oil price fall, the plan was abandoned in 1986.

Subsequently, several biodiesel incentive programs were started and left aside over time. For biodiesel to follow a different course in Brazil, it was necessary to take into account not only economic factors, but also some social and environmental concerns associated with the prospect of the depletion of world oil reserves, increasingly scarce and expensive. In order to reduce dependence on imported diesel to cover the balance deficit and promote social inclusion, the PNPB was established in 2003 (Ministério de Minas e Energia do Brasil, 2004). Regulations derived from it, made the biodiesel-diesel mixture mandatory. Currently, the mixture contains 8 % biodiesel (B8), and a law was enacted that requires the change to B9 by March 2018 and to B10 by 2019 (Lei 13,263, 2016).

Since the implementation of the requirement, Brazilian biodiesel production has increased to 3.8 million cubic meters in 2016 (Figure 2), placing Brazil among the three largest world producers (Table 1).

Figure 2. Annual biodiesel production in Brazil



Source: Prepared by the author based on the analysis above mentioned.

Table 2. Annual biodiesel production and production estimate for 2022 (trillion liters)

Country	Feedstock and Fuel	2016	2022 main	2022 acc.	Brief explanation of accelerated case
United States	MF Biodiesel/ MF HVO	5.9	7.4	9.0	Increase in HVO capacity; switch to producer tax credit; continuation of RFS2 support.
Brazil	SB biodiesel	3.8	5.0	6.2	Stronger diesel demand growth; higher B20 consumption in fleets and public transport.
European Union	MF biodiesel	13.5	13.4	16	Further HVO refinery conversion projects; no scale-down post 2020 in finalised RED update.
China	WR biodiesel	0.9	1.7	2.2	13th FYP target met; mobilise waste and residue feedstocks; new provincial mandates.
India	WR biodiesel	0.0	0.2	1.5	Formatisation of B5 mandate and roll-out of blending programme; use in rail transport.
Indonesia	PO biodiesel	2.8	5.3	8.5	Lowering underutilised capcity; ongoing exports and fully enforced B20 mandate.
Malaysia	PO biodiesel	0.9	1.3	1.8	Move to B15 as outlined in 11th Malaysia plan; ongoing consultation with motor vehicle OEMS.
Argentina	SB biodiesel	3.0	2.5	3.5	Improved export prospects with United States and European Union, as well as new markets.
Singapore	MF HVO	1.1	1.1	1.4	New HVO capacity and debottlenecking of corrente production capacity to increase output.
Additional biodiesel and HVO production in 2022				11.2	

Source: International Energy Agency (2017).

RenovaBio: A new framework in the fuel policy

RenovaBio is a state policy for decarbonization of transport that enters into force in 2019, in line with the commitments that Brazil took on worldwide at the Climate Change Conference. The policy aims to add value to national biofuels, provide energy security, improve air quality in large cities, and encourage technological innovation as well as other benefits.

Unlike traditional measures, RenovaBio does not propose the creation of a carbon tax, subsidies, presumptive credit or volumetric provisions for the addition of biofuels to fuels. The program will operate with two instruments:

1. Definition of national emission reduction goals for the fuel matrix for a period of ten years. National goals will be broken down into individual goals annually for fuel distributors, according to their share in the fossil fuel market.
2. Certification of the biofuel production by assigning different data to each producer, in value inversely proportional to the carbon intensity of the biofuel produced. The note will accurately reflect the individual contribution of each producing agent to mitigate a specific amount of greenhouse gases in relation to its fossil substitute (in terms of tons of carbon dioxide equivalent or CO_2).

The connection between these two instruments will be established by the decarbonization credit for biofuels (CBIO), which will be a financial asset traded on the stock exchange and issued by the biofuel producer from its marketing (invoicing). Fuel distributors should achieve the goal by proving holding of the CBIO in their portfolio.

This model adds value to low-carbon fuels, such as ethanol, biodiesel, biokerosene and biogas. It is expected that 1.4 million new jobs will be created by 2030, associated with ethanol and biodiesel production, and that 500 billion dollars will be invested in expanding the biofuel supply.

Technology Push Policies

The main biofuel incentive policies in Brazil are market demand policies (MP, Pro-Alcohol, PNPB and RenovaBio); however, a series of national technology push policies have also contributed to advancing the Brazilian capacity for biofuel production, especially to increasing efficiency in scientific and technological production processes.

Support Plan for the Industrial Technological Development of the Sucroenergy and Sucrochemistry Sectors (PAISS)

It can be said that, in Brazil, the closest experience of investment policies in bioeconomy was an edition of the Support Plan for the Industrial Technological Development of the Sucroenergy and Sucrochemistry Sectors (PAISS), launched by a joint venture between the Development Bank of Brazil (BNDES) and the Financiadora de Innovação e Pesquisa (Finep) in 2010. This plan was a response to the diagnosis that support programs for these sectors in the country were characterized by very poor coordination among public agencies in promotion and support activities with public resources, in addition to the low amount of resources allocated.

The PAISS plan intended to identify business plans and encourage innovative projects that considered the development, production and marketing of new industrial technologies for biomass processing (2G ethanol and new products) from sugarcane, innovating in the organization of biofuel and bioproducts projects in the same program. According to the BNDES biofuels area, PAISS offered resources in the order of one billion reais in 2014, to be applied in the 2011-2014 period.

Bioenergy research program

The Research Support Foundation of the State of São Paulo (FAPESP) launched in 2008 the Bioenergy Research Program (BIOEN), whose objective is to stimulate and coordinate research and development (R&D) activities using academic and industrial laboratories to promote the advancement of knowledge and its application in bioenergy production-related areas in Brazil. To achieve this goal, BIOEN seeks to:

- Increase sugarcane productivity through innovative research;
- Evaluate and find ways to reduce the environmental and socioeconomic impacts of bioenergy production; and
- Generate knowledge that ensures Brazil's leading position in bioenergy research and production.

The BIOEN R&D areas are divided into pivotal elements composed of five divisions:

- Biomass for bioenergy (focused on sugarcane).
- Biofuel manufacturing process.
- Biorefineries and alcohol chemistry.
- Ethanol applications for automotive engines: internal combustion engines and fuel cells.
- Research into socioeconomic, environmental and land use impacts.

BIOEN aims to articulate public and private research using academic and business laboratories to generate and apply knowledge related to ethanol production in Brazil. The program includes a solid base of academic exploratory research in connection with the aforementioned divisions. These activities are expected to create new knowledge and develop highly qualified human resources, essential to improve the industrial capacity in ethanol-oriented technologies and increasing internal and external competitiveness.

BIOEN includes academic research, and when deemed appropriate, establishes partnerships for the development of cooperative research activities between universities/research institutes in the state of São Paulo and companies, sharing human, material and financial resources. In these partnerships, the specific details of the topics of interest are specified in accordance with the private partner's interests and the FAPESP's commitments in relation to research promotion in the state of São Paulo. Other agencies, both from the federal government and from other states, also participate in BIOEN-FAPESP.

Until 2016, the program received a financial contribution of around 200 million US dollars from the government (including state universities and research institutes), as well as the investment of private initiatives in the form of co-financing. Until 2017, the portfolio of BIOEN projects included proposals with private companies, such as Braskem, ETH Bioenergía, Mahle Metal Leve, Microsoft Research, Oxiteno, PSA Peugeot Citroën de Brasil and Vale. Other important partners of the program include BBSRC, the European Union, BE-Basic Consorcium, Boeing, Dedini, Oak Ridge National Laboratory and United Kingdom research councils. Fapesp also supports research in smaller companies linked to BIOEN strategic areas. Approximately 15 % of the funds received by the program are allocated to associations with small entrepreneurs.

Action plan for science, technology and innovation in bioeconomy

Although there is still no explicit national bioeconomy policy in Brazil, several initiatives —sometimes overlapping and independent— are being carried out in an uncoordinated manner, but certainly contributing to the progress of this area in the country. These initiatives take the form of international collaborations, R&D&I projects, studies and publications, training and knowledge dissemination, actions to defend interests, among others.

In order to articulate the integration of various efforts to promote bioeconomy in Brazil, the Ministry of Science, Technology, Innovation and Communications (MCTIC) formulated the Action Plan for Science, Technology and Innovation in Bioeconomy (PACTI Bioeconomía) given that, in Brazil's National Science, Technology and Innovation Strategy 2016-2019, bioeconomy is one of the strategic areas. The Action Plan intends to produce and apply scientific and technological knowledge for the promotion of social, economic and environmental benefits in order to bridge essential knowledge gaps, foster innovation and provide conditions for the strategic insertion of the Brazilian bioeconomy within the global scenario.

The plan has thematic lines defined according to the productive logic of bioindustries, which are divided into three central lines and a cross-sectional one:

- Biomass
- Processing and biorefineries
- Bioproducts
- Brazilian Observatory of Bioeconomy

Challenges and opportunities for the Brazilian bioeconomy

Despite the long history of investment in production and use of biofuels in Brazil (ethanol since 1930 and biodiesel at the beginning of the 21st century), there have been technical difficulties: ethanol, in particular, encountered a technical development barrier of current processes. Ethanol produced in Brazil is first generation (E1G), which uses only sugarcane juice to produce it by fermentation. E1G technology has a production capacity of 6800 liters per hectare and could reach a maximum of 8500 liters per hectare in 2015. This barrier compromises the reduction of ethanol prices to compete with gasoline.

Brazil is facing the challenge of overcoming this technological barrier with investments in second generation ethanol (E2G) technologies. In this process, ethanol is obtained not only from sugarcane juice, but also from bagasse, which has the potential to increase production to 24,800 liters per hectare by 2025 (Centro de Gestão e Estudos Estratégicos, 2017). These investments include the creation of the National Bioethanol Technology Laboratory and the financing of four E2G production plants; three on a commercial scale and one on a demonstration scale. In any case, the price of E2G has not reached competitive levels yet.

In order to transform E2G production into a competitive process, a series of investments in two policy approaches for technological advances, TP and MP, are required. For TP, it is necessary to invest in the development of more demonstration plants, mainly to solve the limitations in biomass pretreatment and processing, as well as the need of the development of national enzymes for these processes. With regard to MP demand, policies can be formulated to guarantee increased demand by means of public purchases and the requirement for mixing E2G with gasoline. Another MP policy that can be applied is to promote tax incentives and feed-in tariffs.

Application of the PACTI Bioeconomía may be necessary to coordinate all technology development measures for both TP stimulation and MP demand that are underway in order to reduce the production costs of these biofuels. Additionally, the technological development associated with biofuel production may cause several advances and changes, particularly in regard to chemical production from renewable raw materials.

Brazil: Associative production system models. Alimergia: integrated food, environment and energy production

Harold Patino,* Marcelo Leal** and Bernardo Ospina***

Introduction

One of the major current debates in the world is about the relationship between humanity, and the environment and, as a direct consequence, the relations among society, socio-economic development and the use of fossil fuels. One of the available alternatives is biofuel production; however, in the current agricultural production model, this alternative is not sustainable because it contributes to reducing food supply and increasing social and environmental impacts.

In Brazil, organized farmers, through the Small Farmers Movement (MPA), have actively taken part in this and other debates on how to produce food and energy while respecting the environment. However, the class struggle, contradictions and form of organization of society today are quite different and more complex than those to which farmers were used to. This complexity is partly because, following the Green Revolution in the 1970s, the technological agricultural development model of agribusiness was transferred directly to growers' production systems.

In this scenario, it is important to highlight the important role of peasant agriculture in food production. According to data from the last agricultural census conducted in Brazil (2005-2006), published by the Brazilian Institute of Geography and Statistics (IBGE) in 2009, about 70 % of the food on the tables of Brazilian people comes from peasant or family agriculture. In response to all these apparent challenges and contradictions, MPA proposes, together with its grassroots, to build a new conception of production systems based on integrated food, environment and energy production (Alimergia).

Competition between energy production and food production is one of the main contradictions and controversies on renewable energy production since the current system is built

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on monocultures which are highly dependent on the use of agrochemicals and the international market. This model is not suitable for the peasant population because it makes them dependent on multinationals and international capital. However, in peasant systems, energy production can be associated with food production through diversified areas, such as agroforestry, in which waste from energy production (bagasse and by-products cakes) are used in animal production and incorporated into the soil as organic fertilizer. These combined systems guarantee food and energy supply for society and can help to change the entry routes of agricultural production inputs.

Alimergia is the combination of three words that have overly broad concepts and are directly related to our life: food, environment and energy. It is a new form of existing relations in production systems, in which livestock breeding, agriculture and the environment interact in a synergic way through arrangements that ensure the production of green, healthy food and clean energy. Alimergia seeks to promote people's food and energy sovereignty in an integrated manner and in harmony with local ecosystems, by means of ecological-based agricultural and livestock systems. It is not only a concept that aims to unite, in a comprehensive system, food, energy and the environment, but also a proposed new paradigm required to face the challenges and objective needs of society and the survival of life in the biosphere.

Background

The MPA emerged in 1996, in the state of Rio Grande do Sul, Brazil, as an alternative organization of peasant families, many of which were affected by a severe drought that destroyed much of their agricultural production. Families that produced food in a diversified way in their small properties began to mobilize to seek better living conditions in the countryside given that the export model of Brazilian agriculture left them aside from public investment. In the same period, peasant families in the states of Rondonia, Espírito Santo and Santa Catarina were already discussing a different way of organizing because their union representations, such as the Landless Workers' Movement (MST) and the Pastoral Land Commission (CPT) were no longer responding to the needs of the peasantry.

The MPA is a national and popular peasant mass movement consisting of groups of peasant families whose main objective is to guarantee the Brazilian people's food sovereignty, the recovery of peasant culture and identity, and the respect for regional diversities. The MPA is part of the Vía Campesina, the international organization of peasant movements, which fights, along with other movements and sectors of society, for a popular project for Brazil. It currently operates in 17 of the 20 Brazilian states. The main role of the MPA is to devise strategies for the participation of peasants in biofuel production and consumption systems. The concepts of

Alimergia and peasant production systems are proposed by the movement and lay the foundations for the design of projects in cooperatives.

Within this organizational structure, the Cooperativa Mista dos Fumicultores do Brasil Ltda. (Cooperfumos) and the Cooperativa Mista De Produção Industrialização e Comercialização de Biocombustiveis do Brasil Ltda. (Cooperbio) were created in the state of Rio Grande do Sul.

Cooperativa Mista dos Fumicultores do Brasil Ltda.

Cooperfumos was created in 2004 by the MPA in the state of Rio Grande do Sul (MPA-RS), in the city of Santa Cruz do Sul, with the aim of articulate the diversification of agricultural production in small tobacco producing farms and as a mechanism to combat the rapid growth of tobacco companies. This city was selected for being the headquarters of large multinational tobacco companies. Currently, Cooperfumos brings together about twelve thousand members, distributed among tobacco producing peasants and other peasants. Since its foundation, Cooperfumos has been developing several projects to diversify and improve the conditions of agricultural production, strengthen social organizations, and improve the living conditions of peasant men and women.

In 2008, Cooperfumos initiated an integrated food and bioenergy production project in partnership with the Brazilian Petroleum Company (Petrobras) and other institutions. The San Francisco Food, Environment and Energy Training Center, which opened in mid-2009, was built as part of the project. For its construction, the Mayor of the municipality of Santa Cruz do Sul donated an area of 41 hectares, located on the road ERS 412, kilometer 18.

The San Francisco de Asís Peasant Production and Training Center, established to look for ways to diversify tobacco cultivation, is today a focal point for sharing and disseminating theoretical and practical experiences on fuels, from the perspective of peasants' food and energy self-sufficiency, based on agroecological production. In addition, it offers concrete alternatives to facilitate the production, processing and marketing of products obtained in its members' properties. The center works comprehensively on four areas: food production, energy production, agroprocesses and training.

In food production, Voisin's Rational Grazing (VRG) is used in the agro-silvo-pastoral integration system for milk and meat cattle production. Animals have at their disposal mini-distillery co-products (vinasse and bagasse) and the tips of sugarcane for their feeding. There is also an organic vegetable garden that produces vegetables used as food by farmers who participate in the training courses. This orchard is integrated with Creole pigs and chickens for the internal consumption of the complex. There is also a fruit orchard with several species, especially native. Within forestry, the center works on high density tree planting as a source of wood and timber for boilers, using species such as bracatinga (*Mimosa scabrella*) and acacia (*Acacia* spp.). It also works with agroforestry systems using species such as tung (*Vernicia fordii*), jatropha (*Jatropha curcas*), walnut tree (*Juglans regia*) and leucaena (*Leucaena leucocephala*), together with bean, cassava, sweet potato, pumpkin, corn, flaxseed, sunflower, sesame, peanut, sugarcane, sweet sorghum, castor bean, pea, bean, jack bean, pigeon pea, watermelon and oat crops.

The center has a Creole Seed House, which has more than 120 cultivars among the species and varieties in the multiplication phase for subsequent distribution to peasant families. A small medicinal garden has also been implemented for preparing popular infusions and folk remedies, as well as phytotherapeutic products, based on plants that have well-known medicinal properties such as mint, fennel, lemon balm, basil, chamomile, rosemary, aloe, gorse and boldo. The objective of this garden is to provide seedlings of medicinal species to family farmers enrolled in the MPA and Cooperfumos and others who visit the Center.

In biofuel production, the center has an alcohol micro-distillery with the necessary equipment for all stages of sugarcane and sweet sorghum production and processing and for high density tree planting, with good calorific potential to meet the need for wood as an energy source of the boiler. In addition to ethanol production, sugarcane and sweet sorghum byproducts are transformed into brown sugar, honey and brandy. Regarding biofuels, the center also has a biodiesel production micro-plant, which is currently processing leftover frying oils collected from cities in the region —thus contributing to recycling this waste whose management is problematic for restaurants and kitchens—. Both ethanol and biodiesel are used in the cooperative's tractors and trucks.

In agroprocesses (grain storage, drying, processing and distribution), the center has grain storage silos, a vegetable oil extraction unit to supply the biodiesel industry and support the edible vegetable oil agroindustry project. Based on the vegetable oil extraction unit, the organic fertilizer factory and the balanced feed factory are being installed, taking advantage of byproducts, adding value and supplying inputs to farmers at lower cost and with differentiated quality. These initiatives are part of the vision to help farmers to overcome dependence on fossil fuels and start the agroecological transition in productive systems.

The vocational training center is a building that follows the principles of bioconstruction, with accommodation in the form of housing replicable in rural communities, with techniques known as superadobe and straw-earth. In this place there is space for offices, meeting room, auditorium, cafeteria and kitchen, which are used for the education and training of peasant men and women.

Cooperativa Mista De Produção Industrialização e Comercialização de Biocombustiveis do Brasil Ltda.

Founded in 2005, Cooperbio currently has more than 2000 members in the northwest region of Rio Grande do Sul and has offices in the municipalities of Seberi and Frederico Westphalen. The objective of Cooperbio is to develop peasant production systems that integrate food production with renewable energy and environmental preservation. For this, the cooperative intervenes in the agricultural production and agroecological industrialization of food and renewable energies, biomineral input production (biofertilizers and rock flour) for organic agriculture, technical assistance and rural extension for agroecological transition, agroforest implementation, bioconstruction and environmental education.

In December 2012, Cooperbio started the Alimergia project to implement agroforests and territorial centers for environmental education, financed by Petrobras through the Petrobras Social-Environmental Program. This project has allowed the region to become one of the largest areas recovered from degradation. In total, 379 agroforests have been established and more than 200,000 plants of native and fruit tree species have been planted. The impact area of the Alimergia project is located 350 kilometers away from Porto Alegre and includes 35 municipalities. The agricultural structure of the region is characterized by the existence of 45,000 production units, in properties ranging between one and fifty hectares.

In the 1960s, this region received massive subsidies for the adoption of agricultural production models based on the principles of the Green Revolution, such as genetic uniformity, the intensive use of agrochemicals (fertilizers and agrochemicals) and heavy mechanization. These processes have caused ecosystem deterioration with dramatic reduction of native vegetation, decrease in agricultural biodiversity and environmental services, as well as impoverishment of rural populations. Development policies prioritized the expansion of productive chains, such as transgenic soybeans, corn and tobacco, as well as intensive use of mechanization and agrochemicals, which require high investments in infrastructure and homogenize production areas.

Nevertheless, the region has great potential to solve the serious problem of environmental degradation and social exclusion. High participation of peasant family agriculture in the economic base created the necessary conditions for the Brazilian Government to include it in the Territories of Citizenship program of the Ministry of Agricultural Development (MDA), addressed to regions that are highly vulnerable, but with the potential to carry out projects and define integrated regional environmental and socioeconomic agendas. In this context, the Alimergia project seeks to build systemic solutions that integrate environmental service recovery, renewable energy generation and food production, and to create decentralized jobs, reintroducing the society-nature relationship through agroecological practices.

Remarks

The Cooperfumos' and Cooperbio' projects have been implemented in partnership with other MPA organizations, such as Cooperativa Mixta de Producción y Comercialización Campesina de Rio Grande do Sul Ltda. (CPC-RS), Cooperativa de Provisión de Servicios, Asistencia Técnica y Educación Rural Ltda. (Coopsat), Instituto Cultural Padre Josimo and Cooperativa de Vivienda Campesina (Cooperhab).

The practices and conceptions of the Alimergia projects carried out by the two cooperatives were used in the formulation of the Peasant Program, a public policy established in 2013 in the state of Rio Grande do Sul and considered the one with the greatest state impact on agroecological transition and popular food supply. Additionally, territorial cooperation centers took action on environmental planning and education, agroecological training and cooperativism. These centers receive visitors from all over Brazil and, between 2014 and 2015, trained approximately 4000 people.

The consolidation of the Alimergia project was possible due to the joint work of cooperatives and institutions of the Brazilian Government. Cooperbio and Cooperfumos, as cooperative instruments of the members enrolled in the MPA, organized the peasant base, as well as the technical and management teams, and performed the primary production and agroindustrialization projects.

The proposal of the production systems within the concept of Alimergia, used by Cooperfumos and Cooperbio, was made viable by the incentive policies created as part of the national biodiesel program. This program created a favorable environment for the debate on renewable energies and enabled the active participation of MDA and Petrobras as promoters of the sustainable insertion of peasant family agriculture into the biofuel production chain. The MDA was responsible for taking action to incorporate family agriculture into the production chain and monitor private and cooperative projects in order to give them the official social fuel seal. This seal indicated that at least 30 % of raw materials used in biodiesel manufacture came from peasant family agriculture. Within the initial proposal, the MDA was in charge of organizing production diversification projects, evaluating new oilseeds and raw materials for renewable energies, and promoting financing of cooperatives for their use.

Over time, the MDA yielded to pragmatism, reduced the social fuel seal and did not promote soy diversification. Subsequently, the program started weakening because the impetus of the national biodiesel program and the renewable energy actions of the Government decreased with the discovery of oil deposits in the sea (Pre-Sal), which caused a lack of resources and obstructed the institutional environment for the development of activities.

Petrobras is a publicly traded company (corporation) whose largest shareholder is the Government of Brazil, which is why it is considered a mixed-economy state company. It has a monopoly on producing and marketing fuels in Brazil and is responsible for implementing and managing large biodiesel and ethanol units. This is a disadvantage because neither Cooperfumos nor Cooperbio can market the biofuels they produce. To make the Alimergia project viable, financing and incentives came from Petrobras Biocombustibles, through the Petrobras socio-environmental program, which provided the resources for cooperatives to implement training centers and agroindustries.

Clearly, the proposal of the Alimergia project needs public policies that support bioeconomy innovations, policies which currently are not available. The change in production and consumption systems proposed by the Alimergia project requires new institutional and educational structures that allow for the dissemination and promotion of education at all levels in order to successfully meet the challenges of the new paradigm. Universities and research centers should direct their actions and innovations towards agroecosystem technologies and management processes as a strategy to reduce the use of external inputs, emphasizing conservation (soil, water and energy), increased agrobiodiversity and the promotion of nutrient recycling practices (biotic regulation). It is also needed that institutions integrate technical-scientific knowledge with local practices and knowledge, building trust and interdependence relationships between peasants and the urban and rural population.

It is necessary to change the reductionist approach used in existing curricula in most universities, which seeks to solve problems from the perspective of a single discipline and that enhances the use of input-dependent technologies associated with greater productivity gains. There is a lack of a critical mass of professors and researchers who use a holistic and systemic approach since the vast majority privileges their lines of work, according to the number and prestige of publications ("publication-dependent"), compelled by the performance indexes required by the financing institutions related to the Ministry of Education. Graduate professionals lack clear concepts about ethics and its relation with the environmental and social impact of some modern agricultural production systems. Most universities teach agronomists, veterinarians and zootechnicians under the old paradigm, repeating the indications disseminated by the input technology defended by large international companies.

Bioeconomic projects require specific legislation that values environmental preservation as well as approaches for renewable food and energy production and marketing. Public policies and their financing agents require favorable and differentiated conditions to implement bioeconomy, using new indicators and integrating efforts of various sectors in order to support projects until they are technically and financially consolidated and until they reach the social maturity required for their continuity.

Legislation is soft with industrial food and energy products. The tax burden is low for agrochemicals and other products harmful to nature and society. One suggestion is to increase the tax burden for agrochemicals (chemical fertilizers, hormones, antibiotics and oil- and coal-derived energy), creating a fund for bioeconomy development in rural communities. The energy policy is focused on centralized production and marketing systems, leaving cooperatives without legal support to market ethanol and biodiesel produced in regional markets. An appropriate legislative framework will create legal security to implement sustainable undertakings, which have access to financing and a space for marketing their products.

One of the biggest problems confronted by bioeconomy projects (agroecology and organic agriculture) is the lack of infrastructure for the production, storage and processing of products. There is a marked absence of companies engaged in the production of organic inputs used in agriculture, livestock breeding and forestry. While there is a tendency to change the technological paradigm, moving from the agrochemical model to biotechnology, this change is under the control of the same companies that currently produce agrochemicals. Also, due to the lack of storage structures, peasants frequently have to store their organic products mixed with conventional or transgenic products, thus losing their added value.

However, we believe that bioeconomic initiatives have an enormous potential to build a new sustainable production and consumption system, based on the cooperation and leadership of farmers who today are marginalized from markets with higher added value. The success of Alimergia project initiatives depends on the internal strengthening, cooperation and expansion of the relationship with urban societies that support the project politically and economically, since institutional support from the national government is scarce.

Final considerations

Bioeconomic proposals refer to sustainable agricultural production systems that intensively use the integration of knowledge and biodiversity to optimize the use of natural resources and improve the quality of life of producers and consumers. Alimergia is a project that seeks to transform agriculture and society and their relations with the environment through green and clean agricultural activities; food in affordable quantities, qualities and prices; clean and cheap renewable energy; and a new, more humane and democratic society.

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Bioeconomy in Chile

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Introduction

The concept of bioeconomy is not explicitly stated as a public policy in Chile under this definition; however, there are various public and private initiatives that point to the approach of this concept. The creation of the Agency for Sustainability and Climate Change, several Chile Transforma programs as a platform for public-private cooperation (productive and diversified economy), and some legislative modifications requiring that companies change their management somehow drive the development of bioeconomy-related initiatives. Despite this, a more comprehensive vision of bioeconomy could have greater impact and focus on the activities carried out. Biotechnological concepts are not yet expressly integrated, and we still need to understand how the expansion of Industry 4.0 or fourth industrial revolution will influence different aspects of the national economy. This chapter offers an overview of some public-private initiatives currently underway in Chile across its territory and some specific examples of bioeconomic projects in the country.

General framework of public initiatives

Some public initiatives related to the bioeconomy approach are outlined hereafter as examples of instructions and guidance, without it being an exhaustive review. A brief description of the Agency for Sustainability and Climate Change, the *Transforma Alimentos* program and, finally, the new Extended Producer's Liability Act is provided.

Agency for Sustainability and Climate Change

The Agency emerged in 2017 as a surviving organization of the National Clean Production Council to accelerate productive transformations in Chile. It is a committee of the Production Development Corporation (CORFO), whose mission is to encourage inclusion of climate change

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and sustainable development dimensions into the private sector with a territorial perspective. It was incorporated as implementer to facilitate fulfillment of international commitments taken on by Chile, such as the Paris Agreement and the United Nations Sustainable Development Goals.

