

Sérgio A. M. Carbonell
Luís A. B. Cortez
Luís F. C. Madi
Lilian C. Anefalos
Ricardo Baldassin Jr.
Rodrigo L. V. Leal

Tropical Bioeconomy

Roadmaps and Guidelines
for Bioeconomy
Development in Brazil

ISBN: 978-65-994280-3-6



9 786599 428036

a





Sérgio A. M. Carbonell
Luís A. B. Cortez
Luís F. C. Madi
Lilian C. Anefalos
Ricardo Baldassin Jr.
Rodrigo L. V. Leal

Tropical Bioeconomy

Roadmaps and Guidelines
for Bioeconomy
Development in Brazil

Campinas • 2021



áttema

Image provided by Embrapa Territorial

Copyright © 2021 • All rights reserved to the authors.

No part of this book may be reproduced or used in any manner without written permission of the copyright owner.

This publication had the support of the São Paulo State Research Foundation - FAPESP (2016/50198-0)

COVER DESIGN, GRAPHIC DESIGN AND PUBLISHING

Áttema :: Assessoria editorial, Comunicação & Design : www.attema.com.br

IMAGES USED IN THIS BOOK

Embrapa Territorial

COORDINATION

Sérgio A. M. Carbonell

Luís A. B. Cortez

Luís F. C. Madi

Lilian C. Anefalos

Ricardo Baldassin Jr.

Rodrigo L. V. Leal

AGROPOLO CAMPINAS-BRASIL

Executive Secretariat:

Sérgio A. M. Carbonell

Luís A. B. Cortez

Luís F. C. Madi

Lilian C. Anefalos

CATALOG

Dados Internacionais de Catalogação na Publicação (CIP) (Câmara Brasileira do Livro, SP, Brasil)

Tropical bioeconomy [livro eletrônico] : roadmaps and guidelines for bioeconomy development in Brazil / organização Sérgio A. M. Carbonell ... [et al.]. -- 1. ed. -- Santo André, SP : Sian Martins Comunicação, 2021. PDF

Outros organizadores: Luís A. B. Cortez, Luís F. C. Madi, Lilian C. Anefalos, Ricardo Baldassin Jr., Rodrigo L. V. Leal

Título original: Bioeconomia tropical

Vários tradutores.

ISBN 978-65-994280-3-6

1. Biodiversidade - Brasil 2. Bioeconomia 3. Desenvolvimento econômico - Brasil 4. Desenvolvimento social 5. Diretrizes 6. Inovação tecnológica 7. Pesquisa I. Carbonell, Sérgio A. M. II. Cortez, Luís A. B. III. Madi, Luís F. C. IV. Anefalos, Lilian C. V. Baldassin Junior, Ricardo. VI. Leal, Rodrigo L. V.

21-60004

CDD-338.981

Índices para catálogo sistemático:

1. Bioeconomia : Brasil : Desenvolvimento econômico : Economia 338.981

Maria Alice Ferreira - Bibliotecária - CRB-8/7964

Table of Contents

Preface	9
Acknowledgments	11
The city of Campinas and the opportunities in Bioeconomy André Luiz de Camargo von Zuben	
Research in Tropical Bioeconomy	17
Carlos Henrique de Brito Cruz	
The Role of Startups in the Innovative Bioeconomy Ecosystem	19
Flávio Grynspan	
Technology Parks: Innovation and regional competitiveness	23
José Luiz Guazzelli, Lucas Baldoni	
Part I • Bioeconomy	
I.1 Bioeconomy: opportunities and challenges	27
José Vitor Bomtempo, Thiago Falda Leite, Flávia Alves, Fábio Oroshi	
I.2 Innovation Ecosystem in Bioeconomy: Opportunities, Competitive Advantages and Challenges for the Metropolitan Region of Campinas	33
Maurício Serra, Eduardo Gurgel, Celso Barbosa	
I.3 Sustainable agriculture	41
Roberto Rodrigues	
I.4 The food and beverage industry	45
João Dornellas	
I.5 Modern Bioenergy	49
Isaias C. Macedo	
I.6 Biochemicals: challenges & opportunities	55
João Bruno Valentim Bastos, Mariana Doria, Paulo Coutinho, Victoria Santos	
I.7 Opportunities, competitive advantages and key challenges and barriers for Brazil to consolidate as a world reference in “toiletries, fragrances and cosmetics” ...	63
João Carlos Basilio, Francine Leal Franco	
I.8 Constructing the Tropical Bioeconomy for Brazil	69
Luís Cortez	

>>

>>

Part II • Roadmap for Tropical Bioeconomy

The Agropolo's Campinas-Brasil approach

Bioeconomy around the World	75
Sérgio Augusto Morais Carbonell, Lillian Cristina Anefalos, Ricardo Baldassin Jr.	
Roadmap methodology	79
Rodrigo Lima Verde Leal, Ricardo Baldassin Jr., Lillian Cristina Anefalos	
II.1 Agriculture	83
Heitor Cantarella	
II.1.1 Agricultural and urban wastes: energy, nutrient recycling and fertilizers	84
Heitor Cantarella, Ronaldo S. Berton, Bruna de Souza Moraes, Raffaella Rossetto Antonio Carlos Delbin	
II.1.2 Essential oils, medicinal and aromatic plants	88
Marcia Ortiz, Juliana Rolim Salomé Teramoto, Pedro Melillo de Magalhães, Ilio Montanari Junior, Glyn Maria Figueira, Marta Cristina Teixeira Duarte, Sandra Maria Pereira da Silva Maurício Cella	
II.1.3 Precision agriculture	92
Lucas Rios do Amaral, Paulo Sérgio Graziano Magalhães, Luiz Henrique A. Rodrigues Tsen Chung Kang	
II.1.4 Animal system production: low carbon livestock	96
Renata Arnandes, Linda Monica Premazzi, Flávia Maria A. Gimenes, Antônio Batista, Ana Eugênia de C. Campos César de Almeida Franzon	
II.1.5 Sustainable use of water	100
Regina Célia de Matos Pires, José Teixeira Filho Marcus Henrique Tessler	
II.1.6 New Bioeconomy Industry: Coffee	104
Júlio Cesar Mistro, Maria Bernadete Silvarolla, Terezinha de Jesus Garcia Salva, Julieta Andrea Silva de Almeida, Oliveira Guerreiro Filho, Gerson Silva Giomo André Cunha, Tuffi Bichara, Daniella Pelosini	
II.1.7 New Bioeconomy Industry: Citrus	108
Dirceu de Mattos Jr, Marcos Antonio Machado, Mariângela Cristofani-Yaly Ricardo Franzini Krauss	
II.2 Food & Health	113
Luis Fernando Ceribelli Madi	
II.2.1 Ingredients and functional processed foods	114
Airton Vialta, Luis Madi Eduardo Carità	
II.2.2 Food and beverage packaging	118
Eloisa Garcia, Sílvia T. Dantas, Aline B. Lemos, Ana Paula R. Noletto, Anna Lucia Mourad, Beatriz M. C. Soares, Claire Sarantópoulos, Leda Coltro, Marisa Padula Jorge Caminero Gomes	

>>

>>

II.2.3 Food and beverage processing technologies	128
Maria Isabel Berto, Michele Berteli, Izabela Dutra Alvim Fernanda de Oliveira Martins	
II.3 Bioenergy and Green Chemistry	133
Luís Augusto Barbosa Cortez	
II.3.1 Advanced biofuels: aviation and other heavy transport	134
Telma T. Franco, Luuk van der Wielen	
II.3.2 Biomass valorization for chemicals	138
Gustavo Paim Valença	
II.3.3 Enzymes and Green Chemistry	142
Andreas Gombert, Isabel Arends	
II.4 Non-technological roadmap	147
Rodrigo Lima Verde Leal, Ricardo Baldassin Junior, Lillian Cristina Anefalos	

Part III • Guidelines for Bioeconomy Development in Brazil

Guidelines for Bioeconomy Development in Brazil	153
About the images used in the book	158



Preface

Bioeconomy, in particular Tropical Bioeconomy, is an amazing opportunity, primarily for developing countries, to promote economic and social development. It presents a real possibility to reduce the use of fossil resources, and consequently their environmental impact, and improves the sustainability of the exploitation and transformation of natural resources. To date, several countries have integrated the Bioeconomy in their policy strategies worldwide, encouraged by the recent advances in, and future perspectives of, bioscience and biotechnology, and its great potential to boost economic output.

However, the deployment of Bioeconomy, and consequently the achievement of its benefits, will require new and innovative approaches in science, technological developments, business, and especially in global policies and regulatory frameworks that are strongly focused on social development and environmental resource conservancy and preservation.

Tropical Bioeconomy represents a tremendous challenge given that the developed country cultures are located in temperate climates, where most of the advanced world economies are also located. Additionally, while more complex biodiversity in tropical areas of the world, on the one hand, represents more difficulties, on the other, it also presents more opportunities, both by increasing productivity or adding new agricultural areas, and by adding value to commodities (for manufacturers or through branding and marketing).

Brazil, as the largest tropical country in the world, with a medium-income economy, constantly searches for new market opportunities. In this respect, the development of an innovative and sustainable tropical bioeconomy is of paramount importance today.

In order to explore tropical bioeconomy opportunities, a technological roadmapping was performed between June/2015 and June/2018, involving more than 1,500 experts that included researchers, technical experts from the private sector, policymakers, and other stakeholders. The major results of this effort outline the opportunities as well as the technological and non-technological challenges for Brazil in Research, Development, Demonstration, and Deployment (RDD&D) in 13 strategic tropical bioeconomy areas covering agriculture, food, health, bioenergy and green chemistry, and include the major public policies needed.

This research initiative had the support of the São Paulo Research Foundation (FAPESP) within the project “Agropolo Campinas-Brasil: roadmap of the strategic areas of research aiming at creating a world-class bioeconomy ecosystem” (PPBio Project – 2016/50198-0), and the main results of which are summarized in this book.

.....
Agropolo Campinas-Brasil was created in June 2015, as a result of a technical-scientific cooperation agreement between Brazil and France, to develop a world-class innovation ecosystem with a focus on bioeconomy in the city of Campinas, Brazil. Agropolo was born inspired by the regional development model of the city of Montpellier, France, and is based on the concept of collaborative innovation that has been driven by Agropolis International.

During the period 2015-2018 Agropolo activities have been focused on the development of a technology roadmap for Tropical Bioeconomy in order to guide the bioeconomy development in the state of São Paulo. The Agropolo governance is run by representatives from São Paulo state government research centers (the Agronomic Institute-IAC, the Institute of Food Technology-ITAL, the Animal Science Institute-IZ, and the Biological Institute-IB), the University of Campinas (UNICAMP), the São Paulo State Secretariat of Agriculture and Supply (SAA-SP), the São Paulo State Secretariat of Economy, Development, Innovation, Science and Technology (SDECT-SP), the Campinas City Hall (PMC), the TechnoPark Campinas, and Agropolis International/France, with support from the Consulate General of France in São Paulo and the Brazilian Agricultural Research Corporation (Embrapa).

Image provided by Embrapa Territorial



Acknowledgments

Tropical Bioeconomy - Roadmaps and Guidelines for the Development of Bioeconomy in Brazil is a result of the project “Agropolo Campinas-Brasil: roadmap of the strategic areas of research aiming at creating a world-class bioeconomy ecosystem”, funded by the São Paulo Research Foundation - FAPESP (2016 / 50198-0).

The Project was initiated, conceptualized and led by the members of the Agropolo Campinas-Brasil Executive Board: Sérgio Augusto Morais Carbonell, Luís Augusto Barbosa Cortez, Luis Fernando Ceribelli Madi and Lilian Cristina Anefalos, together with management support from Ricardo Baldassin Jr and the members of the Agropolo Campinas-Brasil Administrative Board: Jonas Donizete (Campinas City Hall), José Tadeu Jorge (succeeded by Marcelo Knobel, University of Campinas - UNICAMP), Arnaldo Jardim (São Paulo State Department of Agriculture and Supply - SAA), Márcio França (São Paulo State Department for Economic Development, Science, Technology and Innovation - SDECTI), Miguel Gilberto Pascoal and José Luiz Camargo Guazzelli (Techno Park Campinas), and Bernard Hubert and Eric Fargeas (Agropolis International / Montpellier , France).

Acknowledgments also go to the editors responsible for the book design, review and edition: Sérgio Augusto Morais Carbonell, Luís Augusto Barbosa Cortez, Luis Fernando Ceribelli Madi, Lilian Cristina Anefalos, Ricardo Baldassin Jr, and Rodrigo Lima Verde Leal.

Further acknowledgments go to the Brazilian Agricultural Research Corporation - EMBRAPA, in particular to the EMBRAPA Satellite Monitoring, for the license to use the GeoEye Satellite images presented in the book.

Recognition and thanks are due as well to the Area Coordinators for their governance of the research teams: Heitor Cantarella, Luís Augusto Barbosa Cortez, and Luis Fernando Ceribelli Madi; and to the Strategic Area Coordinators for the thematic workshops planning and execution: Airton Vialta, Aline Brionísio Lemos, Ana Eugênia de Carvalho Campos, Ana Paula Reis Noletto, Andreas Gombert, Anna Lucia Mourad, Antônio Batista, Beatriz Maria Curtio Soares, Bruna de Souza Moraes, Claire Sarantópoulos, Dirceu de Mattos Junior, Eloisa Garcia, Flávia Maria de Andrade Gimenes, Gerson Silva Giomo, Glyn Maria Figueira, Gustavo Paim Valença, Izabela Dutra Alvim, José Teixeira Filho, Juliana Rolim Salomé Teramoto, Julieta Andrea Silva de Almeida, Júlio Cesar Mistro, Leda Coltro, Linda Monica Premazzi, IlioMontanari Junior, Lucas Rios do Amaral, Luiz Henrique Antunes Rodrigues, Luuk van der Wielen, Marcia Ortiz Mayo Marques, Marcos Antonio Machado, Maria Bernadete Silvarolla, Maria Isabel Berto, Mariângela Cristofani-Yaly, Marisa Padula, Marta Cristina Teixeira Duarte, Michele Berteli, Oliveiro Guerreiro Filho, Paulo Sérgio Graziano Magalhães, Pedro Melillo de Magalhães, Raffaella Rossetto, Regina Célia de Matos Pires, Renata Arnandes Branco, Ronaldo Severiano Berton, Sandra Maria Pereira da Silva, Sílvia Tondella Dantas, Telma Teixeira Franco, and Terezinha de Jesus Garcia Salva.

We are also deeply thankful to the external authors: André Cunha, Antonio Carlos Delbin, Celso Barbosa, César de Almeida Franzon, Daniella Pelosini, Eduardo Carità, Eduardo Gurgel, Fábio Oroski, Fernanda de Oliveira Martins, Flávia Alves, Francine Leal Franco, Isabel Arends, Isaias Macedo, João Bruno Valentim Bastos, João Carlos Basilio, João Dornellas, Jorge Caminero Gomes, José Vitor Bomtempo, Luuk van der Wielen, Marcus Henrique Tessler, Mariana Doria, Mauricio Cella, Maurício Serra, Paulo Coutinho, Ricardo Franzini Krauss, Roberto Rodrigues, Thiago Falda Leite, Tsen Chung Kang, Tuffi Bichara, and Victoria Santos.

We also thank the speakers and panelist representatives of academia, industry, civil society, and government for their presentations, opinions and perspectives during the thematic workshops.

Special thanks are given to the workshop participants for their participation and commitment, which were of paramount importance for the success of the roadmapping process. The management and participation of Ricardo Baldassin Jr, in all stages and discussions throughout the thematic workshops, was fundamental for the achievement of the project results and the book development.

We also thank all the support staff who worked intensively, in unison and in a fully collaborative way, for the full development of the project, and which included civil servants, trainees, journalists, and other collaborators from

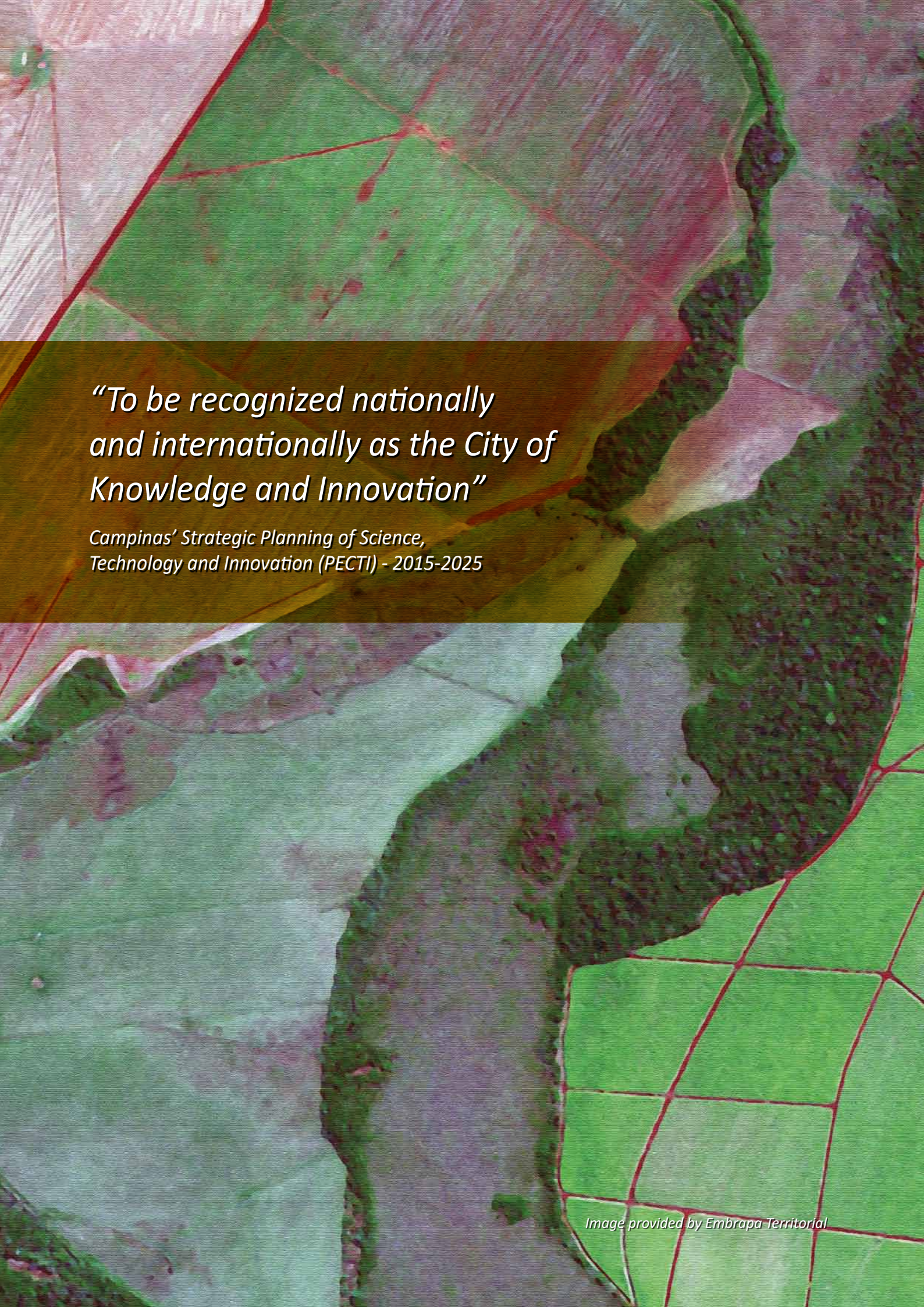
Image provided by Embrapa Territorial

partner institutions. We highlight the contributions of Janice Aparecida de Paulo, who worked intensively on the organization and execution of the thematic workshops.

Recognition and thanks are due to Rodrigo Lima Verde Leal for technical support on roadmap methodology and to the team from Áttema Editorial for the book layout and design.

Additionally, we extend our thanks to the Interdisciplinary Center of Energy Planning – NIPE/UNICAMP, Alibra, Jacto, Brazilian Association of Plant Nutrition Technology Industries – ABISSOLO, School of Chemical Engineering – FEQ/UNICAMP, BASF, DSM, DuasRodas, Pronutrition, Funcional Mikron, Koelnmesse, Sun Foods, SENAI Innovation Institute for Biosynthetic – SENAI CETIQT, Chemical, Biological and Agricultural Pluridisciplinary Research Center – CPQBA/UNICAMP, Braskem, Klabin, Plantic/Kuraray, Fundação de Desenvolvimento da Pesquisa do Agro-negócio - Fundepag, Nestlé do Brasil, Premix, Toledo do Brasil, Brazilian Roundtable on Sustainable Livestock – GTPS, Brazilian Rural Society – SRB, School of Food Engineering – FEA/UNICAMP, TU Delft (Netherlands), School of Agricultural Engineering – FEAGRI/UNICAMP, SANASA Campinas, and Brazilian National Confederation of Industry – CNI, for funding and/or kindly providing institutional support to the thematic workshops.

Finally, we gratefully thank the São Paulo Research Foundation – FAPESP for their full support and financing of the project, and all partners of Agropolo Campinas-Brasil for their contributions in all phases of the project, of which Campinas City Hall, São Paulo State Department of Agriculture and Supply – SAA, Agronomic Institute – IAC, Institute of Food Technology – ITAL, Institute of Animal Science and Pastures – IZ, Biological Institute – IB, University of Campinas – UNICAMP, Techno Park, Agropolis International, Consulate General of France in São Paulo, Brazilian Agricultural Research Corporation - EMBRAPA, Be-Basic (Netherlands), Fundação de Apoio à Pesquisa Agrícola – FUNDAG, Netherlands Consulate-General in São Paulo, Campinas and Region Foreign Trade Chamber – CCCER, Fraunhofer IVV (German), German House for Research and Innovation – São Paulo (DWIH São Paulo), IAR Pole (France), CPqD, New Frontiers in Food Project (Foodvalley, Valorial, Vitagora, Clusaga and Wagrallim), and Brazilian Center for Research in Energy and Materials – CNPEM / Brazilian Bioethanol Science and Technology Laboratory – CTBE.



*“To be recognized nationally
and internationally as the City of
Knowledge and Innovation”*

*Campinas’ Strategic Planning of Science,
Technology and Innovation (PECTI) - 2015-2025*

Image provided by Embrapa Territorial

The city of Campinas and the opportunities in Bioeconomy

André Luiz de Camargo von Zuben – *Secretary of Campinas for Economic, Social and Tourism Development (2017-2020), Campinas City Hall*

The PECTI - 2015-2025 Mission Statement reflects the capacity and the growth potential of the city of Campinas, a capacity based on past vocations and choices and consolidated today by the advances achieved over its 245 year history.

Campinas is considered to be a big city, being the 11th largest GDP and ranking among the 30 best cities to live in Brazil, according to the United Nations (the UN). Its industrial park is a differential: of the 500 largest companies in the world, 50 of them have operations in the Campinas Metropolitan Region (RMC); more than 70,000 companies are headquartered in the city; RMC is the third largest producer of manufactured goods in Brazil; and concentrates over 20% of the food and beverage industry of the state of São Paulo.

Allied with its economic power and performance is its scientific and technological capacity; Campinas is considered to be the 3rd largest research and development pole in Brazil, a result of its many public and private Institutes, research centers and universities. Campinas is the headquarters of the largest complex of technology parks in Brazil, with a total of five, four of which are accredited by the São Paulo System of Technology Parks - SPTec.

The combination of economic, scientific and technological factors combined with the local infrastructure and with the programs being implemented by the public and private sectors makes Campinas the 3rd best city for business and entrepreneurship, thus transforming the potential for innovation into a future reality.

Within this context, sustainability and innovation are the pillars of the Campinas Strategic Master Plan (PDE; Complementary Law No. 189 of 01/08/2018). In this document, two important actions deserve to be highlighted: the Sustainable Cities Program (PCS) and the Campinas Intelligent City Strategic Plan (PECCI).

The Sustainable Cities Program was inspired by the Aalborg Commitments that were agreed in Aalborg, Denmark

in 2004: a political pact with sustainable development which is signed by over 650 municipalities worldwide (although mainly European), including 207 Brazilian municipalities. The program aims to implement agendas for the promotion of sustainability in cities, incorporating in an integrated manner environmental, economic, political and social dimensions in line with the United Nations Sustainable Development Goals (SDGs).

The Campinas’ Intelligent City Strategic Plan - 2019-2029 (PECCI) is a robust effort aimed at enabling the city to undertake a journey of digital transformation, not only through the implementation of information and communication technologies (ICTs), but also through the implementation of solutions that promote sustainable development, infrastructure improvement and active and efficient governance. Like the PCS, the PECCI is also in line with the UN SDGs, thus creating total harmony between their respective goals.

All these factors, combined with the longstanding agronomic vocation of the region – begun with the introduction of sugar cane, and later coffee, during the eighteenth and nineteenth centuries and further stimulated by the creation of the Agronomic Institute (IAC) in the late nineteenth century - and added to the scientific and technological capacity developed since then with the birth of several important institutions (including the Institute of Food Technology - ITAL, the Biological Institute - IB, the Institute of Animal Science and Pastures - IZ, the University of Campinas - UNICAMP, the Brazilian Agricultural Research Corporation - EMBRAPA, the National Center for Research in Energy and Materials - CNPEM, the CTI Renato Archer, the CPqD and the Eldorado Institute, among others) have made the city an important contributor to the development of the national agribusiness, and certainly one of the most favorable environments for the development of the bioeconomy in Brazil. ■



Research in Tropical Bioeconomy

Carlos Henrique de Brito Cruz – *Scientific Director (2005-2020), São Paulo Research Foundation- FAPESP*

There are enormous opportunities for Brazil and for the state of São Paulo in the economic sector recently named bioeconomy, and the work to date in the Campinas region demonstrates the vigorous initiative to make the city one of the most important centers on the subject.

The existence in the Campinas region of some of the most important science and technology institutions in the country makes it possible to mobilize research and development efforts to create new basic and applied knowledge on bioeconomy. FAPESP has encouraged this initiative, initially through the research project “Agropolo Campinas-Brasil: roadmap for identifying strategic research areas aimed at creating a world-class bio-economy ecosystem”, led by Dr. Sérgio Carbonell from Agronomic Institute (IAC) and Prof. Luiz Cortez from University of Campinas (UNICAMP). The project is part of the FAPESP Public Policy Research Program, which stimulates research on topics with clear potential for application in the formulation and implementation of public policies.

The initiative of IAC and UNICAMP to address the important theme of bioeconomy, and the adhesion of the Campinas municipal government to the project, places the region alongside several other countries and regions in the world that have been working on the research agenda in bioeconomy as part of the effort to increase regional and global sustainability.

In this regard, the initiative of Agropolo Campinas-Brasil to organize an initial research proposal, changing the way research groups are composed and focusing on themes considered strategic, is of great importance for FAPESP.

The project, whose results are described herein, sought to avoid a disciplinary approach, organizing the research around economic and environmental objectives. To put together this collaborative research model, the organizers sought inspiration from the experience of the Agropolis International of Montpellier, France.

Ten areas of the bioeconomy were chosen, exploring the complementarity of the participating institutions. A methodology was implemented in order to identify relevant and challenging research topics, which may result in great future contributions and help to maintain the dynamism of the São Paulo state agribusiness economy. Several foreign experts contributed to the group’s research activities, bringing visions and ideas from the best international practices.

As the results of the initial phase are consolidated, it is reasonable to expect that the tropical bioeconomy project will create opportunities for collaborative research between universities, public institutes and private companies, accelerating the regional economic development based on internationally competitive science.

As always with things related to knowledge, getting results never means the job is over. New issues and challenges have been discovered, and much remains to be done. When it comes to applications of knowledge, the complexity of the problem increases significantly, because success does not depend only on the quality of the science created, but mainly on the capacity of the external actors in the world of science - governments, institutions, industry – to act effectively using the knowledge created. The results presented here, obtained in close articulation with government and business sectors, are an important first step towards realizing the promise of scientific, social and economic development based on the sustainable use of existing resources in the tropics. ■

Image provided by Embrapa Territorial



Image provided by Embrapa Territorial

The Role of Startups in the Innovative Bioeconomy Ecosystem

Flávio Grynszpan – Director of the iCorps Brazil Institute and Instructor of the PIPE / FAPESP Program

Startups play a key role in the innovation process, participating both in the transfer of research results from our universities and research institutes, as well as in the incorporation of innovation into companies.

There are countries, such as the United States, where many of the current major players in the economy were until recently startups, including Amazon, Facebook, and Google. More recent examples are Uber, Airbnb and Tesla.

Other countries, such as Israel, have their economy centered on the actions of innovative small startups, largely born of research at Israeli universities. Israel is widely known as “The Startup Nation” or as “The Entrepreneur Country”.

In Brazil, the creation of innovative startups is very recent. But its importance is notable for the intensity with which the topic is being discussed by society, which understands that startups will be of great importance for the generation of new business, for the creation of qualified jobs and for the transformation of our productive sector. The government is already moving forward with legislation that facilitates the creation of new companies and seeks to foster their development with programs such as FAPESP’s PIPE.

Startups and Academic Research

In 2008, the United States suffered a severe financial crisis that quickly spread throughout the world economy. Companies were closed and jobs were lost. The crisis continued in the ensuing years, pressuring governments and institutions to adjust to the new reality.

On January 31, 2011, U.S. President Barack Obama launched the Startup America Program, placing entrepreneurship at the center of discussions regarding how to restart American economic development. Until then, entrepreneurship was limited to a few geographical centers, such as, primarily, Silicon Valley, Boston and New York.

The recession also hit the academic world, forcing the National Science Foundation to ask Congress to boost its budget. Under pressure from the universities, Congress resolved to meet the request, but included a condition for the NSF: that any researcher receiving funding from the agency should actively contribute to the economic recovery effort. To make the researcher’s commitment model viable, the Science and Technology Commission sought out Professor Steve Blank, who taught Stanford and Cal Berkeley business school students how to start new businesses in the Silicon Valley region.

This led to the Innovation Corps Program, or iCorps, at the NSF in 2011. Through iCorps, researchers would transfer the results of NSF-supported research to newly-created startups. As the NSF is one of the most important funding agencies in the United States, entrepreneurship has quickly become a central theme in American academic research. As the initial results were very positive, other management entities quickly joined the program: in 2013, they were the National Institute of Health (NIH) and Small Business Innovation Research (SBIR), a sister entity of FAPESP’s PIPE; in 2014, the Departments of Defense, Energy and NASA; and, from 2015 on, all other federal government funding programs. Today, the iCorps Program is a part of the 83 leading research universities in the United States. The startups developed are expected to form the foundation of the future American manufacturing sector.

To summarize, in the United States startups are becoming the main vector for transferring academic research results to the productive sector.

Startups and Companies

In 1997, in his classic book *The Innovator's Dilemma*, Prof. Clayton Christensen explains why the leading companies in their markets cannot maintain their dominance, and why they are obliged to protect their market, and thus innovate only incrementally. As a result, they are vulnerable when a competitor with a disruptive innovation appears.

A similar conclusion was reached by McKinsey & Company, the worldwide management consulting company, when it modeled the three horizons of innovation. On Horizon 1 are leading companies that focus on improving the execution of their current business model. In this horizon, the company innovates in processes, procedures and costs with its internal staff. This is an Incremental Innovation.

On Horizon 2 are emerging businesses or opportunities that may generate future profits but require additional investment and make the company take some risk as it does not completely control the new environment. Since the company does not want to take this risk, to lessen the uncertainty the company prefers to either partner with or acquire an existing company because it is cheaper and less risky than trying to develop on its own. If the outside company is a startup, it is always willing to take the necessary risk. This is known as Open Innovation.

On Horizon 3 are the most disruptive innovations introduced by startups that practice New Innovation models. These are innovations that, if successful, can substantially affect the market position of the leading company. The solution employed by the leading company is to make a minority investment in the startup to closely monitor its evolution and decide if and when it needs to acquire control of the new market entrant.

In both horizon 2 and horizon 3, startups are central to the ongoing innovation process of leading companies.

The International Insertion of Brazilian Startups

As Brazil is a major player in the bioeconomy world, this area represents a great opportunity to insert our startups internationally. A startup that wants to compete globally must choose one of two strategies:

a) Become a scalable startup – one that goes after venture capital investments to grow. It needs to

be attractive to investors, showing a potential for high growth.

b) Be a buyable startup – one whose role is to drive its disruptive innovation in order to partner with or be absorbed by a medium or large company that is competing in the marketplace.

In both cases, the support of public agencies, such as FAPESP, is essential, both to provide seed capital through the PIPE Program, and to enable startups through PIPE Entrepreneur Training, which helps to adjust its product or service to the real need of the company's market (product x market fit).

Opportunities for Brazilian Startups in Bioeconomy

Brazilian startups can benefit from the fact that the country has already penetrated the main markets of the world with its products through four initiatives:

a) Consolidating its leadership in areas such as agribusiness and bioenergy by creating innovative products and services that use new analytics, big data, machine learning, artificial intelligence and genetic technologies.

b) Increasing the value added in the commodities we export.

c) Addressing the current bottlenecks and internal needs of our supply chain, such as in the production of pesticides and organic fertilizers, improving connectivity in the countryside and bringing solutions to small farmers so as not to widen the gap between big and small producers, all topics recently raised in the startup training program conducted by iCorps in partnership with Agropolo Campinas-Brasil and APTA/SAA.

In the medium term, we will need competitive solutions for: precision agriculture, innovative new products and services with worldwide application, modern food processing technologies and wellness foods.

d) Accelerating the process of international insertion through the participation of our startups in the principal accelerators of the leading countries.

Reviewing the United States market, we identified some priority areas for insertion into that market, exemplified by the following accelerators:

AgTech Accelerator – Priority areas:

- Agriculture Biotech – In farm inputs for crop and animal agriculture, including genetics, microbiome and breeding.

- Bioenergy and Biomaterials – Non-food extraction & processing, feedstock technology.

- Farm Management SW, Sensing and IoT – Data capturing devices, decision support SW, big data analytics.

- Food Marketplace/E-commerce - Online Farm-2Consumer, meal kits, and specialist consumer food delivery.

- Innovative Food - Alternative proteins and novel ingredients.

- Novel Farming Systems - Indoor farms, insect farming, and algae & microbe production.

- Robotics, Mechanization, & Equipment - On-farm machinery, automation, drone manufacturers, and tillage equipment.

- Supply Chain Technologies - Food safety & traceability technology, logistics & transport, and food processing.

Food Accelerator – Priority areas:

- Intersection of food and medicine – Healthy products

- Reduction of waste

- Application of advanced technology

- Sustainable proteins

- Sustainable packaging innovations

Plug & Play Accelerator – Priority areas:

- Personalized nutrition

- Food freshness and safety

- Automation

- Functional food

- Protein alternative

- Waste reduction ■



Technology Parks: Innovation and regional competitiveness

José Luiz Guazzelli – Director of the Technology Park Techno Park Campinas
Lucas Baldoni – ST&I Committee Member of the Techno Park Campinas

Technology parks promote the culture of innovation and regional competitiveness through the flow of knowledge generated and converted into disruptive innovations. In addition, they foster interaction between various actors in the innovation ecosystem, for example, high-tech industries, Institutes of Science and Technology (ISTs), venture capital investors, and the government.

Based on the provision of high value-added services and quality infrastructure, the parks offer favorable location and technical and scientific support so that installed companies can interact with the ecosystem and expand their innovation and technological diffusion processes. The logic of a park's operation demands that it be managed based on private sector rules, as knowledge-intensive companies and industries expect to find agile management without any contingencies of public funding.

Private parks, such as Techno Park Campinas, an enterprise founded by brothers Miguel Gilberto Pascoal and Luis Norberto Pascoal in the late 1990s, have characteristics considered key to competitiveness, to the consolidation of dynamic ecosystems and to the fostering of innovation.

Techno Park Campinas is located in the city of Campinas, state of São Paulo, a region with a strong vocation to attract Technology-Based Companies (TBCs). With its exemplary level of infrastructure and services, it contributes to the development of the region based on its ability to convert knowledge into innovative products through the TBCs. Since its inception, it has attracted a significant number of TBCs as a result of its contemporary business strategy that is based on the conceptualization of sustainable development, prioritizing the quality of the work environment in harmony with nature, as a stimulating factor for creativity. Its total area covers 524,000 m² and through 2018 approximately US\$ 200 million had been invested. It is a modern enterprise and a promoter of the culture of innovation that offers a wide range of facilities and servi-

ces, thus allowing companies to prioritize and focus on those activities that are related to their core business.

Today 62 companies are installed in Techno Park Campinas, of which 47 are TBCs. With more than 5,000 employees, these companies operate in various industrial segments including; information and communication technology; bioeconomy; medical equipment; food and agroenergy; automation; mechanical-automotive; electricity, and logistics. Its primary manager, ASSO-CITECH (Techno Park Campinas Owners Association), operates on three fronts: administrative management, infrastructure operation, and science, technology and innovation. The CT&I Committee is comprised of a team of businessmen and academics with a strong presence in the Campinas innovation ecosystem, with technical advice from LINKAGES company.

Technology parks typically act in partnership with local ISTs and international entities to foster industrial innovation in strategic areas through the network of partners, as is the case of Techno Park with its participation in Agropolo Campinas-Brasil. Another very important aspect of the park's activities is to contribute to the formulation of public policies with a view to increasing the competitiveness of EBTs.

It is noteworthy that Techno Park's network generates positive effects for its TBCs, as it provides for the exchange of information between scientists and businessmen involved in the same field, enabling the creation of Research, Development and Innovation agreements (RD&I) on specific subjects.

The strength of a technology ecosystem is not only linked to the number of actors located in the area, but more importantly, to the links that bind them. It can be concluded, therefore, that technology parks play an important role in the creation of specific environments for the attraction of high technology companies, as well as being facilitating agents for the interaction of these industries with the innovative and entrepreneurial ecosystem located in their region. ■

Image provided by Embrapa Territorial



Part I

Bioeconomy

Image provided by Embrapa Territorial

I.1

Bioeconomy: opportunities and challenges

José Vitor Bomtempo – Bioeconomy Study Group (GEBio), School of Chemistry, Federal University of Rio de Janeiro (UFRJ)

Thiago Falda Leite – Brazilian Bio Innovation Association (ABBI)

Flávia Alves – Bioeconomy Study Group (GEBio), School of Chemistry, Federal University of Rio de Janeiro (UFRJ)

Fábio Oroski – Bioeconomy Study Group (GEBio), School of Chemistry, Federal University of Rio de Janeiro (UFRJ)

This chapter aims to identify the key dimensions of the bioeconomy construction process and to briefly discuss the challenges and opportunities for Brazil. To explore bioeconomy opportunities and challenges, it is important to understand its technological and innovation dynamics. In the following sections, we propose a 5-dimensional reading of this dynamics: feedstocks, technologies, products, business models and regulations. Each dimension is briefly discussed.

What is bioeconomy?

Many definitions can be found. The European Commission proposes a useful and operational definition: “The bioeconomy ... encompasses the **production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, biobased products and bioenergy**. Its sectors and industries have **strong innovation potential** due to their use of a wide range of sciences, enabling industrial technologies, with local and tacit knowledge” (European Commission, 2012). The Brazilian Bioinnovation Association (ABBI), presents a similar definition which puts technological innovations as central to the bioeconomy and adds two important features: to be circular and to generate social and environmental benefits (ABBI, 2019). In summary, bioeconomy means the use of **renewable resources** in an **innovative and sustainable way**.