The document *Recomendaciones para una agenda de trabajo pública privada al año 2030 en materia de sustentabilidad y cambio climático* (Agencia de Sustentabilidad y Cambio Climático [ASCC], 2018) introduces an agenda to 2030 with priority areas in the forestry, aquaculture, agroindustry, transport, basins and water resources, waste and city sectors. In relation to waste, it intends, for example:

> [...] to create a market for products that come from the valorization process, promote a greater supply of recyclable products to meet the demand of recycling plants, and boost the technological development for the recovery of certain products that are not yet valorizable in Chile. (p. 31)

In addition, and complementarily, it suggests advancing alternatives for treatment and recovery of organic waste, both municipal and from the agroindustry, although these are not addressed as priority waste by Law 20.920/ 2016, which provides the framework for waste management, extended producer's liability and recycling promotion. The Agency works with three instruments that bolster sustainable development:

- The Clean Production Fund, whose purpose is to support companies in implementing clean production to increase their efficiency and minimize their impacts on the environment.
- Territorial agreements, which assist in the creation of coordination opportunities among companies, communities, and local actors to work together for territorial sustainability and climate change challenges.
- The Clean Production instrument, applicable to production processes, products, and services to improve productive, environmental, social, and occupational health and safety conditions.

Therefore, the Agency for Sustainability and Climate Change is involved in several matters that may be included in what we understand under the concept of bioeconomy and whose implementation is supported by grants and actor coordination.

Transforma Alimentos Program

The strategic smart specialization programs in Chile, promoted by Corfo in the framework of the Ministry of the Economy's Productivity, Innovation and Growth Agenda, are a set of initiatives to strengthen diversification and sophistication of the Chilean economy, identifying technology and market opportunities worldwide under a smart specialization approach. Regarding bioeconomy, the *Transforma Alimentos* program focuses on:

> [...] the incorporation of sustainable technologies to develop new products from raw materials available, which stand out for their healthy composition and processing. Likewise, it intends to innovate in the packaging of products. This initiative aims to position Chile within the ten leading countries in the production of healthy food for the world.

There is a national program and specific programs in the region focusing at regional sub-sectors such as livestock farming, fruiticulture, horticulture, agroindustry, and value-added food. In the context of this program, several elements related to the foundations of bioeconomy were incorporated, including:

- Zero Raw Material Losses in Agroindustry program. A loss of up to 45 % of raw materials is estimated between primary production and the processing industry, depending on the chain to which it belongs. Using a diagnosis of eight different chains, the objective is to put forward technically and economically viable solutions to reduce losses.
- Technology programs targeted towards the development of functional ingredients and additives, and value addition to resources including native algae, grains, cereals, and dairy products as well as new packaging materials.
- In terms of individual companies, they are supported by grants with the recovery of waste and derivatives of aquaculture and agroindustrial origin.
- The Technology Center for Food Innovation, a consortium of four Chilean universities and two foundations (Pontificia Universidad Católica de Chile, Universidad de Chile, Universidad de la Frontera, Universidad de Talca, Fundación Chile, Transforma Alimentos and Fraunhofer Chile) for the creation of healthy new products, processes and packaging, aims to install infrastructure in the form of pilot plants for ingredients, food and packaging. With these pilot plants, it is intended to promote the development of new products on a semi-industrial scale. The first pilot plant aims to focus on the production of high value-added ingredients.

The *Transforma Alimentos* program is a public-private partnership to carry out a total of 155 projects in the amount of 110.3 million US dollars, of which 37 % are directly financed by companies associated with the projects (Transforma Alimentos, n. d.).

Extended Producer's Liability Act

Chile is implementing the Extended Producer's Liability Act (Law 20.920/2016). It aims to reduce waste generation, promoting reuse and recycling through the extended producer's liability. The Act provides that:

> The obligations to prevent waste generation and foster its reuse, recycling and other recovery shall be established or demanded progressively, depending on the amount and hazardousness of waste, technologies available, social and economic impact, geographic location, etc.

Research and development

In the field of applied research and development, there are many initiatives in different areas of bioeconomy. Two examples of institutions focused more on development and scaling are presented.

Technology Development Unit, Universidad de Concepción

The Technology Development Unit (UDT) at the Universidad de Concepción (https://www.udt.cl) is one of 16 national excellence research centers recognized by the National Commission of Scientific Research and Technology (CONICYT) with long-term core funding. It has positioned as a center for science, technology, and innovation in bioeconomy dedicated to biomaterials, bioenergy and bioproducts. The center has pilot plants in multiple areas for precompetitive scaling.

Fraunhofer Center for Systems Biotechnology

The Fraunhofer Chile Research Center for Systems Biotechnology (FCR-CSB) was the first research center established by the Fundación Fraunhofer Chile Research (https://www.fraunhofer.cl) in the context of the Corfo's *Atracción de Centros de Excelencia* program that aims to promote the relationship between companies and the world of knowledge, complementing the capabilities of the national innovation ecosystem with the expertise of international entities having a recognized track record in technology development and transfer. It is the first in Latin America based on the Fraunhofer's innovation model, which seeks to develop applied science and technology to meet the needs of the industry. The center has a systemic approach and works on agriculture, food, and ingredients, aquaculture, and industrial sustainability. Within agriculture, food and ingredients it starts from knowledge creation on productive ecosystems to waste valorization by extracting high value ingredients in collaboration with academia and the industry.

Case studies

As an example of advances in undertaking with a bioeconomy approach, four model projects with bioeconomic potential in Chile in the areas of value addition to biodiversity, bioenergy and obtaining of bioproducts are discussed.

Case 1. Value addition to biodiversity: Native potatoes from Chile

Fruits and vegetables are a significant contribution to human health because, in addition to their traditional value, they provide secondary metabolites of interest. Together with classic macronutrients, they also have antioxidant properties that may, in turn, intervene in the development of chronic diseases (Ah-Hen et al., 2012). Potatoes are one of the main foods in the world and ranks fourth in world crops, after corn, rice, and wheat (Organisation for Economic Co-operation and Development, n. d.).

Out of the wide variety of potatoes present in southern Chile, there is a particular group (*chilota* native potatoes: *Solanum tuberosum* subsp. *tuberosum* of the Chilotanum group), which is composed of a large number of accessions and shows a broad phenotypical variability in colors and shapes, and of which about 290 accessions are held as a reservoir at the Germplasm Bank of the Universidad Austral de Chile. These varieties produce varying amounts of secondary metabolites, including polyphenols and anthocyanins, which constitute an important source of genes for introgression in high performance potato varieties —in this context, introgression is understood as the movement of genes within the same species as a result of an interspecific hybridization process followed by backcrossing— (Jannink, Lorenz, & Iwata, 2010).

In order to conserve and add value to this unique biodiversity, the MoMaPo (molecular markers for the generation of potatoes with enhanced anthocyanin content) project centered on accelerating the path to the generation of new varieties with enhanced nutritional content (Consorcio Papa Chile, 2017). For this purpose, state-of-the-art consolidated technologies were implemented to study and select genetic markers related to the phenotypic characteristics desired in order to provide a solid platform for the continuous improvement of potato varieties.

The project focused on identifying genes involved in anthocyanin biosynthesis to be used as molecular markers in breeding programs for the ultimate purpose of offering practical tools to improve anthocyanin concentration in potato crops, using underutilized biodiversity of Chilean local varieties. The MoMaPo project was financed by the Germany Federal Ministry of Education and Science's National Commission of Scientific and Technology Research and lay the foundations for the technical cooperation between the Fraunhofer Chile Center for Systems

Biotechnology, the Universidad Austral de Chile and the Fraunhofer Institute for Molecular Biology and Ecology in the field of action "biotechnology: especially nutritional research".

The most outstanding results of the project comprise the establishment of an international collaboration structure organized for biotechnological work in agriculture, which is expected to result in the generation of new crop or food varieties with enhanced nutritional properties, and the supporting information for current and future enhancement projects. The MoMaPo project is a strategic starting point for building science, technology and innovation capacities in Chile and is an example of the application of biotechnological tools to sustainably add value to biodiversity, ensuring conservation of original varieties.

Case 2. Importance of biodiversity for orchard productivity

Chile is one of the world's leading exporters of fresh fruit. This has implied the intensification of production and, in the case of avocado, the surface has extended towards the slopes of hills in the center of the country; therefore, the landscape has changed substantially. Bees, key components of global biodiversity, ensure maintenance of biological processes, including pollination, responsible for the successful reproduction of most plants. The abundance of bees is closely related to the environmental conditions of commercial orchards, for which heterogeneous landscapes tend to affect the parameters of pollination and fruit production.

To assess the effect of the landscape structure on native bee communities, satellite imaging of avocado orchards in the central area of Chile were used to classify land use and coverings. The presence of native and introduced plant species and the abundance of native bees and honeybees present in the edge flora were estimated. Preliminary results suggested that avocado orchards with a higher number of planted hectares (223 ha) have a high percentage of introduced flora species in the landscape, a smaller number of native bees and higher abundance of honeybees compared to landscapes with less extensive plantations (25 ha). These results would show some adverse effects of large tracts of crops on the components of Apoidea diversity.

Case 3. Land use optimization: APV

The profitability of ground-mounted photovoltaic systems is steadily increasing. This increase in competitive advantage leads to new business models for land use. The limited availability of arable land and a growing demand for space will lead to new dimensions in land use competition for at the interfaces among economy, ecology, and society. In 1981, Adolf Goetzberger, founder of the Fraunhofer Institute for Solar Energy Systems (ISE), and Armin Zastrow were the first to propose the concept of resource efficient use of arable land called agrophotovoltaics (APV). They proposed a special system technology that optimizes the performance of photovoltaic energy and photosynthesis.

The APV concept aims to develop energy production systems based on photovoltaic solar technology, in a harmonious and optimized combination with agricultural production. Photovoltaic panels were installed in an arrangement that allows both agricultural activities for a wide variety of crops and a special distribution of panels so that the shading pattern is uniform on the intervened crop. The shading intensity may be defined by the geometry (orientation and inclination) of the system to be installed.

The use of the APV concept has the following positive impacts:

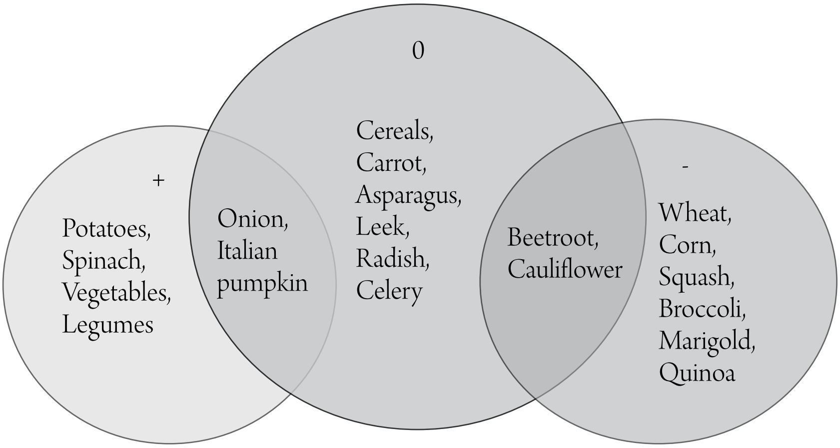
- Prevents land use competition for agriculture and energy, which allows for the harmonious and joint performance of both activities.
- Provides a new source of income for farmers, in the form of cost saving, due to energy self-generation in the same plot, and the sale of surplus energy to distribution networks as provided for in the Distributed Generation Act in force in Chile.
- Opens the possibility of reducing the carbon footprint.

In Chile, a country with a high level of radiation in the north-central area, three APV pilots were installed in the Metropolitan Region of Santiago, where the growth of the urban area competes for space with more than 25 % of vegetable production in the country. Pilots were mounted on horticultural crops to study their behavior with a 30 % increase in shading and to use energy for productive, domestic and network injection purposes. Measurements in pilots are 100 % digital and provide data continuously at low cost.

The benefits of the system are not only for producers: despite the nearly 100 % electric service coverage, rural electric networks do not have the same standard as urban areas, for which outages and frequency or voltage variations are longer and more frequent. APV, in having sources of energy generation distributed in rural networks, may contribute to stabilize networks, and improve service quality.

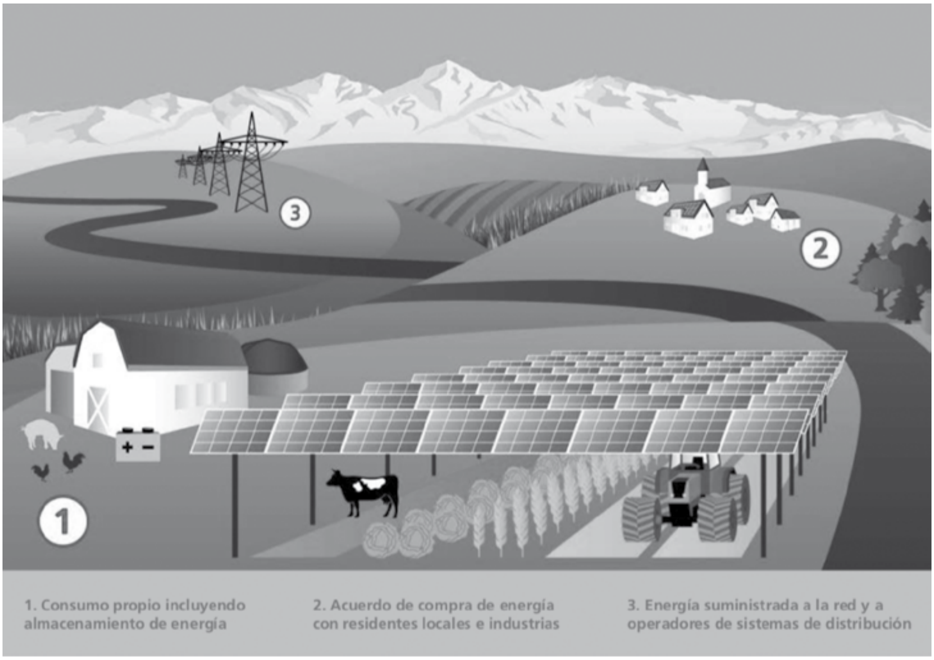
The three pilot plants represent valuable on-site laboratories to assess various crops and test new technologies, such as bifacial photovoltaic panels. The first results show little impact on crops and better moisture retention under the panels. They also intend to seek applications in crops damaged by radiation overexposure (export fruits) and other impacts of climate change (Figures 1, 2 and 3).

Figure 1. Pilot APV studies



Source: Fraunhofer Chile Research (2019).

Figure 2. Pilot diagram



Source: Fraunhofer Chile Research (2019).

Figure 3. Pilot tests

Source: Fraunhofer Chile Research (2019).

Case 4. High value plant products: From discovery to final product

Natural products obtained from plants have been used by human civilization for millennia, providing vital medicines and essential dietary components. More recently, bioactive compounds of plant sources have been given multiple uses, including cosmetics, health supplements and different feeds. Despite important investments, new activities and new sustainable biosources are required to reduce or eliminate chemical refining and, therefore, the environmental impacts of processed products.

In this context, the DISCO project (supported by the European Union Framework Program DISCO) aimed to understand the biosynthetic routes of plants involved in the formation of high value plant products and build new tools for metabolic engineering and molecular enhancement to create new sources of bioactive and industrial phytochemical products. The project was financed by the European Commission within the Seventh Framework Program for Research and Innovation (FP7) with a total budget of 6.5 million euros. The project coordinating institution was the Royal Holloway in the United Kingdom, in a multinational and multidisciplinary expert partnership of 15 academic and industrial institutions, ensuring the participation of actors from both the academic field of discovery and the industry.

Internationally, Fraunhofer Chile participated in tests for the use of carotenoids as dyes in aquaculture feeds (Nogueira et al., 2017). Ketocarotenoids are high value organic pigments used in the food and feed industry for coloring. Aquaculture is a good example, in which the addition of carotenoids to feeds is essential to coloring trout or salmon flesh and, thus, the commercial viability of the product. This study conducted complex metabolic engineering processes in tomato to produce high value ketocarotenoids (such as canthaxanthin, phenytoxanthin or astaxanthin) in order to produce a renewable source of ketocarotenoids for use as additives in fish feeds and possible scaling in field conditions. The production of these compounds in tomatoes has helped to assess this material "generally regarded as safe" in aquacultures tests with minimum bioprocessing and low energy consumption in order to prove the production, technical and economic feasibility of the system.

It was found that plant-based feeds (tomatoes) were more efficient than synthetic feeds to color trout fillets. This achievement represents a possible new paradigm in the bioproduction of volume-specialized chemical compounds to reduce dependence on chemical products derived from fossil fuels and stimulate sustainability and to respond to the consumers' demand for non-artificial dyes.

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Bioeconomy in Colombia

Rafael Aramendis,* Adriana Castaño**

Introduction

The socio-economic environment where the bioeconomy companies take place in Colombia by 2016 is diverse and quite complex. From an internal standpoint, both the regulatory and institutional variables, as well as those coming from public policies, particularly those linked to the agricultural, environmental, science and technology, and competitiveness sectors are driving elements that restrict, condition or foster external factors and, therefore, create either a favorable or unfavorable environment for the consolidation of biocompanies.

The current study was aimed to determine the incidence of external and internal factors on the development of such companies. To do so, ten study cases of Colombian biocompanies were analyzed on their respective Bioenergy/Biorefinery, Biotechnology/Ecological intensification, and Biodiversity in the Pharmaceutical and Cosmetics sectors. Those routes had previously been defined by the ALCUE-KBBE Project. Among the most remarkable findings of the study is the fact that a high percentage (80 %) of the analyzed Colombian biocompanies were set up as self-funded or private-bank-funded family businesses, where most of them exhibit product or process innovation, and export to places like Latin America, Europe, and Asia. These companies operate in highly regulated sectors, and acknowledge the importance of value chains, voluntary certifications, and the implementation of social and environmental responsibility schemes within their operations. They are, however, still very incipient on the management of aspects such as the recognition of intellectual property as a mechanism of protection for their own innovations, in addition to the university-business partnership, and their respective representation within their trade associations.

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The analysis of the context where such bioeconomy takes place requires, at least, an initial assessment of the Country's macroeconomic aspects likewise the public policies related to agricultural, innovative and technological developments, science and technology, competitiveness and environment, and biodiversity issues. This cross-sectional analysis will be key to determine the extent to which the scientific and technological knowledge can be associated with base of the natural resources in order to generate goods and services that, in turn, foster the nation's competitive and sustainable growth.

In terms of economic growth, in 2015 Colombia had a higher growth outlook (3 %) in comparison to the average growth in the region. These results overpassed the expected results for the Latin American and Caribbean region, which ranged between 0.5 % and 1.1 % (Deloitte & Co. S.A., 2015). Nevertheless, when facing the competitiveness challenges, the country was in a medium and quite discrete category. For the 2014-2015 period, the country ranked 66 among 144 countries, having 4.45 for its competitiveness index, which measured the infrastructure, institutions, macroeconomic environment, good health, and primary education. Concurrently, in terms of innovation and sophistication, Colombia ranked 64 among 144 countries with a 3.64 rate, where innovation elements and the level of sophistication in the operation of businesses were assessed. The country was rated as one of thirty economies falling under the efficiency-driven stage. According to the different aspects from the Global Competitiveness Index, Colombia is one of the 20 largest emerging economies around the world, out of which Mexico, Brazil and Argentina are also listed in the Latin America region.

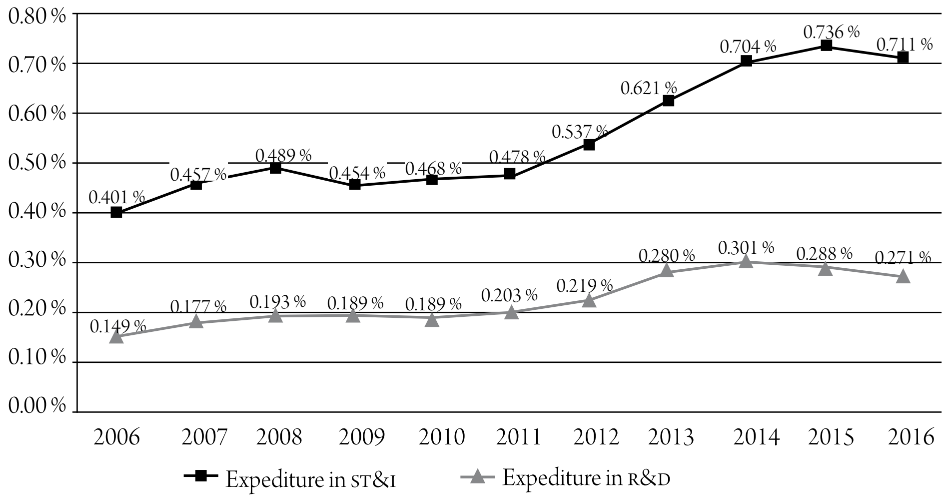
The agricultural policies in the country evidence systematic and progressive abandonment in the rural areas. Given this context, the pathway to bridge the gap between the rural and the urban area has been hindered and, at the same time, limit the coexistence of the small and medium farmers subsistence agriculture together with the industrial agriculture which, in the end, would bring along the benefits of the agricultural innovation to the entire Country (National Administrative Department of Statistics, Dane, 2015). Such scenario is illustrated within the National Agricultural Census indicators listed below:

- Colombia has 44.5 million ha with potential for agricultural activities. Seven millions of these lands are already used in crop production, out of which 74.8 % is under permanent crop of products like sugarcane, palm trees, rubber trees, bananas, flowers, and coffee; and, 16 % is devoted to temporary crops such as rice, potatoes, corn, soy, and vegetables.
- 80.4 % of the rural area is dedicated to pastures; and only 19 % to sowing.

- Of the scattered Colombian rural areas that went through the Census, 50.6 % corresponds to natural forests, 40.6 % is devoted to agricultural use, 7.25 % has non- agricultural use, and 1.5 % is under urban development.
- The Colombian agricultural sector is characterized by a high number of small production units with small area compared to a small number of large production units, with larger areas. This fact demonstrates the high levels of ownership concentration and land tenure. Of the registered census area, 70 % of the production units have less than 5 % of the area, and there is high fragmentation as the amount of household increases and children migrate to cities.
- 83 % of farmers do not have agricultural machinery; an equivalent percentage claims they do not have agricultural infrastructure.
- 90 % of the producers claim they do not receive agricultural technical assistance, which directly impacts the lack of productivity, competitiveness, and the efficiency of the agricultural sector.
- The Multidimensional Poverty Index (MPI) for the Colombian rural areas went up to 44.7 % as of 2015, in comparison with 21. 9 % in 2014.

Regarding Science and Technology, the indicators are not optimistic either. According to the information from The Colombian Observatory of Science and Technology (OCyT), the investment in Science, Technology and Innovation (STI) as a percentage coming from the Gross Domestic Product (GDP) was 0.271 % in 2016 (862,675 thousand million pesos) showing a steady decrease since 2014, when it exhibited its highest investment peak, with 0.301 % in relation to GDP, corresponding to 757,065 thousand million pesos. These investment percentages match the net investment in STI, not including the activities related to Research and Development (R&D): technological services, support to scientific education and training, management and other support activities (Lucio et al., 2016). Figure 1 shows the STI investment behavior in Colombia for the last ten years in comparison with the investment that included R&D activities. In none of these figures, the GDP investment gets close to 1 %, which is quite far or different in comparison with the R&D investment in other countries from the same region, or other developed countries, make based on their own economy.

Figure 1. R&D investment evolution as percentage of GDP, 2006-2016



Source: Taken from Lucio et al. (2016).

Within the environment and biodiversity framework, Colombia is part of most of the agreements, and multilateral or regional treaties resulting from the Convention on Biological Diversity that, in turn, affect the bioeconomy development. Some of those agreements or treaties include: Convention on Biological Diversity, The Andean Community Decision 391 establishing the Common Regime on Access to Genetic Resources, The Cartagena Protocol on Biosafety, The Nagoya Protocol, and the Nagoya Kuala Lumpur Supplementary Protocol. This latter one, together with The Paris Agreement, is currently under ratification process before the Congress of the Republic of Colombia.

Case study methodology

As a means to define the bioeconomy companies, which would be the subject of this study, a sequential process consisting of the following stages was carried out:

1. Analysis of the elements that support bioeconomy development in Colombia.
2. Delimitation of the sectors or pathways where the companies would be classified into.
3. Preliminary filtering of the biocompanies that would be included in the study.
4. Selection of the biocompanies to be analyzed.

As part of the analysis, policies related to bionenergy, sustainable use of natural resources, environment, agriculture, science and technology, and innovation and development were thoroughly studied. With regard to institutionality, four institutional levels were identified out of those entities from which the bioeconomy development takes its leverage within the Country. In terms of human resources, the academic background and availability of professionals holding master and doctorate degrees were analyzed as their capacity to support the different scientific and technological areas that converge into bioeconomy. The regulatory frameworks that were analyzed had to do with biofuels, biotechnology (including the regulation for genetically modified organisms, bioassays, natural resources, access to genetic resources, biopharmaceutics, and biocosmetics), biocommerce and industrial property related to intellectual property, and the plant breeder's rights. To conclude, some studies concerning the current potential socio-economic impact of biotechnology on the country were also examined.

Setting up this context was possible based on analysis of official government documents, or queries on the websites of different trade associations, both public and private, related to the topic. Bibliographical consultation of recent national and international studies on biotechnology, biodiversity and biotrade was also conducted. This context was also enriched with the experience and participation of the consulting team members, which had been set up three years before through different world meetings related to the subject matter of this study.

The structure for the case analysis of the selected biocompanies was based on the sectors/pathways selected for the consultancy in the Colombian scenario and in accordance with the guidelines provided in the ALCUE-KBBE project (Towards a Latin America and Caribbean knowledge based bio-economy in partnership with Europe) (Trigo et al., 2014):

1. Bioenergy sector: It is comprised by companies devoted to sugarcane (bioethanol), and palm oil (biodiesel) based biofuels production.
2. Biotechnology sector: It is comprised by companies using or producing genetically modified crops (GMC), bioinputs, bioremediation, as well as applications in the chemical industry and the health sector.
3. Biodiversity sector: Focused to pharmaceutical companies producing phytomedicines, and also companies producing biocosmetics, or devoted to obtaining natural ingredients for the cosmetics manufacture.

Having in mind each of the selected routes, in a preliminary way, some companies were thoroughly examined given their good standing for their success on integrating bioeconomy activities to their productive processes in order to process their goods or services. Within this examination, different size, legal and organizational corporate structure, and origin (domestic, mixed, or foreign) companies were analyzed. The selected companies are listed in Table 1.

Table 1. Preliminary selected companies

Sector	Subsector	Targeted companies
Bionergy	Sugarcane sector: Bioethanol	Manuelita Riopaila Mayaguez Providencia Risaralda Cauca Bioenergy
	Palm oil sector: Biodiesel	Odin Energy Oleoflores Ecodiesel de Colombia Bio D S. A. Aceites Manuelita Biocastilla
Biotechnology and ecological intensification	Genetically Modified Organisms (GMOs)	Pajonales Aliar
	Bioinputs	Ecoflora Agro Biocultivos S. A. Bioinsumos S. A. Soluciones Microbiológicas del Trópico
	Bioremediation	Llano Ambiental S. A. Solubact Ecocert
	Chemical Industry	Smurfit Cartón de Colombia Disaromas
Biodiversity for health	Pharmaceutical	Labfarve Aral Thel Pronabell SAS Phitoter Naturfar
	Biocosmetics	Apiflower Ecoflora Care Neyber Waliwa
	Health applications	Corpogen Histolab Vecol

Source: Prepared by the authors based on the analysis above mentioned.

The implemented methodology for the current research included a triple filter selection process through which the scope of companies was initially selected by route, and, subsequently, was sieved as follows:

- First filter: compliance with the economic and market criteria
- Second filter: compliance with regulatory and normative variables and use of instruments of intellectual property, as well as environmental and social compliance within their corporate practice.
- Third filter: As a positive selection criteria, those companies with more than one good or service in one pathway, or goods and services in more than one pathway would also be selected.

For each selected company, in 90 % of the cases, a face-to-face interview was held with the Company's General Manager or Operational Manager in order to, subsequently, prepare a summary file to be later validated by the Corporate Manager of each Company. These summary files were constitutive elements for the analysis of each case and each sector by means of the implementation of SWOT analysis.