Bioeconomy as a complex environment under structuration

Bioeconomy sectors are still emerging and have no defined industrial structure yet. Competition in bioeconomy sectors is based on innovation. The lack of an established competition pattern creates a window of opportunity for the country to exploit its comparative advantages. But, how to identify in these emerging sectors the nature of opportunities and challenges?

Previous works on bioeconomy and innovation (Bomtempo e Alves, 2014; Bomtempo, Alves e Oroski, 2017; IEL/Bomtempo, 2018) have identified four key dimensions which coevolve in this structuring process: feedstocks, technologies, products and business models. These dimensions are embedded in the macro environment that the existing transition literature identifies as the socio-technical landscape. Figure 1 illustrates the innovation dynamics which is central to bioeconomy evolution. In the following section, these four dimensions are discussed, with an added complementary discussion on regulatory aspects. Regulation is critical in the bioeconomy structuring process, being a key factor in the innovators’ strategies.

Feedstocks are a historical structuring factor in the energy and chemical industries. At the industry level, the bioeconomy requires that new supply chains and

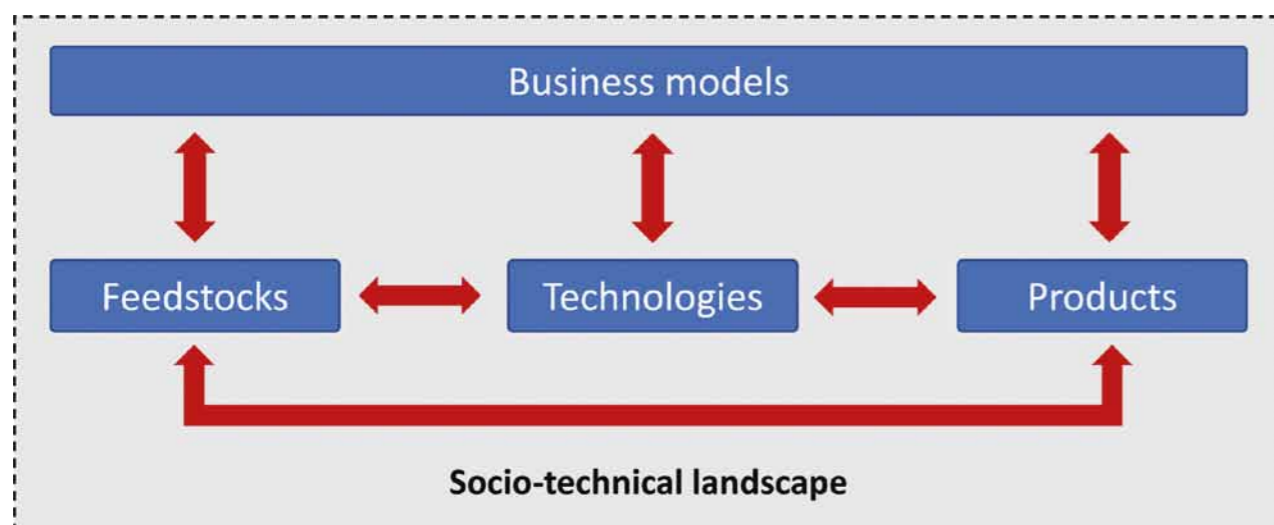


Figure 1. Structuring the bioeconomy: Feedstocks, technologies, products, business models and regulation

logistics must be developed in order to use biomass as feedstock. These developments are very complex and call for competencies that are lacking in many innovating firms entering the bioeconomy. In some cases, such as with agri-food and urban residues, biodiversity specialties and new energy crops, the supplying market is not yet organized.

In the Brazilian case, the supply chain is well developed for commodities (sugar cane, paper and pulp industry and agribusiness in general), giving it a key competitive advantage. However, for the residues and biodiversity specialties it is a challenge to be faced by innovators.

The feedstock availability is part of an innovation process that seeks to build the bioeconomy and goes through agronomic developments (plant genetics, productivity, suitability for use in industrial processes), agricultural technology (management, planting, harvesting), and the implementation of a sustainable supply chain (Niko et al. 2013; Meléndez, LeBel and Stuart, 2013)

In addition, the treatment of biomass to obtain the starting products - sugars, cellulose, lignin, glycerin, bio-oils etc. - to be processed by conversion technologies can be quite challenging. This is the case, for example, of obtaining sugars from lignocellulosic materials, which has been a significant obstacle in the development of the bioeconomy (IEL/Bomtempo, 2018).

Multiple opportunities exist in renewable raw materials, but structuring an offer articulated with the corresponding conversion technologies, products and business models is a construction that challenges the industry's innovative capacity. There are a multitude of technological alternatives under development for biomass conversion, including biochemical, thermochemical and chemical routes. Fermentation processes can

be conducted by microorganisms naturally selected, produced by classical breeding, genetically modified or developed using New Breeding Techniques (NBTs). Particularly relevant is the concept of synthetic biology that allow for the direct acquisition of new molecules of interest, consolidating, in a single step, routes that would otherwise require several reaction steps (Bomtempo e Alves, 2014; IEL/Bomtempo, 2018).

An additional challenge is related to biorefineries as a new plant concept (OECD, 2019). Considering the nature of the feedstocks and the types of treatment and conversion technologies, the conventional wisdom in plant concept concerning scale, scope, localization and integration is being challenged.

Coevolving with raw materials and technologies, the bioproduct field has become increasingly diversified. Innovative opportunities and initiatives are identified (IEA, 2017; Golden and Handfield, 2014; E4tech, nova-Institute, BTG and DECHEMA, 2019) in advanced bio-fuels, bioplastics, biochemicals and human and animal nutrition. Despite the high potential, the choice of which new biobased product to develop and launch is challenging. Innovating firms face at least three dilemmas. The bioproducts may be final or intermediate; commodity or specialty; and drop-in or non-drop-in. Each of these dilemmas constitutes a major challenge for innovators in bioeconomy (Oroski, Alves and Bomtempo, 2014).

As one would expect, business models are very diverse and innovative. Innovating firms try to explore their particular competencies and at the same time acquire the complementary ones needed in order to experiment business models capable of combining feedstocks, technologies and products in a viable solution (Teixeira, Bomtempo, and Oroski, 2019). And, even more, these business models must also meet regulatory requirements.

In this structuring area, it is possible to find a diverse set of companies of different sizes, backgrounds and knowledge bases, including: technology-based startups; companies from established industries such as the chemical and petrochemical industry; oil and gas producers; agribusiness; food industries; pulp and paper companies and even brand-owners. Regulatory framework conditions are a crucial factor in innovation activities. If the cost of regulation and compliance as well as of the bureaucracy involved is too high, it will certainly discourage investment and influence negatively the innovation process. On the other hand, it is necessary to ensure the safety of both process and products, as well as the rights and benefits of those involved in its development. In the bioeconomy context, the rapid development of molecular biology techniques, the dramatic decrease of biological sequencing costs and the incredible potential of biodiversity to provide specialty bioproducts make the regulation of biosafety and biodiversity crucial to its development.

Identifying the challenges

Considering the key dimensions discussed in the previous section – feedstocks, technologies, products, business models and regulation – innovating firms must face challenges in order to explore the bioeconomy opportunities. The competitiveness attributes (IEL/Bomtempo, 2018) described below can be taken as a basis for formulating policy and strategy in bioeconomy:

- Ability to capture the innovation dynamics of the sector and to guide investments and policies within a structuring environment.
- Establishment of advanced scientific, technological and operational knowledge in industrial biotechnology and, in particular, in synthetic biology.
- Recognition of intellectual property (IP) of genetic material and genetic engineering processes, fundamental in biomass conversions.
- Effective carbon pricing policy
- Capacity for structuring biomass supply.
- Ability to scale up and operate new processes, particularly those involving advanced biotechnology.
- Capabilities in product innovations, particularly in application and market development.
- Frequent updating and modernization of regulatory frameworks, guaranteeing sufficient regulation to ensure the necessary security and avoid unnecessary costs and bureaucracy.

Conclusions

Brazil's comparative advantages are significant, but they depend on technological and business efforts to become competitive and give the country a prominent position in the biobased industry of the future.

Competition in the bioeconomy is based on innovation, which includes not only process and product innovations but also the ability to shape new sectors of biobased industries. The lack of an established pattern of competition creates an opportunity for the country to exploit its comparative advantages. Although there are segments, such as synthetic biology, where a catch-up strategy is required, the use of renewable biological resources has important local specificity, which requires the creation of innovative path-creating solutions. Public policies and strategies must consider and address the unique challenges of building the bioeconomy, a new paradigm that will be central to the 21st century economy.

References

- ABBI. Associação Brasileira de Bioinovação, 2019. Available on: www.abbi.org.br
- Bomtempo, J. V.; Alves, F. Innovation dynamics in the biobased industry. *Chemical and Biological Technologies in Agriculture*, 1:19, 2014.
- Bomtempo, J. V.; Alves, F. C.; Oroski, F. A. Developing new platform chemicals: what is required for a new biobased molecule to become a platform chemical in the bioeconomy?. *Faraday Discussions*, 202, 213, 2017.
- E4tech, nova-Institute, BTG, DECHEMA. Road-to-Bio: Roadmap for the Chemical Industry in Europe towards a Bioeconomy, 2019. Available on: www.roadtobio.eu/uploads/publications/roadmap/RoadToBio_strategy_document.pdf
- European Commission. Innovation for sustainable growth: A bioeconomy for Europe, 2012. Available on: <https://op.europa.eu/en/publication-detail/-/publication/1f0d8515-8dc0-4435-ba53-9570e47dbd51>
- Golden, J.S., and R.B. Handfield. Why Biobased? Opportunities in the Emerging Bioeconomy. Washington, D.C.: U. S. Department of Agriculture, Office of Procurement and Property Management, 2014. Available on: www.biopreferred.gov/files/WhyBiobased.pdf
- IEA Technology Roadmap: Delivering Sustainable Bioenergy, 2017. Available on: www.ieabioenergy.com/wpcontent/uploads/2017/11/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
- IEL/Bomtempo J. V. Nota técnica: Química e Bioeconomia, projeto Indústria 2027. MEI/CNI, 2018. Available on: www.industria2027.com.br
- Meléndez, J., LeBel, L., Stuart, P. A Literature Review of Biomass Feedstocks for a Biorefinery, Chapter 15. In:


Stuart, P.; El-Halwagi. M. (ed.), *Integrated Biorefineries*, CRC Press, 2013.

Niko, D., Valente, M., Milanez, A., Tanaka, A., Rodrigues, A. A evolução das tecnologias agrícolas do setor sucroenergético: estagnação passageira ou crise estrutural?. *BNDES Setorial*, 37, 399 – 442, 2013.

OECD. *Innovation Ecosystems in The Bioeconomy*, in *OECD Science, Technology and Industry Policy Papers*, N. 76, 2019. Available on: www.oecd-ilibrary.org/science-and-technology/innovation-ecosystems-in-the-bioeconomy_e2e3d8a1-en

Oroski, F. A.; Alves, F. C.; Bomtempo, J. V. Bioplastics Tipping Point: drop-in or non-drop-in?. *Journal of Business Chemistry*, 2014. Available on: www.businesschemistry.org/article/?article=187

Teixeira, L.; Bomtempo, J. V.; Oroski, F.; Alves, F. Exploring business model dynamics in fast-changing environments: the case of the bioeconomy. Apresentação realizada em LA BIOÉCONOMIE - Organisation, Innovation, Soutenabilité et Territoire, Reims, França, 2019. ■



I.2

Innovation Ecosystem in Bioeconomy: Opportunities, Competitive Advantages and Challenges for the Metropolitan Region of Campinas

Maurício Serra – Professor at the Institute of Economics (IE), University of Campinas (UNICAMP)

Eduardo Gurgel – Director of Unicamp Science and Technology Park, University of Campinas (UNICAMP)
and current President of the Innovative Campinas Forum Foundation (FFCI)

Celso Barbosa – Deputy Director of Technology of the Center for Industries of the State of São Paulo (CIESP)
and former President of the National Association for Research and Development of Innovative Companies (ANPEI)

There is a broad consensus in literature that the economic success of a region is the result of a set of factors. The channeling of financial resources toward both innovation and infrastructure to support innovative activities in specific geographic or sectorial contexts is a necessary but not exclusive condition to ensure it. Successful regions depend, to a large extent, on a dynamic interaction between different actors who share knowledge and experience, thus encouraging co-operative activities. The regions can facilitate these interactions, as well as human creativity and the organization of economic activities. From this perception emerges the concept of the innovation ecosystem, which is intrinsically related to the creative, dynamic and interactive environment in which innovations are born and flourish. The term has clear connections not only with the notion of national and regional innovation systems (Wessner, 2007; Oh et al., 2016) - and it is no mere coincidence that the concept of innovation ecosystem is applied to both national (Frenkel et al., 2011; Frenkel & Maital, 2014) and regional (Lappalainen et al., 2015; Markkula & Kune, 2015a; EU/CoR, 2016) contexts -, but also with that of clusters (Estrin, 2009). An illustrative example of the

latter is provided by Porter (1998), who referred to Silicon Valley as being one of the best-known clusters in the world.

In view of the pressure of a growing world population and the serious problems generated by an economy dependent on fossil-based natural resources, the bioeconomy has been perceived by governments and experts as a real opportunity to achieve economic growth in harmony with the goals of sustainability. As the bioeconomy is essentially based on knowledge, any strategy that aims to boost or strengthen it should be mainly focused on research and innovation. However, if isolated, these ingredients are unable to promote the hoped-for socio-economic and environmental prosperity. Therefore, the provision of highly-skilled human capital, the interplay between higher education institutions and the productive sector, and a proactive role of governments are essential elements in this process and part of an innovation ecosystem. Within this context, Campinas emerges as a potential region to develop an innovation ecosystem in bioeconomy inasmuch as it brings together all the aforementioned elements and, at the same time, has a natural entrepreneurial vocation.

Image provided by Embrapa Territorial

This chapter analyzes the opportunities and challenges for setting up a regional innovation ecosystem in bioeconomy in Campinas. The chapter is organized as follows: section one briefly discusses the concept of an innovation ecosystem; section two highlights the importance of the bioeconomy not only in generating considerable positive externalities, but also in future-oriented regional development strategies. This section also argues that the state of São Paulo has a tremendous potential to host an innovation ecosystem in bioeconomy in which the locus par excellence is Campinas, which is the focus of attention of the next section. The fourth and last section summarizes the main findings and draws some conclusions.

Innovation Ecosystem: a brief overview

The concept of the innovation ecosystem is more comprehensive than other similar concepts insofar as it incorporates the main constituent elements of the relevant theoretical approaches and, at the same time, provides a solid analytical framework to better understand and explain the structural and dynamic factors responsible for an intense and continuous process of technological innovation. This means that innovation ecosystems are potential engines of regional social and economic development.

In general, an innovation ecosystem is characterized by encompassing a broad and diverse set of actors and, at the same time, complex and dynamic collaborative processes that together generate continuous and systemic innovations. According to Oksanen and Hautamäki (2014), some characteristics are common to all ecosystems, such as; the presence of renowned universities and research institutions; a satisfactory level of funding for new firms and research projects; an interactive arrangement of large established enterprises and new startups; the specialization of enterprises and cooperation between them; the existence of service companies specialized in the needs of local firms; a sufficiently large local market for new innovative products; a global network that is connected with other innovation centers; and a community of fate, i.e. a community in which regional actors perceive that their success is associated with the success of the entire region.

These elements become powerful transformation mechanisms when they work together because when isolated they are unable to replicate the dynamism and flexibility so characteristic of innovation ecosystems. In addition, other elements are also relevant to their success, highlighted by the talent or the quality of the individuals involved. As innovations are directly

related to collective actions and networks, their quality depends fundamentally on the quality or talent of individuals (Lawton Smith et al., 2005). In fact, stocking and training talent are also important factors for building regional advantages and, especially, for the region's own development.

If the institutional structure and the regional knowledge base are important for the generation of innovations, the creative, dynamic and cooperative environments, which are remarkable characteristics of innovation ecosystems, are key. Silicon Valley is the classic example and, probably, the most illustrative of a dynamic and creative innovation environment. This rich and vibrant environment cannot be dissociated at all from a strong entrepreneurial culture that stimulates creativity, supports the desire to experiment, and instigates willingness to take risks.

Although each innovation ecosystem has specific characteristics, which makes it impossible - even undesirable - to replicate them, successful examples such as Silicon Valley, which remains a relevant reference for other initiatives around the world, serve as an inexhaustible source of learning. The growth and success of Silicon Valley is due to the continuous rearrangement of a multiplicity of distinct and specialized actors who support and, above all, interact with each other (Bahrami & Evans, 2000). In fact, this "flexible recycling" process not only nourishes and renews the ecosystem, but also provides a necessary stability for the development of new and existing enterprises, which can become potential sources of innovation and employment and, at the same time, remain flexible enough to absorb the ongoing changes.

"Recycling" is also pointed out by Saxenian (2006) as an important feature of the Silicon Valley ecosystem because the continuous flow of people greatly favors the establishment of informal networks, which are excellent channels for the dissemination of information and ideas. In this line, Estrin (2009) stresses that the innovation ecosystem is composed of three communities - research, development and application - of people with multiple and distinct skills and abilities, from which innovation is a direct result of the interaction between these communities. The success of that ecosystem also lies in organizational innovations (Saxenian, 2006), which stimulate the formation of networks capable of rapidly mobilizing the resources needed to create enterprises due to business opportunities.

The combination of all these elements creates the atmosphere necessary for an effective interaction between the actors of the innovation ecosystem, who feel stimulated and encouraged to broaden the potential and economic impact of their research and in-

novation. In fact, the flexibility, dynamism, openness, quality and intensity of existing interactions between actors are good indicators not only of the health and efficiency of an innovation ecosystem, but mainly of a promising innovative performance and a substantial contribution to regional development. The European Union recommendation (EU/CoR, 2013) to exploit regional innovation ecosystems is due precisely to the potential and characteristics of ecosystems.

In addition, innovation ecosystems fit perfectly into the new European regional development strategy: smart specialization, which was drawn up for the 2014-2020 period and plays an extremely important role in investment in research and innovation in Europe, as it is a precondition for access to the European Regional Development Fund (McCann, 2015). This strategy is directed toward economic growth based on innovation, and focuses on the competitive potential and the essential characteristics of the regions, which means that regional diversity is strongly encouraged (McCann & Ortega-Argilés, 2011; Foray et al., 2012; McCann, 2015). Recognition of European regional diversity - both within and between countries - implies that there is no single model of innovation policy to be replicated in any region, and therefore a distinct regional innovation policy approach is essential (Tödtling & Trippel, 2005).

An illustrative example of the combination of smart specialization strategy and regional innovation ecosystems is provided by Markkula and Kune (2015a; 2015b), which shows the experience of the Helsinki region in designing and implementing its smart specialization based on its innovation ecosystem. These authors emphasize the need for a collaborative and joint-creation approach involving all the actors of society in formulating a regional policy that focuses its attention on the generation of new opportunities to increase economic growth, competition and quality of life. Joint learning is a fundamental part of collaboration in an innovation ecosystem and the direct involvement of all actors, according to both authors, is a prerequisite for the transformation of the regional potential into a better quality of life in which the flowering of the regions is intrinsically related to the development of attractive places to work and live. Universities have the mission of instilling knowledge in the region, where the creation of knowledge, its dissemination and its use are essential elements to make regions become or remain "intelligent".

São Paulo: a great potential for building the bioeconomy

The key point is that innovation ecosystems, in view of their transformation potential, have increasingly

attracted the attention of governments, which seek to stimulate through innovation policies the development of their regions and countries. Regarding Brazil, some of its regions have promising capabilities for the development of innovation ecosystems. In this respect, the state of São Paulo assumes special importance not only for its economic dynamism, but also for its strength in science, technology and innovation (ST&I). This condition is confirmed by some expressive and significant figures, which indicate that São Paulo accounted for 32.2% of the Brazilian GDP and 38.6% of the manufacturing industry (IBGE, 2016); holds 29.5% of all PhD programs in the country and 55% of those in the Southeast region (CGEE, 2016); and was responsible for 37% of the PhDs in the country and 61% of those in the Southeast region in 2014, a year in which it almost doubled the number of doctors in the South region, which is the second most developed Brazilian macro-region (CGEE, 2016).

It is worth highlighting that São Paulo also holds a prominent position with regard to research and development (R&D) expenditures, which corresponded to 1.61% of its GDP in 2011 (this index is called R&D expenditure intensity), a percentage higher than that of the Brazilian government, whose expenditure was 1.14% of GDP. It should be noted that in 2011 the intensity of R&D expenditure in São Paulo was also higher than in several European countries, such as Italy (1.25%), Spain (1.33%) and Portugal (1.49%), and close to countries like Canada and the United Kingdom (FAPESP, 2014). In addition, São Paulo presents a unique feature that distinguishes it from the other Brazilian states: in 2011, private companies contributed the largest share of R&D expenditures, while public spending predominates in the rest of the country. This particularity brings São Paulo closer to the industrialized economies (FAPESP, 2014).

Indeed, São Paulo is acknowledged to be the Brazilian state with the highest prominence in ST&I and its strength and vitality are reflected in important sectors of the economy linked to the bioeconomy. Indeed, bioeconomy is perceived as a crucial opportunity to achieve economic growth and development in consonance with environmental protection. As a direct result of a true revolution in innovations applied to the biological sciences, bioeconomy encompasses agriculture, forestry, fisheries, food and pulp and paper production, and also parts of the chemical, biotechnological and energy industries. It is important to stress that these sectors have a high innovation potential because of their use of a number of sciences (agronomy, ecology, food science, life sciences and social sciences), which enable industrial technologies (nanotechnology, information and communication technologies, engi-

neering, and biotechnology), and increase local and tacit knowledge (EC, 2012; 2014; 2017).

By producing approximately €2.3 trillion (approximately US\$ 2.55 trillion) of turnover and accounting for 8.2% of the European Union's workforce, the bioeconomy is considered a key element not only for the functioning of the European Union's economy, but mainly for its success, which is inextricably linked with job creation and competitiveness. In fact, in 2015 the bioeconomy generated €621 billion (approximately US\$ 686 billion) of value added in the European Union (which equals 4.2% of its GDP) and employed over 18 million people (roughly one in ten workers) in the region. With regard to the bio-based industries, one million new jobs are expected to be created by 2030 (EC, 2018). Biotechnology and other modern technologies will be of vital importance for this boom inasmuch as they provide new ways to improve and raise productivity, efficiency and robustness in other sectors.

Due to its remarkable potential to generate positive socioeconomic and environmental impacts, the bioeconomy will play a pivotal role in future-oriented policies. Within this context, most European countries have drawn up development strategies for exploiting the potential of the bioeconomy on their own (EC, 2017). This is in line with the conclusions drawn at the Bratislava Bioeconomy Conference, which highlighted not only that regions are of fundamental importance for the European bioeconomy, but also that countries as well as regions should be stimulated to devise their national and regional bioeconomy strategies in synergy with their smart specialisation strategies (BBEC, 2016). Despite the existing differences, the main point is that bioeconomy strategies have been developed and implemented by European countries and regions in order to pave the way for more innovative, resource efficient, and competitive societies that are capable of harmonizing economic growth with environmental preservation.

The European bioeconomy strategies are highly illustrative in many respects. In fact, they show the distinct characteristics of the bioeconomy in the European Union and also a growing enthusiasm for promoting it in the coming years. This feeling of excitement and interest is, to a large extent, a direct result of a great diversity of drivers that stimulate European countries and regions to invest in the bioeconomy. The key point, however, is that the main drivers are essentially based on endogenous factors (EC, 2017), which means that they are available in the regions, where their natural and biological resources and assets can be found and valued by means of innovative techniques and processes. Irrespective of the strength of the economic sector, it is worth stressing that a well-established

and dynamic entrepreneurial sector, renowned higher education institutions, governments (of all tiers) capable of acting and forging a vision of the future, and the willingness of all actors to cooperate between themselves are essential ingredients of a successful regional bioeconomy ecosystem.

Bioeconomy: real opportunities for Campinas

Looking back to the state of São Paulo, it becomes very clear that it meets all the necessary conditions to host an innovation ecosystem in bioeconomy. However, it should be underlined that its ST&I infrastructure and technological assets are not uniformly distributed throughout its territory (Suzigan et al., 2011). Within this context, Campinas gains even more relevance due to its high spatial concentration of knowledge-intensive economic activities. An emblematic example of its importance and dynamism is the biotechnology sector, which is at the heart of bioeconomy. In fact, about half of biotechnology companies in Brazil are concentrated in São Paulo, and most of them are located in Campinas (Cebrap & BRBiotec, 2011; Bianchi, 2013; Freire, 2014).

It is worth highlighting that Campinas has an innate entrepreneurial vocation. A growing body of literature (Etzkowitz & Klofsten, 2005; Etzkowitz, 2008; Lawton Smith, 2013; Feldman, 2014) points out that a crucial element in the construction of regional competitive advantages is entrepreneurship, whose ethos must be embedded in a region's firms, policy actors and research institutions. Indeed, this is a prerequisite for building consensus spaces (Etzkowitz, 2008) or entrepreneurial visions (Lawton Smith, 2013), which work, through a network of different actors, as a fruitful mechanism of collective action in promoting regional economic development. It is precisely in these spaces that a collective vision is forged and financial resources are allocated to common ends, which are materialized by means of coordinated activities.

However, it should be stressed that the connection between entrepreneurial activity and regional prosperity is neither automatic nor deterministic. According to Feldman (2014), what matters most is the character of the place, i.e. the spirit of authenticity, commitment and common purpose of the region. This character is essentially determined by the economic actors who are located in the region and can create institutions and make decisions. Successful regions depend, to a certain extent, on a dynamic interaction between several actors who share knowledge and experience, thus encouraging cooperative activities. Therefore, the regions facilitate these interactions, human creativity and the organization of economic activities (Feldman & Kloeger, 2010; Feldman, 2014).

In addition to bringing together an outstanding public university (Unicamp) and several private universities, incubators, science and technology (S&T) parks, research institutes, R&D laboratories, technology companies and technological services institutions, Campinas has an excellent logistics infrastructure, an entrepreneurial spirit, capital availability, a strategic geographical location, various firms operating in several specific sectors of the bioeconomy, and political actors who understand innovation and sustainability as levers of economic growth. In short, Campinas offers highly favorable conditions for setting up an innovation ecosystem in bioeconomy. This means that the opportunities for, and the competitive advantages of the region to enable an innovation ecosystem are concrete.

Despite this promising context, there are substantial challenges to be faced in order to turn all the existing potential into an effective reality. In this regard, the main difficulty lies in the fact that regional actors are scattered and operate according to their own logic and interests, which implies uncoordinated and isolated actions. In fact, interactions and co-operation between all actors are weak and uncertain, as they do not feel (or feel very little) stimulated to work together or even share knowledge. This feeble synergy reveals the lack not only of regional cohesion, but also of a collective vision for the region's future. There is an inextricable connection between this collective vision and a community of fate (as defined above) insofar as both individual and collective perceptions are convergent, i.e. the success of a company is intertwined with that of the entire region. It should also be noted that this collective vision is in line with the consensus space - is a neutral ground where distinct regional actors come together to generate as well as support new ideas in order to promote socioeconomic development - or entrepreneurial vision mentioned above. The main point, however, is that interaction, co-operation, cohesion and a collective vision are key factors for the growth and consolidation of an innovation ecosystem. Therefore, the ability not only to co-ordinate joint efforts, but also to forge a common vision among all regional actors is crucial.

There is a growing awareness in the region of the need to fill this gap. In this regard, two illustrative examples should be mentioned here: the creation of the Innovative Campinas Forum Foundation (FFCI) and the implementation of Agropolo Campinas-Brazil. The FFCI, which is made up of representatives from the productive sector, the government and research and higher education institutions, was set up to articulate all the necessary efforts in favor of sustainable regional socioeconomic development, a goal that will only be achieved through a common vision of the region's future as well as by joint actions. The Agropolo, which has the French model

(Agropolis International, Montpellier) as its inspiration, is an interinstitutional platform between universities (including Unicamp), centers and research institutes, and high-tech companies, whose main objective is to develop technical co-operation projects in the bioeconomy areas (agriculture, food, health, green chemistry, and bioenergy). With the strong support from the governments of Campinas and the state of São Paulo, and of the Technopark Owners Association of Campinas (Associtech) and the Agropolis International, this initiative aims at promoting a closer interplay between all regional actors, in which the expected outcome is the generation of and increase in income and the number of jobs in bioeconomy activities.

Concluding remarks

Due to its economic, social and environmental potential, the bioeconomy has attracted growing interest from different government tiers around the world and will certainly play a crucial role in future-oriented regional development strategies. As research and innovation are decisive drivers of the bioeconomy, the state of São Paulo stands out in the Brazilian landscape not only for its economic dynamism, but principally for its strength in ST&I. However, its infrastructure and technological assets are unevenly dispersed throughout the territory. Within this context, Campinas comes up as the primary region to develop an innovation ecosystem in bioeconomy because of its many attributes, ranging from the presence of a remarkable university (Unicamp), research institutions, important companies that operate in distinct areas of the bioeconomy, an excellent logistics infrastructure, and a natural entrepreneurial vocation. This implies that the opportunities for and the competitive advantages of the Campinas region to build a bioeconomy innovation ecosystem viable are considerable.

The Gordian knot of a bioeconomy innovation ecosystem in Campinas lies in poor interactions and co-operation between all regional actors. This clearly shows the lack of both regional cohesion and a collective vision for the region's future. It is always opportune and necessary to emphasize here that what matters most is the spirit of authenticity, commitment and common purpose of the region (Feldman, 2014). In this regard, the ability not only to forge a common vision among all regional actors, but also co-ordinate joint efforts is crucial to the current and future prosperity of the regional innovation ecosystem in bioeconomy. Despite this real challenge, promising initiatives, such as the creation of the FFCI and the implementation of Agropolo, have taken place in Campinas, suggesting that the existing obstacles are on course to being overcome.

References

- Bahrami, H.; Evans, S. Flexible Recycling and High-Technology Entrepreneurship. In: Kenney, M. (ed.), *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*, Stanford, CA: Stanford University Press, p.165-189, 2000.
- BBEC. BBEC Conclusions: The Role of Regions in European Bioeconomy. Bratislava Bioeconomy Conference, Slovakia, October, 2016. Available on: www.bioeconomybratislava2016.eu/conclusion.html
- Bianchi, C. A Indústria Brasileira de Biotecnologia: Montando o Quebra-Cabeça. *Revista Economia & Tecnologia*, 9 (2): 90-107, 2013.
- CEBRAP & BRBIOTEC. Brazil Biotech Map 2011. São Paulo: Cebrap, 2011.
- CGEE/MCTIC. Mestres e Doutores 2015: Estudos da demografia da Base Técnico-Científica Brasileira, Brasília-DF: CGEE/MCTIC, 2016.
- EC. *Innovating for Sustainable Growth: A Bioeconomy for Europe*. Brussel: European Union, 2012.
- EC. *Where Next for the European Bioeconomy?*. Brussel: European Union, 2014.
- EC. *Bioeconomy Development in EU Regions: Mapping of EU Member State/Regions' Research and Innovation Plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy*. Brussel: European Union, 2017.
- EC. *A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment*. Brussel: European Union, 2018.
- Estrin, J. *Closing the Innovation Gap: Reigniting the spark of Creativity in a Global Economy*. New York: McGraw Hill, 2009.
- Etzkowitz, H. *The Triple Helix: University-Industry-Government Innovation in Action*. Routledge: New York, 2008.
- Etzkowitz, H. & Klofsten, M. *The Innovating Region: Toward a Theory of Knowledge-based Regional Development*. *R&D Management*, 35 (3): 243-255, 2005.
- EU/CoR. *Opinion of the CoR on "Closing the Innovation Divide"*. Official Journal of the EU, v. 56, p.12–21, 2013.
- EU/CoR. *Regional Innovation Ecosystems: Learning from the EU's Cities and Regions*. Brussel: European Union, 2016.
- FAPESP. *Indicadores FAPESP de CT&I. Fundação de Amparo à Pesquisa do Estado de São Paulo, Boletim N. 4*, São Paulo: FAPESP, maio de 2014.
- FAPESP. *Indicadores FAPESP de CT&I. Fundação de Amparo à Pesquisa do Estado de São Paulo, Boletim N. 5*, São Paulo: FAPESP, dezembro de 2014.
- Feldman, M. *The Character of Innovative Places: Entrepreneurial Strategy, Economic Development, and Prosperity*. *Small Business Economics*, 43 (1): 9-20, 2014.
- Feldman, M.; Koegler, D. *Stylized Facts in the Geography of Innovation*. In: Hall, B.; Rosenberg, N. (ed.), *Handbook of the Economics of Innovation*, New York: North Holland, p. 381- 410, 2010.
- Foray, D. et al. *Guide to Research and Innovation Strategies for Smart Specialisation*. Brussels: European Commission, 2012.
- Freire, C. E. *Biotecnologia no Brasil: Uma Atividade Econômica baseada em Empresa, Academia e Estado*. Tese de Doutorado, Programa de Pós-Graduação em Sociologia, São Paulo: USP, 2014.
- Frenkel, A. et al. *Towards Mapping National Innovation Ecosystems: Israel's Innovation Ecosystem*. Technion City, Haifa: Samuel Neaman Institute, 2011.
- Frenkel, A.; Maital, S. *Mapping National Innovation Ecosystems: Foundations for Policy Consensus*. Cheltenham, UK: Edward Elgar, 2014.
- IBGE. *Contas Regionais do Brasil: 2010-2014*. Rio de Janeiro: IBGE - Instituto Brasileiro de Geografia e Estatística, 2016.
- Lappalainen, P. et al. *Orchestrating Regional Innovation Ecosystems*. Otavan Kirjapaino Oy: Aalto and Laurea Universities/Built Environment RYM Ltd, 2015.
- Lawton Smith, H. et al. *The Geography of Talent: Entrepreneurship and Local Economic Development in Oxfordshire*. *Entrepreneurship & Regional Development*, 17(6): 449-478, 2005.
- Lawton Smith, H. et al. *Entrepreneurial Regions: Evidence from Oxfordshire and Cambridgeshire*. *Social Science Information*, 52 (4): 653–673, 2013.
- Markkula, M.; Kune, H. *Making Smart Regions Smarter: Smart Specialisation and the Role of Universities in Regional Innovation Ecosystems*. *Technology Innovation Management Review*, 5(10): 7-15, 2015a.
- Markkula, M.; Kune, H. *Toward Smart Regions: Highlighting the Role of Universities*. In: Lappalainen, P. et al. (ed.), *Orchestrating Regional Innovation Ecosystems*. Otavan Kirjapaino Oy: Aalto University/Laurea University/Built Environment RYM Ltd., p. 51-66, 2015b.
- McCann, P.; Ortega-Argilés, R. *Smart Specialisation, Regional Growth and Applications to EU Cohesion Policy*. *Economic Geography Working Paper*, University of Groningen: Faculty of Spatial Sciences, 2011.
- McCann, P. *The Regional and Urban Policy of the European Union: Cohesion, Results-Oriented and Smart Specialisation*. Cheltham: Edward Elgar, 2015.
- Oh, D. et al. *Innovation Ecosystems: A Critical Examination*. *Technovation*, v. 54, p.1-6, 2016.
- Oksanen, K.; Hautamäki, A. *Transforming Regions into Innovation Ecosystems: A Model for Renewing Local Industrial Structures*. *The Innovation Journal: The Public Sector Innovation Journal*, 19 (2), article 5, 2014.
- Porter, M. *Clusters and the New Economics of Competition*. *Harvard Business Review*, 76 (6): 77-90, 1998.
- Saxenian, A. *The New Argonauts: Regional Advantage in a Global Economy*. Harvard, MA: Harvard University Press, 2006.
- Suzigan, W. et al. *Elementos para a Caracterização do Padrão de Interação Universidade-Empresa no Estado de São Paulo*. In: Suzigan, W. et al. (orgs.), *Em Busca da Inovação: Interação Universidade-Empresa no Brasil*, p.73-108, Belo Horizonte: Autêntica, 2011.
- Wessner, C. *Innovation Policies for the 21st Century: Report of a Symposium*. Washington: The National Academies Press, 2007. ■

I.3

Sustainable agriculture

Roberto Rodrigues – Coordinator of the Getulio Vargas Foundation Agribusiness Center (FGV) and FAO Special Ambassador for Cooperatives

At the beginning of the 21st century the United Nations (UN) launched a study showing that by 2050 world food production would grow by around 60% to ensure food security for all the world's inhabitants, which by then will total more than 1.6 billion. Since one of the UN's objectives is to defend and guarantee universal peace, the study made perfect sense, as there will be no peace while there is hunger. The tragic deaths that occur almost every week in the Mediterranean are the most recent and striking proof of this reality: people flee war and hunger in their countries of origin in Africa, Asia and wherever else there is such misfortune.

And that marks one of humanity's greatest challenges today: producing food permanently for everyone without destroying natural resources. In other words, produce sustainably. It is worth stressing that sustainability is not a fad word: it is a basic condition of competitiveness. Whoever wants to conquer markets will have to invest in the most modern and nature-saving technologies to produce products acceptable to consumers of all quarters. And there is no major difficulty in this: research institutions in all areas are deeply into plans and projects with this goal, notably in view of the announced climate changes, the increasingly frequent extreme events, and especially the global water use and shortages.

There are dozens of serious studies on this topic. One of the best has been done by the Organization for Economic Cooperation and Development (OECD) in conjunction with the Food and Agriculture Organization of the United Nations (FAO) in the early 21st century. This study was more recently adopted by the US Department of Agriculture (USDA), looking 10 years ahead, and is reviewed annually. The study shows that food supply will need to be increased by 20% over the 10 year period to meet global

demand. It sounds easy, but it is not: in the United States the increase will be 10%, in the European Union 12%, in Russia 7%, in China 15%, and so on. In order to increase supply by 20%, says the study, Brazil will have to expand its supply by 41%, double what will need to be grown worldwide. This is an unprecedented "outside-in" challenge that we cannot ignore: the international organizations has presented us with a formidable appeal that will lead us to becoming the world champion in food security and therefore help secure world peace.

Why have these studies concluded that we can increase our food production by 41% in 10 years? Based on three main reasons particular to Brazil: we have sustainable tropical technology in the countryside, we have sufficient land available to farm, and we have well-prepared people in every link of the supply chain. There are other relevant reasons, such as agro-stimulating public policies (and we have had some very important ones, including the increase of financing available at lower interest rates), and enterprising farmers, but these are also found in other countries.