This selection process has the limitation that not all companies have their financial information publicly disclosed; therefore, the external analysis information related to the logistics, supply and commercial chains was taken mainly from two sources: (i) available online information the companies' respective websites, and (ii) particular knowledge of the consultant team about the activities of the bioenterprise. This matrix criterion was very accurate for companies in the bioenergy sector as they annually report their consolidated information using the Global Report Initiative (GRI) methodology and which has associates that put it together and consolidate it (e.g. Asocaña and Fedebiocombustibles).

As for the biodiversity sector, which is emerging in the country, the economic information was inferred from that provided by different institutions like: the National Association of Industrialists (ANDI), the Pharmaceutical Industry Chamber, and the Cosmetic Chamber, besides the external variables coming from the available and public information of each company.

The economic performance of each company was drawn upon the reports coming from the Colombian Superintendence of Companies, as of December 2014. The above-mentioned interviews set the basis for the description of the selected cases, which considered the following aspects:

1. Descriptive elements of the company: company name, business lines, business activity, operational base (domestic, regional or global).
2. Used and processed biodiversity good or obtained services, and bioeconomic pathway according to the ALCUE-KBBE Project.

3. Company's historical and conformation aspects
4. Implemented innovations
5. National, local or regional public policies. Especially those related to STI, to understand whether they have supported or hindered the development of the biocompany.
6. Intellectual protection strategies
7. Applicable national regulations and identified barriers or obstacles for the development of the biocompany, its developments, and its bioproducts.
8. International cooperation support for the setting up of the company and its products.
9. Impact on human, technical, logistics, social infrastructure, economic and environmental resources.
10. Potential of the bioenterprise evolution.
11. Financial data.
12. Sustainability criteria.

As a result of this analysis, each company had a fact sheet with a matching SWOT analysis by sector and biocompany to be assessed together with a cross-sectional analysis of the different evaluated sectors/routes.

An additional criterion to select the model biocompany for the case studio analysis was the inner execution of more than one bioactivity, in any of the selected routes. This is what we called *technological hybridization,* which also referred to the company's activities in more than one of the pathways defined in the ALCUE-KBBE Project.

Presentation of the case studies

The selected companies for each pathway were those that exhibited the best economic performance and sustainability for each of their sectors at the end of the immediately prior to the study fiscal year, and also those which complied with all or most of the external analysis variables: in terms of compliance with the normative and regulatory parameters, those of existence and visibility of logistic and commercial chains for the development of their operations, existence of academia-business partnerships and academic or industrial recognition. The economic variables under analysis were: sales, operating profit, net income and equity.

Based on the two-filter biocompany selection methodology, described above, the selected companies are listed as follows:

1. Biofuels sector (biodiesel): Grupo Empresarial Manuelita (Aceites Manuelita, as of today Manuelita Aceites y Energía).
2. Biotechnology / Eco-intensification Sector:

- GMOS: Organización Pajonales, Aliar.
- Bioinputs: Ecoflora Agro, Organización Pajonales, Biocultivos S. A.
- Health applications: Corpogen.

3. Valuation of biodiversity sector:
    - Phytomedicines: Laboratorios Labfarve.
    - Biocosmetics / toilet and cleaning: Ecoflora Care, Neyber, Apiflower.

Bioenergy sector

The industrial sector for the bioethanol production in Colombia is based on sugar mills, some of which were set one hundred or more years ago and whose initial main activity was focused on the production of raw and refined sugar, to migrate later to the ethanol production. Some of these refineries diversified their business lines based on the government policies focused on fostering biodiesel production from alternative sources like palm oil.

Nowadays, Colombia is the second leading country in bioethanol production after Brazil. The country has an oxygenated gasoline program with a scope ranging between 8 % and 10 % that covers 83 % of the national market and which will guarantee the future development of the sector. It is foreseen that by 2020, it will grow up to five times its current level (UPME-MME, 2009). Currently, the ethanol production is linked to the existence of a bioindustrial cluster of sugar in the geographic valley of the Cauca River, a cluster with important forward and backward linkages.

As a result of the first filter, related to the analysis of the economic data of those companies producing bioethanol and biodiesel, the company with the best individual economic performance during 2014, given the sales and operating profit, was Aceites Manuelita. Likewise, when compared to the economic performance with companies from the same sector, it also ranked first.

When applying the second filter where the compliance and development of market aspects, commitment and implementation of the environmental, social, normative and regulatory variables were assessed, it was found that the same company has, in addition to an outstanding performance nationally speaking, a broad international recognition.

Biotechnology and eco-intensification sector

In order to select the companies of this sector / pathway, it is important to mention that, unlike the bioenergy sector scenario, individual financial information is not available, since the companies of this sector are not grouped in trade associations. Besides, some of those companies report their consolidated economic information through their financial matrix, as it happens with

Organización Pajonales, which is owned by the Financial Group Corficolombiana. The financial information for this research was provided during the conducted interviews.

As for the GMOs, Organización Pajonales and Aliar S.A. are two of the largest agricultural companies in the country that plant genetically modified crops (cotton or maize) which are part of an important value chain that complies with the environmental, social, and biosafety regulations. It is worth mentioning that, for this study, only the seeding value chain was analyzed, not the complete GMO use and consumption chain. Additionally, the company Aliar S.A. is one of the study cases of agricultural innovation at Harvard University; while the Pajonales Organization was one of the selected study cases for bioinputs, because they have an exclusive production line for them, which also meets the selection criteria for the selected case studies.

The Aliar case was not only selected due to the compliance with planting genetically modified materials (GM) criteria, but also because it is a model of integration of the swine and poultry chains as it starts right from the sowing process and the required inputs for the development of such chains (maize and soy).

With reference to the bioinputs companies, Ecoflora Agro and Biocultivos S.A. are worth mentioning. Ecoflora Agro is considered to be a bioeconomy innovative model company (Pisón and Betancur, 2014), since they are positioned in a specific market niche, develop biodiversity products, implement intellectual property protection strategies, and use sustainability criteria properly for the management of their operations, and to select their suppliers carefully. Biocultivos S.A. is a successful spin-off case in Colombia, emerging from the Institute of Biotechnology of the Universidad Nacional de Colombia, and a group of private investors from the Tolima region, that, as of today, continues to produce biofertilizers and biopesticides holding their own brand and records.

Regarding health applications, there are few companies in the country using biotechnology products and processes to obtain any goods and services. An example is Corpogen, which was selected as a case study as it is an initiative of researchers with business vision along with broad international recognition in the areas of tuberculosis and malaria. They have also developed products by means of various applications based on the implementation of molecular biology tools.

Bioremediation processes

There are not any public nor private companies providing bioremediation services in Colombia. This activity is essentially developed within academic and research scenarios focused on identifying strains of microorganisms capable of degrading substances or compounds, studying their behavior or the metabolites produced by them. It focuses on the environmental area research groups from the Pontificia Universidad Javeriana, Universidad Nacional de Colombia, Universidad de

Los Andes, and the Universidad de Antioquia, as well as some support projects from the academy to the mining sector. There are also some consulting companies providing assistance for the treatment of both, hazardous and non-hazardous solid and liquid waste, or to provide assistance on the implementation of environmental management systems and regulatory compliance. Out of the review performed, it was evidenced that none of the companies currently develops or takes on bioremediation or bioaugmentation processes; therefore, it was not possible to carry analyze any case in this pathway.

Chemical industry

Based on the information from the Superintendence of Industry and Commerce for the industrial and chemical industry, 58 companies were pinpointed as the most representative ones (Revista Semana, 2015). Those companies were allocated within three sectors: (i) industrial gases, (ii) flavourings and colourings, and (iii) chemical products. Within this group, no companies could be considered biobased companies, since none of them uses or processes renewable natural resources to obtain goods or services, except Smurfit Cartón de Colombia.

Biodiversity valuation in the pharmaceutical and cosmetics sector

The Laboratory Foundation of Plant Pharmacology (Labfarve) was selected as a case study since it utilizes biodiversity to obtain products with pharmaceutical use. This company has been recognized as the first national laboratory of research on Colombian medicinal flora and phytotherapeutic products accepted by the National Institute for Drug and Food Surveillance (INVIMA). It has also a university-business partnership (Fundación Escuela Colombiana de Medicina Juan N. Corpas) as one of its main foundations. Another key element for its selection had to do with its pioneer participation in the regulation of the phytotherapeutic medicines obtained from natural resources in Colombia.

In the biocosmetics area, three companies were selected to be part of the case study: Ecoflora Care, Neyber and Apiflower. Besides the rationale above exposed for Ecoflora Agro, Ecoflora Care has been positioned as an emergent trademark in the market of basic body care and household cleaning bioproducts obtained from biodiversity, products which are, in turn, the result of the university-business developments.

Apiflower and Neyber SAS were selected as they are two successful micro-companies in the development of biocosmetics and the obtainment of raw material coming from Colombian biodiversity. These micro-companies receive support and are considered to be leading companies within the Program of Productive Transformation (PTP) from the Ministry of Commerce, Industry, and Tourism, as they have been awarded as innovative companies in the country and are also positioning their products in the international markets with increasing volumes of exports to markets such as the European Union and the United States.

Analysis of the selected study cases of bioeconomy in Colombia

An individual SWOT analysis is presented (tables 2, 3, and 4) for each of the pathways for the study, and a cross-sectional analysis was also made for the three selected pathways (table 5). This latter analysis includes 18 corporate business and normative and regulatory compliance variables, that show the company's performance under economic, social, and environmental sustainability criteria. Besides that, having in mind the analysis for each of the selected companies, both, the opportunities and restrictions for the development of each bioeconomy pathways for Colombia were duly identified (Table 6).

Table 2. SWOT Analysis for the bioenergy sector

Strengths	Weaknesses
– There is in place a National Policy on Biofuels. – There is an institutional and regulatory framework in the country. – Implementation and measurement of sustainability actions.	– Monoculture – Social perception on the oil palm cultivation. – Reduced research on new biofuels sources in the country (jatropha, cassava, pastures, residues, etc.).
Limitations	**Opportunities**
– Colombia's land ownership and distribution issue. – Need to adapt the regulation in relation to mixtures for different kinds of vehicle engines.	– Introduction to the oleochemistry market. – Completion of their products' life cycle.
Threats	
– Country costs. – Climate change and El Niño phenomenon. – Changes on tariff rates for sugar, which would indirectly impact the bioethanol production. – Food security vs. biofuels production.	

Source: Prepared by the authors based on the analysis above mentioned.

Table 3. SWOT Analysis for the biotechnology and ecological intensification sector

Strengths	Weaknesses
– The biotechnology sector is provided with a policy instrument (Conpes 3697, 2007). – Institutions and regulations for gmos, seeds, bioinputs and diagnosis in place and operating. – Implementation of different intellectual property systems. – Broad national recognition. – Deeply rooted in R&D, which is evidenced on the development of their products. – Great microbial diversity. – Strong scientific capacity (124 groups from 47 public and private national universities whose research projects are independently developed on subjects related to biodiversity and biotechnological applications. The human capacity of those 124 groups is represented in 442 doctorates and 374 master degrees).	– The Conpes 3697 regulation has not been put into operation, nor has it been provided with financial resources. – Changes in the interpretation and enforcement of the regulations due to the officers' rotation within the different institutions. – Great interest on using GMOS, although they are designed to be used in a temperate, but not tropical area.
Limitations	**Opportunities**
– There isn't any association that groups the companies' interests together and leads them as the biotechnology sector*. – Colombia's land ownership and distribution issue. – Low scaling capacity. – Operational relocation of those companies that own the Genetic Modification Technology (Monsanto, Syngenta). – Farmers' lack of confidence regarding bioinputs when compared with the chemical inputs.	– Broadening of international markets through bioinputs exports (Central America and South America). – Earning environmental and social responsibility certificates. – More university-business partnership to promote new spin-offs. – Development of a farmer-based market.
Threats	
– Climate change. – Country costs. – Volatility in the representative market rate.	

*The AgroBio and Ilsi associations are excluded, they group some companies, but for the purpose of education, training or publication. Associations such as Fedegan, SAC and Asoporciola, were also excluded as they group specific companies for specific commercial purposes.

Source: Prepared by the authors based on the analysis above mentioned.

Table 4. SWOT Analysis for the pharmaceutical and cosmetic sector

Strengths	Weaknesses
– The cosmetic sector was considered by the State as one of the world class sectors in the country. – The instruments the State is provided with to support this sector have been key in the strengthening and broadening of markets stages. – Wide base of genetic and biological associated resources in Colombia, as it is a mega-biodiverse country. – Sector's value chains recognition and development.	– Changes in the interpretation and enforcement of the regulations due to the officers' rotation within the different institutions. – Difficulty of compliance with regulatory requirements, especially those coming from the European market (preservatives, labels, packaging, records, studies). – Absence of phytochemical and ethnobotanical studies to set a baseline. – The association that groups them together (Fenad) is not representative enough yet.
Limitations	**Opportunities**
– Limited State resources to set up companies. – Lack of clarity regarding the application and associated procedures for the regulation of access to genetic resources. – Outdated (vademecum of plants) or restrictive (access to resources) regulation that limits the use of biological diversity. – Sufficient production of raw material with adequate quality standards (best practices).	– Support from the State entities to comply and access the regulatory requirements from foreign markets, especially the European one. – Biodiversity as the country's growth foundation, aligned with the 20 UN Sustainable Development Goals SDGs. – Broadening of the international markets under the comparative advantage that would mean the use of innovative biodiversity-based products with some degree of added value. These products would also comply with the demands of the international market (fair trade, sustainability, work with indigenous communities and farmers, etc.).
Threats	
– Country costs. – The regulatory criteria for biodiversity-based biocosmetics and biopharmaceuticals are being assimilated to the synthesis cosmetics and pharmaceutics products. – Biopiracy. – Rejection of the use of plant-based medicines to be included and accepted as alternative treatments to allopathic medicine by the General Health System. – Climate change. – Volatility in the representative market rate.	

Source: Prepared by the authors based on the analysis above mentioned.

The three analyzed sectors share some strengths and weaknesses. The Strengths analysis evidences that such strengths are quite relative. Although there are public policies for the three different pathways: for the bioenergy sector, the National Policy on Biofuels; for the biotechnology sector, the biotechnology policy (Conpes 3069); and also the policy guidelines (recognition of the cosmetic sector as world class industry), these instruments have been fairly slow when responding. As an example, for the biofuels case, changes in supply, surplus of installed capacity in the sector, technological changes that can increase the productivity and profitability of the sector or, in the case of biotechnologies, these elements are not translated into real financial resources allocation aimed to support the sector. Furthermore, they are not provided with an adequate instrument that allocates resources to development plans by the Superior Council of Fiscal Policy (CONFIS).

The threats the three sectors share have to do with the high country costs, the lack of inclusion of the climate change variable for the companies' production and sustainability processes; and the recurrent issues related to normative and regulatory aspects expressed by the legal gaps as well as discretionarily interpretation of the regulations, and slow and cumbersome bureaucratic processes in the country's environmental agencies.

The cross-sectional analysis for the three selected routes and the assessment of the matrix regarding opportunities and restrictions by sector prove that 80 % of the companies subject of analysis within the sample, part of the three established pathways for the bioeconomy study in Colombia, were set up as self-funded or private-bank-funded family businesses. Those companies did not use any state resources for their conformation.

All the bioeconomy-based companies that were analyzed in the sample of the selected pathways acknowledge the importance and the need for setting and operating value chains (or networks) as critical aspects in competitiveness, exports diversification, and access to markets. If such chain is not yet developed within the specific sector, or it is under development, some companies have undertaken the task of developing those value chains for their immediate environment.

Table 5. Cross-section analysis by alcue-kbbe routes

Variable	Bioenergy pathway	Biotechnology / Ecointensification pathway	Biodiverse-based pharmaceutical and cosmetics pathway
Companies' classification (Ley 905 de 2004)*	Large company	Diverse	MSMES and SMES and medium companies
Total staff	> 500	10-> 500	10-200

Variable	Bioenergy pathway	Biotechnology / Ecointensification pathway	Biodiverse-based pharmaceutical and cosmetics pathway
Sales Average/Year (COP)	Over 1000 millions	250 millions. Over 1000 millions	1000 millions, average
Year of foundation	+ 50 years	15 years average	15 years average
Reason for foundation	Implementation of National Policy on Biofuels	Response to a specific issue from the business or sector	Personal or professional interest on new products
Type of corporate constitution	Family	Family	Family
Value chain	Yes. Full coverage from farming to trading	Yes. Value chain integration	Yes. Value chain integration
Resources for corporate foundation	Own resources	Own and private banking	Own and private banking
R&D	Technology adaptation Environmental protection innovation and power generation	Yes	Yes Prospection of Amazonian fruits, identification of new plant compounds uses
Consideration of national policies in order to strengthen them or create them, if necessary	Yes	No	Yes Cosmetic sector considered to be a World Class sector Government support for the strengthening stage
Technological hybridization	Yes	Yes	No
Intellectual property	No	Yes (patents, DOV)	No Under exploration
Regulation	Regulated, not an obstacle	Regulated, an obstacle in terms of the regulations enforcement	Regulated, an obstacle in terms of the regulations enforcement and regulations loopholes

Variable	Bioenergy pathway	Biotechnology / Ecointensification pathway	Biodiverse-based pharmaceutical and cosmetics pathway
Voluntary certifications	Yes	Yes	Yes
University-business partnership	Poor	High Bioinputs scenario: spin-off	High and projected to innovate
Environmental and social sustainability	Yes	Yes	Yes
Exports	Yes	Yes (Latin America, United States)	Yes (European Union, Asia, Latin America, Eastern Europe, United States)
Associative representation	Yes	No	Yes, but under consideration

*Colombian SMEs are responsible for 40 % of the National GDP. MSMEs, in turn, are responsible for 80.8 % of the employment in Colombia allocated as follows: 50.3 % in micro-enterprises, 17.6 % in small enterprises, and 12.9 % in small enterprises.
Source: Prepared by the authors based on the analysis above mentioned.

Table 6. Opportunities and restrictions matrix by bioeconomy route

Route	Opportunities	Restrictions / Limitations
Bionergy	Protecting all their innovations by means of protecting intellectual property Increasing the university-business partnership Extending and diversifying their exports destination	Provided with limited State resources to set up new businesses
Biotechnology / Biointensification	Extending and diversifying their exports destination	Provided with limited State resources to set up new businesses Regulation with enforcement discretionarily interpretation and regulatory gaps

Route	Opportunities	Restrictions / Limitations
Biodiversity in the pharmaceutical and cosmetics sector	Technological hybridization implementation Protecting all their innovations by means of protecting intellectual property Extending and diversifying their exports destination Strengthening their associative representation, especially for the phytomedicines sector	Provided with limited State resources to set up new businesses in this sector Regulation with enforcement discretionarily interpretation and regulatory gaps

Source: Prepared by the authors based on the analysis above mentioned.

Conclusions

The three pathways are provided with legal and regulatory development by the competent authorities; but this regulatory framework is perceived as an obstacle when enforcing and complying with it for the biotechnology and the biodiversity routes. There are mainly three reasons for this perception: (i) regulatory gaps, (ii) slow bureaucratic processes, and (iii) discretionarily interpretation when government officials in turn interpret some of those regulations.

The companies analyzed for three different pathways, acknowledge with more or lesser intensity, the need to implement environmental and social sustainability schemes. They also acknowledge the importance of earning voluntary certifications, which are mainly required by external markets (for instance, fair trade, child labor free, environmental protection, quality systems, and type of products certifications, among others).

Most of the companies that went under this analysis are exporting finished goods; if not, they are entering international markets to different destinations (European Union, Eastern Europe, the United States, or Latin America). It is worth noting that, once the biobased company has been fully established for the biodiversity sector, the government support has become a determining factor for the opening up of new markets and the compliance with the legal and regulatory requirements from the destination countries.

For the three analyzed pathways, the university-business partnership is at different levels in intensity and depth, which goes all the way from scarce or little to high. It is remarkable that for the bioinputs and health sector, it was evidenced a positive trend towards the emergence, maintenance and consolidation of spin-offs.

The national policies have not necessarily been an emergence and strengthening element for the different companies from each sector. The bioenergy companies emerged as a result of the existence of the National Policy on Biofuels on the premise that they would have the enough installed capacity and risk capital in order to complete new investments and expand operations within the sector (mainly from ethanol to biodiesel). On the other hand, the biotechnology/ecointensification and biodiversity companies do not emerge as the result of the existence of any policy from their sector. Policies have been proven to be useful, to some specific cases, for strengthening existing companies and leading them into possible international expansion.

The bioenergy pathway in Colombia adapts and transfers biofuel technology (ethanol and biodiesel), and also completes some innovative ideas regarding environmental protection (biogas produced from waste biomass) and the generation of renewable energy power. Nonetheless, this contribution to the Country's economy might be broader if it makes strategic decisions related to its participation in the secondary and tertiary value chain (oleochemistry), and also if it generates energy sources that contribute to the growth of the country's energetic matrix.

The companies from the analyzed sample, which are part of the biotechnology and biodiversity (biopharmaceutics and biocosmetics) pathways, carry out consistent innovations in the generation of new products, new processes or new uses for existing products.

In two of the analyzed pathways (bioenergy and biotechnology), the companies are entering into technological hybridization initiatives (use of the best state of the art technology and simultaneous use of GMOs) as a key element to enhance their competitiveness in global scenarios.

The analyzed biotechnology/ecointensification and biodiversity routes (biopharmaceutics and cosmetics) are just starting to acknowledge the importance of protecting their innovations by means of the intellectual property protection.

In order to implement the required changes, the National Government must guarantee the minimum conditions to create a favorable context to the bioeconomy development having in mind, at least, the following aspects: (i) increase, with established priorities and focus the investment on STI that, as of the study date, was 0.271 % of the GDP; (ii) thorough assessment on how the STI resources are allocated by the General System of Royalties (SGR); (iii) strengthening and integration with Colciencias as the STI apex regulatory body in the Country; and (iv) adjustments on the legal regulations that govern the biotechnology and biodiversity pathways, especially regarding the access to genetic resources, as the current frameworks create over-regulation and protectionism which, in turn, limit the access and sustainable use of the biologic diversity, as well as the adequate and timely introduction of new technologies to the country.

The different actors in the system, both, public and private (universities, research centers, and technological adoption and transfer institutions), should focus their efforts in, at least, guaranteeing the compliance with the following respects: (i) inclusion of the climate change variable when setting the decision matrix related to productivity, competitiveness, and efficiency; (ii) integration, coordination, and focalization of all the institutions and actors in charge of transferring the research and development results from the research centers to the private sector; (iii) ensuring no duplication or overlapping efforts among the entities in charge of funding and promoting STI activities under the role of investing angels, which is an angel investment network and State agencies like Innpulsa, Innova, Invest, and Connect, among others.

With regard to the financial sector, it is critical to guarantee the compliance with the following aspects: (i) creation and management of capital market lines in order to boost biologic-based private entrepreneurship initiatives which, once prove their sustainability, can be subject of financial leverage by means of the existing state financing and supporting mechanisms; (ii) promotion of establishing partnerships with national or international private investors along with the selection of strategic partners to go into biobusiness with; and (iii) creation of private support lines in order to set up MSMEs, SMEs and medium companies linked to bioeconomy.

A deep and meaningful change should be promoted within the bioeconomy businesses, especially among all the participating parts of this sub-system, in terms of the way in which STI and its corresponding value as the foundation for their own businesses along with the country's competitiveness. It is also key that the biocompanies work in compliance with social and environmental responsibility mandatory or voluntary international standards.

In summary, for the country to have competitive and sustainable bio-business, each authority and each actor must exercise a clear and determined role: the central government in charge of providing resources, public goods, clear and transparent regulatory frameworks and adequate infrastructure and, the innovation and technology transfer state authorities in charge of redefining their role within the framework of national and regional agendas related to competitiveness; and also, the private sector which should be encouraged to change their mindset responding to the urgent need to take on innovation and development as part of the survival strategy of their companies.

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Bioeconomy in Costa Rica*

Adrián G. Rodríguez-Vargas**

Introduction

Costa Rica has the potential to become a bioeconomy world leader due to the investments made by the country over the last few decades in education, and in areas such as biodiversity, forestry, climate change, sustainable agriculture, and clean energy. Moreover, bioeconomy can serve as a concept to articulate such initiatives around the great national goal of decarbonization of fossil fuels since bioeconomy is, in essence, the alternative to fossil fuel economy.

The purpose of this chapter is to highlight the potential of bioeconomy as a framework for guiding productive development and innovation policies in Costa Rica, taking as a reference the national aspiration to achieve fossil fuel decarbonization. To do this, the existing institutional and public policies development bases were identified, opportunities were analyzed and the potential of bioeconomy is illustrated with specific cases. The document concludes with some comments on how to strengthen bioeconomy development in the country, emphasizing the importance of articulating policies and aligning incentives.

Political and institutional framework for bioeconomy development in Costa Rica

Legislation

Costa Rica has a long tradition in the development of legal and institutional frameworks and relevant public policies to boost bioeconomy development. The construction of this legal framework

* The views expressed in this document are the sole responsibility of the author and may not coincide with those of the United Nations Economic Commission for Latin America and the Caribbean (ECLAC).

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goes back to the period between the late 1940s and 1960s, with the creation of Instituto Costarricense de Electricidad (Costa Rican Electricity Institute -ICE) in 1949 (Law 449), a pioneer institution in the development of clean power sources; the declaration of volcanic craters as national parks with a tourist approach, in 1955 (Costa Rican Institute of Tourism Organic Law), a fundamental milestone for the promotion of ecotourism in Costa Rica; and the creation of the Cabo Blanco nature reserve in 1963, which opens the path for biodiversity conservation policies. In 1970, the General Forestry Directorate (DGF), as part of the Ministry of Agriculture and Livestock (MAG) was created and the Wildlife Conservation Act (Law 4551, as amended in 1984 by Law 6919) was issued; in 1977, the National Parks Service (Law 6184) was also created (Fournier, 1985).

The environmental institutionality began to be articulated as such by the end of 1980s, with the creation of the Ministry of Natural Resources, Energy and Mines (Mirenem) in 1988, through the transformation of the Ministry of Industry, Energy and Mines (MIEC) in two different entities: the Miremem, which keeps being in charge of energy-related issues and incorporates competencies in terms of forest, flora, wildlife, protected wild areas and meteorology, and the Ministry of Economy, Trade and Industry (MEIC). This framework is consolidated in the 1990s through five laws:[1] 1) The Environment Organic Law (7554 of 1995), which creates the current Ministry of Environment and Energy (MINAE); 2) The Forest Law (1996), which introduces the definition of environmental services;[2] 3) The Regulatory Authority of Public Services Law (7593 of 1996), which authorizes charges for the provision of water; 4) The Soil Conservation Law (7779 of 1998), and 5) The Biodiversity Act (Law 7788 of 1998).

Other laws and relevant legal instruments, issued during the past three decades, are: Promotion of Scientific and Technological Development Law (7169 of 1990); Phytosanitary Protection Law (7664 of 1997); Law on Adoption of the Cartagena Protocol on Biosafety (8537 of 2006); Law on Plant Variety Protection (8631 of 2008); Executive Decree on Regulation of Biodiversity (34433-MINAE of 2008); Executive Decree on Regulation and Operation of the Domestic Carbon Markets (37.923-MINAE of 2009); Integrated Waste Management Law (8839 of 2010); Country Carbon Neutrality Program Agreement (36-MINAE of 2012); Domestic Carbon Market

1 Together, these laws set the framework within which the implementation of the Environmental Services Payment Program (PSA) is conducted, which can be consulted in http://www.fonafifo.go.cr/psa/

2 The law recognizes four services: a) the mitigation of greenhouse gas emissions (fixation, reduction, sequestration, storage, and absorption); b) protection of water for urban, rural, or hydroelectric power use; c) protection of biodiversity for conservation and sustainability, scientific and pharmaceutical use, research and genetic improvement, as well as for the protection of ecosystems and life forms; and d) natural scenic beauty for tourism and scientific purposes.

Regulation and Operation (Executive Decree 37926-MINAE); Liquid Biofuels and their Mixtures Regulation (Executive Decree 40050-MINAE-MAG of 2016); Approval of the Paris Agreement (Legislative Decree 9405 of 2016); Law of Promotion of Electric Transport (49405 of 2017), and the Agreement between the Ministry of Environment and Energy and the Ministry of Agriculture and Livestock to reduce emissions in the agricultural sector (2018).

Relevant national policies, plans and strategies

In Costa Rica, as in other countries within the region, there are already public policy initiatives relevant to the development of bioeconomy (Aramendis, Rodríguez, and Krieger, 2018). These include: The National Organic Agriculture Program (1994); the National Biofuels Program (2008); the National Climate Change Strategy (2007); the National Strategy Action Plan on Climate Change (2010); the National Plan for Sustainable Tourism 2010-2016 (2010); the National Forestry Development Plan 2011-2020 (2011); the National Biodiversity Policy (2015); the National Biodiversity Strategy 2015-2025 (2015); the National REDD Strategy + Costa Rica (2015); the VII National Energy Plan 2015-2030 (2015); the National Plan on Science, Technology, and Innovation 2015-2021 (2015); the National Waste Management Plan, 2016-2021 (2016); the National Wastewater Sanitation Policy, 2016-2030 (2016); the National Society and Economy Knowledge-Based Policy, 2017-2030 (2016); and the National Wetlands Policy, 2017-2030 (2017).

It is also worth mentioning the existence of Nationally Appropriate Mitigation Actions [NAMA] in the agricultural sector, within the framework of the United Nations Framework Convention on Climate Change (UNFCCC), one in the coffee sector and another in the livestock sector, both ongoing. The NAMA Coffee expects the decrease in the use of nitrogen fertilizers, the efficient use of water and energy in coffe milling, as well as the promotion of agroforestry systems and waste management. The NAMA livestock seeks to promote the implementation of technology and measures to adapt and mitigate climate change, seeking, at the same time, that producers increase their productivity and income.

A NAMA biomass-energy has also been prepared as part of the VII National Energy Plan 2015-2030, with the aim of encouraging the use of organic agricultural residues (RAO), generated by the agricultural and agro-industrial sector, in the generation of clean energies. In April 2018, the guidelines to design and implement the Low-Carbon Musaceae Production Strategy, which are resilient and adapted to climate change (EPMBC), were concluded, with a vision of the productive chain, which includes primary production, packaging, and transport.

Public and private institutions

The Ministry of Science, Technology and Telecommunications (MICITT) is the entity that leads bioeconomy activities in the country, within the framework of the process of accession of Costa Rica to the Organisation for Economic Co-operation and Development (OECD).[3]

Among the relevant ministries participating in the elaboration of a Bioeconomy Strategy, the MINAE, the MAG, the Ministry of Health, the MEIC, the Ministry of Foreign Trade (Comex), and the Ministry of National Planning and Economic Policy (Mideplan) are highlighted. Other entities (autonomous, semi-autonomous, and consultative) with relevant roles are the National Council for Scientific and Technological Research (CONICYT, 1972), the Technical Biosafety Commission (Law 7664 and Law 7788), the National Commission for Biodiversity Management (CONAGEBIO, 1998), and the Foreign Trade Promoter of Costa Rica (PROCOMER); as well as several other decentralized entities of the agricultural sector, especially the National Institute for Agricultural Technology Research and Transfer (INTA), the National Office of Seeds, the National Animal Health Service (SENASA), and the Phytosanitary State Service.

In R&D field, the country has more than 30 research centers in biological sciences, sustainability and areas relevant to the promotion of bioeconomy, in the three main public universities - The Costa Rica Institute of Technology (ITCR), the University of Costa Rica (UCR), and the National University of Costa Rica (UNA)- (Table 1). In addition, two regional training and research entities complement the biological sciences research area: 1) The Tropical Agricultural Research and Higher Education Center (CATIE), which develops research activities and offers several postgraduate programs, and 2) the Earth University, an international, non-profit, private higher education organization dedicated to train professionals in agricultural sciences.

3 In "The Process of Accession to the OECD: Institutional Articulation and Coherence of Policies" section, further details are given.

Table I. Costa Rica: research centers in biological sciences, sustainable development and areas relevant to the development of bioeconomy (three main public universities)

University of Costa Rica	National University	The Costa Rica Institute of Technology
Agri-sciences – Grains and Seeds Research Center (CIGRAS) – Research Center in Animal Nutrition (CINA) – Agricultural Economics and Agribusiness Development Research Center (CIEDA) – Agricultural Research Center (CIA) – National Science and Food Technology Center (CITA) – Crop Protection Research Center (CIPROC) – Agricultural Research Institute (IIA) Basic Sciences – Research Center in Electrochemistry and Chemical Energy (CELEQ) – Environmental Pollution Research Center (CICA) – Materials Science and Engineering Research Center (CICIMA) – Center for Research in Microscopic Structures (CIEMIC) – National Center for Natural Products Research (CIPRONA) – Marine Sciences and Limnology Research Center (CIMAR) – Centre for Cellular and Molecular Biology (CIBCM)	Land and Sea School – Research and Forest Services Institute (INISEFOR) – International Institute on Wildlife Conservation and Management (ICOMVIS) – Tropical Bee Research Center (CINAT) – Mesoamerican Sustainable Development Center of Dry Tropic (CEMEDE) – Water Center For Latin America and the Caribbean (HIDROCEC) Social Sciences School International Centre for Trade and Sustainable Development (CINPE)	Central Headquarters, Cartago – Center for Administration, Economics, and Technology Management Research (CIADEG-TEC) – Center for Research in Biotechnology (IBC) – Center for Research and Agribusiness Management (CIGA) – Housing and Building National Research Center (CIVCO) – Forestry Innovation Research Center (CIF) – Center for Research and Materials Engineering Extension (Ciemtec) – Environmental Protection Research Center (CIPA) – Center for Research and Chemical and Microbiological Services (CEQIATEC)

University of Costa Rica	National University	The Costa Rica Institute of Technology
Health Sciences		Santa Clara Regional Center, San Carlos
– Biological Tests Laboratory (IEBI)		
– Clodomiro Picado Institute (ICP)		Center for Research and Sustainable Agriculture Development for the Humid Tropics (CIDASTH)
– Pharmaceutical Research Institute (INIFAR)		
– Tropical Disease Research Center (CIET)		
Social Sciences		
– Sustainable Development Research Centre (CIEDES)		

Source: Prepared by the author.

Additionally, as a way to support innovation, the High Technology National Center (CENAT) has been created, and as part of it, the National Nanotechnology Laboratory was created (2004); both instances are part of the institutionality of public universities in Costa Rica (CONARE).

In the private sphere, among the significant entities are the CR- Biomed Cluster and the National Biodiversity Institute (INBIO). Likewise, there are certain institutions within the agricultural sector that can be highlighted, including: the Coffee Institute of Costa Rica (ICAFE), the National Banana Corporation (CORBANA), the Livestock Development Corporation (CORFOGA), the Agricultural Industrial League of Sugar Cane (LAICA), the National Rice Corporation (CONARROZ), and the Horticultural Corporation. Among them, both Icafe and Corbana invest in R&D and innovation through the Coffee Research Center (CICAFE) and the Banana Research Center, both being research leader entities within the region.

Other private entities with important roles for bioeconomy development include the National Forestry Office (ONF), the National Chamber of Agriculture and Agroindustry (CNAA), the Costa Rican Chamber of the Food Industry (CACIA), the Costa Rican Association of Energy Producers (ACOPE), the Biogas Association of Costa Rica, and the Costa Rican Coalition of Development Initiatives (CINDE). There are no specific funds to support bioeconomy; however, among existing funds that could meet this purpose are the Incentive Fund for Scientific and Technological Development, the Propyme Fund and the National Forestry Financing Fund.

Opportunities for bioeconomy development in Costa Rica

There are at least four ongoing processes that pose opportunities for implementing a national bioeconomy strategy or policy in Costa Rica: a) the adherence process to the OECD, as a framework for structuring public policies and institutional chores; b) the development of a National Decarbonization Plan, as an alternative to boost the full use of biomass and the circular economy production processes; c) the structural change towards a knowledge-based bioeconomy, harnessing the resources of biodiversity, and d) the public-private partnership that is being generated in areas related to bioeconomy, based on the creation of the CR- Biomed cluster.

The process of accession to OECD: Institutional articulation and coherence of policies

The OECD (2017), when reviewing the innovation policy, recommended Costa Rica: a) to encourage innovation in order to increase productivity; b) to strengthen the long-term commitment to science, technology, and innovation; c) to *strengthen the coherence of policies and their implementation*; d) to strengthen the contribution of public research to innovation, and e) to improve the information base to formulate policies on science, technology, and innovation.

The MICITT considers that bioeconomy provides a framework for policy design which is in line with these recommendations, based on the strengths and opportunities such agency highlights for Costa Rica in terms of innovation. For example, strengths in terms of diversification of the export base are the Country Brand (Marca País), the development of relevant industries (agroindustry, specialized manufacturing, medical devices, digital economy, and eco-tourism), the commitment to invest in education, human capital quality, exceptional biodiversity resources and great attention to the protection of the environment. The OECD has also identified opportunities in the Costa Rican innovation system that are relevant for enhancing bioeconomy. For example, the implementation of the National Quality System (Law 8279 of 2002) and the improvement of its use by national companies, the capitalization of the comparative advantage the country has in terms of research on biodiversity and the environment, the consolidation of knowledge-intensive emerging industries (*software* and biotechnology) and initiatives to address social challenges (for example, energy efficiency, environment, and health).

Two of the OECD recommendations can be considered in the development of a strategy for bioeconomy development: fostering innovation to increase productivity and strengthening policy coherence, and their implementation. For the former, the OECD emphasized the need to support SMEs in order to enhance their capacities to access and adopt new technologies and knowledge, so that they become relevant and innovative actors and integrate fully into global value chains. This is of great importance, considering that many innovative business developments in areas related to bioeconomy are SMEs and high-tech startups created by young entrepreneurs. Supporting these initiatives is key for a knowledge-based bioeconomy.

With regard to strengthening the innovation policies coherence and their implementation, the OECD stressed the need to overcome fragmentation and weak coordination among relevant actors. This is also important in order to articulate bioeconomy to the science, technology, and innovation system and, in general, to align policies, institutions, and incentives in order to encourage bioeconomy, which is by its nature, not sectoral. The formulation of bioeconomy strategies should start by identifying and articulating initiatives that already exist, along with dialogs with the private sector and other relevant actors, especially in the academic and research communities. The development of policies for bioeconomy also requires aligning already existing incentives, especially those designed to promote innovation and entrepreneurship (Rodríguez, Mondaini, and Hitschfeld, 2017).

Global leadership to go from carbon-neutrality to decarbonization of fossil fuels

In his inagural speech on May 8, 2018, president Carlos Alvarado suggested that "for COP 26 in the year 2020, as well as in its Bicentenary,[4] Costa Rica must have already been leading the Paris agreements on climate change, becoming the global decarbonization laboratory" (Alvarado, 2018). In the words of President Alvarado:

> In environmental matters, for our Bicentenary, we have the ethical duty to lead the world, as we have done in the past. We must be agile and innovative. We are called to safeguard ecosystems and protect biodiversity, seriously affected by the fast pace of climate and weather-related disasters. We need not only to improve our national parks management and the environmental and human balance in protected areas, but we also have the titanic and beautiful task to abolish the use of fossil fuels in our economy to give way to the use of clean and renewable energy sources. Decarbonization is our generation greatest task, and Costa Rica should not only be among the first countries of the world succeeding in such task, but the first.

The aspiration expressed by President Carlos Alvarado to make Costa Rica a global decarbonization laboratory and the desire to be among the first countries to achieve it, represents the culmination of a process that began with the goal of carbon neutrality and with the development of instruments to support it. The objective of achieving carbon neutrality by 2021 had been proposed in the National Strategy for National Climate Change in 2007 and as a goal in the 2010-2014 National Development Plan. With regard to the creation of instruments, Costa Rica formalized the Carbon Neutrality Country Program (Agreement 36-2012-MINAE), which defines that the INTE standard 12-01-06:2011, National Standard to Demonstrate C-Neutrality, is the only standard recognized by the Government of Costa Rica to demonstrate carbon neutrality[5] and its compliance is a condition to granting the C-Neutral label (a registered trademark in the National Property Register belonging to the Government of Costa Rica). The creation of instruments was complemented in 2013 with the publication of the *Domestic Carbon Market Rules and Operation* (Executive Decree 37926-MINAE). The development of the NAMAs in the agricultural sector (coffee and livestock) is part of that instrument creation process to support carbon neutrality.

Existing incentives are also relevant, such as the Ecological Blue Flag and the Certificate for Sustainable Tourism. The Ecological Blue Flag is an annual award that rewards the efforts and

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4 Costa Rica will celebrate its 200th anniversary on September 15, 2021.

5 The INTE Standard 12-01-06:2011 had already been formalized in 2011 as the "Management System to Demonstrate C-neutrality: Requirements" (Agreement 70-2011 MINAE).

voluntary work in the search for conservation and development, in accordance with the protection of natural resources, the implementation of actions to tackle climate change, the search for better hygienic and sanitary conditions, and the improvement of public health for the inhabitants of Costa Rica.[6] In turn, the Certificate for Sustainable Tourism is designed to help categorize and differentiate tourism companies according to the extent to which their operations get closer to a model of sustainability, in terms of natural, cultural, and social resources.

The first decarbonization actions have been focused on supporting clean energy sources, public transport, and urban mobility, taking the Promotion of Electric Transport Act of 2017 as a reference frame. This is to create sound bonds between the trajectory and the country's ability to generate electricity from clean and renewable sources (water, wind, geothermal, solar, and biomass), considering the fact that the sector that most generates greenhouse gases is the transport sector. From the public policies standpoint, the decarbonization project has been included as one of the pillars of the 2019-2022 National Development Plan and a National Decarbonization Plan has been developed, guided by three principles: a) promotion of structural transformations rather than incremental changes, b) providing the principles of a new paradigm for the development of Costa Rica, and c) development measures to ensure that the productive transformation towards decarbonization is inclusive.

Deepening the structural change towards a high added-value, knowledge-based bioeconomy

An approximation to the economic importance of bioeconomy can be obtained from its contribution to exports. In a study for Latin America and the Caribbean, Rodriguez et al. (2017) classified exports in five categories:[7] 1) commodities bioeconomy,[8] 2) value-added commodities bioeconomy,[9]

6 The program includes the following categories: agriculture, climate change, education centers, neutral climate community, communities, sustainable construction, ecclesiastic-ecological initiatives, eco-diplomacy, protected natural spaces, special events, sustainable homes, microbasins, municipalities, beaches, and community health.

7 Based on the classification of the Harmonized System products and using the Comtrade exports database.

8 Products derived directly from biological base primary sectors (agriculture and agro-industry; fisheries, aquaculture and by-products; forest products, and wood industry).

9 Products with some degree of processing, from biological base in primary sectors (food industry; wood pulp and paper industry; textiles based on natural fibers and leather products; biodiesel; bioethanol and other alcohols; solid bioenergy).

3) high added-value, knowledge-based bioeconomy,[10] 4) mineral and fossil economy[11], and 5) other manufactures.[12]

Bioeconomy exports in Costa Rica reached 43.5 % of the total value of exports between 2013 and 2015 (Table 2), out of which 28.1 % corresponded to bioeconomy commodities; 13.3 % to added-value commodities bioeconomy, and 2.1 % to high added-value bioeconomy products. Compared to the 2000-2002 period, the items with the biggest growth are added-value commodities bioeconomy items (9.1 % to 13.4 %) and high added-value bioeconomy items (1.2 % to 2.1 %).

Rodriguez et al. (2017) placed Costa Rica among the countries with a high proportion of exports of bioeconomy (higher than the regional average) and with a greater proportion of manufactures exports than mineral and fossil resources. This group includes countries in which bioeconomy would have a greater potential, since they already have an important bioeconomy export rate and an important manufactures export rate, which would facilitate expanding the production of bioeconomic manufacture production.

Table 2 shows some bioeconomy-related phenomena and its development in Costa Rica and its potential. When comparing the 2000-2002 and 2013-2015 periods, it is noted that:

- The largest growth takes place in the exports of high added-value bioeconomy, with an average annual cumulative growth rate of 10.5 % between 2000-2002 and 2013-2015. In this category, the highest growth is for biopharmaceutical (40.5 %) and biocosmetic (13.1 %) products.
- Biopharmaceuticals and biocosmetic exports rates contrast with the lack of dynamism of pharmaceutical and cosmetic products exports. Therefore, there is evidence of a change in the profile of these two industries towards the development of biobased products.
- Bioeconomy exports grow in a proportion almost equivalent (five percentage points) to the reduction experienced by the exports of manufacturing sectors (-4.8 percentage points). Gains in bioeconomy exports are generated by added-value bioeconomy items, especially in basic sectors, such as the food industry, and through the exports of high added-value bioeconomy products. The fall in the manufactures exports rate is explained almost entirely by the reduction in exports of textiles and clothing. Therefore, rather than a deindustrialization process, the fall the exports of manufactures is

10 Manufacturing sectors with biological-base raw materials (bio-based chemicals; biological-origin pharmaceuticals; bio-plastics; and biological-origin perfumery and cosmetics).

11 Mining-derived and fossil-based products.

12 The rest of the sectors, which are all manufacturing producing sectors.

proof of structural changes, in which the loss of importance of a traditional manufacturing sector begins to be compensated by the dynamism of biological-base manufacturing sectors (food industry, biopharmaceuticals, and biocosmetics).

Table 2. Costa Rica: indicators of the significance of exports by type of economy, compound annual growth rate (CAGR), and percentages

Classification	CAGR 2013-2015 vs. 2000-2002	Composition in selected subperiods		
		2000-2002	2007-2009	2013-2015
Bioeconomy	7.0	38.55	35.05	43.52
Natural resources bioeconomy	5.9	28.24	22.89	28.07
Agriculture and Agro-industry	6.3	25.22	21.36	26.07
Fisheries and Aquaculture	0.8	2.59	1.11	1.35
Wood and Forest Products	9.3	0.43	0.42	0.65
Natural Resources Added-value Bioeconomy	9.2	9.08	11.13	13.35
Food Industry	10.9	6.49	8.41	11.68
Pulp and Paper Industry	3.3	1.44	1.72	1.02
Natural Fibers, Textiles and Leather	-2.4	0.98	0.58	0.33
Biodiesel				
Solid Bioenergy	2.6	0.00	0.00	0.00
High Added-Value Bioeconomy	10.5	1.22	1.03	2.10
Biological-Base Chemicals	5.3	1.16	0.95	1.07
Biopharmaceuticals	40.5	0.02	0.02	0.96
Bioplastics	3.8	0.01	0.02	0.01
Biocosmetics	13.1	0.03	0.04	0.06
Mineral and Fossil Origin Products	5.6	4.55	4.85	4.35
Mineral Origin Products	7.2	3.73	4.18	4.32
Fossil Origin Products	-16.8	0.82	0.67	0.04
Manufactures	5.3	56.90	60.10	52.13
Metallurgy	9.0	0.75	0.98	1.07
Machinery and Equipment	6.0	38.64	37.84	38.64
Chemical Industry	9.9	1.39	1.42	2.22
Plastics and Rubber	9.3	3.34	3.41	4.99
Textile and Clothing Industry	-8.0	8.16	2.67	1.30
Pharmaceutical and Cosmetic Industry	0.5	3.61	3.62	1.81
Other Manufactures	12.0	1.02	10.16	2.10
Total	6.0	100.00	100.00	100.00

Source: Rodríguez et al. (2017).

Rodríguez et al. (2017) also identified those bioeconomy items that are better positioned in terms of competitiveness, using a simple version of the revealed comparative advantage (RCA) indicator through exports. Costa Rica ranks as one of the best positioned countries within the region, with a positive RCA in 7 of the 12 items (agriculture and agro-industry; fisheries, aquaculture and by-products; food industry; pulp and paper industry; bioethanol; biopharmaceutical, and biocosmetics), only below Brazil (9 items) and Uruguay (8 items). Costa Rica, together with Argentina, Brazil, and Uruguay are the only countries with anRCA in more than one sector of the high added-value bioeconomy products. And Costa Rica is the only country with RCA in the biopharmaceuticals and biocosmetics sectors.

Public-private links in R&D relevant for bioeconomy: The CR-biomed cluster

CR-Biomed is a non-profit partnership established in 2012 (re-founded in 2014) by a group of entrepreneurs, scientists, professionals, scholars, and public and private sector representatives, to promote and optimize the biotechnology, medical devices, and related to life sciences sectors. Led by the private sector, this partnership integrates academic and governmental sectors around the promotion of scientific activities and business driven by innovation.

CR- Biomed members include consolidated enterprises (Trisan Group and its Laquinsa and Bio Engineering business units; BIOTD; Florex), consulting and services companies (Bufete Arias, Marketplaza, Salud a un Clic), research centers (National Nanotechnology Laboratory and the Inciensa Foundation), biotechnology-based/synthetic biology startups (Bromé, Magenta Biolabs, Speratum, Cibus 3.0, Surek Biotechnology) and venture capital funds (Carao Ventures). The organization has the sponsorship of ITCR, Procomer, the Costa Rican Development Initiatives Coalition and the High Technology National Center.

CR-Biomed has three thematic areas: a) awareness (to establish a strategy for effective communication with the different sector and society actors on the benefits and impact of biotechnology in the economy and quality of life), b) improving competitiveness (to influence national policies and establish a regulatory framework in the field of biotechnology, so that the sector can develop in an efficient way, increasing competitiveness in international markets), and c) internationalization (to generate conditions and opportunities so that the biotech industry in Costa Rica is inserted and compete effectively in international markets).

Bioeconomy experiences in the private sector

In addition to a policy and institutional framework conducive to bioeconomy development, there are relevant, worth noting private experiences in different areas around Costa Rica. This section summarizes some of them, including some bioentrepreneurship innitiatives carried out by young people.

National Institute of Biodiversity: Management of biodiversity

A very important precedent for Latin America in terms of biodiversity management was the creation of Inbio, in 1989, as a private center (public interest) for research and management of biodiversity, with the aim of supporting efforts to strengthen the protection and knowledge of biodiversity and promote its sustainable use.

During its first stage (until 2015), Inbio promoted a management model based on the concepts of protection, knowledge, and sustainable use of biodiversity. To achieve this, the institute concentrated its efforts on five lines of action: 1) development of country inventories and monitoring of species and ecosystems (includes organisms associated with agricultural production); 2) conservation of biodiversity; 3) communication and education to promote environmental awareness in decisions made by the population; 4) bioinformatics, through the application of computer tools to support administration processes, analysis and dissemination of information on biodiversity, 5) bioprospecting to search for sustainable uses and commercial application of biodiversity resources. To support environmental education activities, the Inbio Park was built in 2000 in which the four forest types that represent most of the ecosystems of Costa Rica can be found.[13]

During the first two decades of its operation, Inbio depended heavily on external international cooperation resources. However, the institution failed to consolidate its financial self-sufficiency due to the gradual reduction of such resources and the insufficiency of income resulting from intellectual property or other income derived from biodiversity. This led the institution to a deep financial crisis, which significantly reduced its activities. The responsibility for the maintenance of biological collections was given to the National Museum and became part of its heritage; the Inbio Park became part of the National System of Conservation Areas (SINAC).

With the compensation paid by the government for land and other assets, the Institute entered into a new phase since March 2016, giving continuity to its environmental education mission. Inbio has also been working to find uses and applications for biodiversity, based on its wealth of data, as well as to comply with its sale of services to over 40 countries.

13 Central valley forests, rain forests, dry forests and wetlands.

The financial crisis faced by Inbio Park proves that its model was successful in terms of managing biological collections to generate knowledge, but without emphasis on their use for potential commercial developments. That was the main task of the Bioprospecting Unit, through the search for new sources of biological compounds, genes, proteins, microorganisms and other natural products that might be of interest for their potential to the pharmaceutical, cosmetic, agricultural and biotechnology industry. To move in that direction, Inbio must adhere to the CR-Biomed cluster,[14] with the aiming at complementing the efforts already made, adding science assessment capabilities along with other national public and private entities, as well as other science, technology, and innovation sectors.

Grupo Trisán: Agricultural bioinputs and solutions for wastewater treatment

Trisán is a corporate group funded with Costa Rican capital. It was established in 1961 as a distributor of products intended for animal health and, four years later, it expanded its product range to provide raw materials for the food industry and chemicals for the agriculture industry. Trisán represents international manufacturers of specialized inputs and works in the introduction, development, and commercialization of products and services for technological innovation, as well as environmentally friendly biosolutions for the agricultural, veterinary, agro-industrial, and industrial sectors. It has offices in all the countries of Central America and in the Dominican Republic.

Grupo Trisán currently has five business divisions: 1) Trisán Agro, dedicated to the commercialization of plant protection products, hybrid seeds, and products for agriculture, such as biostimulants and soil correctives; 2) Industrial Chemical Laboratories (Laquinsa), a company Trisán acquired a major participation in 1992, dedicated to the development of products for animal health and plant protection; 3) Trisán Food & Tech, a company that focuses on the food industry (marketing of raw materials, additives and functional ingredients); 4) Bio-Engineering S. A., known as Trisán Agua, created in 2005, which provides solutions for wastewater treatment, both industrial and domestic, and solid by-products generated by such activity, and 5) Trisán Ciencias Pecuarias S.A., created in 2005 and dedicated to the commercialization of Medicines, and products for health and animal production.

The activities dealing with bioeconomy are developed in Laquinsa and Bio Engenieering S.A., both members of the CR-Biomed cluster. Laquinsa is the group company responsible for carrying

14 Information verifiable at the close of this chapter (August 2018).

out R&D activities, and has obtained important patents in biocides and bacteriophages for shrimp farming activities and for biocontrol for the poultry activity, among others.

Industria Porcina Americana S.A.: Conversion of waste in bioenergy

Porcina American S.A., founded in 1977 is one of the country's largest pig farms, with an annual production of around 75,000 pigs (daily operation is around 300 pigs) running the entire production cycle: from gestation to delivery to the end consumer. In 2011, the environmental and health authorities initiated a closure process as a result of problems related with excreta, fat, and blood management.[15] Given the situation, the company decided to install a biodigester, which is the country's largest currently, and developed a project for its self-sufficiency in energy.

The process was guided by Ingenya Consultores S.A. in an alliance with Program 4E (Renewable Energy and Efficiency) of the German Agency for Technical Cooperation (GIZ), and the support of the Biogas Program of the Costa Rican Electricity Institute (ICE). The installed biodigester produces energy during 16 hours a day; its capacity is 3000 cubic meters of biogas, which is harnessed in a generator synchronized with the grid, and a capacity of 250 kilowatts per hour, with the use of 160 cubic meters of excreta per day.

The installation of the biodigester to harness residual biomass has made it possible to save approximately US$250,000 in energy. Although the company has a high demand for energy in its operation (1,149,750 kilowatts an hour in a year), the project generates a surplus of biogás, which is expected to be used to generate electricity for sale through an interconnection to the national grid.

Corporación Manza Té: Production of herbal teas, honey and snacks

Manza Té was born from the acquisition of a small artisanal plant dedicated to the production of chamomile infusion (*Chamaemelum nobile*), founded ten years ago. After a process of industrialization and diversification, the company currently produces and distributes honey, oatmeal, and processed granola, as well as a wide variety of natural, aromatic, fruit teas, and a mixture of herbs. The company has three product lines: 1) infusions, under the Manza Té brand, being chamomile its flagship product; 2) Bee honey, under the La Abejita brand, and 3) low total and saturated fat oat and granola, sweetened with honey bee, under the La Selva brand.

The chamomile used is produced on a farm owned by the company and is complemented by a network of suppliers located in different parts of the country. It currently produces 600,000

15 Despite having three oxidation ponds to pour their waste water, over time these were losing their capacity as a result sedimentation and wastewater ended up being discharged in a body of water.

boxes of tea per month and the brand represents 65 % of the national market of herbal teas. The company operates under the philosophy of "supporting national farmers", so it purchases from small herb farmers to produce other types of infusions (such as lime and mallow), in which a group of household head women in the San Carlos area, in the northern part of the country, is the main supplier.

The Corporation is also a leader in the honey market. Initially, the Company imported raw material because the honey produced in Costa Rica was of a very varied quality, insufficient production, and there was the possibility of adulterated honeys. In that bleak situation, the Corporation initiated a process of technical assistance with national beekeepers to improve honey quality and increase their production, as well as build trust with producers through stabilization of purchase prices and market conditions. To this end, the Corporation established training programs; costs and quality control advice, and an alliance looking to agree on prices, honor agreements, and establish short deadlines to pay for raw materials.