The first reason is the quality of our sustainable tropical technology, generated, disseminated and applied by farmers. The numbers in this regard are enlightening. Using the so-called Collor Plan of March 1990 as a starting point, we find that the area planted with grain in Brazil grew from 38 Mha in 1990 to 62 Mha in 2018, an increase of 63%. But grain production jumped even more: from 58 million tons to 228 million, or an increase of 293%! These data are impressive in themselves, but behind them is something even more remarkable: if we had the same yield per hectare today as we had on the day of the Collor Plan announcement, we would have had to clear another 87 Mha to harvest the actual 2018 grain crop. In other words, this amount of forests and/or savannas has been spared,

Image provided by Embrapa Territorial

which indicates high sustainability. And it is not just a grain productivity gain. Sugarcane, now occupying 9 Mha across the country, would need to be 6 Mha larger to harvest the actual current crop.

And it is not just in agriculture. From the Collor Plan to the present day the production of chicken meat grew 462%, pork 255% and others 89%, while the pasture area decreased by 16%. And all very sustainably.

On the other hand, agroenergy has been a major factor in reducing greenhouse gas emissions. Sugarcane ethanol, for example, emits only 11% of the CO₂ equivalent emitted by gasoline. And we already have in the country a flex fleet of over 77% of all cars in circulation and another 30% of motorcycles. The cogeneration of electricity produced by the sugar and alcohol industries, in turn, occurs exactly during the sugarcane harvest that takes place in the dry winter of the midwest / southeast regions, so that it enters the electricity distribution networks complementary to the hydroelectric ones, whose reserves of water decrease in the period. It is not for any other reason that sugarcane energy already corresponds to 17% of that produced in the country, above the hydroelectric level and, at least for the time being, only below that of fossil origin. Also, there is already corn ethanol coming that will be incorporated with sugarcane ethanol to further improve the sustainability of the sector.

And further innovations in the field keep coming: the ABC Plan (Low Carbon Agriculture) has been gaining more adherents every year. Crop / livestock / forest integration, for example, already occupies more than 14 Mha, revolutionizing livestock technology and increasing meat productivity per hectare. So too are there ABC projects for “no-till” (no tillage), precision farming, biological nitrogen fixation to the soil, and recovery of degraded areas that are systematically growing. By the way, we already have about 10 Mha newly planted with forests, and we should reach 12 Mha by 2030.

All these facts will give the rural sector a prominent role in meeting the GHG emission reduction targets set by the Brazilian government at the COP 21 that was held in Paris in 2015, according to which we must reduce emissions by 43% by 2030, based on the amount issued in 2005.

The second condition is the availability of land. According to the Brazilian Agricultural Research Corporation (Embrapa), of the 850 Mha of our territory, only 9% are occupied with agricultural crops, including planted forests. Another 21.2% have pastures. Putting it all together (pastures and cultivated areas) we have only 30.2% of the Brazilian territory occupied with ALL our agro-silvo-pastoral activities. And 74.3% of the territory is still filled with protected, preserved and conserved vegetation. Improved livestock farming will produ-

ce more meat and milk in fewer pastures, and about 10 million ha of this could be turned into agriculture. This will make it possible for Brazil to offer the world 40% more exportable food in 10 to 12 years.

We certainly need people to do that, and there is a brilliant generation of young graduates from high schools and colleges of agrarian sciences throughout the country, now working in farms, cooperatives and rural associations, doing research, teaching and giving technical assistance, in both the public and private sectors, to the input and service companies and in the equipment and food industries. This mass of young people is committed to the future of the country and will play a central role in the generation and diffusion of technological innovations along agro production supply chains.

The economic data encourages us to believe that we will achieve this goal. Agribusiness represents about 21% of Brazil's GDP, and has grown each year more than the country's total GDP. It generates 20% of jobs and has been one of the job-preserving sectors by improving the average wage at the time of the highest unemployment in our recent history. And it has been responsible for Brazil's foreign trade surplus. In 2018, for example, agribusiness's share of our exports was 42.4%. But the sector's surplus was US \$ 87.6 billion, while the total trade balance was only US\$ 58.7 billion, as the other sectors were in deficit.

In fact, agribusiness exports jumped from US \$ 20.6 billion in 2000 to US \$ 101.7 billion in 2018, a growth of almost 5 times, in a period marked by the great economic crisis of 2008/2010 that was characterized by reduced trade. And that figure encompasses still another notable mark: in 2000 about 59% of our agro exports went to the United States and the European Union, while in 2018 this percentage dropped to 24.2%. (Of course, there has been an exponential increase in markets in emerging countries such as China and others in Asia that contributed to this shift in markets). This performance ranks us as the world's largest exporter of sugar, coffee, orange juice, soy, chicken, second in corn and beef, fourth in pork, and growing in cotton, fruits and organic food. Sectors such as milk and dairy products, fish, wheat, peanuts, sorghum and other grains are expanding their global presence, but there is still much growth available to them.

All of this, which we already have, is necessary to meet global food demand within the above timeframe, but it is not enough. To achieve the great goal of making our country the world champion of food security we will need a strategy that will demand the commitment of all Brazilians and not just the farmers. This makes sense: to evolve in the field, the producer depends on research done in scientific organizations and/or uni-

versities, which are urban entities; fertilizers and pesticides are produced in urban industries, as well as is machinery, equipment and vehicles; technical assistance, credit and insurance services are provided by banks or urban companies. Road, rail and port builders and the food industry are urban, as are packaging industries, supermarkets and trading companies. In short, every Brazilian citizen participates directly or indirectly in actions that take place in the countryside: when he does not contribute to production, he is responsible for consumption. We need to understand that the governments of developed countries stimulate and/or subsidize their rural producers in order to supply urban consumers, because they are much more numerous, and political and social stability depends on them. And urban consumers support rural income assurance policies by paying taxes because they feel reassured about their supply. The over-protectionist Common Agricultural Policy was a decision by European governments to pursue food self-sufficiency as a result of the famine experienced in World War II. Therefore, urban and rural dwellers are Siamese twins.

For the strategy to work, we will need, first and foremost, the structural reforms that organize the public accounts, such as social security, taxes and even political reforms. And then, of course, we will need: more investment in science and technology because this is the foundation of productivity; legal certainty that ensures the formation of public-private partnerships to invest in railways, highways, waterways and ports that eliminate infrastructure and logistics bottlenecks, inhibiting our competitiveness; a trade policy that brings bilateral agreements with large consumer countries, reducing tariff escalation and allowing value to be added (and this is not a trivial challenge given the current skirmishes between Western and Asian countries that may trigger a new protectionist escalation); an income policy that prioritizes rural insurance and credit modernization and bureaucracy, because private banks and fast-growing cooperative banks will have an interest in financing agro; a health defense that eliminates episodes like Weak Meat and guarantees the quality consumers around the world want; stimulating programs that end illegal deforestation, such as the Payment for Environmental Services provided for in the Forest Code and recently approved in our Chamber of Deputies; supporting cooperativism and associativism, which provide the essential scale for the survival and growth of the small producers; implementing plans such as RenovaBio that can be a major revolution in the renewable energy agro chapter; the training of specialized human resources; land regularization that allows the producer, based on social programs, the guarantees necessary to offer to the financial agents. And above all, attention to sustainability, a priority factor for the international competitiveness of

any product. And all this is feasible, but must be methodically explained to all of society, the ultimate beneficiary of the whole process.

And so they are all themes of a strategy that encompasses the state, not just the government. Recently a trade agreement between the European Union and Mercosur was announced (although not yet ratified by either side). Perhaps this is the most significant signal for setting up the necessary strategy. The “trade war” between the United States and China - the two largest economies in the world - that has as its core the pursuit of commercial hegemony, as well as electoral interests, has been producing neoprotectionism among the richest countries, which will eventually affect emerging countries who are unable to compete with their wealth. This announced agreement, if and when signed, will mitigate the protectionist wave and bring us back to the great trading game from which we were excluded since the “death” of the Free Trade Area of the Americas (FTAA) and our exclusion from the Trans Pacific Agreement (TPP). This, coupled with our lack of bilateral agreements with major consumer countries, has left us dangerously on the fringes of world markets. The deal opens a new opportunity: after all, the two blocs together represent 25% of Earth's population with a large share of global GDP. But its implementation will depend on its ability to show how sustainable our productive activity in agribusiness supply chains is. And we need to forcefully express our condemnation of illegal deforestation - not just in the Amazon, but across the country - as well as improve our non-compliance in battling recent wildfires across the country, as well as the criminal advances of gold mining and logging on indigenous lands and in legal reserves. In this regard, it will be necessary to introduce a broad campaign of internal and external dissemination of the real condition of our agricultural and agro-industrial technology regarding its sustainability, as well as with our intolerance of any illegalities committed throughout the national territory.

We are reaching an extraordinary one billion tons in the harvest of grains, sugar cane, fruits and vegetables, coffee, cotton and other fibers, meat, eggs, dairy, organic food and wood. This abundance already serves all Brazilians and more than one billion people around the world. And it can serve many more people, including the vast and growing vegetarian and vegan population on every continent. And our technological advances need to continue to take place to increase productivity, reduce production costs and product prices, making them more accessible to the poor and thus also contributing to lower inflation rates.

We are heading towards being the world champion of food security and hence universal peace, the greatest reward we can hope for for our children and grandchildren. ■

1.4

The food and beverage industry

João Dornellas – Executive President, Brazilian Association of Food Industries (ABIA)

Responsible for about 10 percent of total gross domestic product (GDP), the food and beverage industry is one of Brazil's leading development engines, with revenues of US\$ 179.5 billion and investments of US\$ 5.9 billion in mergers and acquisitions in 2018.

The largest Brazilian manufacturing industry processes 58% of everything produced in the field, brings together

more than 35,000 companies and generates more than 1.6 million direct jobs and a total of 7.9 million in the production chain. In the foreign market, it is notable for exporting food to over 180 countries. (ABIA, 2019)

To measure the importance of this international performance, it is worth noting that over 50% of the total positive Brazilian trade balance in 2018 came from the food industry. (ABIA, 2019)

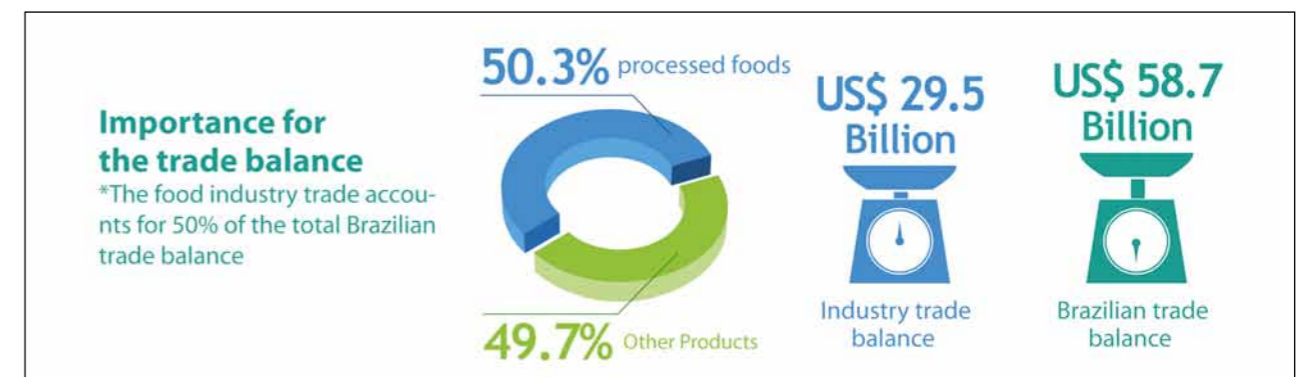


Image provided by Embrapa Territorial

2050: 9.7 billion people to feed

In the international context, a report from the UN (United Nations) points out that the world population will rise from the current 7.5 billion people to 9.7 billion by 2050. In terms of food, the current food supply is considered sufficient for the planet, but unequally distributed. The latest FAO (United Nations Food and Agriculture Organization) report states that more than 800 million people (roughly 11%) are undernourished in the world, while an estimated 30% of the population is obese.

Institutions such as the OECD (Organization for Economic Co-operation and Development), the FAO and the USDA (US Department of Agriculture) have been reiterating that in ten years food production in the world needs to grow by 20% to effectively feed the entire planet, and for that to happen, Brazil will have to increase its production by 40%.

To figure among the protagonists and become one of the main food supply centers on the planet will require from Brazil a performance more aligned with the best practices and experiences in the areas of technology and innovation.

It's a big challenge and we fully believe Brazil will live up to it. We are innovative, with sustainable practices, and the world's second largest exporter of industrialized foods. And this is all the result of hard work and a winning equation. We have water, land, sustainable tropical agricultural technology and skilled professionals in all links of the production chains, as well as excellent research and technology institutions. (ABIA, 2019)

In the field of innovation, agroindustry has made a huge advance in biotechnology, providing technology for farmers and allowing them to do more with less, that is, to increase production using the same physical space. In this regard, Brazil is an example to the world in terms of conserving green areas without impacting economic development.

The future is bright as long as sustainable practices are consolidated throughout the supply chain. The productive and administrative processes need constant updating and investments in automation and intelligence systems by private companies, representative associations, agribusiness and small and medium rural producers.

On the other hand, reduction of red tape, easy access to credit, encouraging entrepreneurship and productivity, and the implementation of tax and social security reforms are already beginning to be unleashed in order to promote the resumption of sustainable economic and social growth in our country.

The industry: innovation and responsibility

Imagine a world without industrialized food. Is it possible? Desirable? Coherent? The food and beverage industry plays a key and responsible role in food production and supply worldwide. It allows food to be available with quality, safety and affordability.

As obvious as it may seem, we need to keep reminding ourselves that virtually all the food we eat goes through some sort of processing that makes it fit for consumption, take better advantage of edible parts, make it suitable for culinary preparation, maintain freshness, produce ingredients and by-products from fresh food and allow for food to be transported long distances and be stored.

Many of these processes were created by mankind thousands or hundreds of years ago. Large-scale production began only from the seventeenth century and expanded the distribution of foods that had been part of our eating habits for centuries.

From pasteurized milk to astronaut food

In 1862, French scientist Louis Pasteur discovered a thermal process capable of killing pathogenic bacteria, those that cause disease. The technique is to heat the food to a certain temperature for a certain time and then cool it to a lower temperature. It was a revolution. The novelty – a technology that is evolving to this day – has helped fight off infections, reduced deaths, and improved the quality of life by allowing products such as milk to be sterilized and transported without spoiling.

The technique of freezing food has evolved and led to lyophilization (or freeze-drying), a dehydration process that consists of removing water from food by vacuum free-

zing. It is an important technology that has helped make space travel possible, such as Project Mercury, NASA's first manned space project, running from 1958 to 1963.

It is also important to remember the evolution of conservation techniques with the emergence of canned and dehydrated foods, which are essential for social programs around the world targeting malnutrition in poor countries, and the distribution of food in regions that have experienced natural tragedies such as earthquakes and hurricanes.

Over time, the industry has always faced obstacles: sometimes the biggest difficulty was getting food to the consumer. Other problems are to provide a rich and varied diet. Still others involve guaranteeing food safety conditions. Whatever new challenge presents itself, the food industry has always worked to resolve it.

Recent challenges and those yet to come

Through research and implementation of new technologies, the industry has been successfully developing for some time improved and differentiated foods, such as those fortified with vitamins and nutrients, fiber-enriched, and foods for special regimens, including light, diet, and gluten and lactose free.

Major innovations also allow for the production of foods with low levels of sodium, sugar and fats. The beverage industry has been expanding its portfolio for years with zero sugar options and no preservatives. With pasteurization and packaging techniques, for example, it has become possible to have 100% safe products without the use of conservatives. Packaging in different sizes was also launched to meet consumer preferences.

The industry has to reinvent itself to cope with new demands, which are challenging and considered essential by new generations. Consumers want foods that are unique, innovative, additive-free, personalized, and that are produced with respect for the environment, animals and the people who work in every link in the chain. And at the same time, they want this food to last and be available all year round at an affordable price. And all this with the speed common to current times: accelerated.

The dynamism that has become common in today's world brings transformations in R&D creations and projects, making room for partnerships with all sorts of food-related startups that are constantly appearing on the horizon. On the packaging side, the challenges are no less. Society calls for a world without plastic and favorably differentiates those who invest in modern, smart, biodegradable and customized packaging.

Concerns over the quality of industrialized foods and their nutritional composition are not recent, but they grow over time and spur debate and pressure for the food industry to increasingly invest in communication and transparency.

In recent years, Brazilian industry has innovated and implemented several actions aimed at the health and welfare of the population. Since 2007, ABIA has had a Technical Cooperation Agreement with the Ministry of Health to build a National Plan for Healthy Living, which includes improving the nutritional profile of industrialized foods.

In a joint effort by member companies, 310,000 tons of trans fats and more than 17,000 tons of sodium have been removed from 35 industrialized food categories. There is also the goal of removing 144,000 tons of sugars from food by 2022.

The commitment to transparency is fundamental. Proof of this is the new model of frontal nutrition labeling presented to Anvisa (Brazilian Health Regulatory Agency) by Rede Rotulagem, which brings together more than 20 associations and more than 2,000 companies in the food and beverage sector. The proposal is for a label on the front of the packaging that provides complete information on the nutritional composition of the food, in a clear, accessible manner without alarmism.

The intense debate over the new nutritional labeling of foods in Brazil brings to light the enormous dichotomy on the subject. This is not a Brazilian discussion: industrialized foods are viewed with disbelief by much of the public around the world, which reveals the size of the challenge to be overcome: bringing quality, reliable and scientifically-backed information to all.

The polarization of this subject and the lack of balance in debates as well regarding the overall food and nutrition sectors do not benefit anyone and only harm the consumer. The health of the population and the food industry have never been on opposite sides and it is superficial and simplistic to think that way.

There are thousands of scientists around the globe right now working on finding and implementing the best practices and technologies in food production. Working together - from the productive sector to academia and society - is the way that will surely bring the best results. And to properly feed 9.7 billion people, we will need just that: the best solutions.

Reference

ABIA. Associação Brasileira da Indústria de Alimentos – ABIA, 2019. Available on: www.abia.org.br ■

Highlights

 World's largest orange juice producer and exporter

 World's largest meat producer (second in exports)

 World's largest sugar producer and exporter

 World's second largest instant coffee exporter

 World's second largest soybean oil exporter

Source: USDA e INTracen (2018)

I.5

Modern Bioenergy

Isaias C. Macedo – University of Campinas (UNICAMP)

Modern bioenergy must increase its participation in the **total primary energy supply** (TPES) in the coming decades. Some challenges and opportunities are considered here, globally and in the Brazilian context.

The energy context today

Bioenergy is the energy content in products derived from biomass feedstocks and biogas. Renewable energy includes bioenergy and hydro, solar (PV and thermal), wind, geothermal and tidal energy. The total world TPES, including renewable and non-renewable energy sources, was 572 EJ in 2016, with 13.7% being renewable; bioenergy equaled 10% of the TPES (IEA 2018a).

Solid biomass has widespread use in residential heating and cooking; this is called *Traditional Bioenergy*, while the remaining bioenergy (combustion in modern boilers and thermal or biological processes to create gases or liquid biofuels) is called *Modern Bioenergy*.

From 1990 to 2016 the global annual increase rate in TPES was 1.7%; renewable energy grew at 2%. Bioenergy annual growth was 12.3% for biogases, 10.0% for liquid biofuels, and 1.1% for solid biofuels.

Future decades and the climate change problems

Energy production and changes needed in the participation of energy sources for the coming decades have been extensively analyzed and include the following important considerations:

— *Population and economic growth and the demand for food and energy:* world population is expected to grow from 7.5 billion (today) to 9 billion people

by 2050, reaching approximately 10 billion by 2100. Food and energy demands (maintaining *current production / utilization efficiencies*) should increase more than the population growth, considering the increase in world wealth, but both food and energy production and usage today include very large losses. About 30%–50% of all food produced (~ 4 billion t/year) is lost before consumption, from harvesting until reaching the consumer (IME). The Efficient World Scenario (IEA 2018b), based on available energy savings alone plus cost-effective technologies, show that the global GDP could double between 2017 – 2040 with a marginal increase in TPES.

— *The restriction needed in fossil fuels utilization:* the continued emissions of GHG (at current rates) may lead to an increase in the temperature of land / sea surfaces much beyond 2°C (taken as the “limit” to avoid significant adverse impacts on the climate) (IPCC 2014a). Fossil fuels are the main source of GHG anthropogenic emissions (65%; 32 Gt CO₂/year), while generating 87% of all energy in 2010 (IPCC 2014b). GHG emission scenarios (including some gains in energy efficiencies) have been used to estimate the global warming in 2100. The scenarios likely to keep temperature increases below 2°C (IPCC 2014a) must have reductions of total annual emissions of 40% – 70% of the 2010 value, and of zero by 2100. This corresponds to a severe restriction on fossil fuel use.

— *Bioenergy for GHG emissions mitigation:* renewables may mitigate GHG emission when substituting fossil fuels. Some modern bioenergy pathways utilized commercially present high levels of emission mitigation: ethanol from sugar cane (75%) and from corn (43%), both substituting gasoline (IPCC 2014a); and rapeseed biodiesel (33-58%) and soy biodiesel (32 -38%), substituting diesel (Edwards, 2013). In electricity gene-

Image provided by Embrapa Territorial

ration, the substitution in large plants of solid biomass (wood waste and forest residues) in the place of coal, oil or natural gas eliminates 93%, 90% and 83% of the GHG emission respectively (SCOPE 2015a). These figures exclude Land Use Change (LUC) GHG emissions; the direct LUC related emissions are site specific. The changes in carbon stocks (soil organic carbon (SOC) and biomass vegetation) from the original culture to the bioenergy crop may result in positive or negative emissions. Methodologies, data and default values to estimate direct LUC emissions are presented in IPCC (2006). In general, perennial cultures lead to a higher SOC than annual cultures; low intensity tillage and high use of inputs (fertilizers, organic residues) also increase SOC.

Indirect LUC (iLUC) emissions (SCOPE 2015a) were proposed to account for the direct LUC emissions when the crop displaced by the biofuel crop moves to another area. First estimates of iLUC (2008) used unrealistic assumptions and models (SCOPE 2015a). Better data and models led to large reductions in the estimated iLUC emissions (up to ~90% for ethanol from corn or sugarcane). Legislation for sustainable land use (including for food production) is probably the best way to reduce (or even eliminate) iLUC emissions.

Most of the low carbon energy scenarios project strong growth in bioenergy utilization. The SRREN review (IPCC 2011) has bioenergy levels in 2050 reaching from 75 to 150 EJ/year (for ~440–600 ppm CO₂eq concentration targets) and from 115 to 190 EJ/year (<440 ppm CO₂eq target).

Pathways to bioenergy production are in different stages of development, using many biomass sources (from dedicated crops or residues), and processes for either burning or thermal conversion (pyrolysis, gasification, F-T processes), as well as biochemical conversion (hydrolysis and fermentation to biofuels) or anaerobic conversion of residues. Specific products (aviation fuels, for example) are under investigation. The largest efforts have been made towards the efficient and cost effective biochemical conversion of lignocellulosic material to biofuels to make biofuels production possible almost anywhere.

— *Land availability for food and bioenergy production*: worldwide, there are up to 1400 Mha of suitable land available for sustainable rain-fed agriculture (SCOPE 2015b), and a further 1500 Mha of marginal “spare and usable” land. About 960 Mha are in Latin America and sub-Saharan Africa (FAO 2014), mostly used for low intensity grazing. Additional land demand for food production in 2050, even considering low yields for food crops, is estimated at 130-219 Mha. A comprehensive review (SCOPE 2015b) indi-

cates that to produce 135 EJ of modern bioenergy in 2050, plus 65 EJ of traditional bioenergy, 200 Mha would be needed. In 2050 surplus land suitable for rain fed agriculture would be 905 Mha; ‘moderately’ suitable land adds another 1000 Mha. In addition, synergies between food and bioenergy production are significant (SCOPE 2015b)

— Sustainable intensification (pasture and crops) is a very important factor in increasing land availability. Pasture and meadow areas (3.4 Gha) are much larger than the food crop area (1.5 Gha) worldwide (FAO); and 40% of the pasture area does not have cattle grazing on it (Sheehan, 2014). Pastureland intensification could liberate 950 Mha more (IRENA, 2018). In Brazil, the implementation of sustainable intensification systems (various ILPF, crop/pasture/ forest integrated systems already 11.5 Mha in 2016), tillage reduction and direct planting (86% in soy, corn and beans, 2014), and multiple crops / year is likely to increase in the next decades (Embrapa, 2018).

In conclusion, the land available is enough to support an important contribution to global sustainable energy needs. The problem is, rather than having a global competition for land, to decide where and how each bioenergy pathway can be sustainably incorporated. From 2010-2017, the number of countries supporting renewable electricity doubled to 120, and those introducing biofuel mandates almost tripled to 90. *Bioenergy, although essential to helping solve the problem of global warming, may not be a suitable resource for every country, or uniformly used within a country.*

Bioenergy in Brazil: opportunities and challenges

Brazil employs the highest share of renewables among the world’s largest energy consumers: 42% of TPES, with 28% from bioenergy. In 2018, bioethanol consumption was 33.1 Mm³, biodiesel was 4.5 Mm³, and electricity from cane residues totaled 52.5 TWh (8.3% of Brazilian demand). Brazil has acquired great experience in the last 40 years, with bioenergy products (mainly ethanol, electricity and biodiesel) being utilized on a large scale. Relative advantages for bioenergy deployment in Brazil in the coming decades are:

The great availability of suitable land for production of both food and bioenergy; out of 851 Mha, Brazil has 66% with natural vegetation, only 9% used for agriculture and 21% with pastures (with an estimated 40% having some degradation). Intensification and recovery of degraded areas in due time may reach an additional 19 Mha in 2030, out of a much larger potential

area (Embrapa, 2018). Agroecological Zoning surveys indicate an additional 65 Mha of land for sugar cane (ZAE Cana, 2010), and 35 Mha for palm.

The expanding internal market; bioenergy will definitely expand in the internal market; the increase in external markets will depend on the implementation of measures to reduce fossil fuel use worldwide.

The experience in biomass production (sugar cane, soy, wood), including different types of selection, cultivation, harvesting and agricultural equipment for very large units (sugar cane, up to 150 000.ha / unit); transportation and conversion (sugar cane; 367 units to ethanol, 209 units that also sell surplus electricity); and the final use (from blending ethanol with/ gasoline to 100% ethanol). In all these steps significant increases in efficiencies were obtained (Walter, 2014).

The RD&I system, based on private sector technology centers and equipment manufacturers, the automotive industry, academic institutions (universities and research institutes) and government funded research institutions, as well as on joint programs with foreign groups.

The main challenges are related to the development of governance, with adequate legislation to *fully include bioenergy in national energy policies*, considering externalities (energy security, social impacts, environmental benefits) and support for eventual volatilities. Modern bioenergy in Brazil started with the implementation of the Proálcool program in 1975 and the biodiesel program (PNPB) from 2005 - 2010 with appropriate mandates and support prices. Exporting electricity from sugar mills to the grid was established after 2000.

The Brazilian programs are relatively extensive, with impacts on many sectors. The main stakeholders include the private sector (producers), automotive industries, equipment manufacturers and government agencies (environment, economy, energy, labor). The drivers which have changed and overlapped since 1970 include reducing oil imports (1975), increasing jobs in rural areas and reducing air pollution in urban areas (1980), and reducing GHG emissions (after 1990). Legislation (environmental protection, social issues) was gradually implemented, as well as adjustments in mandates. It has not been a smooth road, with internal changes in drivers and unstable world energy prices; better governance is still much needed. The recent RenovaBio legislation (Law 13.576/2017) helps in this direction, through the establishment of GHG emission targets for the fuel distribution system, and of de-carbonization credits (renovabio.org.br).

Bioenergy in Brazil: needed research and technological development

This subject has been extensively treated by many relevant groups, including the private sector, equipment producers, universities and government R&D institutions. Some topics are listed here; they include needs for continuous improvements, as well as for basic research and new processes:

- Sustainable intensification of crops and pastures, and recovery of degraded land for biomass production.
- Conventional breeding, genetic engineering and synthetic biology for new varieties.
- Precision agriculture and digital transformation in biomass production.
- Biological control of pests and diseases.
- Nutrient recycling, soil/plant/microorganism interaction, and better soil N₂O emission data.
- Impact and risks of climate change for biomass production in Brazil.
- Processes for lignocellulosic material conversion to ethanol; and for BTL, Pyrolysis and HVO.
- Processes for aviation biofuels and renewable diesel.
- End use of biofuels in the transport sector: high efficiency engines, fuel cells and hybrids.

References

- EDWARDS, R.; et al. Well-to-tank report v 4.0, JEC Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context, Italy, 2013
- EMBRAPA. Visão 2030: o futuro da agricultura brasileira. Embrapa e Ministério da Agricultura, Pecuária e Abastecimento, Brasília, 2018.
- FAO. Land Resources domain data. Food and Agriculture Organization of the United Nations - FAO, 2014. Available on: <http://faostat3.fao.org/faostat-gateway/go/to/download/R/ RL/E>
- IEA. Renewables Information 2018: Analysis and Forecasts to 2023. OECD/IEA, 2018a
- IEA. Energy Efficiency 2018: Analysis and Outlook to 2040. OECD/IEA, 2018b
- IME. Global Food: Waste Not, Want Not. Institution of Mechanical Engineers, London, 2013. Available on: www.imeche.org/environment
- IPCC. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 4 -Agriculture, Forestry and Other Land Use. The National Greenhouse Gas Inventories Programme - IPCC, Japan, 2006.

- IPCC. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN). The National Greenhouse Gas Inventories Programme – IPCC: Cambridge University Press, Cambridge, UK / New York, 2011.
- IPCC. Climate Change 2014: Mitigation of Climate Change. Contribution of WG3 to the AR5. The National Greenhouse Gas Inventories Programme – IPCC: Cambridge University Press, Cambridge, UK/New York, 2014a.
- IPCC. Climate Change 2014: Impacts and Vulnerability. Contribution of WG2 to the AR5. The National Greenhouse Gas Inventories Programme – IPCC: Cambridge University Press, Cambridge, U K/New York, 2014b
- IRENA. Sustainable pastureland intensification: Making room for energy crops without harming biodiversity. IRENA, Abu Dhabi, 2018. Available on: www.irena.org/publications.
- SCOPE. Ch 17: Greenhouse Gas Emissions from Bioenergy. In: SCOPE 72. Bioenergy and Sustainability: Bridging the Gaps, São Paulo, 2015a.
- SCOPE. Ch 9: Land and Bioenergy. In: SCOPE 72. Bioenergy and Sustainability: Bridging the Gaps, São Paulo, 2015b.
- SCOPE. Ch 4: Land and Food Security. In: SCOPE 72. Bioenergy and Sustainability: Bridging the Gaps, São Paulo, 2015c.
- SHEEHAN, J. et al. Evaluation of the global pasture performance gap using climate binning. Livestock, Climate Change & Food Security, Madrid, May 19 - 20, 2014.
- WALTER, A. et al. Brazilian sugarcane ethanol: developments so far and challenges for the future. Wires Energy Environ, 3:70–92, 2014.
- ZAE CANA. Zoneamento Agroecológico da Cana de Açúcar. MAPA, Embrapa, 2010. ■

I.6

Biochemicals: challenges & opportunities

João Bruno Valentim Bastos, Mariana Doria, Paulo Coutinho, Victoria Santos
– SENAI Innovation Institute for Biosynthetic (SENAI CETIQT)

The perception of the unsustainable use of the Earth's natural resources and its consequences for future generations started toward the second half of the 20th century. Governments, academia and companies have been restlessly seeking solutions to reduce the impact of human society on the planet. Regulations, research agendas, and business strategies for sustainability have been constantly revisited and renewed.

The chemical industry began to respond to these ambitions in the 1980s by creating the Responsible Care Program, an environmental management program started in Canada that quickly spread to over 60 countries. In Brazil it was adopted in 1992 by the national chemical industry association (ABIQUIM).

In this regard, a set of twelve principles intended to guide the practice of a sustainable chemistry industry was published in 1998 by Paul Anastas and John Warner. These principles steer the development of chemical products and processes in a way that the use and generation of harmful substances are either eliminated or reduced and chemical processes and products are designed to intrinsically guarantee the safety and the responsible use of natural resources.

With the emergence of the bioeconomy in the first decade of the 21st century, the chemical industry is currently being challenged to cope with Green Chemistry principles and to re-set its raw materials base (White House, 2012). The transition towards a bio-based economy has still a long way to go and several challenges to overcome. In that sense, this work takes the perspective of the chemical sector to offer a brief outlook on biobased chemicals. It is subdivided in four sections. First, it discusses bioeconomy

within the scope of the chemical industry. Second, it describes enabling technologies to ensure competitiveness of renewable chemicals. Third, it presents renewable products and processes currently under development and discusses aspects that can lead to their consolidation in the market. Finally, some conclusions are outlined.

The chemical industry & bioeconomy

Raw material is a key issue for the development of the chemical industry. Its costs, reflected by its availability and ease of transportation are crucial for the industry's survival, and that is why petroleum is still a vital component in it. The speed of the transition from fossil-based to renewable raw materials depends then on the competitiveness of biomass in comparison with petroleum. Considering a price forecast below US\$ 100 per barrel of petroleum (World Bank, 2018), this shift may take longer than expected.

The use of biotechnology and other new techniques in agriculture can offset this perspective by greatly reducing the cost of biomass. In parallel, the current availability of waste material is a potential material that is still to be explored. Therefore, the industry should focus on the development of new technologies.

New technologies have emerged in the last few decades: process intensification, biotechnology, nanotechnology, and other information and communication technologies. These are key enabling technologies with the potential to leverage the penetration of biobased chemicals into the market.

Image provided by Embrapa Territorial

Key enabling technologies

PROCESS INTENSIFICATION

The best definition of process intensification (PI) in the chemical industry would be “the development of innovative devices and techniques that offer drastic improvements in the manufacture and processing of chemicals, substantially reducing equipment volume, energy consumption, or waste formation, leading to cheaper, safer and more sustainable technologies” (Stankiewicz et al, 2000). Therefore, PI stands for the miniaturization of equipment or the consolidation in a single equipment of two or more unit operations. It is comprised of, for example, the use of high performance micro- or milli-flow reactors, reactive distillation systems, and fermentation and reaction systems with membranes, among others.

The use of PI reduces dimensions and investments, leading to a reduction in the importance of the scale factor. This may make biobased chemical processes more competitive.

BIOTECHNOLOGY & SYNTHETIC BIOLOGY

Biotechnology has long been responsible for supplying products to humanity. Its first uses were in the production of beer, cheese and bread via natural fermentation. The production of penicillin via large-scale fermentation during the World War II is a milestone for industrial biotechnology in modern society. It was followed by the production of synthetic human insulin in 1978, commercialized by Genentech in 1982 (Johnson, 1983).

Today, biotechnology has been rebuilt as a result of the exponential advances of technologies and the emergence of sophisticated bioengineering tools, impacting on the sustainable production of chemicals in many sectors.

Obtaining chemical compounds and materials from renewable carbon sources, such as lignocellulosic biomass, has been made possible through the development of genetically modified microorganisms using tools that make up the newly developed metabolic engineering systems (Nielsen et al., 2014).

The advent of new tools for the construction and optimization of metabolic pathways, the emergence of extremely sophisticated equipment, and the expansion of bioinformatics have allowed a strong acceleration in the research cycle in this area, leading to increased process efficiency, yield and productivity of routes. This set of new tools has been fundamental in the

growing competitiveness of biotechnological routes in the face of traditional petrochemical ones.

Synthetic biology can also be considered as a process intensification tool, given that microorganisms can be designed to produce in a single fermentation stage products that are conventionally produced from several reactional steps. Butanediol and adipic acid are representative examples. Their conventional petrochemical processes require at least three reaction and purification steps, while companies like GENOMATICA (www.genomatica.com) and VERDEZYNES introduced their production in only one stage of fermentation from genetically modified microorganisms.

NANOTECHNOLOGY

Nanotechnology emerged in the last decades of the 20th century and still has challenges to be fully employed by the industry.

Because of their scale, nanomaterials may have new chemical and physical properties such as strength, electrical properties, thermal conductivity and ability to change properties with the addition of functional groups. This means they have the potential to be used in a wide range of applications, including composites, sensors and electronics being rapidly exploited in medicine, biotechnology, electronics, and material science. These promising developments also involve the agricultural and energy sectors, among others.

Today nanotechnology is used by the chemical industry in the production of novel materials, and has been responsible for enabling lighter and better performing materials. For instance, in the agricultural sector it may reduce the amount of sprayed chemical products by smart delivery of active ingredients, minimize nutrient losses in fertilization and increase yields through optimized water and nutrient management.

Besides biotechnology and synthetic biology, nanotechnology has also a key role in the competitiveness of renewable raw materials, given the unpredictable properties of materials in the atomic, molecular and macromolecular scales.

AUTOMATION & DIGITALIZATION

Since the 1980s, the chemical industry has undergone a growing process of automation of its factories. This point gained strength and derivations from developments in hardware and software in the areas of information technology and computing.

From the 2000s onwards, there was an increase in the capacity and speed of process sensors, the implementation of data acquisition systems, the growth of analy-

sis tools and the use of neural networks. Most recently this has been consolidated as the fourth industrial revolution, Industry 4.0, an expression that encompasses technologies for automation and data exchange and uses concepts from cyber-physical systems, the internet of things and cloud computing. These new techniques, in agreement with the concept of technological convergence (fusion of different sciences), impacts and is impacted by the technologies mentioned above.

According to the Industry 4.0 concept, intelligent production systems that tend to emerge in the coming years will have the following characteristics: real-time operating capability (virtually instantaneous data acquisition and processing with real-time decision making); virtualization (virtual copy of the intelligent factories, which allows remote traceability and monitoring of all processes through the numerous sensors spread throughout the plant); decentralization (decision making made by the cyber-physical systems according to the needs of real time production); service orientation (service-oriented software architectures coupled with the Internet of Services concept); and modularity (Production according to demand).

The impact of Industry 4.0 extends to the entire chemical chain and its processes. Research and development are optimized from the automation of operations, the use of new sensors, the acquisition and analysis of data, and intelligent and predictive systems. In the end, costs and risks in the activity are reduced.

Predictive maintenance becomes dominant, 3D printing reduces the need for spares, customer monitoring reduces the need for working capital (right delivery at the right time). The entire supply chain becomes digital causing new business models to emerge. Companies at the beginning of the chain control operations in companies at different stages of the chain, optimizing processes and capital cost, and hence reduce costs that can be transferred to prices for the final consumer.

Technological convergence makes this revolution different from previous ones. The combination between gene sequencing and nanotechnology associated with evolution from conventional to quantum computing leads to gains that cannot be computed yet.

The advances of artificial intelligence from 2030 on will lead to the so-called technological singularity (Vinge, 1993). For the chemical industry, this means the development of software capable of assertively designed molecules for certain applications as well as catalysts for specific reactions.

Chemical products

Since the early 2000s the chemical industry has seen an increase in the effort to produce chemicals from biobased sources. However, progress was hampered by the fall in petroleum prices beginning in 2013. In terms of market value, biobased chemicals represent less than 15% all chemicals produced in the world. In volume, this number falls below 5% (OECD, 2009). However, there are some controversies about this data. This section presents several examples of these efforts.