The process began with an association of eight producers of Jicaral (Guanacaste), producing 15 barrels of honey per year and currently involves 30 families (200 people) that supply six hundred barrels, which are packaged in a plant owned jointly by the association of producers and the Corporation. The program, which also includes associations of beekeepers in various parts of the country (North and South Pacific, Los Santos), is considered as a success case of good beekeeping practices. In the process, they have had the support of the National Health Service (SENASA). Currently, the Corporation works with beekeepers specialized in breeding queen bees, as well as in veterinary health. The Corporation supports beekeeper associations in the import of machinery, with advice on how to ensure quality, purity, and homogeneity of honey, as well as in marketing.

Corporación Manza Té has registered its trademarks in Costa Rica and the rest of Central America, as well as the color of the boxes for distributing its products and the bottle design to pack and distribute honey. The company follows the standards of the World Health Organization and the European Union for quality assurance of its products and sets procedure standards with the aim of obtaining the certification for organic products. The Corporation is certified for ISO 14001 and ISO 22000, and it is also certified as Marca País by Procomer, a special certification granted by Costa Rica to domestic products that guarantee special quality conditions, as well as the Ecological Blue Flag certificate, in the category of climate change, which is the first step to be Carbon Neutral certified[16] and obtain the C-Neutral label.

16 The Ecological Blue Flag is an annual award that rewards the efforts and voluntary work in the search for conservation and development, in accordance with the protection of natural resources, the implementation of actions to tackle climate change, the search for better hygienic and sanitary conditions, and the improvement of public health for the inhabitants of Costa Rica. The program

The Corporation has established commitments to sustainable development and inclusion. As part of the first, it replaced the use of methyl bromide by ozone in 2008, to cleanse and purify raw materials, which earned it the Award for Excellence in Environmental Management of the Chamber of Industries of Costa Rica. In addition, the company hires personnel with disabilities for certain processes or functions, which is considered as an exemplary impact for the rest of the collaborators.

Bioland S.A.: Natural foods and biocosmetics

Bioland (http://bio-land.org) is a family business founded in 1982 with the idea of revolutionizing the conventional industry of food products and personal care, offering natural products in a sustainable way. The company settled initially in a small plant in Cantón de Desamparados, south of San José, where it produced products for its own points of sale. In 1985, the company changed this policy and started to sell its own products in supermarkets and also exported personal care products to the Middle East, Europe, and North America. However, in the early 1990s, the company stopped exporting to grow in a more orderly manner, concentrating its expansion in the domestic market. In the late 1990s, the company moved to its current site, in Cantón de Tres Rios, to the east of San José.

The development of the company has been based on the design of a gradual process, planned to meet several stages, in accordance with the fulfilment of the following actions: a) to introduce a renewed vision and specific quality concept, in relation to the real advantages for the consumer; b) to contact healthy and nature-friendly raw materials producers and establish a support mechanism, offering guarantees to acquire their products and, in some cases, financing, and c) to replace those ingredients considered harmful, for other products that favor the aspects of human health and the environment. At the same time, it established a plan to contribute to the environment, recognizing that environmental responsibility should not be separated from industry practices.

Nowadays, the company produces over 300 products in the nutrition and cosmetics lines, made from organic ingredients. In the first line, it included dietary supplements, snacks, and cereals, and under the biocosmetics line, it offers three lines of products under the brands Vegetus (soap),

includes the following categories: agriculture, climate change, education centers, neutral climate community, communities, sustainable construction, ecclesiastic-ecological initiatives, ecodiplomacy, protected natural spaces, special events, sustainable homes, microbasins, municipalities, beaches, and community health (https://banderaazulecologica.org/).

Organics (hair care), and Dermia (facial care). To develop new business ventures, Bioland features innovative processes and an intensive R&D program.

The only export market the company has kept for the past fifteen years is Panama. It has also been focused on the development of a unique line of organic cosmetics marketed in Costa Rica, by opening its first store. In addition, it has opened outlets in the Juan Santamaria International Airport in Costa Rica and in Tocumen International Airport in Panama, and has exported its three lines of cosmetics to Guatemala. Bioland's expansion plan also includes selling the franchise in other countries, for which they have received offers from interested parties in Spain, Holland, Canada, United States, Mexico, South America, and several other countries in Central America. The expansion plans for the next three years involve exporting its Organics brand products throughout Central America, as well as the Dominican Republic, Puerto Rico, Trinidad and Tobago, and Jamaica, ending in North America.

Agribiotecnología de Costa Rica S.A.: micropropagation of in vitro plants

Agribiotecnología de Costa Rica S.A.- Agribio- (http://agribiocr.com) is an agricultural biotechnology company with 100 % Costa Rican capital, created in July 1985 by Óscar Arias Moreira.[17] This is the first private biotechnology laboratory of Costa Rica that began as a small tissue culture laboratory that produced ornamental plants for the United States market. Currently, its installed capacity allows the production of approximately fifteen million *in-vitro* plants per year, being the largest Latin American micropropagation laboratory.

Agribio produces disease-free plants with high genetic stability. It has over 250 propagation protocols for musaceae, coffee, pineapple, sugar cane, vanilla, forest products, orchids, ornamental plants, energy crops, roots, and tubers. It has standardized quality management processes certified under the INTE ISO 9001:2008 standard. It currently exports its products to the United States, Central America, South America, the Caribbean, Europe, and Africa, and has strategic alliances in Ecuador, Peru, El Salvador, Dominican Republic, Africa, Mexico, among others.

Agribio has an active research and development program in the field of biotechnology as in modern agricultural production systems. It offers services such as a) research and development services for in vitro propagation protocols and other commercial propagation techniques (development of plant propagation systems, through the use of *in vitro* and *ex vitro* techniques, in search of quality, safety and efficiency); b) development and administration of agroindustrial

17 Research in agricultural biotechnology in Costa Rica originated at the end of the 1970s, when, at the initiative of Óscar Arias Moreira, the first Plant Biotechnology Laboratory, under the Agricultural Research Center of the University of Costa Rica, was created.

projects (offering integral solutions for forest production projects, pineapple and banana, production and industrialization of juice and pulp, and production and exporting of decorative plants, and c) technical support and scientific project support (planning/structuring, financial analysis, development, implementation and agroindustrial projects with musaceae, pineapple, fores products, citrus, decorative plants, roots, tubers, and biofuels. Other services include virus cleaning, germoplasm conservation, somaclonal selection improvement, and seed viability analysis.

The company also cooperates with several national institutions sucha as Corbana, Icafe, the School of the Humid Tropics, the UCR, the Costa Rica Institute of Technology (TEC) and Inbio. It also cooperates with the Latin American and the Caribbean Consortium to Support Cassava Research and Development, which brings together entities and institutions linked to production, processing, marketing, and use of cassava and other roots and tubers, in countries of Latin America and the Caribbean, and in Africa.

Aware of the significance of environmental sustainability, Agribio focuses on energy saving, efficient use of water, low use of conventional fertilizers, and integrated pest and disease management, using alternative systems, beneficial microorganisms, and bioproducts. In 1999, the Chamber of Exporters of Costa Rica awarded it with the Prize to the Exporting Effort, and in 2005 and 2012, the Presidency of the Republic, and the Ministry of Agriculture, conferred its president with the National Medal of Agricultural Merit.

Bioentrepreneurships

Bromé: Bromelain and microcrystalline cellulose from pineapple waste

Bromé is a startup focused on the extraction biocompounds of interest from pineapple crop residues for the food and pharmaceutical industries, through biotechnology. The company was set up by Daniel Mendez during his time as a student of biotechnology at UNA, in Heredia, Costa Rica, motivated by providing a solution to the problem of pollution generated by the pineapple production. This is a very important agro-export activity in the country, since Costa Rica is the world's leading exporter of pineapple, with over 60,000 hectares dedicated to its production. The activity generates about 8-10 million tonnes of waste that is not harnessed, becoming an environmental pollution problem. In addition, of particular importance is the proliferation of the fly *Stomacxys calcitrans*, which affects livestock activity.

The initiative was born with the name of Reuti Piña, which emphasized the resource used (residues of pineapple production). Bromé highlights its main product: *bromelain*, and its orientation is to produce an enzyme technology to provide solutions to the food and pharmaceutical industries. Bromelain is an enzyme present in the bromeliads, the pineapple family (*Ananas comosus*), which has the ability to break the proteins in the same way as the *pepsin*, an enzyme that is part of the gastric juice, so it is used in the food and beverage industries.

Bromé has also developed a technology for the production of *microcrystalline cellulose* (MCC), based on pineapple waste, once bromelain is removed. The product can be used as an ingredient in drug manufacturing processes. For example, it can be combined with other excipients in tablet compression processes; it offers advantages in terms of the resistance of the tablet, the sensitivity to the lubricant and wet granulation; it serves as a binder suitable in tableting processes as a result of its hardness and compressivity, and it is not a toxic nor a reactive substance.

In its initial phase, Reuti Piña/Bromé received support from the UNA Incuba program. In its current phase, it has received support from the National Center for Biotechnological Innovations (Cenibiot) and the Costa Rica Exports Program, Procomer. Bromé is one of the founding members of CR-Biomed.

Magenta Biolabs: Biocosmetics from agricultural waste

Magenta Biolabs (http://magenta-biolabs.webflow.io/) is a startup created by biotechnology students of the TEC. Its beginnings go back to early 2015, when their founders (Marcelo Castro, Rafael Wolf, Joseph Paul Mendez and Sofia Miranda) participated in the national competition called *Startup Weekend*, which allowed them to gain access to program of pre incubation of the TEC by the end of the year. Although it was difficult to obtain funding to carry out their project, they had the opportunity to particiapte in Indie Bio (https://indiebio.co) in early 2016. The students were accepted in the competition that year, which allowed them access to financing and training in business tools in the Indie Bio accelerator, in Ireland.

Magenta Biolabs is working on the development of a process to produce hyaluronic acid from agricultural waste. The hyaluronic acid is part of certain tissues such as joints, nerves, and skin, and acts as a shock absorber, lubricant, and moisturizer agent. With age, the body loses its ability to produce this component, which makes the skin to lose hydration and firmness. Magenta seeks to give a solution to this problem at a lower cost than traditional anti-aging cosmetics. The hyaluronic acid, in conjunction with collagen and elastin, provide firmness and a more youthful skin appearance. Magenta uses agricultural waste in its production processes, working in conjunction with producers cooperatives which subsequently will reap economic rewards from sales.

Hemoalgae: Anticoagulants from microalgae

Hemoalgae (http://hemoalgae.com) is a synthetic biology startup oriented to the development of hirudin, an anticoagulant obtained from microalgae that acts as an inhibitor of thrombin, an enzyme generated from coagulation. This would reduce production costs of the traditional anticoagulant drugs, with a product of better assimilation and effectiveness than these. Additionally, rapid growth and obtaining of raw materials can be ensured.

Hemoalgae was created at the end of 2016 by biotechnology students of the TEC, after their founders (Myrka Rojas, Diana Mendoza and Luis Barboza) participated and won the first place in the *Synbio Thon* synthetic biology competition, in which teams of students work during a weekend to create a genetic device that can solve a community problem. After obtaining the first place, the startup began its pre-incubation process guided by the TEC. A few months after its creation (April 2017), *Hemoalgae* won the support of RebelBio,[18] an Irish Bio-Accelerator company especialized in synthetic-biology biotechnology. The agreement with this global-reach company included training, infrastructure provision, and financing to entrepreneurs in exchange for an 8 % of the property participation. In addition, at the end of 2017, *Hemoalgae* won the first place in its category in the *Get in the Ring* competition (oriented to the identification of innovative startups and accompaniment to its consolidation) in Costa Rica and represented Costa Rica in June 2018 in the international contest.

Jeca Pharma: Pharmaceutical products obtained from ginger

Jeca Pharma (http://www.jecapharma.com) is a startup founded by Jean Carlo González Guevara, a pharmacist who graduated from Universidad Latina de Costa Rica, in 2015. The company develops innovative pharmaceutical products based on mushrooms and medicinal plants, through the application of nanotechnology and biotechnology. In 2016, the company won the Rodolfo Jiménez Borbón award within the Framework of *Yo Emprendedor* competition in Central America, for its enterprising attitude. The company is currently developing two products. The first is called JenGel, a gel with antimicrobial properties, capable of preventing the growth of main common bacteria that cause skin infections. The gel is obtained from ginger (*Zingiber officinale*) extracts and is used in the treatment of burns, wounds, and ulcers. The second product was derived from the JenGel research and is called JenVag Ovules, also made from ginger extracts and used to combat vaginal infections caused by the *Candida albicans* fungus.

18 Rebelbio (https://rebelbio.co/) is one of the world's most important biotechnology projects accelerators.

Flores y Follajes del Caribe: Biotechnology for the development of orchids

Flores y Follajes del Caribe (https://agribiotechnologies.com) is a family company founded in 2015, located in Guácimo, in the Costa Rican Caribbean region, founded by agronomist Marco Antonio Córdoba. The company was created to export tropical flowers; however, it turned its business towards the development of a supply of products with greater incorporation of technology and added value. Currently, the company focuses on the genetics of orchids in a biotechnology laboratory of plants, and is dedicated to the production of three types of orchids, special for cut flowers and exhibitions. A second line of business is agritourism, which is developed in the Caribbean Botanical Garden, a botanical garden of 4.5 hectares owned by the company, with trails, thematic gardens and areas dedicated to the development of tourism projects. Flores y Follajes del Caribe has been supported by Procomer and also receives cooperation from Cenibiot to develop new products. In 2017, the company won the first place in the national Seedstar competition, hosted by Procomer. The company plans to export products to Mexico, Chile, Central America, Canada, and the United States; it also aims to reach Europe with cut flowers. In addition, the company is developing a hybrid of white orchids for the wedding-oriented flower market.

Cibus 3.0: Biodiesel from residual whey from the dairy industry

Cibus 3.0 was created in 2011 by a group of students and graduates of the Biotechnology program of the ITCR, who conform the first synthetic-biology group of Costa Rica, focused on the transformation of industrial waste into bioenergies. The product developed by Cibus 3.0 is biodiesel made from milk whey, called *lactodiesel*. To do this, they designed and constructed a bacterium capable of transforming lactose (milk sugar) into lipids (fats), which then, the same bacteria uses to produce biodiesel. The bacteria is designed so that once the process is complete, it will disintegrates and release the biodiesel. This product allows to dodge the *food vs. fuel* dilemma and reduce potential land use conflicts as a result of the expansion of energy crops. The project would give use and economic value to the more than 800,000 tonnes of milk whey generated as waste on the part of the dairy industry in the country.

The main objective was to participate in the International Genetically Engineered Machine (IGEM) competition, organized by the Massachusetts Institute of Technology (MIT), in 2012, a global event oriented mainly to young undergraduates to develop a specific-theme, synthetic-biology project. The Cibus 3.0 team has participated twice in Latin American competitions and, until now, is the sole representative of Costa Rica. In 2012, the team participated and won the first place in the Ecofriendly Projects category in the Business Ideas Fair of the ITCR and, the same year, participated in the business plan contest called *Yo Emprendedor*, where they received three awards (Elevator Pitch, Idea with the greatest projection, and first place in the Clean Energy category). In 2013, the team participated and won the third place in the CleanTech Open competition, held in the United States, in the Global Ideas category, although they received the first place in the Transport category. Finally, in 2015, the team was a finalist in the Talent and Innovation Competition of the Americas, in the Economic Innovation Category.

Conclusions and final remarks

Costa Rica has a set of conditions that place it in a very favorable position to make rapid progress in the development of a national bioeconomy strategy. Further, the proper implementation of this strategy may allow the country, within a reasonable period of time, become a global leader in the bioeconomy field.

Several circumstances come together: first, the desire expressed during the last decade, at the highest political level, to move towards decarbonization. This aspiration is initially expressed as a goal of neutrality for the 2021, in the 2007 National Climate Change Strategy and in the 2010-2014 National Development Plan. Also, ratified by president Carlos Alvarado, in his office assumption speech, on May 8, 2018, by stating that "decarbonization is the great task of our generation, and Costa Rica should not only be among the world's first countries to succeed in it, but the first". Secondly, and within the framework of advancing to decarbonization, Costa Rica's reputation as a sustainability leader must continue. A global leadership that is widely acknowledged, for example, in the development of a system of areas for the protection of its biodiversity, in sustainable tourism, clean energy production, and climate change. Thirdly, the country has institutional frameworks and public policies in place in areas relevant to the development of bioeconomy, such as biodiversity, sustainable agriculture and livestock, bioenergy, environmental services payment, and development of an internal market for carbon dioxide. In many of these fields, Costa Rica has been a pioneer: the implementation of a system of environmental services payment, and the development of NAMAS in the agricultural sector (coffee and livestock) are notable examples. A fourth element, but no less important, is the availability of a good human capital base, as a result of the investment the country has made in education, as well as scientific capabilities in the areas of biological sciences, as recognized by the OECD (2017). The country has more than 30 research centers in biological sciences, sustainable development, and relevant areas to implement bioeconomy at the main public universities (Table 1). The Cenibiot and the National Nanotechnology Laboratory work as a shared platform for public universities to work hadn in hand with the national productive sector.

Finally, and in relation to the previous point —although there is no systematized evidence in this regard—, there are indications that innovative scientific-based enterprises in bioeconomy-related areas are increasing, especially created by young entrepreneurs, many of them students and graduates of ITCR, UNA and UCR schools of biotechnology. Such initiatives provide signs about alternative niches for new business and value chains, such as harnessing biomass from waste to generate high added-value products. The creation of the CR-Biomed cluster - whose membership includes both consolidated companies and under consolidation companies- is considered as a crucial step in the creation of an ecosystem to boost bioeconomy base companies.

In summary, the will expressed by governments of different political parties during the last decade and the leadership of the country in the field of sustainable development, along with the path in the creation of institutional frameworks and policies, and the existence of technical and scientific capacity and a climate favorable to innovation in such relevant areas, are elements that should be on the basis of a Bioeconomy Strategy, in Costa Rica. The formulation of this strategy poses articulation, alignment, and convergence challenges. It is important to articulate public policies with the institutional actions derived from them; for example, in areas related to the sustainable use of biodiversity and ecosystem services, with the sustainable intensification of agricultural production and the development of closed-cycle production systems (circular economy) in which a full utilization of biomass, among others, is achieved. Likewise, it is necessary to articulate both public and private initiatives, as well as science and technology innovations in these areas; to align incentives and public and private investment, and the convergence of visions, interests, and wills. The goal is decarbonization; the path is bioeconomy. Turning the country into a world reference laboratory for decarbonization of fossil fuels through bioeconomy.

The formulation of a bioeconomy strategy should involve, at least: a) the establishment of a governance system which defines the roles and responsibilities of the entities involved; b) the definition of a model that ensures economic and financial sustainability for the process and makes viable the purpose of reaching several markets through bioeconomy innovations, and c) a communications, coordination, and political dialog system with different social actors (Aramendis, Rodríguez, and Krieger, 2018). It should also bring clarity in terms of the legal framework and the regulations, provide mechanisms for access information on market access and intellectual property issues and contemplate the development of monitoring and evaluation mechanisms.

A bioeconomy strategy built under such premises should also be framed in the two major policy frameworks defined by the international community: the 2030 Agenda for Sustainable

Development and the Paris Agreement on Climate Change. It should also be functional to two great national objectives: on the one hand, the great goal of decarbonization, which should go hand in hand with processes of innovation and productive diversification; and on the other hand, the inclusion of territorial development and social inclusion objectives.

Such a strategy should also be supported in complementary fields, in particular: a) *strengthening the national system of science, technology, and innovation*, from the biological sciences and its convergence with other disciplines, such as nanotechnology and digital technologies; b) *diversification of exports* and taking advantage of the opportunities offered by free trade agreements Costa Rica has signed; c) *Investment attraction* towards biological-base sectors in which high technological development and added-value conditions are combined, with the creation of quality jobs and regional development opportunities; and d) *creating conditions to develop entrepreneurship*, especially by youngsters and women, and the creation of new value chains.

A final comment on the National System of Science, Technology, and Innovation *vis-a-vis* the creation of conditions for bioeconomy development is the need to strengthen the role of the agricultural sector. The National Plan for Science, Technology, and Innovation 2015-2021 (MICITT 2015) includes, the area of food and agriculture as one of its five areas to impact; however, in the description of the institutions of the science, technology, and telecommunications sector, the only two entities related with this area are the National Science and Food Technology Center (CITES) and Cenibiot. Given the structure of the State, INTA is not included as it belongs to the agri-food sector. However, the agricultural sector is central in research, development, and innovation fields in Costa Rica; for example, at least ten research centers, out of the 34 research centers listed in Table 1, directly fall under the food and agriculture area. And only in the agricultural sector, there are private research centers funded directly by associated entities (Icafe and Corbana).

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Bioeconomy in Mexico

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Introduction

As an emerging economy, Mexico is now positioned in the international scenario as a country with a very interesting potential due to the mobility of its products, its proximity to the American market, and also due to its undoubtedly leading position in the field of Latin American exports. The country has, to date, a very extensive network of free trade agreements with 46 countries, 32 agreements on reciprocal promotion and protection of different investments, 9 limited scope representation agreements, and it is also a member of the Trans-Pacific Partnership Treaty (TPP). Among the principal countries that Mexico trades with under such schemes are the United States and Canada (North American Free Trade Agreement, NAFTA). Currently, the country is going through renegotiations with the republican government, the Southern Cone and Central American countries, the Costa Rica Free Trade Agreement (FTA), El Salvador, Guatemala, and Nicaragua; and also, a FTA with Peru, another one with Panama, besides some agreements with Colombia, Venezuela, Costa Rica, Nicaragua, Chile, Guatemala, Honduras, El Salvador, Uruguay, and the Free Trade Agreement between the European Union and Mexico (FTAEUM), a FTA with Israel, and a FTA with Iceland, Lichtenstein, Norway, Switzerland, and Japan (ProMéxico, 2017).

It is worth highlighting that there is a misconception around the *bioeconomy* term, as it is usually connected to the genomics and medical bioecomony areas, where many successful companies are thriving. Such companies are devoted to the production of medical devices, health care, pharmaceutical research, and lately, medical tourism. Thanks to ProMexico -a subdivision of the Mexican Secretariat of Economy- the biotechnology industry has been estimated to be worth 307,000 million dollars. Such estimation also includes the pharmaceutical and health industry, which are industries where Mexico occupies a leading position (ProMexico, 2016).

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Regarding the public policies related to bioeconomy, they are focused on the development of bioenergetics, in conformity with the Inter-secretarial Bioenergetics Strategy (2009), and also supported by the Law of Bioenergetics Promotion and Development, 2018. This fact has allowed the country to diversify its mix of energy sources. The generation of bioenergy finds its support from the State Secretariats of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA); The Secretariat of Environment and Natural Resources (SEMARNAT); The Secretariat of Energy (SENER); The Office of Economic Affairs (SE); and the Secretariat of Finance and Public Credit (SHCP).

The knowledge-based bioeconomy seems to be incipient within the Government speech, which does not mean that the country is not working on producing goods and services based on biological resources or biorefineries. That is why the present document gives an account of some selected Mexican companies with a bioeconomy base that have managed to be positioned both in the national and international economy, despite the decrease in financial support, Mexican patents, and technology and innovation, which numbers are much lower in comparison with other countries (table 1). Some of the main issues the new knowledge-based bio-companies have to face, besides the above mentioned, have to do with a heavy administrative burden, especially for startups, as well as a much lower proportion of sustaining capital and the increasing need to promote the national research integration as a means to have greater and more often technology transference coming from academic and research scenarios in the future (Organization for Economic Cooperation and Development [OECD], 2013).

Table 1 Biotechnology submitted patents by institutional sector from some Latin American selected countries

	2006	2007	2008	2009
Public Research Institutions				
Brazil	0	2	2	1
Chile	0	0	0	0
Colombia	4	0	0	1
Mexico	1	1	3	0
Higher Education Public Institutions				
Brazil	15	14	17	14
Chile	1	4	7	5
Colombia	1	0	0	1
Mexico	1	3	3	3
Total of Research Institutions				
Brazil	15	16	19	15
Chile	1	4	7	5
Colombia	5	0	0	2
Mexico	2	4	6	3

Source: Taken and adapted from OECD (2013).

There exists however, an important infrastructure for research in the country. In addition, Mexico has some advantages at hand: it has a great potential based on its mega-diversity of ecosystems and species, besides its high qualified human resources (table 1); it is also important to consider the manufacture costs in the country, which are considerably competitive, and also the country's beneficial geographical position, close to the largest market for the commercial block of the North American Free Trade Agreement (NAFTA), namely The United States (ProMéxico, 2016) Another aspect the Government is in charge of is the adjustment of the current legislation, since the Country is part of The Nagoya Protocol on Access to Genetic Resources, a program sponsored by the United Nations Development Programme (PNUD, 2017), whose main objective is:

> To protect traditional knowledge and improve the capacities of indigenous people, local communities, and other stakeholders as to create social awareness on the conservation and sustainable use of biodiversity, genetic resources (GR), and Associated Traditional Knowledge (TK); as well as the distribution of benefits generated from such access and its use.

Figure 1. Examples of biodiversity in Mexico

Source: Mexican Commission for the Knowledge and Use of Biodiversity (CONABIO, 2016).

According to OECD, by 2013, the most important barriers or obstacles to develop new biotechnology-based companies can be linked to the constant weakness to provide seed funding, risk capital and angel investment, as well as the effects of low leverage of public support to such capital. The existing technological parks have had a limited success, but they are indisputably functioning and there are several successful companies in the country. It is necessary to increase the entrepreneurial capacity of highly specialized human resources, as a means to better meet industrial and technological needs, and as such contribute to a sustainable bioeconomy. Accordding to ProMéxico (2016), by 2016, there were more than 400 companies using or developing modern biotechnology distributed as follows: 75 companies in agriculture, 82 in environment, 54 in human health, 85 in food products, and the remaining 118 in various industries like animal health, aquaculture, and others.

Selected cases

By 2050, Mexico will be challenged to provide inputs for more than 150 million inhabitants. That explains why a national (socio-economic) model oriented towards those sectors of bio-based companies is needed in order to take advantage, in a practical way, of the existing technology, generate jobs for the scientific and technological human resources that are graduating from college every year, and also get enough financial support so the corporate networks and clusters can be sustained in present and future times. In that way, it would be possible to improve the interaction between the institutions and associations that represent the interesting parties of the bioeconomy in the country.

Case 1. Biofábrica Siglo XXI

This company is devoted to the production of biofertilizers based on microorganisms coming from Mexican soils obtained by national research agencies. It is a spin-off company from Universidad Nacional Autónoma de México (UNAM), based in Mexico city, which is linked to innovation for a sustainable agriculture. Biofábrica Siglo XXI has cooperation agreements with the best national research agencies working on biotechnological and agricultural research. It has also taken part in some programs of the Mexican Government. Its product list include formulated biofertilizers based on *Rhizobium etli, Azospirillum brasilens*, and mycorrhiza *Glomus intraradices*. It also produces vinasse-and-cachaça based biological compost, both feedstocks being subproducts of the sugarcane industry and the ethanol production, added with biofertilizers. All its products use microorganisms that are beneficial to plants and soil, therefore achieving to produce better crops. One of the most important results from this company has to do with the increase in the corn-plant root size which, in turn, strengthen this crop as a whole (Figure 2). Currently, there are conducting research aimed at using antagonistic bacteria against fungal *Phytophtora* and *Fusarium*, two prevalent fungi in Mexican soils that cause fungal attacks, especially in potatoes and corn crops. Thus, they expect to have a better biological control over these phytopatogenic fungi. Its new biofertilizers will have enriched formulations with these antagonistic microorganisms.

Figure 2. Examples of root development achieved by using Biofábrica Siglo XXI biofertilizers

Source: Biofábrica Siglo XXI.

Case 2. Agro & Biotecnia S. de R. L. de C. V.

Agrobiotecnia produces Fungifree AB® (Figure 3), which is a broad spectrum biofungicide. It was first developed and marketed in Mexico, and it won the Innovators of America award in 2014. This product, which active ingredient is *Bacillus subtilis* 83 spores, has been formulated based on technology from the UNAM Biotechnology Institute and the Research Center in Food and Development (CIAD Culiacán). Fungifree AB® makes it possible to reduce the use of chemical pesticides while harvesting good quality (safe) fruits and, therefore it contributes to the alternative management of pests in a sustainable manner. Founded in 2008, this company is associated to Agroquímica de México FMC, a trading company. As such, Agrobiotecnia has managed to accomplish an appropriate commercial distribution, and also be able to tackle one of the most common causes for failure for companies: the lack of financial support for domestic, and eventually international, distribution and commercialization.

The development of this product is an example of the team work of phytopathologists, microbiologists and process engineers who managed to develop an effective formulation for the control of various phytopathogenic fungi that affect more than twenty crops of commercial importance such as mango, avocado, citrus, berries, tomatoes, chili, zucchini, etc., without risk to the consumer. Thanks to the group of scientists associated with the company, it has been possible to obtain -from the bacteria-, the production of various compounds such as antibiotics, stimulators of the plant's immune system, and plant growth regulators. This explains the product's broad spectrum of use in several agricultural crops. Fungifree AB® is an innocuous product that holds a certification of the Organic Materials Review Institute (OMRI), which grants its use in organic production, and subsequently enhances the export capacity of Mexico (Calzada Rovirosa, 2015).

Figure 3. Fungifree AB®

Source: Agro&Biotecnia.

Case 3. Kurago Bioteck

This company is based in the state of Jalisco, a place with an important tradition of the use of *Agave tequilana* var: Weber for the production of tequila. The Kurago Biotek company uses biotechnology of synergistic symbiosis by means of the biological interaction between prebiotics, probiotics and nutrients, in non-dairy bases, unique in the market containing agave fructans as a means of support for microorganisms and, in turn, as a prebiotic for the consumer. Their best-known product is Ventro (Figure 4). To date, they have 19 functional products in the market within different distribution chains: supermarkets, medical nutrition, direct sales networks, and industrial dining-rooms.

Figure 4. Ventro

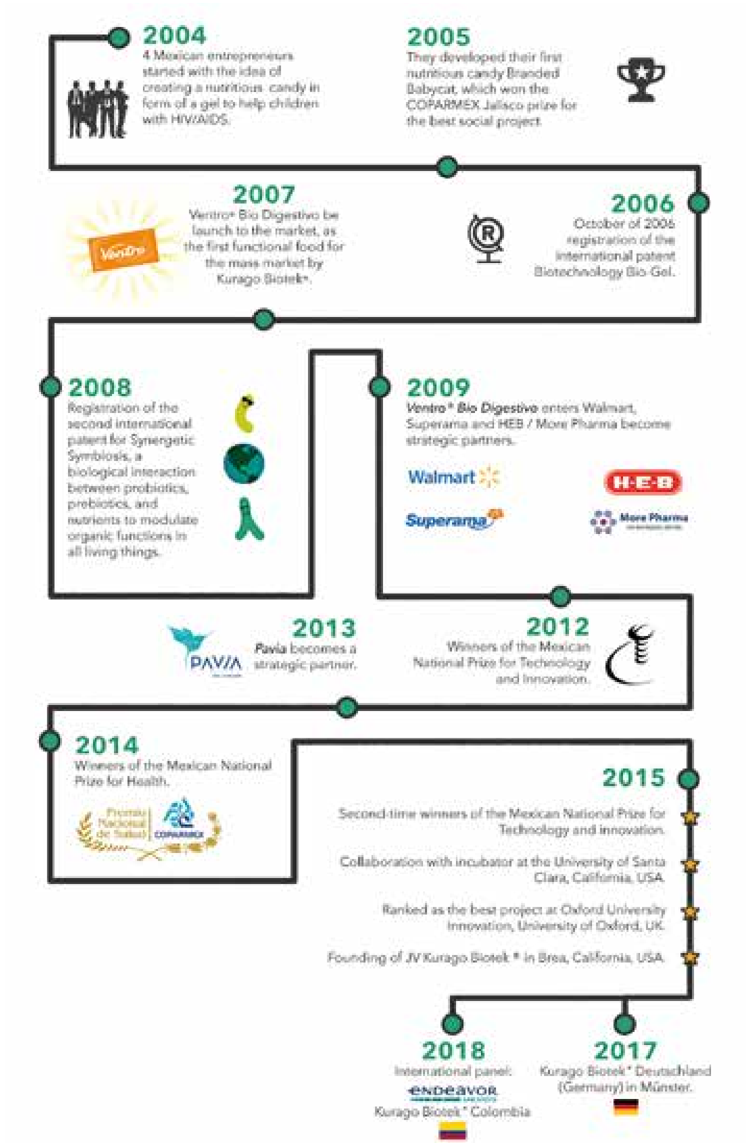
Source: Kurago Biotek Holdings SAPI de CV.

By means of the biogel patent, this matrix is used as a vehicle for living and metabolically active nutrients and microorganisms. The resulting functional food is able to modulate organic functions, such as uremic toxins in chronic kidney reduction, adjuvant chemo- and radiotherapy, muscle mass construction, and cholesterol reduction as a result of low-density lipoproteins (LDL), among others. The initial idea was developed with the clear objective of modernizing those foods that have ages old tradition among Mexicans. This constitutes, undeniably, a competition for the polysaccharides-based products coming from different sources such as chicory or Jerusalem artichoke. This feature provides their product with a novel competitive advantage, while it uses a purely Mexican resource: fructan polysaccharides agave, which, in the end, is their differentiating factor.

The Company's expertise (know-how) relies on the polysaccharide bonds that microorganisms are able to use, together with their molecular weight, to grow and restore populations in the gut microbiota, as well as in a selective fermentation by design of bioprocesses that give way to the segregation of metabolites like enzymes, proteins and acids by microorganisms. The Company develops its products aided by its in-house scientists, and also by means of collaborations with national and international research and development institutions.

Lately, the Company has managed to become incorporated with the Münster Industrial Park in Germany, and it has managed food biotechnology transference to Europe. Likewise, the company succeeded in having this transference to the United States. Figure 5 presents the Kurago Biotek strategic development plan. You can find the TED conference on this matter under the link: https://www.youtube.com/watch?v=ky6aNq0Xf6k&t=20s

Figure 5. Kurago Biotek strategic development plan scheme



Source: Kurago Biotek Holdings SAPI de CV.

Case 4. Industrias Vepinsa

This industry is devoted to the production of natural colorants as nutraceuticals for sale in pharmacies. Founded in 1969, this company started producing natural colorants for the poultry industry, and diversified their product lines to include pigments for the biotechonological sector since. Their specialty is the production of lutein (esters and concentrate) for eye care. Similarly, they conduct different research projects on the use of different biomasses such as agricultural or fisheries waste, in order to extract their nutraceutical elements. Besides, they exploit primary production materials such as blue corn, hot peppers and Jamaica flower for the production of anthocyanins, lycopene and carotenoids. The company is located in the northwest of the country (in the state of Sinaloa), it exports 40 % of its production to the United States and 10 other countries in Central and South America, Europe and Asia. To date, it owns 10 patents in the biotechnology sector. Figure 6 presents two logos of its core products.

Figure 6. Logos of its main nutraceutical products

Source: http://vepinsa.com.mx/espanol/linea-humana/nutraceuticos/lutiplen-e/

Case 5. Enmex

Enmex is a leading company in the biotechnology sector in Mexico. It was founded in 1972. It has more than forty years of experience in fermentation processes for the manufacture of industrial microbial enzymes for the food industry, besides its use for proteins hydrolysis, animal nutrition and the brewing, starch, dairy, juice, and bakery industry, among others. In addition to meeting the tannery and textile industries' needs with enzymes, it also produces enzymes for detergents and biological soaps. It exports 60 % of its production to North America, Central America, South America, the European Union, Asia and Middle East. The enzymes they produce are used in many day-to-day consumer products available in the supermarket. Holding a wide range of products, this company is one of the oldest in the Mexican industry (Figure 7).

Figure 7. Enmex Production Facility in the State of Mexico

Source: http://www.enmex.com.mx/index.html

Case 6. Benthos Bioscience/Coco Chavita

This is a marine biotechnology company founded and based in Escuinapa, Sinaloa, in 2008. Devoted to the extraction and processing of bioactive compounds, mainly the *Isostichopus fuscus* sea cucumber also called brown sea cucumber, under one of the eight commercial permits granted in the country by SEMARNAT. The bioactive compound extraction technology has been developed in Mexico and has been transferred to Asia and North America. Through this technology, the specimens are used to extract collagen fibers, in a more efficient way for the pharmaceutical and cosmetic industries. Thanks to this technology, it is possible to collect top priced collagen fibers.

In terms of research, the company takes advantage of the Isostichopus specimens' microbiota in search for beneficial microorganisms that may contribute to the control of diseases in critical aquiculture activities in Mexico, such as shrimp. Similarly, they work on the improvement of health conditions for the sea cucumber species. Likewise, they conduct research on how to use other echinoderms species from Mexican waters and their biodiversity. Besides, they use sea cucumber breeding technology, improved and adapted to Mexican conditions and recognized as a leading technology in innovation and development of the area by the Food and Agriculture Organization of the United Nations (FAO). This technology, in turn, will contribute to the repopulation of the used species. It is worth mentioning that the above mentioned specimens are collected and processed by inhabitants of those coastal communities where they conduct their operations.

Case 7. BioFields

This is a Mexican industrial group created in 2007 to generate clean photovoltaic energy, as well as to produce high value oils and biofuels in an environmentally-friendly manner. Its agricultural division produces castor oil beans on more than 14 thousand ha — by contract and on company lands in the Sonora and Sinaloa state, in the northeast part of the country- (Figure 8) for the Castor oil production with applications to the plastic industry, synthetic fibers, inks, nail polish, lubricating products, cosmetics, among other industries. It takes advantage of the fact that castor oil contain about 45 %-55 % oil in its mass on wet basis.

Figure 8. Ricinus plant (castorbean) farm at El Sahuaral

Source: http://www.biofields.com/

Bioethanol, which is the most innovative company's product, is being produced together with the American company, Algenol. It is important mentioning that this innovation is based on the direct production from blue-green algae (cyanobacteria) ethanol production, autotrophic prokaryotes which, when exposed to solar radiation (photosynthesis) and as a CO_2 source (coming from a plant of the Federal Electricity Commission), accumulate the necessary glycogen in order to produce ethanol (Figure 9). This process prevents any competition with food production, as the algae cultivation facilities are located in desert areas and marginal lands with no possibilities for agricultural use and extreme weather condition —sunny 328 days a year—. They also use an easy scalable system, given its proximity to seawater, necessary for the algae. They are located near Puerto Libertad by Mar de Cortés.

Figure 9. Algenol Algae Farm Facilities at Puerto Libertad, Sonora

Source: http://www.biofields.com/

Case 8. Bioplásticos y Polímeros Biofase SAPI de C. V.

Biofase is a Mexican company, founded in 2013, devoted to produce a family of biodegradable resins that can be processed by any method of molding plastics, as the one coming from an existing polymer in avocado seeds, which are an agro-industrial waste. It can replace certain applications of polyethylene, polypropylene and polystyrene. Their technology is patented, they produce plastic cutlery containing, at least, 70 % of the seed polymers, which are also biodegradable, even in garbage dumps. However, there are no composting systems that produce gas. This innovative process has been acknowledged as one of the five best bioplastics in the world. The processing plant, which currently has a capacity for 700 tons a month is located in Morelia, Michoacán, is very close to the major avocado production farms in the country, where discarted seeds can certainly be found. The two main technologies of the company are the Avoplast hybrid resins, with 70 % avocado biopolymer, or the compostable resins with 100 % biopolymer, for the different applications, depending on the required properties for the molding processes (Figure 10).

Figure 10. Biofase specifications for the two avocado seed biopolymers formulations

AVOPLAST
Hybrid Resins

Property	Unit	Method	Value
Flow Rate (200°C/5Kg)	g/10minn	ASTM D1238	10.0
Yield strength	MPa	ASTM D638	19.4
Yield elongation	%	ASTM D638	16.0
Breaking strain	MPa	ASTM D638	14.5
Elastic Modulus	MPa	ASTM D638	621
Melting point	°C	-	205

- ✓ Replaces up to 70 % of the oil content per plant matter
- ✓ Biodegradable
- ✓ Significantly reduces carbon footprint
- ✓ Replaces applications of polystyrene, polypropylene and polyethylene
- ✓ Excellent for injection products such as cutlery, rigid packaging, etc.

AVOPLAST
Compostable Resins

Property	Unit	Method	Value
Flow Rate (200°C/5Kg)	g/10minn	ASTM D1238	9
Yield strength	MPa	ASTM D638	20
Yield elongation	%	ASTM D638	3
Breaking strain	MPa	ASTM D638	17
Elastic Modulus	MPa	ASTM D638	5
Melting point	°C	-	210

- ✓ A proprietary blend containing 100 % biopolymers of avocado seed together are other biodegradable elements
- ✓ Biodegradable and Compostable
- ✓ Significantly reduces carbon footprint
- ✓ Replaces applications of polystyrene, polypropylene and polyethylene
- ✓ Excellent for injection molding products, thermoforming and blowing such as cutlery, rigid, flexible packaging, bags, and bottles

Source: https://www.biofase.com.mx/bioplastico

Conclusions

Mexico has various competitive advantages that help the country to be a good business partner; however, the country should walk the required pathway to align its industry with the knowledge-based bioeconomy, as the need to strengthen the university-business partnership is evident. Most of the national companies that produce goods and services based on biological resources do not have innovation and development departments, so the generation of patents in the area is quite poor. However, the discussed cases clearly evidence that the country has a good scientific and technological level. They also prove that the number of patents are not necessarily a reflection of the true potential of the country. The vast extension of the National Territory, two million square kilometers, and the wide variety of micro-climates, coupled with the country's mega-biodiversity, mark a great potential that is already showing to be the main supplier of agricultural products in the United States, surpassing Canada and the European Union, according to the Department of Agriculture (USDA). The Mexican foreign market in the food industry is currently dominated by exports of primary products (fruits, vegetables and meat). However, the biotechnological development of the country already evidences several efforts, certainly not the only ones reported here, but we hope that this sample is an important indicator regarding the excellent possibilities of conquering markets in the country with higher added value products, as well as in markets of the NAFTA commercial block and other countries which Mexico has trade agreements with.

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Bioentrepreneurship in Latin America: Young Entrepreneurs

Emilia Díaz*

Introduction

"The relentless pursuit of opportunity without regards to resources currently controlled" (Eisenmann, 2013) is the definition of *Entrepreneurship* by Howard Stevenson, a scholar at the University of Harvard, recognized by this unique description, which is today considered as one of the most successful within the field. Although entrepreneurship as a movement has turn out to be globally important, even to become a sort of fashion, its biotechnological aspect has not experienced such a rapid expansion, and its knowledge and implementation is often limited to a few players in different geographical regions.

According to the Global Entrepreneurship Monitor (GEM, 2018), entrepreneurship as a commercial activity covers the whole new business creation, in any area of the commercial endeavor that implies creating value for end users. Likewise, apparently dissimilar projects such as the development of a new industrial application software and a native crafts shop are part of this category. According to the *2017-2018 Global Entrepreneurship Monitor* (GEM), the Latin American and the Caribbean (LAC) region has the highest *total early-stage entrepreneurial activity* (TEA), which measures the percentage of population between 18 and 64 years old who has started their own business and has been operating for less than 3.5 years (GEM, 2018) within the region. Unfortunately, the LAC region shows also the world's lowest rate of innovation intensity, in addition to be the second lowest employment generation rate. One of the possible explanations to this duality is that technology-based businesses are not created, which are inherently innovative and allow qualified-personnel employment creation, in addition to presenting better economic sustainability conditions over time, by generating added value.

Entrepreneurship conditions in Latin America are admittedly dissimilar, with countries such as Mexico, Brazil, and Chile where doing business is very easy and entrepreneurship

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ecosystems are established; while entrepreneurship in most of the territories take place out of necessity, being considered as a tool of social mobility, instead of an alternative option to traditional professional training. Regarding new biotechnology and science ventures in general, it is crucial to consider that labor conditions for young scientists within the region are largely deficient and have led to numerous social events and change initiatives to do quality science throughout the continent (Hirschfeld, 2017; Díaz, 2015).

In such a context, it should be considered that the choice to generate new biotechnology developments in Latin America is usually done under markedly unfavorable conditions. If *bioentrepreneurship* is defined as the creation of a technology-based business directly or indirectly linked to biotechnology tools, a key feature that differentiates *bioentrepreneurship* from traditional entrepreneurship is its high risk and the intensive use of capital it implies. According to the *2017 Biotechnology Report: Beyond Borders. Staying the Course* (Ernst and Young, 2017), the costs associated with a new biopharmaceutical product is between 1000 and 2500 million dollars, in addition to ten years of development. In the case of diagnostic systems, 25 to 100 million dollars are needed for new products, according to Bio Resource International (2014). On the other hand, a software venture can use a little more than 1000 USD (Jarvis, 2016). And considering that failure rates in both drug development and other biotechnology areas are usually 95 %, what is the real likelihood of generating biotechnological advances in Latin America through entrepreneurship?

Fortunately, there are great examples in the LAC region of the capacity to generate innovation with limited resources. Despite the fact that there is not a so called "unicorn" among the biotechnology-based enterprises within the region, numerous projects are making the LAC bioeconomic sector grow by generating new materials from biological origin, redesigning processes through biotechnology, and creating solutions to agricultural, medical, and social services problems.

It must be noted that a large part of these new bioentrepreneurship initiatives are carried out by young people, a growing trend observed in the general entrepreneurial activity within the region. According to the GEM (2018), Latin America and the Caribbean are the territories with the highest entrepreneurial activity: 16.5 % of the entrepreneurs within the region are 34 years old or less. North America is the second region in the list, with 14 % of entrepreneurs in this age group. The importance of creating new businesses and technologies by young people was highlighted in 2017 by the Organization for Economic Cooperation and Development (OECD), the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and the Andean Development Corporation (CAF), in their study called *Latin American Economic Outlook 2017: Youth, Skills and Entrepreneurship.* In such work, the crucial importance of empowering this sector of the population is highlighted as there are more than 163 million people between 15 and

29 years within the region. The report suggests "to empower young people as economic, social, and political actors, through policies to strengthen their skills and promote their venture", ensuring that "if young people have more and better skills and have greater opportunities for entrepreneurship, they will promote an inclusive economic growth".

The following are various examples of how young people in Latin America are injecting more knowledge in our economy through technological innovations that have an economic and social impact by being supported by biotechnology and bioeconomy, in different application areas.

New foods

In 2018, 815 million people did not have a sustainable and safe food source, according to data from the United Nations, and in the coming years, the world must be able to radically increase their food production capacity to safeguard the survival of the estimated 9 billion people who will populate the Earth in 2050 (United Nations, 2018; Roser, 2018). Given the current overexploitation of oceans, farmlands, and forests, new strategies that allow feeding the growing population in a sustainable manner must be identified.

Companies like Impossible Foods, Wild Earth, Finless Foods, Clara Foods and Modern Meadow are now internationally recognized due to their interesting premise: use biotechnology advances to reimagine food. From burgers to fish, substitutes for eggs and even pet food, these bioentrepreneurships have been able to produce "lab-developed" food that does not require the use of animal life or arable land and are suitable for consumption of individuals with food restrictions. In Latin America, developers of new foods generate sustainable substitutes, new sources of protein, among others.

The Not Company (Chile)

The Not Company (NotCo) is described as a company that "uses artificial intelligence to create exceptional food" (http://www.thenotcompany.com/). In 2016, The Not Company launched its NotMayo product, a 100 % vegetal mayonnaise substitute and the demonstration of the implementation of its unique invention: Giuseppe, an artificial intelligence trained with knowledge of molecular biology to generate patterns with vegetable ingredients to reproduce the texture and taste of animal-based foods. They have already succeeded in imitating the consistency and flavor of milk, yogurt, and cheese, products that are sold in Chile under the names NotYogurt, NotCheese, and NotMilk.

According to its founder, Matias Muchnick, the contribution of NotCo technology is that it provides a tool to replace a feeding system based on animal breeding and production, providing a suitable alternative, which could lay the groundwork for a network of more sustainable and environmentally friendly food production. NotCo participated in the IndieBio Acceleration program, hosted in Silicon Valley in 2017, and currently employs six people in Chile aiming at generating operations in United States (The Not Company, 2018).

ArtroFood (Colombia)

This company produces cricket flour with the hope of making them a regular part of the diet of people in the continent and the whole world. According to the company, a portion of cricket flour provides 3.5 times more protein than a portion of beef; additionally, it generates 85 times less greenhouse gases, using 11,000 liters of water less (https://www.arthrofood.co/). Given that this is a low cost and environmentally friendly process, ArtroFood's solution could hold the key to achieving food security in developing countries, by providing a low-cost source of protein, generating employment sources for vulnerable communities.

Currently, the company seeks to build the first insect farm for human consumption in Latin America and is selling its flour in a 70 % wheat flour and 30 % cricket flour format as a pilot plan. According to the company, its corporate purpose seeks to "transfer the knowledge of producing insects to vulnerable populations in Colombia, so that they become the producers and suppliers of safe food sources" (ArthroFood, 2017).

Bioproducts

Bioproducts can be divided in two types: on the one hand, objects, entities, or biologically created reactive elements, by using organisms able to manufacture them from the inside, as if they were small *biofactories*. This category includes, for example, recombinant vaccines and high added value ingredients like omega 3, generated within organisms (such as bacteria, yeast, and microalgae optimized for these purposes). On the other hand, there are bioproducts that may have been manufactured in non-biological environments, such as fermenters, but intrinsically they are a biological entity in themselves, as is the case of several enzymes.

The concept of using living organisms as factories capable of generating high added value products with minimal food needs has been widely used around the world, in the fields of medicine, nutrition, agriculture, and energy. Particularly in Latin America, numerous projects were implemented looking forward to generate biofuels from algae and other organisms, but without achieving the optimization and added value required to accomplish the necessary economic sustainability. New techniques of metabolic engineering and gene editing, such as synthetic biology and CRISPR-CAS9, are paving the way to a new generation of optimization of producer organisms, bearing in mind the intrinsic biodiversity of the continent, making Latin America to be positioned as an interesting pioneer in the creation of new sustainable bioinputs for medicine, nutrition, and a myriad of applications.

Some examples of international companies that have generated interesting developments in this area are Microsynbiotix, which develops and produces functional vaccines for aquaculture in genetically modified microorganisms, and Bolt Threads, an American company that produces silk from synthetic-biology generated organisms, which has recently signed an agreement with designer Stella McCartney to produce sustainable clothing from biological origin (Iredale, 2017).

Kura Biotec (Chile)

This company was established in 2013 after discovering the potential of the enzymes present in the south of Chile, as the basis for drug detection and treatment platforms. Kura Biotec (https://www.kurabiotec.com) used abalone (gastropods molluscs of the Haliotidae family) industry waste for the development of a high global impact application: the creation of a catalog of enzymes used as detectors for analytical toxicology and diagnosis of traces of drugs and explosives in high security locations. The company's enzymology toxicological information work has been recognized in numerous competitions and has allowed it to expand its business into four continents; in 2017, the company established a subsidiary in the United States. Kura Biotec continues working in more sophisticated models and applying all the technical tools available to generate the fastest and most accurate enzymes in the market.

Additionally, this company, highlights the importance of understanding technical innovation as a holistic system that must place the positive impacts at the center of operations. Besides to generating more reliable and accurate tests that directly impact human health, Kura donates 1 % of its total sales (or 10 % of its profit, if greater) to initiatives that support the preservation of the environment through recycling initiatives, reforestation or other ecological programs, and also to social initiatives involving community development, rehabilitation, education, sports, culture, among others.

Hemoalgae (Costa Rica)

It is estimated that 2 % of the world's population should consume daily doses of anticoagulants to survive. Although traditional medications can extend the lives of people suffering from syndromes such as blood clots and heart attack risks, its effects can be so severe that in certain cases can be worse than the disease itself. Hemoalgae (http://hemoalgae.com/) was created to provide a new generation of anticoagulants to those most in need, by obtaining the polypeptide hirudin (the most successful and highly sensitivity anticoagulant on the market) in modified algal biofactories. Hemoalgae seeks to replace warfarin, produced with leeches, also used as a rat poison, by a natural version of a rational design and without negative side effects for those who must consume it (Umaña Venegas, 2017).

Although this is a young company, Hemoalgae has already been recognized internationally by providing new inputs for medicine in a sustainable manner (see the Costa Rica Chapter in this book). It was part of the 2017 Rebel Bio Acceleration Program, as well as part of the investment fund SOSV, which is a company accelerator, sister of IndieBio, already mentioned above. Its purpose of generating a platform for producing high-demand modified medicines at a reduced cost, would provide a sustainable path to develop new clinical advances within the region, improving the life quality of those who currently suffer from ailments related to the extensive use of anticoagulants.

Phage Technologies, S. A. (Chile)/Milkeeper

Phage Technologies (https://pht.cl/) focuses on the production of food additives using bacteriophages which act as microbiological controllers inside food, in a safely, efficiently and sustainable manner. The company develops pseudo vaccines for the dairy industry, which are based on bacteriophages, which are viruses that infect bacteria and that could be easily called bacteria's natural predators. These phages are added to the feed of calves during their first weeks of life, contributing to the elimination of pathogenic bacteria that usually attack them, causing them growth stagnation and even death. Phage Technologies (http://milkeeper.com/ Milkeeper) products decrease diseases in calves up to 80 % and decreases deaths up to 90 %. The product focuses on specific and non-toxic actions, so it does not generate clinical problems in calves at the same time that increases farmers productivity.

Phage Technologies managed to position itself not only due to its technical progress, but also because it became one of the first Latin ventures closing a deal with a giant multinational corporation: Bayer. In 2016, the official contract was closed by delivering the distribution of Milkeeper to Bayer in Latin America during an initial period of five years. This dramatically boosted this technology within the region to continue its positive impact. Having the support of an internationally renowned company such as Bayer is key to achieving a proper internationalization of this technology. As one of its co-founders, Diego Belmar, mentioned in an interview with Redbionova portal: "People receive our product in a different way and (the deal) opens the doors to reach all the countries of interest we had always wanted to reach, but we knew it was going to be difficult" (Abarca, 2017). It is expected that, once the good results within the region have been confirmed, this technology will be marketed in the rest of the world.

Artificial intelligence at the service of biotechnology

Great innovations occur when disciplines intersect. The more dissimilar, the more exciting its implementation. This is the case of the interaction between biotechnology and artificial intelligence (AI), a field of technological convergence which is increasingly becoming more and more popular.

Artificial intelligence must be understood as something more than a disembodied robot able to defeat a *Go* champion. AI is a powerful tool for data processing and problem resolution; a sort of natural evolution of programming and software design that has led to the creation of private entities with expertise in certain areas - or as called in the artificial intelligence language, "trained"- in certain databases.

Although in previous decades there were small incursions from computer science towards biotechnology, the truth is that this path was not paved until biology achieved two crucial milestones: the accelerated decline in the cost of whole-genome sequencing and the exponential improvement in taking and generating data from biological systems. The existence of almost unmanageable amounts of information to which biotechnology is currently exposed is the perfect field for AI to play its best role, unraveling patterns and connections that once were elusive to put them at the service of scientists, who are more and more connected among themselves and granting them with access to clear information to serve their interests. A pioneer company in this interesting combination is Asimov.io, an American initiative that promises to standardize the rational design of new organisms from connections and biological circuits unraveled by an artificial intelligence trained with the world's largest database available on the topic.

Gea Enzymes (Chile)

The Chilean company Gea Enzymes (https://geaenzymes.com) is one of the most successful cases of bioentrepreneurship in recent years. In 2018, all its partners were less than 26 years old and with less than 4 years of operations, this *startup* has managed over $1 million USD in investments, thanks to the technology they have developed: *Molecular Affinity Dynamics Interface* (MADI), the world's first automated industrial protein designing bioinformatics platform. It is an AI app which is constantly learning and with sufficient data to predict the three-dimensional patterns certain sequence of amino acids will take; it can even manage to design an optimal dubbing pattern of the final required protein. This platform uses several *machine learning* and *deep learning* tools, among other AI programming tools, enabling the simulation of various candidates so that the optimal candidate meeting the specific needs required by the industry can be obtained.