Many of these products are specialty or fine chemicals. The complexity of the molecules in these sectors and their scale of production make the biobased products unique or more competitive because of the difficulty and costs of using molecules composed only of carbon and hydrogen (from fossil raw materials) as a basis. These chemicals are marketed based on performance rather than cost.

The fossil to biobased transition requires then a significant increase in volume, assuming that there are biobased products capable of competing in cost, or that bring some attractive cost-benefit relationship to the market. This presumes the full use of biomass, given that high yields require keeping atoms, other than H and C, in the product chain.

Cost design involves three distinct parameters: raw material yield, productivity and production scale. Productivity and production scale are intrinsically linked to the investment per ton and account for the fixed cost added to the product. The scale is also impacted by availability and logistics. For instance, one can at first affirm that there would be no distance limits for the transportation of petroleum. However, this is not the case with biomass transportation. The Brazilian case shows the unfeasibility of transportation beyond 40 km for sugarcane and 200 km for wood. This limits the capacities of the sugarcane and pulp mills and the production scales of a biorefinery based on these raw materials.

A good example for the yield-productivity-scale paradigm is the production of biobutanol. The production of this alcohol by fermentation of sugar, the ABE process (coproduction of acetone, butanol and ethanol), has been known since the 19th century and for a long time was the process used commercially to produce butanol. This changed in the second half of the last century with the advent of butanol production via petrochemicals.

In the early 2000s, with the relationship between the price of a barrel of petroleum and high sugar prices, several startups saw the opportunity to produce butanol from sugar from different sources (COBALT, GREEN BIOLOGICS, GS CALTEX, among others). They all loo-

ked to modify microorganisms in order to increase the yield of butanol and at the same time use PI to increase the productivity.

The theoretical maximum yield in the fermentation was 0.40 kg butanol/ kg of sugar and the yields in the conventional process would be around 0.5 g/ L/ h. Far below ethanol productivity, for example, which is of the order of 8 g/ L/ h. No information is available on the values that these companies reached, but it can be inferred that their final yields were below 0.35 and that productivity (even with stripping techniques or use of membranes to remove butanol) did not exceed 2 g/ L/ h. Thus, an ethanol plant, when converted to butanol, would produce only about 25% of the original production capacity.

With the fall in petroleum prices, there was a reduction of the butanol market price from US\$ 1,600 per ton to less than US\$ 1,000 per ton. Therefore, it can be said that the bio product would not be competitive in the market.

Of these companies, COBALT left the market and sold all the intellectual property generated to SOLVAY. GREEN BIOLOGICS converted an ethanol plant in the US to its process and it still operates today. Given governmental incentives received for biobased products, they may have some profitability.

Developments in the area are still ongoing. New studies in the field of synthetic biology show metabolic pathways with the potential to raise the theoretical yield to numbers above 0.7 kg of butanol per kg of sugar, and new separation lines by membranes could exceed 2 g/ L/ h of productivity. This could lead to a competitive product in comparison to fossil-based butanol.

Since 2005, DUPONT TATE & LILE BIOPRODUCTS has produced 1.3 propanediol (1.3 PDO) in the US via direct fermentation of corn sugar. Its production capacity is about 60,000t per year. The product is used to produce polytetramethylene terephthalate (PTT/ SORONA), polyethers (CERENOL), elastomeric polyesters (HYTREL), and personal care products (emollients, humectants, and carriers for active ingredients, among others).

The French company Metabolic Explorer plans to build a 1.3 PDO plant in Malaysia using direct fermentation of glycerin. In 2009, SHELL CHEMICAL's latest 1.3 PDO plant using fossil sources (hydroformylation of ethylene oxide) was closed.

ADM (US), GLOBAL BIO-CHEM (China), and OLEON (Belgium, with production sites in Malaysia and Europe) have facilities to produce about 220.000t per year (8% of total installed capacity) of propylene glycol (1.2 PDO). ADM and OLEON produce 1.2 PDO from glycerol. This

product is used to produce polyester resins, antifreeze, food, personal care products and pharmaceuticals.

In February 2012, VINYTHAI (a company with SOLVAY and PTT GLOBAL CHEMICALS as the main shareholders) started a plant to produce epichlorohydrin from glycerol in Malaysia. In the same year, with similar proprietary technology, two other Chinese companies started production in China. Today, together they account for about 12% (300,000 t per year) of installed capacity in epichlorohydrin in the world for a total market of about 1,300 thousand t per year.

According to SOLVAY, its EPICEROL process leads to an epichlorohydrin with 60% reduction in greenhouse gas emissions and 88% reduction in the generation of chlorinated effluents in relation to the conventional process from propene. As with the 1.3 PDO, it is expected that in ten years' time there will be no production of epichlorohydrin from propene. The product is used in the production of epoxy resins (coatings, adhesives, composites, etc.)

Lactic acid has been produced and marketed worldwide since the middle of the last century. With a theoretical yield of 0.7 kg of lactic acid per kg of sugar, it quickly rendered impossible any production via fossil-based raw material. It is used in the production of solvents for food, pharmaceutical and cosmetic industries, among others. It is also the basis to produce PLA.

NATUREWORKS (CARGIL) produces PLA from corn (marketed under the name INGEO; 140,000t per year nominal, not yet reached) and plans a new facility in Europe or Asia. This product is marketed as a plastic and as a fiber. Although its main market is the packaging industry, there is an expansion effort for other uses with more durable products. It still suffers from having low performance, which often forces it to be used in blends with other fossil-based polymers. It competes mainly with polypropylene and polystyrene.

CORBION is also seeking a significant stake in this business. The company has a tradition in the production of lactic acid and suggests that it can achieve economies of scale by associating lactic acid, lactose and PLA productions. Currently their production facility in Spain sells to the pharmaceutical and health industries with high added value. They would use the same technology to produce products with improved thermal properties (a group of D or L isomers). CORBION has been seeking to reposition the product in the engineering plastics market to compete with ABS. It is the quest to transform it into a specialty product and to escape the competition based on cost in the plastic commodities market.

BRASKEM's biobased polyethylene (PE) is a success. However, the theoretical yield of the sugar-ethylene

transformation, 0.30 kg of ethylene per kg of sugar, shows that the product would not be competitive with the fossil-based PE. The company definitely sells with it at a premium and reaches niche markets that agree to pay this price over the biobased product.

This shows that there would be room for non-competitive biobased products, but that this space would be limited to certain niches or where there is specific regulations benefiting these products, the fuel market in the United States, for example.

Several companies already produce succinic acid by fermenting sugars with genetically modified microorganisms. This process has great advantages over the current petrochemical process. Its theoretical yield is higher than 1.1 kg of succinic acid per kg of sugar, resulting in a cost reduction of over 40% compared to its petrochemical counterpart, and its CO₂ balance is extremely attractive because the microorganism needs the same to produce succinic acid. Consumption today is close to 100,000t per year.

REVERDIA, a joint venture between DSM and ROQUETTE, launched in December of 2012 the first commercial plant to produce 10,000t per year of succinic acid in Cassano, Italy. BASF formed a joint venture with CORBION, SUCCINITY, which has a 25,000t per year production plant in Barcelona, Spain. BIOAMBER has established partnerships with DUPONT, CARGILL, LANXESS and MITSUI, among others. Its production plant accounts for 34,000t per year of the product in Sarnia, Canada. MYRIANT negotiated its technology with PTT and MITSUBISHI for the construction of a facility in Thailand of 36,000t per year.

Succinic acid can be used in the production of polymers, food, and drugs, among other products. SENAI Innovation Institute for Biosynthetics modeled a succinic acid plant using ASPEN software. From this model, the price that would lead to a rate of return of 15% for the amount invested would be around US\$ 3.00 per kg, which is very close to the price of US\$ 2.80 per kg that is practiced in the market today. Using a developed model, a plant with a capacity of 300,000t per year (current scale of terephthalate plants) could commercialize the product in the range of US\$ 1.50 per kg, thus being extremely competitive with the petrochemical diacids (adipic and paraterephthalic) and from there to its derivatives. This would open doors to new markets for esters and polyesters from succinic acid.

Succinic acid is the best example of the dilemma of non-drop-in production. Non-drop-in molecules have little or no market volume either because they do not exist or because of their high price compared to their production costs by the conventional fossil

route. By 2012 succinic acid prices were in excess of US\$ 7,000.00 per t. With the advent of the biobased product, prices have fallen rapidly, and its market has grown from 40,000t per year to 100,000t per year in less than five years. However, it seems that it has reached its limit. To enter new markets, prices must fall below US\$ 2,000.00 per t. This requires production plants with scale above 100,000 t per year, thus, equaling the size of the current market. This has been delaying the entry of facilities by companies that are waiting for the consolidation of the current market and signaling the acceptance of the product in future potential sectors. Therefore, efforts are being made to develop new product applications.

In 2013, AMYRIS opened its industrial plant to produce farnesene in Brotas, Brazil. They used sugar cane as raw material and their technology was based on fermentation from genetically modified yeasts. Farnesene is a specialty with potential use in personal care products, lubricants, surfactants, polymer modifiers and thermoplastic elastomers. It should be mentioned that AMYRIS's initial objective was to produce a biodiesel, which it would obtain from the hydrogenation of farnesene itself. However, this process is not economically viable. Apparently, the sugar-farnesene yield targets initially defined by the company in its research considered a petroleum-sugar price ratio different from the current one. With the rise in sugar prices from 2007 onwards, and the fall in petroleum prices from 2013 onwards, this yield was no longer enough to ensure the commercial viability of the process for biofuel. AMYRIS today focuses on developing applications for its specialties, although their R&D continues to look for ways to increase sugar-farnesene yield, thus enabling the biofuels business.

In 2017, AMYRIS sold its production plant in Brazil to DSM, which will start producing farnesene to use in its production of vitamin E. Currently, AMYRIS is developing a project to install a new production site in Brazil, but only for specialty chemicals, all based on its farnesene metabolic platform. There is also the need to develop applications for this molecule.

Another aspect that should be considered is Amyris' strategy. From energy and commodities, the company changed their focus to specialties. This had an impact on its relationship with the market itself. Initially it did not provide farnesene samples for clients or academia for the development of applications. When it did, it required the intellectual property of what was being developed. Today, AMYRIS makes the product available for sale in small quantities with much less control over future intellectual property.

Conclusion

The chemical industry is part of people's everyday lives. It is present in drugs, food, agriculture, clothing, housing, transport, etc. The advent of these key enabling technologies should bring to this sector a whole new wave of innovations in the coming decades.

The challenges posed to society by global warming and the increasing consumption of the planet's resources, rather than a threat, provide an opportunity for the chemical industry and a whole new economic development trend – the bioeconomy. It is possible to assume that this sector can, through its processes and products, store CO₂. This is the case of polymers applied to sectors of the durable goods and construction industries, among others.

The growth of the bioeconomy, which presupposes an increase in the availability and use of biobased chemicals, seems to be an open path for this industry. The key enabling technologies will play a leading role in this growth, bringing competitive products to the market.

Although technology plays a vital role, other aspects such as raw material availability, production scales, product types, application development and speed of introduction of non-drop-in products, and companies' strategies, for instance, will also be responsible for the success or failure of initiatives in this area.

The need to speed this new economy, however, may require some type of CO₂ taxation or other regulatory incentives in order to guarantee competitiveness for these new developments.

Brazil may have a leading position in the world in this new economic sector. The country has land, water, sun and competitive agriculture thanks to research institutions such as EMBRAPA. However, none of the key enabling technologies discussed here are fully developed,

they are all still in the early stages of evolution. The country has the basis for their development, but choices must be made since the financial resources available today are scarce due to economic and political instability. These resources should be focused towards technologies with the greatest potential and products with guaranteed competitiveness.

There is still another opportunity that should not be ruled out: the investment in the development of applications of molecules with high yields in relation to renewable raw materials, and consequently with high competitiveness against fossil products that could leverage some specific markets.

References

- Stankiewicz, A. I.; Moulijn, J. A. Process intensification: transforming chemical engineering. *Chem Eng Prog.* 96, 22–34, 2000.
- The White House. National Bioeconomy Blueprint. Washington, 2012.
- Johnson, I. S. Human insulin from recombinant DNA technology. *Science.* 4585, 632–637, 2019.
- Nielsen, J. et al. Engineering synergy in biotechnology. *Nature Chemical Biology*, 5, 2014.
- Vinge, V. *Technological Singularity*, 1993.
- OECD. *The Bioeconomy to 2030: designing a policy agenda*. OECD Publishing, Paris, 2009.
- BNDES. *Potencial de diversificação da Indústria Química Brasileira*. Banco Nacional de Desenvolvimento Econômico e Social – BNDES, Rio de Janeiro, 2014. ■

I.7

Opportunities, competitive advantages and key challenges and barriers for Brazil to consolidate as a world reference in “toiletries, fragrances and cosmetics”

João Carlos Basilio and Francine Leal Franco – Brazilian Association of the Cosmetics, Toiletry and Fragrance Industry (ABIHPEC)

When we talk about bioeconomy in the toiletries, fragrances and cosmetics (HPPC) sector, we naturally associate it with Brazilian biodiversity, which presents great potential for application in this sector with its natural active ingredients.

The Biodiversity Law in Brazil brought, as its main objective, a reduction in the bureaucratic obstacles to research and innovation in exploring the country's biodiversity actives. In the HPPC industry, natural actives have great application potential, especially Brazilian actives that, in addition to enabling new discoveries, have a very attractive marketing appeal, not only for the Brazilian consumer, but also for the international market. The Brazilian regulatory framework brings great opportunities for industries compared to other international regulatory systems.

The sustainable use of biodiversity in the sector is an opportunity to build an innovative value chain, aligned with consumers' expectations in terms of naturalness and transparency, as well as contributing to a positive socio-environmental impact on the planet.

Let's talk a little about the history and relationship of HPPC products with natural actives - which translates into a modern, yet also ancient concept: The Bioeconomy!

We can say that the birth of cosmetic products takes us back to Cleopatra's time. She was the first woman in history known to express concern for personal care. Since that time there has been talk of using honey, milk and vegetable elements to make pastes combined with animal fats or beeswax to make skin creams. Body painting gave rise to makeup, which was initially used as protection from the sun and for spiritual rituals, not only by women, but also by children and men. And since that time people have used perfumed oils and essences such as camphor and myrrh.

The Egyptians also gifted us with another great heritage, perfumes: burning scented resins in religious ceremonies. At that time, it was believed that a path

Image provided by Embrapa Territorial

connected heaven to earth, and smoke would follow that path, connecting the two worlds. Thus from Latin came the name of what today we do not live without: perfume (*per fumum*) - through smoke.

Taking a large millenary leap, we come to the discovery of Brazil, and here, one more curiosity: the meaning of the name of our country, the result of the first major economic milestone, is due to the logging of *ibirapitanga* - or in Portuguese, “redwood”. But it is worth mentioning that part of this interest in redwood was precisely about the reddish pigment taken from the wood resin. The local natives used this pigment for body painting, and it could only be done by the Portuguese using indigenous knowledge.

But in the middle of a dense forest, among so many trees and animals, how did the Portuguese discover this wealth? The answer is simple: through traditional indigenous know-how.

Here is a summary of the basic concepts defining the historical use of natural actives in HPPC products:

1. The use of natural actives for personal care is millennial and without these attributes there would be no beauty science and no HPPC product development.
2. It is millennial, often spiritual, knowledge passed down from generation to generation that enriches the possibilities for developing HPPC and pharmaceutical products.
3. Bioeconomy has been successfully practiced in Brazil since the beginning of its history.

With these elements, and with the history of redwood, we also have some basic concepts regarding the regulation of the use of natural actives in the world: the concepts of genetic resources - or genetic heritage - and associated traditional knowledge. These two elements are protected by the Convention on Biological Diversity (CBD), the Nagoya Protocol, two international agreements, and Brazil’s Law 13.123 of May 2015.

Less history and more standardization.

For the HPPC industry, we know that products that are increasingly natural and have sustainable appeal are a trend fed by consumer longing. But like any change in paradigms or pre-established models, new trends also pose challenges. And one of the challenges of nature-inspired products developed with biodiversity actives is precisely related to the regulatory aspects and obligations contained in the **Biodiversity Law**.

What we have today is just the fear of the unknown: regulatory processes and the system developed to

manage research on Brazilian biodiversity actives are simple and need to be better disseminated and understood.

First of all, we need to keep in mind that this is not an obligation defined only in Brazil, but an international convention with more than 100 countries having ratified their commitment to comply with the norms set out in the **Nagoya Protocol**.

This protocol regulates access to genetic resources and the fair and equitable sharing of the benefits of their use, thereby contributing to the conservation of biological diversity and the sustainable use of its components.

In this sense, it appears that this is a worldwide concern, and countries are creating their own rules on the use of biodiversity. Therefore, the use of natural resources will be regulated worldwide, making this a crucial point in the decisions of companies that work with natural products, whether in Brazil or anywhere else in the world.

In Brazil, the regulation of the subject was initially dealt with by a federal Provisional Measure in 2001 (MP 2.186-16 / 01). However, the rules were difficult to interpret and highly bureaucratic, which led to many infractions, causing huge penalties being levied by the regulatory agencies, and consequentially discouraging research and development of products derived from Brazilian biodiversity.

After several discussions in 2015, new legislation came into force with the promise of providing safety, agility and research incentives in Brazil: Law 13.123 / 2015, known as the Biodiversity Law. The objective is to promote the sustainable use of genetic resources of biodiversity and to arouse the interest of companies for their use and the regularization of their activities, through a self-declaration system of registration of activities that use Brazilian biodiversity.

Based on the “Brogotá Project” (access and benefit sharing in the world scenario: Brazilian law compared to international standards (CNI, 2017)), more than 100 countries have already acceded to the Nagoya Protocol, which creates binding rules across borders, with about 80 of these countries having domestic laws similar to those of Brazil.

From this study, we can observe two major movements:

- From a public and political point of view, countries have initiated the creation (or adaptation for those countries who, like Brazil, already had passed legislation following the Convention on Biological Diversity - CBD) of their own Access and Benefit-Sharing regulations (ABS).

- Some companies in the private sector that use and maintain business relationships in countries that provide biological diversity and associated traditional knowledge, began to prepare for internationalization of the theme in their business models and to comply with ABS legislation in these countries.

In short, Brazil is not alone in having legislation to regulate the use and benefit sharing of natural actives with traditional communities through the economic exploitation of products derived from access to genetic resources (biodiversity) and traditional knowledge. Regulation and bioeconomy are world trends; here are some examples:

South Africa: has complex legislation, including well-defined concepts and penalties for irregular access. The country has 24 Internationally Recognized Certificates of Compliance (IRCCs) issued, all for commercial purposes.

Argentina: has several federal and provincial rules. Seventeen types of monetary and non-monetary benefit sharing were legally established.

Colombia: Although there are no IRCCs in the Access and Benefit-Sharing Clearing-House (ABSCH), the study found that there are lists of projects authorized by the Colombian Government that already have an access contract, including contracts for research purposes in cosmetics.

Costa Rica: The applicant for the authorization must pay up to 10% of the value of scientific research and up to 50% in royalties to the National System of Conservation Areas, or to the indigenous territory, or to the private owner that provides the sample of the genetic resource to be accessed. If the applicant for the access authorization is the owner himself, the amount of up to 50% in royalties must be paid in favor of CONAGE-BIO, the local competent agency.

India: The national ABS guide states that benefit sharing may vary from 0.1% to 5.0%, depending on specific situations. To date, the country has issued 86 IRCCs, demonstrating that authorization procedures have been widely followed.

Peru: has a complex and prior administrative procedure for obtaining access authorization. Although not specifying benefit-sharing amounts in the case of access to genetic heritage, a minimum value of 10% of gross sales resulting from products developed from collective knowledge was stipulated for access to that collective knowledge.