The Gea Enzymes case sadly illustrates the lack of openness towards innovation that can still be perceived in the continent. As mentioned by one of its co-founders, Leonardo Álvarez, in an interview with Chile's main newspaper, there was no interest on the part of Chile's productive companies that could have benefited from this technology as it represented a risk they were not willing to take. In the United States, by contrast, the story was different: several companies contacted them directly to develop solutions. According to Leonardo:

> All the companies there (USA) are looking for innovation because they know that it is the way to remain in the market. Several companies have created a new division in charge of searching for technologies created by startups. (Díaz, 2018)

Success stories such as that of Gea are precisely what is required so that more Latin American companies open their doors to technological innovation and integrate science and knowledge much more in their production processes, until our region become a leader in such field.

Agroindustry

For centuries, Latin America has been characterized by its close connection with the countryside and agriculture. Despite the initiatives supported by public policies and academia in most of the countries of the region, extractive industries and, above all, those industries linked to agricultural production are still an important part of the economic activities in Latin America, with the pros and cons this implies.

The reality is that the countryside in Latin America has not yet reached its maximum potential. When studying cases such as that of the Netherlands and its optimization of spaces for cultivation, the following question arises almost immediately: How is it possible that a country with four hundred times less area that our entire region is today more prepared to feed the rest of the world than us?

The Dutch miracle, like so many others, is not magic, is about technology. Land crammed with sensors, connected one to each other and feeding data bases capable of finding new optimizations and readjusting crop parameters, have been the basis for the development of first level precision agriculture in significantly reduced spaces.

While Latin America has a long way to reach the performance levels of the Netherlands, there are new businesses focused on accelerating this process and ensuring that our region produces enough for all its inhabitants and, why not, even for the whole world.

Agrosmart (Brazil)

Current manager and co-founder of Agrosmart, Mariana Vasconcelos, was just 23 years old when she set up her own company. Originally from Itajuba, Mariana grew up surrounded by her parents corn and sugar cane crops; however she did not have any particular interest in the countryside. However, this changed when she was a student at university and understood how much farmers like her parents could benefit from integrating technologies in their processes. Agrosmart (https://agrosmart.com.br) is the result of such idea, an agricultural monitoring platform (digital agriculture) which allows users to optimize resources and minimize costs associated with pest and disease control, among other issues; that is to say, the search of greater efficiency in the use of inputs with a criterion of sustainability.

The key innovation of the company is the use of sensors capable of measuring numerous environmental variables that feed a database which is then matched to satellite images to deliver an image with recommendations and critical information points for the specific spot being analyzed. Smart agronomic models adjusted to specific conditions are generated based on the genetic material, soil type, and the microclimate of each plot of land. These tools are a powerful precision agriculture platform that directly influences the performance of croplands and achieves savings up to 60 % in water and 40 % in power, in addition to generate yield increases up to 20 %. Although many potential customers closed their doors to Agrosmart by considering Mariana and her team too young, today - only four years later- they are supported by Google, they monitor crops for Coca-Cola and Syngenta, and they have numerous private investors who have contributed millions of dollars, trusting in the impact this technology has in Brazil and that can be expanded to the rest of the agricultural world.

Beeflow (Argentina)

Beeflow (http://www.beeflow.co/) is an Argentine company that provides pollination services with 21st century technology. The company develops "strong and intelligent" bees that improve the performance of pollinated crops up to 90 %, reducing, in addition, bee mortality and generating new sources of income for beekeepers. This startup has been supported by two high-level networks: the incubator Indie Bio, already mentioned above and the Argentine company-builder, Grid Exponential.

Its official portal describes its technology as "bees + science". Its technology is based on previous researches conducted by its founders on bee learning and memory, molecules able to reduce mortality, and design of apiaries based on flight patterns analysis. With those elements, the team was able to design different formulations that vary from crop to crop and that are previously supplied to bees in their food so that they can remember the smell and prioritize its source during the pollination stage.

The Yield Lab (Argentina)

Although The Yield Lab (https://www.theyieldlab.com/latin-america) is not an bioentrepreneurship, it should be considered at the time of mapping the future of the countryside within the region. It is a bioentrepreneurship accelerator; that is to say, an entity dedicated to the search, support, financing, and growth of high impact enterprises in the Agroindustry 2.0 area. The Yield Lab operates in the United States, Ireland, Singapore and, more recently, Argentina. This responds to the potential observed in the region on the part of the main enterprise accelerator of the United States, which in less than one year of implementation has already supported three projects in this area, as a way to support agricultural production efficiency through precision agriculture; that is to say, higher sustainability:

Agree Market (https://www.agreemarket.com/) is a virtual market that seeks to digitize and make the commodities marketing process transparent. It is a platform designed for marketing in which users can easily buy or sell products from any connected device, both in national and international markets.

Kilimo, the second company supported by The Yield (http://www.kilimo.com.ar/), has an integrated irrigation management system for agriculture in large areas. By using an algorithm developed by its team, Kilimo provides recommendations for optimal irrigation depending on the type of crop. By using a platform to manage irrigation in extensive farming, the app uses satellite and climate information as well as in-field data to feed a *big data* engine and recommend the optimal irrigation model for each crop, improving yields up to 30 % and water use efficiency up to 70 %. This technology has successfully been used in Argentina and, recently, in the United States.

Eiwa (https://www.eiwa.ag/es/) is a company that delivers image taking and processing services that combine drones and computer vision for modeling the behavior of various crops, with a special focus on genetic improvement programs, which provide information to generate more optimal species. Among its featured clients, Eiwa provides services to Syngenta and DowDuPont.

Energy and sustainability

Our planet energy crisis is the chronicle of an announced death that has been proclaimed for decades. As fossil fuels deplete and fossil fuels are being replaced with renewable energies in the search of sustainability and the reduction of greenhouse gas emissions, efforts to increase clean energy production have been redoubled in recent years all around the world yet failing to replace still unsustainable traditional methods that highly and dangerously pollute our planet.

To tackle this issue, many industries have begun to delve into the sustainable concept to *close the cycle* or *circular economy*, which reimagine the life cycle of products so that it goes from the traditional linear production, use and disposal model, to a closed cycle where "waste" may become input to obtain a new product, ideally eliminating the concept of waste in the years to come. This concept has been applied in industrial processes to manufacture clothing as well as in power production plants and mining operations, and has reduced the environmental impact of production and at the same time has generated a positive social, economic, and environmental impact (Ellen McArthur Foundation, 2017).

If a company is not able to close the cycle within its own operations, the importance of new initiatives that revalue waste as high added-value input for other industries will continue being highlighted. It is at this particular point where Latin America, with its extensive production activity that involve extraction industries, can establish a new paradigm of sustainability, based on agricultural, mining, and forestry revaluation, among other production fields.

Bromé (Costa Rica)

Brome, formerly known as Reuti-Piña (http://reuti-pinacr.com/), is a Costa Rican startup focused on the valorization of the pineapple industry waste. This company seeks to remove commercially important biocompounds from the unusable mass involved in the industrial processes of pineapple production. According to Bromé, more than 10 million tons of usable waste are generated every year in more than 60 thousand hectares of pineapple crops in Costa Rica. From these residues, the company has managed to extract bromelain, an enzyme of interest for the brewing industry, capable of improving the appearance, flavor, and aroma of beer (see the chapter on Costa Rica herein).

The company started to contact potential customers in 2014 and gained the attention of beer brewers in Latin America. Once its product was tested out in the industrial field, its expansion plan included venturing also with the pharmaceutical industries and wine production companies, in order to take advantage of all the benefits of bromelain in various areas of industrial manufacturing. Today, Bromé has employs 27 people and has obtained resources from Banca para el Desarrollo (Development Banking) in addition to private investment and even initial sales to customers in the pharmaceutical sector. In an interview with the *El Financiero* newspaper at the end of 2017, Bromé founder and sales development manager mentioned that the company "expects to make sales in the beer and wine market next year", with a focus on high production countries such as the Dominican Republic and Chile (Cordero, 2017).

Initiatives within the traditional industry: Aguas Andinas and Arauco (Chile)

While most of the innovations covered in this chapter come from small-sized teams seeking to generate disruptive technologies and science-based processes, it is crucial to approach traditional companies cases that have adopted innovation models similar to those of a startup to resolve their internal problems. This is the case of Forestal Arauco and its Más Maqui Project (https://www.masmaqui.com/) and the Biofactoria initiative (https://www.biofactoria.cl/) of Aguas Andinas.

According to Francisco Lozano, Manager of Innovation of Forestal Arauco, the Más Maqui project started in 2011, when a high volume of maqui berry was detected in the grounds of the native forest of the company. This non-timber product was not of direct interest for Arauco, but fortunately the company recognized its potential value in terms of improving sustainability and generating a positive impact. In an interview with *Diario Financiero*, Lozano said: "We had an asset with value that had to be captured in a sustainable way and with the support of the community. In Chile, maqui harvests reach between 300 and 500 tons per year, but we have more than that" (Orellana, 2015). To enhance the impact, the project is based on a network of local collectors, who are trained in silvicultural techniques and local entrepreneurship. Community participation and shared value have been encouraged by intervening the ecosystem minimally through sustainable harvest techniques.

In turn, the Biofactoria initiative of Aguas Andinas seeks to "transform waste into resources" by using their own water treatment systems to generate a fertilizer for agricultural use as a by-product, as the first step in the selective recovery of nutrients of commercial interest. In addition to this, the plant seeks to achieve complete energy self-sufficiency using renewable energy sources and has implemented a system to control emissions to minimize environmental impacts, gradually regenerating those ecosystems previously damaged by the industrial action. As shown on its official portal, the initiative seeks to "understand the world as the metabolism of a living being, as a system of interrelation and interdependence" (Aguas Andinas, 2017).

As a conclusion

The examples presented above are not an exhaustive list of all forms in which knowledge is being generated and applied to industry in our continent. It simply seeks to show some of the areas currently exploring science-based innovation, seeking to be a disruptive element of old industrial standards so that we can find our routes as countries, continents and planet, towards a more sustainable, fair, and harmonious future.

Science-based innovation will be key to building the best possible future. Entrepreneurship, in general, and bioentrepreneurship, in particular, are presented as powerful tools to bring new ideas and increase the speed in which processes change since changes currently take too long and do not harness all the available potential. We need the new ideas and minds that our continent can produce, and we must ensure they concentrate their efforts on resolving immediate and future problems within the region. Now, more than ever, it is crucial to establish ties and cooperation actions among different countries, industries, and areas of knowledge, connecting and facilitating new developments, new ideas, and new dreams. This is just a sample of the future we are building today.

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Bioeconomy in Latin America: Strategic Resources, Public Policies and Institutionality*

Adrián G. Rodríguez-Vargas**

Introduction

Bioeconomy has gained special importance during the last decade serving as a reference framework for the design and implementation of policies for productive development and innovation, especially facing the need to move to production methods in which waste generation and waste itself is minimized or eliminated as well as the use of fossil fuels (Hess, Lamers, Stichnothe, Beermann and Jungmeier, 2016). Despite its potential relevance to Latin America, the concept of bioeconomy has received little attention in the implementation of the public policies of the countries in the region. As of today, unlike Europe, there are not any strategies devoted to bioeconomy. There are, however, some initiatives that may serve as a foundation for its respective development such as the bioenergy, biotechnology, biodiversity fields as well as environmental services.

The most formal process for the development of a framework strategy made up with regional bioeconomy strategies is the one under implementation in Argentina,[1] which is linked to the concept of smart territories. Likewise, in Colombia, in 2016, the then-president, Juan Manuel Santos, highlighted the opportunity bioeconomy meant at the end of the armed conflict in the country in order to:

* The herein opinions are the exclusive responsibility of the author; they may not coincide with CEPAL's standpoint.

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1 More information on Argentinian Bioeconomy can be queried at http://www.bioeconomia.mincyt.gob.ar/

> […] strengthen a new economy with greater utilization of our resources while vindicating our environment […]. We want to reach the year 2025 as a bioeconomy based on science, technology and innovation, able to make the most out of our immense natural wealth. (Cited in "El compromiso del gobierno", 2016, par. 3)

This chapter is aimed to highlight potential of the bioeconomy as a reference framework to guide the productive development and innovation public policies, within the context of the 2030 Sustainable Development Agenda. The institutional bases and development of public policies already existing in the region will be pinpointed. Besides the introduction, this chapter is arranged in four different sections. The second section underlines bioeconomy as a framework to develop public policies emphazising its contribution for the implementation of the 2030 Sustainable Development Agenda as well as its contribution to the sustainability-based structural change. The third section highlights the broad variety of biological resources, and identifies those considered to be strategic to foster the bioeconomy development in the short and medium term in Latin America. The fourth section introduces the existing institutional and regulatory frameworks currently available in the region, which set a baseline for the integration of bioeconomy strategies. The provided information therein assesses 10 countries and discusses innovation strategies, bioeconomy-related development policies (e.g. sustainable agriculture, sustainable livestock production, green growth, etc.), as well as the areas of biotechnology, biodiversity, natural resources, bioenergy, and waste management. The relevant incentives within public policies and the key actor from the private sector are also pinpointed. To conclude, the fifth section focuses on the opportunities and challenges to be faced in order to develop bioeconomy in the region.

Bioeconomy: New courses for the public policies

The bioeconomy provides a conceptual framework for implementing policies focused on addressing the major challenges of society and the concerns of sustainable development established in the 2030 Development Agenda (El-Chichakli, Braun, Lang, Barben and Philp, 2016). Having the 2030 Agenda as a benchmark, the bioeconomy represents an alternative for the smart specialization of territories, as well as innovation and the structural change based on sustainability, while strengthening rural and agricultural development policies.

Bioeconomy and the 2030 Agenda for Sustainable Development

The bioeconomy promotes structural change towards a post-fossil fuel economy, based on the sustainable and full use of biological resources, including waste resources.

Therefore, bioeconomy is a real alternative for the fossil decarbonization of the economy as it can play a key role in climate action, in line with the Sustainable Development Goal (SDG) 13 (to combat climate change). However, the contributions coming from bioeconomy can go far beyond its role on combating climate change:

- Bioeconomy is closely related to the sustainable production of healthy foods and the sustainable intensification of agricultural production, therefore, it can also contribute to the accomplishment of the SDG 2 (by means of sustainable food production), the SDG 3 (healthy lifestyles), and the SDG 15 (protection of terrestrial ecosystems).
- Bioeconomy is based on new production models, such as biorefineries and bio-industry, which allow the development of products to be used as inputs by other productive sectors (biomaterials for construction, bio-inputs for agriculture), while substituting petrochemical inputs; or products that fulfill new demands on the part of consumers (functional foods or biocosmetics). Consequently, in addition to its contribution to the SDG 2 (sustainable food production), the bioeconomy can also be instrumental in achieving SDG 7 (sustainable and affordable energy for all), and SDG 8 (new sources of decent work and sustainable economic development) and SDG 9 (industry and innovation).
- Associated to the refinery concept, there is also the possibility of closing productive cycles, through the productive use of waste biomass (residual) derived from production and consumption. That is why, the bioeconomy is essential for the achievement of SDG 12 (responsible production and consumption) and of SDG 11 (sustainable cities and communities).
- The possibility of developing products, processes and systems by repeating observed systems in nature is an innovative element of the bioeconomy. This, can lead to new value chains that foster the promotion to SDG 9(Industry and innovation), SDG 14 (Sustainable use of underwater biodiversity), and SDG 15 (Sustainable use of terrestrial biodiversity).
- Bioeconomy also covers the development of bioremediation alternatives to face environmental pollution problems. For instance, for the recovery of degraded or contaminated soils and for the treatment of water for human consumption and wastewater. Therefore, it offers alternatives to support the SDG 6 (clean water and sanitation for all), and SDG 15 (related to the prevention of soil degradation).

Smart specialization, innovation y and structural change based on sustainability

The biological resources baseline conditions the bioeconomy development in specific territorial environments; that is why, it is pertinent to refer to bioeconomies, rather than bioeconomy, in generic terms. Such features make the bioeconomy approach become an alternative to intensify the specialization of the territories according to their competitive advantages by means of productive evolution and innovation strategies, driven by demand, innovation associations focused on greater coordination between the different social actors, and the alignment of resources and strategies between private and public actors in the different governance areas.[2] Such approach is under implementation in Argentina in order to enforce bioeconomy subnational strategies where the biological resources and the existing capacities within the territories are combined together.

The bioeconomy approach is consistent with the creation of knowledge-intensive innovation strategies for the agricultural and agroindustrial sector, in order to enhance capacities and promote the collaboration in biotechnologies and other enabling technologies, to strengthen bioenergy developments (biomass bioenergy, solar bioenergy, biogas), to diversify the economic base of regional economies (not only food production, but also biomass in a broader sense), and also to the increase value addition (e.g. rural agroindustry, new bio-based value chains).

Bioeconomy is also a path to start a structural change from a sustainable perspective. The bioeconomy approach is consistent with the 2030 Development Agenda, the mitigation goals, the emissions reduction, and the adaptation to climate change, as well as the hopes for economic and social inclusion. As far as one of its main goals consists of reducing or eliminating the use of energy from fossil resources, bioeconomy represents an effective strategy to boost a structural change focused at decarbonizing the economy.

Relevance of the concept for the agricultural and rural development policies

An important characteristic of biological resources, especially biomass resources (cultivated and waste), is its high transport cost, which, in turn, is an incentive for its processing directly in the territory where it is produced, wich also has great potential to trigger inclusive processes of local development. In Latin America and the Caribbean, the bioeconomy provides new options for the rural and agricultural development and for the creation of quality jobs by means of, for instance:

2 For further review, check The European Commission's Cohesion Policy example under the following linkhttps://ec.europa.eu/jrc/en/research-topic/smart-specialisation

(i) opening up new opportunities for agriculture, as activities are not exclusively devoted to food and ingredients production, but also to biomass production for multiple uses; (ii) generating opportunities for new value chains based on the use of non-food biomass, together with waste biomass and the production of bioinputs for agriculture itself (such as biofertilizers, bionematicides, biopesticides, biofungicides and bioconditioners); and (iii) enabling the creation of knowledge-based SMEs, incorporated within new value chains providing job opportunities and business development for women and youth.

New productive paradigms

As it was previously stated, the main bioeconomy contribution is related to the transit towards an economy where the use of fossil-fuel energy is gradually eliminated; hence, it is an authentic strategy to move towards the fossil decarbonization of the economy. The concept of biorefinery is critical within this new productive model. This concept, in turn, is the equivalent to the petrochemical refinery concept, but biorefinery uses biological inputs instead (Sauvée y Viaggi, 2016; Koltuniewicz y Dabrowska, 2016).

Biorefinery is a productive model through which bioenergy and bioproducts are obtained by means of the complete biomass usage. It allows the creation of value cascades around the biomass, while minimizing or eliminating the "waste" discharge into the environment. A biorefinery can work using either cultivated biomass or "waste biomass", regardless their agricultural, agro-industrial or domiciliary origin. The products derived from biorefinery processes are varied and depend on the used biomasses and the type of technologies used in their transformation (Venkata Mohan et al., 2016; Jungmeir, 2014).

Bioeconomy is also consistent with the closed-cycle productive approaches, as part of the industrial ecology/ecosystem (Frosch y Gallopoulos, 1989) and the industrial symbiosis (Lombardi y Laybourn, 2012), as well as the concepts of biomimicry (Benyus, 1997) and blue economy (Pauli, 2011). These are productive systems where every residue produced as part of the production and consumption processes are taken advantage of, so their discharge to the environment can be gradually minimized or eliminated. These systems also place the innovative element of replication/imitation of natural processes at their core of their productive processes.

New technologies

Biotechnologies, in general terms, and technological convergence in particularly (among biotechnologies, nanotechnology and digital technologies) are crucial to promote the development of bioeconomy, since they expand the limits for the sustainable use of the full range of available biological resources (for example, bacteria, viruses, microorganisms, algae, plants and larger organisms, and also different types of biomass).

They are also key to understand and repeat the behaviors and processes developed by organisms throughout thousands of millions of years in order to adapt themselves to different environmental conditions and process their waste at the same time.

There are plenty of biotechnological applications that have been included in different strategies for the development of bioeconomy; among those, white biotechnology (industrial applications), gray biotechnology (applications for the solution of environmental problems), green biotechnology (applications in agriculture), blue biotechnology (applications in the field of marine resources) and red biotechnology (applications in the field of medicine). Other scientific areas relevant to bioeconomy include disciplines such as genomics and green chemistry, as well as tools that emerge from interdisciplinarity and technological convergence, such as bioinformatics.

Strategic resources to encourage bioeconomy development in Latin America

In the short and medium term, there are three types of resources considered to be key to boost bioeconomy development within the region: (i) biodiversity resources, including agrobiodiversity; (ii) crop biomass; and (iii) waste biomass (residual), derived from production and consumption processes. These resources are associated to processes of diverse nature such as bioprospection, biotechnology implementation, bio innovation and biorefineries, from which bioenergy, biomaterials, agricultural bio inputs, biopharmaceuticals and biocosmetics are derived, among others.

Biodiversity resources

The region is home to eight of the seventeen most megadiverse countries on the planet, those countries are located in the Andean-Amazon basin (Bolivia, Brazil, Colombia, Ecuador, Peru and Venezuela) and in Mesoamerica (Costa Rica and Mexico). The broad biodiversity can also be found in other ecosystems unique to the region, such as the desert of northern Chile - south of Peru, the Argentine pampas and the Argentine-Chilean Patagonia. *And*, of course, the least known marine biodiversity, both in the Pacific and in the Caribbean and the Atlantic Ocean. The development of a bioeconomy based on biodiversity should be based on a strategy that seeks its protection, knowledge and sustainable use. In order to use biodiversity in a productive and sustainable way, it is necessary to know it; however, the only way to get to know its potential is by protecting it.

Cultivated biomass

Latin America, together with Africa, is well-known due to its potential to expand its agricultural frontier. Such potential can be taken advantage of in order to increase the biomass production, not only for feeding purposes, but also for fibers, fodder, bioenergy and bioproducts, in general terms (e.g. bioplastics). In a broader sense, the crop biomass has to do not only with food production and traditional crops to produce bioenergy (e.g. soybeans, corn and oil palm), but also with non-feeding energetic crops (e.g. giant miscanthus, switchgrass, jatropha), as well as forest crops and algae culture.

However, the potential for the biomass production is not evenly distributed and its utilization should have in mind the food safety and fragile ecosystem conservation considerations. Particularly speaking, the biomass goals and production targets for energetic use should meet the food safety, conservation and development of new productive and more intense and sustainable systems goals. Having this context, it is of special importance the sustainable intensification of agricultural production concept as it refers to those practices driven to enhance the environmental performance of different agricultural activities without compromising the existing productivity. Its final aim is to achieve a balance among the agricultural, environmental, economic and social benefits by seeking a more efficient use of the energetic resources while focusing on reducing the use of fossil fuels, pesticides, and other pollutant substances. Some examples of specific sustainable intensification strategies include direct seeding practices, precision agriculture strategies, integrated management of pests and nutrients, as well as the use of bio inputs.

Waste biomass (residual)

The region is well-known due to its contribution to the global production of food and agricultural raw materials. However, the produced waste, both in agricultural and agroindustrial production processes, continues to be seen as a contamination problem. Bioeconomy —in line with the circular economy approach— considers the biomass waste as another resource for the production of new foods, materials and energy under the concept of biorefinery. The interest in the waste use in the region is just emerging, but the potential is, undoubtedly, substantial if the production of agricultural raw materials is minded. Being aware of the true potential of this resource demands the elaboration of detailed inventories of the different types available waste biomass that, in turn, will determine the technical potentials of utilization, not forgetting what must be left in the field for the maintenance of ecosystem services (Ronzon and Piotrowski, 2017; Brosowski et al., 2016).

Relevant political and institutional frameworks

The three resources identified in the previous section, aimed to promote the development of bioeconomy in Latin America, are associated with bioprospection, application of biotechnologies, bioinnovation and biorefineries, out of which bioenergies, biomaterials, agricultural bioinputs, biopharmaceuticals and biocosmetics are derived, among others. In this section, institutional and policy areas within the region are identified as relevant entities to create bioeconomy strategies based on the identified resources. Innovation and sustainability policies are included for related areas (sustainable agriculture, sustainable livestock production, environmental services payment, among others), as well as biotechnological applications, biodiversity harnessing, forest resources, waste management and bioenergy production. Following, a brief summary on the situation of those areas in 10 different countries is presented.[3] Such review includes the elements to be considered noteworthy; therefore, it is not quite thorough.

Institutional and innovation policy frameworks

There is institutional support regarding innovation in all the assessed countries. This includes the existence of ministries or secretariats for science, technology or innovation (in all countries), national innovation systems (in all countries), national science and technology/innovation plans (in all countries, except Ecuador), science and technology/innovation regulations (in all countries, except Ecuador), and incentive mechanisms (in all countries). Besides, four of the ten assessed countries (Chile, Costa Rica, Colombia, and Peru) have competitiveness commissions or councils where the private sector takes part in. Table 1 summarizes the main pinpointed elements.

Table 1. Latin America and The Caribbean (10 countries): Institutional frameworks on innovation

Elements	AR	BR	CL	CO	CR	CU	EC	MX	PE	UY
Science and technology	L, M	L, M	M	L, M	L, M	L, M	M	L, M	L, M	L, C
National Plans on Science and Technology/Innovation	X	X	X	X	X	X	X	X	X	X
National Innovation System	X	X	X	X	X	X	X	X	X	X
Incentive mechanisms	X	X	X	X	X	X	X	X	X	X
National competitiveness institutions			X	X	X				X	

L: Law; M: Ministry or Secretariat; C: Commission or institution of lower rank to ministry or secretariat;
X: There is another mechanism.
Source: Rodríguez et al. (2017).

3 Those countries are Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Mexico, Peru and Uruguay. The herein information is updated to December, 2017.

In some countries, the ministries or secretariats take part in other additional subjects; for instance, higher education in Ecuador (Secretariat of Higher Education, Science, Technology and Innovation), telecommunications in Costa Rica (Ministry of Science, Technology and Telecommunications), and environment in Cuba (Ministry of Science, Technology and Environment). In Argentina, besides the Ministry, there is also the National Scientific and Technical Research Council (CONICET), and the National Council for Scientific and Technological Research (CONICIT) in Costa Rica.

Related sustainable development policies

In all countries, there are, at least, two programs in one of the following areas (Table 2): sustainable aquaculture (except Ecuador and Cuba), sustainable livestock production (except Cuba and Peru), sustainable agriculture (except Argentina, Colombia, Ecuador and Mexico), rural development / family farming (except Ecuador and Cuba).

Table 2. Latin America and the Caribbean (10 countries): Institutional and political frameworks in areas related to bioeconomy

Elements	AR	BR	CL	CO	CR	CU	EC	MX	PE	UY
Sustainable Agriculture	L	L	L		L	E		L	L	
Sustainable livestock production		E	E	E	E	E	E	E	E	E
Sustainable aquaculture	E	E	E	E	E			E	E	E
Family Farming / Rural Development	L	L	E	E	E			L	E	L
Climate Change	L	L	X	L	X	X	X	L	X	L
Adoption of unfccc	L	L	L	L	L	L	L	L	L	L
Adoption of Paris Agreement	L	L	L	L	L	L	L	L	L	L
Green Growth			E	E					E	
Biocommerce / Green businesses				E					E	

L: Law or Regulation; M: Ministry or Secretariat; E: Political strategies, programs, projects or plans;
X: There is another mechanism.
Source: Rodríguez et al. (2017).

All countries have ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, and therefore have initiatives on that regard. Six of these countries included mitigation initiatives as part of their expected contributions established at the national level within the UNFCCC framework (Argentina, Brazil, Colombia, Costa Rica, Mexico and Uruguay). In addition, three countries have "green growth" initiatives (Chile, Colombia and Peru) and two of them take part in the biocommerce / green trade area (Colombia and Peru).

The following initiatives are listed as the most outstanding ones: From Brazil, the Low Carbon Agriculture Program (ABC); from Chile, the Incentives Program for the Agroenvironmental Sustainability of Agricultural Soils; from Costa Rica, the appropriate mitigation actions for the national coffee sector (NAMA), as well as the Low Carbon Strategy, and from Uruguay, the Law of Conservation, Use and Appropriate Management of Soils and Waters. It is also worth mentioning the regulations and programs related to the family farming, which had an important boost within the International Year of Family Farming (2014)

Promotion and regulation of biotechnology

Even though, every country has, at least, one of the pinpointed instruments (Table 3), the situation on this regard is more diverse. In all countries there is either a law of plant variety for genetically modified organisms (GMOs) or for seeds. In seven of these countries (except Chile, Ecuador and Peru), there is a biosafety commission or a biotechnology commission; and in seven of these countries, there is a biosafety law (except Argentina, Chile and Ecuador). On the other hand, seven of these ten countries have adopted the Cartagena Protocol on Biosafety to the Convention on Biological Diversity; and there are laws or regulations for the promotion of biotechnology in six of these countries (except Costa Rica, Cuba, Mexico, and Peru). The distinctive element in this case resides in the presence of GMO's moratorium law (Peru), or the Country free of GMOs regulation (Ecuador).

Table 3. Latin America and The Caribbean (10 countries): Institutional frameworks on biotechnology

Elements	AR	BR	CL	CO	CR	CU	EC	MX	PE	UY
Promotion	L	L	L	L					E	L
Seeds / Plants or similar Variety Law	X	X	X	X	X	X	X	X	X	X
Adoption of the Cartagena Protocol				X	X	X	X	X	X	X
GMO Free Country / Moratory Law							P		M	
Biosafety regulation, GMO or similar		L				L		L	L	L
Biosafety or Biotechnology Council	Bt	Bt		Bs	Bs	Bs		Bs		Bs

L: Laws or regulations; E: Strategies, policies, programs, projects or plans; P: Free Country of GMO; M: GMO moratory law; Bt: National Biotechnology Commission; Bs: National Biosafety Commission or similar;
X: There is another mechanism.
Source: Rodríguez et al. 2017.

Biodiversity and the forest sector

These are both areas where there is a greater institutional and political density (Table 4).

Table 4. Latin America and The Caribbean (10 countries): Institutional frameworks on biodiversity and forest subjects

Elements	AR	BR	CL	CO	CR	CU	EC	MX	PE	UY
Environment	L	L	L	L	L	L	L	L	L	L
Biodiversity / Wildlife	E	L, E	E	L, E	L, E	E	E	L, E	L, E	E
Adoption of Biodiversity Agreement	L	L	L	L	L	L	L	L	L	L
Forest Sector	L, If	L, If	L, If	L, If	L, If	L, If	L, If	L, If	L, If	L, If
Consulting Commissions	B	B	B, F	B, F	B, F	B, F	B, F	B, F	B, F	B, F
Payment mechanisms for environmental and similar services				X	X	X	X			
Seeds	L, Is	L	L	L	L, Is	L, Is	L	L	L	L, Is

L: Laws or Regulations; E: Strategies or National Plans; If: Forest Incentives; B: Biodiversity Consulting Commission or similar; F: Forest Consulting Commission; Is: Institute for seeds or similar;
X: There is another mechanism.
Source: Rodríguez et al. (2017).

There are environment laws in all the ten assessed countries. All countries have ratified the Convention on Biological Diversity (CBD) and have biodiversity strategies or national policies in place. In addition, five countries have specific laws on biodiversity or wildlife (Brazil, Colombia, Costa Rica, Mexico and Peru).

In all countries, there are also laws and forest incentives and, in nine cases (except Colombia), there is a National Forestry Commission. The most remarkable element is the existence of payment mechanisms for environmental services in four countries (Colombia, Costa Rica, Ecuador and Mexico).

Bioenergy and Waste Use

In all countries, there are either laws or initiatives to promote biofuels, renewable energies or waste management projects. On the other hand, there are specific initiatives for the use of agricultural waste, especially in the production of bioenergy (table 5).

Table 5. Latin America and The Caribbean (10 countries): Institutional frameworks on bioenergy and waste management

Elements	AR	BR	CL	CO	CR	CU	EC	MX	PE	UY
Biofuels	L	L	L	L	E	E	E	L	L	L
Renewable Energy Sources	L	L	L	L	E	E	E	L	L	L
Waste management / handling	L	L	L	E	L	L	E	L	L	L
Agricultural waste usage	E	E			E			E		E

L: Laws or regulations; E: Strategies, policies, programs, projects, or plans.
Source: Rodríguez et al. (2017).

Regarding biofuels, seven countries have some kind of legislation (except Costa Rica, Cuba, and Ecuador). Such legislation is diverse and may refer to either the promotion of their production or the market development, which usually happens by means of regulations over mixes with fossil biofuels. A specific case where all dimensions are explicit is the Uruguayan case through the Law for the Promotion and Regulation of the Production, Commercialization and Use of Agrofuels (Law 18.195). In Costa Rica and Ecuador, there are national programs; while there are initiatives, mainly on research, in Cuba. Besides, in some cases the agricultural industry role is highlighted as they explicitly refer to the AgroEnergy (in Ecuador, The Biofuels and Agro-Energy Program), and agrofuel (in Uruguay) production.

Regarding to the waste biomass utilization, two noteworthy initiatives are the Project for the Promotion of Energy Derived from Biomass, in Argentina, executed by the Ministry of Agroindustry, and the Bio Value Project from Uruguay, an initiative that seeks to support the agricultural and agroindustrial sector in the transformation of its waste into energy or other value products.

Incentives

All countries have some kind of financial incentive, either in the science, technology and innovation area or in specific sectors, which are relevant to promote the bioeconomy development (table 6).

Table 6. Latin America and The Caribbean (10 countries): Relevant incentives to promote bioeconomy

Country	Incentive
Argentina	Fondo para la Investigación Científica y Tecnológica Fondo Tecnológico Argentino Fondo Argentino Sectorial
Brazil	Fondo Nacional de Desarrollo Científico y Tecnológico Fondo Brasileño para la Biodiversidad Fondo Amazonas
Chile	Fondo Nacional de Desarrollo Científico, Tecnología e Innovación Fondo de Fomento al Desarrollo Científico y Tecnológico Fondo de Financiamiento de Centros de Investigación en Áreas Prioritarias Fondo de Innovación para la Competitividad Fondo de Investigación Pesquera y de Acuicultura
Colombia	Fondo Nacional de Financiamiento de la Ciencia y la Tecnología Francisco José de Caldas
Costa Rica	Fondo de Incentivos al Desarrollo Científico y Tecnológico Programa Nacional de Innovación y Capital Humano para la Innovación Fondo Nacional de Financiamiento Forestal
Cuba	Fondo Financiero para la Ciencia y la Innovación
Ecuador	Fideicomiso para el Emprendimiento y la Innovación Fondos Concursos de la Secretaría de Educación Superior, Ciencia, Tecnología e Innovación (SENESCYT) Fondo Capital de Riesgo
México	Fondo de Cooperación Internacional en Ciencia y Tecnología Fondo Institucional de Fomento Regional para el Desarrollo Científico y Tecnológico y la Innovación Fondo Sectorial del Conacyt-Secretaría de Energía-Sustentabilidad Energética Fondo Sectorial de Investigación del CONACYT-INEGI Fondo Sectorial de Innovación
Perú	Fondo Nacional de Desarrollo de la Ciencia, Tecnología e Innovación Tecnológica Fondo para la Innovación, la Ciencia y la Tecnología Fondo de Investigación y Desarrollo de la Competitividad Fondo Marco para la Investigación en Ciencia y Tecnología Fondo Nacional para el Desarrollo de la Investigación Peruana
Uruguay	Fondos de la Agencia Nacional de Innovación (innovación, emprendimiento, investigación y formación)

Source: Prepared by the author.

In all countries there is a fund aimed to support either scientific and technological research (Argentina), scientific and technological development (Brazil, Colombia and Costa Rica), scientific and technological development and innovation (Chile and Peru), science and innovation (Cuba), science and technology (Colombia and Mexico), and research (Peru and Uruguay) or research in priority areas (Chile).

Some specific funds are also aimed to support technological development (Argentina), innovation (Costa Rica, Mexico and Uruguay), entrepreneurship (Uruguay), entrepreneurship and innovation (Ecuador), competitiveness (Chile and Peru) and training (Ecuador and Uruguay).

In addition, there are general sectoral funds (Argentina) and specific funds (Chile: fisheries and aquaculture, Costa Rica: forestry and environmental services, Brazil: biodiversity, Mexico: energy sustainability), as well as regional funds (Brazil and Mexico), venture capital (Ecuador) and for SMEs (Costa Rica).

Private sector

The private sector has a central role in all the strategies devoted to bioeconomy that have been developed around the world. Table 7 presents the relevant private institutions in the biotechnology, bioenergy and other areas, within the ten assessed countries.

In all cases, there is at least one institution in each of these areas, including trade associations and private or public-private research centers and think-tanks.

Table 7. Latin America and The Caribbean (10 countries): Private institutions in areas relevant to the bioeconomy development

Country	Biotechnology	Bioenergy	Other
Argentina	– Asociación de Semilleros Argentinos – Instituto de Agrobiotecnología Rosario – Consejo Argentino para la Información y Desarrollo de la Biotecnología – Cámara Argentina de Biotecnología	– Cámara Argentina de Energías Renovables – Cámara de Empresas Pyme Regionales Elaboradoras de Biocombustibles – Cámara Argentina de Biocombustibles	– Bolsa de Cereales de Buenos Aires – Consejo Argentino para el Desarrollo Sostenible – Fundación Argentina de Nanotecnología – Asociación Argentina de Agricultura de Precisión

Country	Biotechnology	Bioenergy	Other
Brazil	– Biotechnology Information Council – Brazilian Industrial Biotech Association	– Brazilian Sugarcane Industry Association – Brazilian Alliance for Aviation Biofuels – Brazilian Biodiesel and Biokerosene Union – Brazilian Biodiesel Producers Association – Brazilian Animal Recycling Association	– Brazilian Petroleum, Gas and Biofuels Institute – Center of Strategic Studies and Management (cgee) – Brazilian National Articulation of Agroecology
Chile	– Instituto de Dinámica Celular y Biotecnología – Asociación Nacional de Productores de Semillas – Asociación Gremial Chile Bio Crop Life – All Biotech	– Asociación Chilena de Energías Renovables	– Instituto de Fomento Pesquero
Colombia	– Asociación Colombiana de Ciencia y Tecnología de Alimentos	– Federación Nacional de Cultivadores de Palma de Aceite – Asociación de Cultivadores de Caña de Azúcar de Colombia – Federación Nacional de Biocombustibles de Colombia	– Consejo Privado de Competitividad – Centro para la Investigación en Sistemas de Producción Agropecuaria – Corporación Biocomercio de Colombia
Costa Rica	– Centro Nacional de Innovaciones Biotecnológicas – Consorcio de Empresas de Biotecnología de Costa Rica (cr-Biomed)	– Asociación Costarricense de Productores de Energía – Asociación Biogás	– Instituto Nacional de Biodiversidad – Centro Nacional de Alta Tecnología

Country	Biotechnology	Bioenergy	Other
Cuba	– BioCubaFarma	– Cuba Solar	– Asociación Cubana para la Ciencia y la Tecnología de los Alimentos
Ecuador	– Cámara Ecuatoriana de la Industria de la Innovación y Tecnología Agrícola	– Fundación de Fomento de Exportaciones de Aceite de Palma y sus Derivados de Origen Nacional – Corporación para la Investigación Energética – Centro de Investigaciones de la Caña de Azúcar	– Alianza para el Emprendimiento y la Innovación
México	– Sociedad Mexicana de Biotecnología y Bioingeniería, A. C. – Sociedad Mexicana de Biología Celular – Sociedad Mexicana de Ciencias Genómicas – Agro Bio México – Clústeres de biotecnología en Guanajuato, Jalisco, Morelos, Nuevo León y Querétaro	– Red Mexicana de Bioenergía – Asociación Nacional de Energía Solar – Asociación Mexicana de Energía Eólica	– Sociedad Mexicana de Bioquímica (SMB), A. C. – Laboratorio Nacional de Nanotecnología – Instituto Nacional de Medicina Genómica (Inmegen) – Asociación Mexicana de Industrias de Investigación Farmacéutica A. C.
Perú	– Asociación Peruana para el Desarrollo de la Biotecnología	– Cámara Peruana de Energías Renovables	– Cámara Peruana de Medio Ambiente y Desarrollo Sostenible
Uruguay	– Asociación Uruguaya de Biotecnología – Cámara Uruguaya de Semillas	– Cámara Solar del Uruguay	– Centro Uruguayo de Tecnologías Apropiadas

Source: Prepared by the author.

Regarding biotechnology, seed companies and similar associations (Argentina, Chile and Uruguay), together with Chambers, Councils and Companies Associations (Argentina, Brazil, Chile, Costa Rica, Ecuador, Mexico, Peru and Uruguay) stand out. It is also noteworthy the existence of research Centers with public-private participation in Argentina (Rosario Agrobiotechnology Institute), Chile (Institute for Cell Dynamics and Biotechnology), and Costa Rica (National Center for Biotechnology Innovations). There are also institutions devoted to the dissemination of information and development of biotechnology in Argentina (Argentine Council for Information and Development of Biotechnology), Brazil (Information Council on Biotechnology) and Chile (ChileBio). Additionally, there are business consortia in Costa Rica (Costa Rica Biotechnology-based business consortium) and Cuba (BioCubaFarma).

In terms of bioenergy, institutions related to the biofuels production are dominant (Argentina, Brazil and Colombia), in general terms, with renewable energies (Argentina, Chile, Costa Rica and Peru) or in specific areas such as solar (Cuba, Mexico and Uruguay) and wind (Mexico) energy. As for the raw materials for the bioenergy production, some institutions related to the sugarcane (Brazil, Colombia and Ecuador), and oil palm or biodiesel (Brazil, Colombia and Ecuador) production stand out.

In other areas, the following aspects are to be highlighted:

- In Argentina, the Bolsa de Cereales de Buenos Aires, has pioneered within the private sector through bioeconomy promotion and research. They were responsible for the first quantification of such importance in the country's economy (Wierny, Coremberg, Costa, Trigo and Regúnada, 2015).
- In Brazil, the Centro de Gestão e Estudos Estratégicos is in charge of supporting decision-making processes on issues related to science, technology and innovation, by means of prospective studies and strategic assessment based on broad articulation with specialists and institutions from the System National Science, Technology and Innovation.
- In Colombia, the Consejo Privado de Competitividad de Colombia is actively contributing to the construction of a bioeconomy strategy for the country, as well as the Corporación Biocomercio.
- In Costa Rica, the Centro Nacional de Alta Tecnología, equipped with laboratories for enabling technologies for the development of the bioeconomy (biotechnology, nanotechnology and information and communication technologies).
- In Ecuador, Alianza para el Emprendimiento y la Innovación, which is a network of public, private and academic actors, seeks to promote entrepreneurship and innovation.

- In Uruguay, the Centro Uruguayo de Tecnologías Apropiadas, an independent, non-profit foundation is devoted to disseminating, researching and training in the use of appropriate technologies.

Besides, there are private corporate institutions in the sustainable development area in Argentina (Argentine Council for Sustainable Development) and Peru (Peruvian Chamber of Environment and Sustainable Development).

Opportunities and challenges

There is potential for the development of the bioeconomy in Latin America. This is to be understood as an alternative for productive diversification in rural areas, especially in the agricultural and agroindustrial sectors. Biodiversity (including agrobiodiversity), especially in megadiverse countries with unique ecosystems, the ability to produce biomass for multiple uses (food, fiber, fodder, bioenergy and bioproducts), and the availability of agricultural and agroindustrial waste are three biological resources that can serve as a foundation for national and subnational bioeconomy strategies in Latin America.

In order to take advantage of the potential offered by the bioeconomy, it is necessary to know adequately the baseline of available biological resources as well as the scientific and technological capabilities that exist for their utilization. With respect to biodiversity, it is crucial to know how to protect it in order to get to know its potential. Therefore, bioeconomy strategies based on biodiversity require institutional schemes that link policies oriented to its protection together with innovation and productive development policies.

Biomass production for different uses other than food (energy uses) must be balanced with the objectives of food security and conservation, as well as the development of new more intensive and sustainable production systems, in which energy resources are used more efficiently, and where the use of fossil fuels, pesticides and other inputs derived from petrochemicals is reduced. All this, therefore, opens opportunities for the bioeconomy; for example, through biotechnological applications, the introduction of bioinputs and some value addition to the primary production processes. Harnessing the potential offered by the waste biomass involves the elaboration of detailed inventories of the different types of available waste biomass, in order to determine the technical potentials of use, not forgetting the amount that should be left in the field for the maintenance of ecosystem services which are necessary for the agricultural production. This knowledge must be complemented with the identification of capacities and deficiencies in the industrial baseline, which could, in turn, enhance or limit its use.

Argentina and Colombia have taken the regional leadership in the development of dedicated bioeconomy strategies. Many other countries have ongoing policy frameworks or have developed them around related areas - for example, innovation policies; bioenergy strategies, not only in the biofuels area, but also in some others; biotechnology policies; forest and biodiversity policies; policies and initiatives linked to climate action, among others. There are also private or public-private collaboration initiatives as in the production of bioenergy, the development of biotechnological applications for agriculture and the development of bioproducts, with a significant participation of SMEs.

The presented review evidences that there is already a long road travelled in the region regarding the development of relevant public policies and institutions to promote the development of bioeconomy. It also evidences that there are incentive mechanisms that can be used for the above mentioned purpose and that there are instances where it is possible to initiate dialogue processes concerning policies for the bioeconomy in the private sector. The formulation of bioeconomy strategies in the countries of the region, therefore, should start from the identification and articulation of the initiatives that already exist, together with dialog processes with the private sector and other relevant actors, especially in the academic and research community.

In various forums, the potential of the bioeconomy for the countries of the region has been recognized (for example, CEPAL, 2015, 2018); but it has also been recognized that their use may be hampered by factors such as: (i) lack of adequate regulatory frameworks, (ii) inadequate and disjointed regulatory frameworks, (iii) insufficient coordination of existing technical and technological capabilities, (iv) restrictions on entry to the market of small bioeconomy companies and (v) lack of funding for the creation of innovative bioeconomy companies.

Therefore, developing the bioeconomy potential requires different actions to be taken on various fronts, especially on:

- Appropriate regulatory frameworks in areas such as biosafety and regulation of biological risks, protection of biodiversity, access to genetic resources, regulation of GMOs, protection of property rights and patent requirements.
- The articulation of existing policy initiatives, especially in research, development and innovation in areas such as clean non-fossil energy, biotechnology in agriculture, human and animal health, carbon-free agricultural development, payments for ecosystem services and improvements in the efficiency and sustainability of the food system.
- Better coordination of the already existing technical and technological capabilities in the countries.
- Policies for bioeconomic SMEs aimed at building capacities, while facilitating their entry into concentrated markets and providing adequate funding for innovative ventures.

Other important enabling factors rely on:

- Promoting a better understanding of the bioeconomy concept.
- Promoting policy dialogs, exchange and understanding among bioeconomy stakeholders, both private and public.
- Strengthening the understanding on the potential of bioeconomy and the bioeconomical growth in order to achieve and inclusive, competitive an sustainable development.
- Systematizing successful bioeconomy experiences, especially in market and business development, public-private collaboration and university-business partnerships.
- Promoting the exchange of successful experiences on bioeconomy from the region in local, national and regional areas.
- Exploring ways for the development of the bioeconomy that could be of national interest.
- Escalating bioeconomy to a higher political level to reinforce its potential contributions to pave the way towards a decarbonized economy, a better environment and more inclusive societies.

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Conclusion and Perspectives

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Latin America and the Caribbean region's greatest strength to harness the potential of the bioeconomy lies on its abundant, although little explored and poorly valued, biological resources. To harness such advantages, it is necessary to go from isolated and uncoordinated actions to defined policies, government plans, and estimate the social and economic impacts biological resources can generate (Paul Ekins, Rodriguez and Krieger, 2018). As seen in the case studies presented herein, the region has much to gain by adopting development models based on bioeconomy approaches, particularly if political, socio-economic, and environmental objectives are considered as they coincide in most of the countries within the region - Sustainable Development Goals (SDG) or other-, and the opportunity derived from its generous richness of natural resources.

The importance of this alternative lies in its potential for the productive development of the countries of the region and, in particular, the revitalization of rural areas, in which, in many cases, extreme poverty is still common. Beyond this, bioeconomy allows us to rethink old dichotomies between agriculture and industry, which, undoubtedly, have delayed its adoption and development. On the other hand, bioeconomy allows countries moving forward and achieving sustainability goals, which are increasingly important, both in terms of the regional agenda, as well as globally. Biodiversity, including agro-biodiversity, in mega-diverse countries and with unique ecosystems, with the ability to produce biomass for various uses and availability of agricultural and agro-industrial waste, are examples of biological resources that can serve as a basis for the development and implementation of national and regional bioeconomy strategies and favor territorial development (Rodríguez, Mondaini and Hitschfeld, 2017).

Given the great heterogeneity of the conditions, characteristics, capabilities and multiple national policies, bioeconomy development in Latin America and the Caribbean region can hardly

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occur through a regional dynamics of a custom union as it has occurred in the European Union; inevitably, its evolution will reflect, as has already begun, the particular dynamics of each situation (country). In fact, that is the reflection of the experiences we have discussed, with marked differences in terms of scale, (de)centralization, institutionalism, actors, and scope. The Argentinian case reflects, clearly, a very interesting lesson as to how its capacities in science and technology, agriculture and agro-industry are the country's initial platforms and how the diversity of the regional economies is reflected in the productive paths taken.

On the other hand, in Brazil, there is still a historical bias complemented with the weight of bioenergy (sugar cane ethanol), although, in fact, at federal level, within the Ministry of Science and Technology, a program of bioeconomy exists and several States are already moving ahead with initiatives of their own (with a strong momentum of its industry associations). Colombia, in turn, has recently formulated a first draft of its bioeconomy strategy, within the scope of the so-called Green Growth Taskforce, which already has a document from the National Council of Economic and Social Policy (CONPES), the Planning Authority, which includes a Green Growth policy for Colombia.

Regarding the six bioeconomy development pathways, initially (2014) identified in the EC financed project "Towards a Latin American and Caribbean Knowledge Based Bio-Economy in partnership with Europe" (Hodson, 2014), coupled with the analysis of the case studies in different countries (Argentina, Colombia, Mexico, Brazil, Costa Rica and Chile), as well as secondary information available on some other countries, bio-based activities and industries initially increased mainly towards the Bioenergy and Biotechnology (GMOS) pathways, complemented by a strong adoption of environmentally friendly cultural practices, as the minimum tillage or zero tillage, especially in the Southern Cone. At present, the region shows ample evidence of an evolution towards increasingly higher valued bio-processes and bio-products. At the same time, cascade products increasingly show use breadth in its product range. An example is the steady increase in the use of residual biomass and waste streams or by-products on the part of agro-industries, and even the use of different types of urban waste for the production of bioenergy and other biobased products (see Groba, 2018).

As introduced by Adrian G. Rodriguez in Chapter 9 of this work, most countries have institutional frameworks (rules, regulations, agencies and promotional funds) directly or indirectly related to bioeconomy. However, it cannot be said that public policies have been the inducing force of the developments observed in the region; on the contrary, the lack of incentives (credit, institutional strengthening, technological training), training of human resources and the presence of too restrictive rules in terms of access to natural resources are often identified as barriers to promote the implementation of bioeconomy and a higher production of products, processes, and biobased services.

In line with the above, the analysis of the different experiences highlights the importance of new knowledge and science, technology, and innovation policies during the initial bioeconomy development stages; a parallel observation with what has been experienced in other parts of the world (the European Union and the United States), where processes and products innovation have been, undoubtedly, strategic axes. This also includes the limitations to move forward with innovative products and processes for greater penetration of domestic or international markets. In general, moving forward in this type of pathways requires the establishment of new companies and, the region, in general terms, does not have a history of good performance in the field. Despite the existence of public programs for the promotion of innovation, the weakness of capital markets makes it difficult to have access to the (start-up) funds necessary to finance investments required for the, usually expensive, process of entering the market as faced by small businesses and laboratories.

This has led, in this first phase of the cycle, to contribute to placing the leadership of the process in those more "traditional/common" products immersed in more structured markets and, consequently, with lower technology and market wise risks than those posed by new high-tech products, for which entering markets is much more complex. In this regard, bioenergy-based and waste-use processes and products would appear to be the most advanced ones and, *vis-à-vis*, the most innovative ones with a greater long-term potential, just like those products derived from a greater use of the immense biodiversity resources available in the region could be. This has been highlighted in almost all the chapters of this book and it highlights the region's potential to value the residual biomass as an economic source of abundant biomass, which also generates a very significant positive impact on the environment, which is one of the most significant drivers to the future bioeconomy development in the countries of region.

In this regard, visualizing the three categories/groups of biomass addressed in the previous chapter on public policies is particularly relevant: a) raw materials from agricultural crops, in which important considerations are to be made in terms of possible food security and environment competition; b) biodiversity, especially important within the region as it is one of the world's greatest diverse region, although conditioned to face major challenges in terms of standards, markets, policies, institutionalism, etc.; and c) waste streams, where disputes are much lower, given that, in addition, they generate significant positive environmental effects, but still new rules and policies are required.

One aspect directly linked to this is the existence of a low degree of integration between the academy, as a generator of new knowledge (ideas, information, processes, technologies and products), and the industry (consumer, processor, and marketer of these products). This topic, by the way, is neither new nor unique to bioeconomy; it rather affects the entire innovation space. However, in this case, it is the result of having many processes that are not only disruptive in technological terms, but also pose the need for other types of transformations, both "upstream" (new inputs and logistical chains) and "downstream" (regulations and markets). Such situation is further worsened by the scarcity of venture capital and, in many cases, regulations are not designed in line to the characteristics and needs of the new biobased products.

All of the above highlights the urgent need for the region to strengthen scientific and technological capabilities through multiple training activities, which include everything from higher academic degrees (Masters' and PhD's degrees), specific training in priority areas of interest, to the development of management and negotiation skills; additionally, as an essential component for competitiveness, knowledge and proper implementation of all international norms and standards to introduce advances, products, processes, and services obtained through bioeconomy activities have to be implemented.

All of these aspects highlight the key role of those issues related to governance and policies to promote bioeconomy. Considerations such as the detailed inventories of the various biomass sources available per country, region, crop etc.; open and effective participation of all stakeholders concerned; permanent coordination mechanisms to formulate and manage bioeconomy policies/strategies; articulation between national and regional approaches, within the framework of a clear identification of areas and strategic objectives; formulation of policies and instruments in support of such strategies and objectives, and permanent monitoring of its evolution, including consultation and feedback with stakeholders, are some of the specific topics to be considered.

Beyond these aspects, future development calls for a series of actions in various areas, including a greater understanding and acceptance of the potential of bioeconomy by society as a whole. Much progress has been made in disseminating the concepts behind this vision, but there is still little information about their true potential, especially in relation to what its effective contribution to solving the problems of employment and poverty faced by almost all of the countries of the region could be. All of the evidence shown in this book highlights the need for and the importance of new institutions and public policies so that this potentially relevant option to be effectively transformed in a new opportunity for sustained development within the region. However, such transformations will hardly materialize without being expressly aware of the potential benefits.

Once such greater awareness has an effect. The agenda to be undertaken will take time as new challenges and risks will be posed and then incorporated in a clear and precise manner to policies and institutional means so that such benefits come true. Many of such problems have to do with the particular characteristics of the applications of the new biology to productive systems, and the way they perceive and differ from conventional technological systems. Other problems have to do with new approaches being associated with emerging sectors which, in some cases, involve important changes on how natural resources are used and how they arise and are integrated to the new value chains, which is called bioeconomy.

In this regard, similarly to what happened in earlier cycles, the transition to the bioeconomy implies not only a different knowledge base. It also requires broader changes within the economic and social hierarchy, as well as in the behavior of individual actors -orientation of investment, productive decisions, and consumer choices. Many of these are strongly influenced by policies and regulations that help generate and contain new processes, as well as handle the transaction costs involved in the transition from "old" to "new". The visions of the new bioeconomy reflect mostly the future implications of the current economic practices. Future events are already being seen in specific situations, but are not yet reflected in the current market signals. In general terms, the common denominator of the emerging system is the growing complexity of the new environment compared with the existing systems, and this is perhaps the most basic criteria to address future decisions.

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