And in Brazil:

Based on the results obtained, Brazilian legislation is visionary, with fewer gaps and legal insecurities com-

pared to the countries studied. It can be said that this is due to the opening of dialogue between the government and other sectors, including the business sector that was and is still participatory in the elaboration of Brazilian ABS standards.

Although there are other countries with defined values, Brazil is the only one to foresee benefit sharing exemption situations, as in the following hypotheses:

- Reduction of benefit sharing to 0.1% in the case of sectoral agreements;
- Exemption of several actors: micro and small companies, for example;
- Application of benefit sharing in a single link (the manufacturer of the finished product);
- On the finished product, only when the genetic resource is one of the main elements of value added or there is general market appeal;
- No incidence of patent allocation.

In addition, Brazil allows for the possibility to reduce the benefit-sharing amount by 0.75% of net revenue when benefit-sharing is done directly with communities or in biodiversity conservation projects, and when there is enhancement of associated traditional knowledge - which may be reversed into image gains for the company and spontaneous marketing.

No other country has created an online self-reporting system such as the new Biodiversity Act in Brazil. Sis-Gen, an electronic platform managed by the Brazilian Environment Ministry, is a major international advance in the process of traceability of natural inputs and a modern mechanism for recording information. In short, Brazil has only to gain from the development of products increasingly based on our natural wealth.

Brazilian laws in this area are enforced by a single body, the Council for Genetic Heritage Management (CGen), while in many countries it is common to find more than two public bodies responsible for “sub-themes” regarding ABS, making procedures clearly more bureaucratic in these countries.

Finally, the CGen is an experienced and mature organ in conducting this theme, being comprised of representatives from all areas involved: government, industry, academia and entities or organizations representing indigenous peoples, traditional communities and traditional farmers. This format was designed to broaden the participation of civil society, which was already remarkable even before the enactment of Law No. 13123/2015. Representation of the private sector is through the National Confederation of Industries (CNI), where the Brazilian Association of the Personal

Hygiene, Perfumery and Cosmetics Industry (ABIHPEC) has a seat and actively participates in meetings and decision-making, including being responsible for suggesting and drafting various regulations.

In short, the purpose of these standards is to conserve and encourage sustainable use of natural resources, to value associated traditional knowledge, and to ensure a fair and equitable sharing of benefits when these resources are used in product development, while also ensuring national sovereignty over our natural resources.

And for Brazilian industry, it is important to understand that - whether Brazil is part of the Nagoya Protocol or not - rules for the use of exotic actives are also a risk to the business and image of the company. Valuing our inputs, conserving biodiversity and valuing our peoples' ancestral knowledge is, in addition to their businesses being based on ethics and responsibility, adding value to the reputation of their brands and companies. This is all part of the new green economy, or in a more technological way of thinking, a clear example of bioeconomy in the HPPC industry.

In practice! HPPC products and natural ingredients

To illustrate a little of all this, let's look at some of the most commonly used natural ingredients in the HPPC industry: cocoa, castor oil, tonka (cumaru), palm oil, and coconuts.

Cocoa comes from South and Central American countries, including Peru, Brazil, and Costa Rica. Tonka, the ingredient widely used in fragrances, is from South America, including Peru and Brazil. Castor oil comes from South Africa and coconut is from India. The palm oil is from Mozambique.

This means that in order to use all these ingredients, the biodiversity legislation need to be properly studied. Using cocoa or tonka from Brazil is less bureaucratic and less expensive than other ingredients! Therefore, the fear of the national industry regarding the use of Brazilian actives is unfounded. Using natural actives from Brazil remains a great competitive advantage!

Nature, globalization, biodiversity, consumers, industry and laws. What do these represent in our life and in the HPPC industry in the coming years?

Consumers, especially younger consumers, are increasingly seeking information about the products they buy, the food they eat, the clothes they wear. With toiletries, perfumery and cosmetics it is no different. Consumers are increasingly looking for natural products and are showing growing concern about the sustainability, impacts and traceability of the raw materials used. People have begun to analyze products and their origins, and demand a commitment to maintain certain standards in these areas in their brands.

Brazil has an important role in this whole scenario. In addition to being one of the largest consumer markets for HPPC products in the world, it is one of the richest biodiversity countries on the planet. Of course, Brazilian products, especially with Amazonian appeal, are a hit everywhere in the world!

This is the potential of the bioeconomy for the personal hygiene, perfumery and cosmetics sector and, above all, for Brazil!

Reference

CNI. Acesso e repartição de benefícios no cenário mundial: a lei brasileira em comparação com as normas internacionais. Confederação Nacional da Indústria - CNI, GSS Sustentabilidade e Bioinovação, Natura Inovação e Tecnologia de Produtos: Brasília, 2017. Available on: www.portaldaindustria.com.br/publicacoes/2017/11/acesso-e-reparticao-de-beneficios-no-cenario-mundial-lei-brasileira-em-comparacao-com-normas-internacionais/ ■

I.8

Constructing the Tropical Bioeconomy for Brazil

Luís Cortez – University of Campinas (UNICAMP)

Brazil is the largest tropical country in the world, with the greatest biodiversity. According to a study published by BUTLER (2016), Brazil has 17.6% of birds, 13.6% of amphibians, 11.8% of mammals, 7.9% of reptiles, 13.7% of fish, and 20.8% of vascular plants in the world, and has the highest “BioD Index”. Due to its characteristics of biodiversity and size, Brazil is perhaps the country with the greatest development potential in bioeconomy areas.

Also, Brazil is already the world’s 1st and 2nd largest producer and exporter of several important agribusiness products¹ and probably presents the greatest potential for growth in agricultural production. This growth can happen both by increasing productivity and by adding new agricultural areas, but also by adding value by creating new opportunities via what we call tropical bioeconomy.

Today, the agribusiness sector represents nearly 50% of Brazilian foreign trade, and is internationally accepted as being highly competitive in this sector. Despite this outstanding performance, of all the products listed in the footnote below, curiously, none actually originated naturally in Brazil². Probably this happened because the markets for these products were not initially developed nor controlled by Brazil from the beginning.

In this sense, of course, the proper exploration of Brazil’s full potential represents both a challenge and an immense opportunity. In this regard, compared with other tropical areas of the world, Brazil can pro-

bably be considered the country with the greatest as yet undeveloped potential of its vast natural resources, more specifically bioresources.

The need for an innovation strategy in Brazil

Despite the large biodiversity potential and significant gains recorded in recent decades in various sectors of its agribusiness, Brazil doesn’t present the same performance in innovation, where it is ranked 64th in the Global Innovation Index 2018 (GII).

A few examples can demonstrate the gap that needs to be crossed through innovation between “the biodiversity potential” in tropical bioeconomy and its realization: there is probably no better case than coffee, a product that is almost a symbol of Brazil. The country is the world’s largest producer and exporter of coffee, but it has neither a worldwide trade strategy nor any world-class company in this segment. Fruits are another case. Considered the 3rd largest producer, its fruit exports don’t even total US\$ 1 billion. For instance, Brazil is practically absent in the international banana trade, the most important traded fruit worldwide that happens to be totally controlled by non-producing countries.

So, in order to rectify this situation, the country should get its main stakeholders to work together, using the Agropolo Campinas-Brasil platform and the expertise developed in the FAPESP PPPBio Project, and develop

¹ Brazil is the largest producer of coffee, sugar, oranges; the 2nd largest of soybeans, ethanol, and the 3rd largest of beef, corn and poultry. The country is also the largest exporter of coffee, sugar, oranges, beef, poultry and eucalyptus cellulose and the 2nd largest of ethanol and corn (FGV, 2015).

² Probably Brazil’s first emblematic endogenous crop is cassava (*Manihot esculenta*), a tuberous plant not yet properly economically developed. First used as source of starch, it was partially substituted by wheat flour. Despite its diverse uses in Brazil, Nigeria and Thailand, cassava has not yet conquered the status of other important starch sources worldwide, such as rice and potatoes.

Image provided by Embrapa Territorial

a clear Tropical Bioeconomy strategy in an effort to create a project that integrates all aspects involved, from science to business.

The steps to be taken towards a Tropical Bioeconomy

Using the trial-and-error type of approach utilized so far is not the best solution to address the existing opportunities in Brazil's tropical biomes, such as the Amazon rain forest, the Atlantic forest, the Cerrado and the Pantanal, to mention the largest ones. An overall innovation strategy needs to be created, a strategy constituted by the following steps:

1st Step: The first and fundamental step to construct a Tropical Bioeconomy is to identify the problems to be solved. On their way to economic progress, the developed nations of today were able to clearly define their problems and deploy the necessary resources (qualified people, capital, effort) to overcome the difficulties encountered. Examples of that are the development of refrigeration technology to transport fruit & vegetables from California to New York, and the water desalination technology developed by Israel. A nation that undertakes this first step and then ends up solving the identified problems, creates self-confidence and becomes more prepared for more challenging projects.

For instance, Brazil tried, at least partially, to implement a few projects such as the Proalcool program and the hydroelectric dams project in an attempt to solve existing problems. However, in neither of these two cases was Brazil able to achieve the threshold beyond which the innovation would create a "virtuous cycle". A virtuous cycle is important because it will become the "passport" to long lasting socio-economic development. On the other hand, when a virtuous cycle is not created, the nation should not try to solve more difficult problems. The risk of failing again is enormous...

Examples can be given of problems that are probably too difficult for Brazil to tackle, such as going to space, eliminating housing and sanitation deficits, or developing a second generation ethanol technology (ethanol 2G³).

Therefore, in order to develop the Tropical Bioeconomy the country needs first to consider solving more modest type of problems to acquire the necessary confidence and experience. The exercise begins by identifying modest problems and solving them, until the cycle is completed, creating confidence and a ge-

neration of scientists and entrepreneurs committed to working closely with the market.

To adequately and fully realize its existing tropical bioeconomy potential, Brazil has to put together qualified teams of researchers with strong scientific backgrounds (**2nd Step**) in specific areas such as biology, agronomy, medicine and agricultural, food, and chemical engineering (among others). Ideally, these qualified research teams should work in cooperation with the private sector which can be expected to be more focused.

Several rich countries of today have already followed this path. Brazil does have a solid scientific community and a strong consumer market. In addition, Brazil is in a unique position to sustainably utilize its vast natural resources. If there is anything in the country's human resources that is missing, it is know-how in business and a problem solving mentality, but these traits are maturing and in the coming years I believe the country will finally find its way up.

The **3rd Step** is to try to understand "what the market needs" and then cross that information with "what is out there in the tropical environment", to create an adequate roadmap for the problem to be solved. The matrix is then built crossing the biological mapping with needs, or opportunities, thereby creating a problem-solving technique.

The process of constant interaction with the market and working together on possible solutions can be considered preliminary, followed by generating spin-off companies (**4th Step**) that will have greater chances to succeed due to their possessing market-oriented solutions. The research team initiates the process, followed, at the appropriate time, by the business link.

The proper and timely interaction with the market is critical in all steps, from the beginning where the problem is defined and the need for additional scientific knowledge is understood. Researchers must work together to correctly define the problem to be solved and then create a strong innovation strategy that will engineer a proper solution, thereby leading to the creation of, where necessary, spin-off companies able to enter the market with conditions necessary to succeed.

On the other hand, simply copying or importing a solution from other countries would not only give the false impression of having solved the problem but, worse, create a bad habit of dependence: "somebody else will do it..."

Since, the biodiversity and problems encountered in Brazil are unique, solutions cannot be simply impor-

ted. The identified problems need to be studied here, and all efforts should be made to overcome them.

The figure below gives an idea of the steps and stakeholders involved in the entire innovation process, and is intended to show a clearer picture of the overall strategy involved in constructing a Tropical Bioeconomy in Brazil.

city to understand the real problems that need to be solved and persist down this road until the solution is found. Also, scientists from the public sector should work more closely with the private sector, in particular with Brazilian companies, until the solution is achieved and the accumulated knowledge can be transformed into successful businesses.

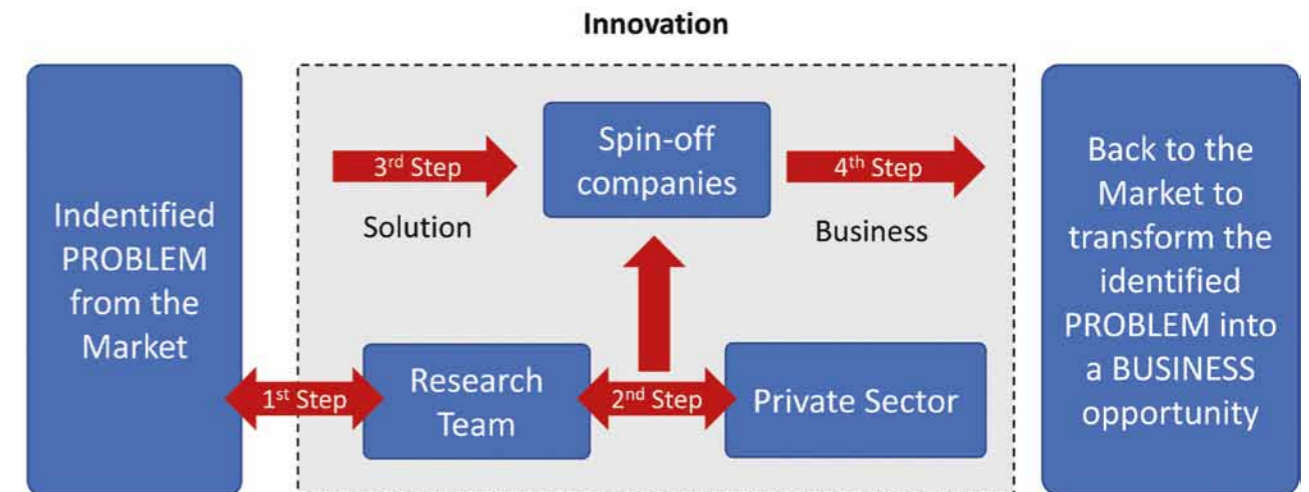


Figure 1. From identifying the problem to working on the solution: the 4 fundamental steps towards the construction of the Tropical Bioeconomy strategy.

Conclusions

Brazil has an immense potential in developing its tropical bioeconomy. The country has already demonstrated capacity to be competitive in agribusiness. However, in order to construct a sustainable tropical bioeconomy, adding to its products, the country needs to define a strategy, following fundamental steps from scientific knowledge to business opportunities. Among the necessary things to be done is to create a capa-

References

- BUTLER, R. A. The Top 10 Most Biodiverse Countries. 2016. Available on: <https://news.mongabay.com/2016/05/top-10-biodiverse-countries/>
- FGV. Brazilian Agribusiness Overview. Fundação Getúlio Vargas – FGV, N. 25, 83p, Rio de Janeiro, 2015.
- GII. Global Innovation Index 2018. Available on: <https://globalinnovationindex.org> ■

³ The production of ethanol from lignocellulosic materials such as sugarcane bagasse.



Part II

Roadmap for Tropical Bioeconomy

The Agropolo's
Campinas-Brasil approach

Image provided by Embrapa Territorial

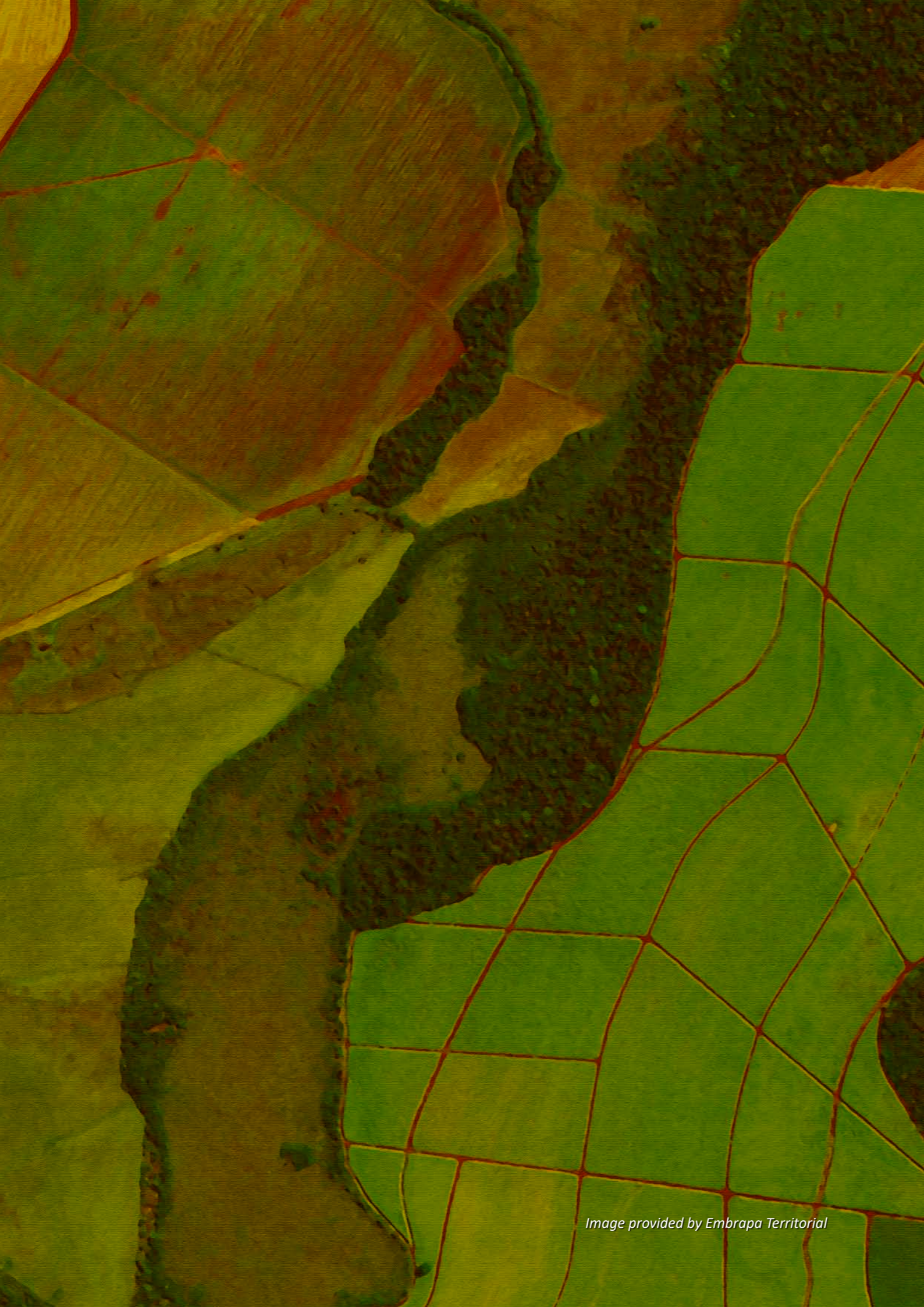


Image provided by Embrapa Territorial

Bioeconomy around the World

Sérgio Augusto Morais Carbonell, Lilian Cristina Anefalos and Ricardo Baldassin Jr.
– Agronomic Institute (IAC)

The first national strategic bioeconomy action was implemented by Germany in 2011. Since then, other countries have sought to align their development plans and, consequently, the deployment of their science and technology resources to meet the new guidelines. According to a survey conducted by the German Bioeconomy Council in 2018, approximately 50 countries around the world have worked to incorporate the bioeconomy into their strategic policies, of which 15 are from the European Union and the Nordic countries (Bioeconomy Council, 2018).

Recent efforts to consolidate their bioeconomy strategies are not restricted to public policies, but are also composed of private sector initiatives stimulated by market opportunities and actions to exploit the synergy between the public and private sectors, in particular between industry and public science and technology institutions, through cluster and hub formations. In this sense, initiatives have been instituted for the development of specific regions according to their natural vocations, macro-regions or driven by the interests and opportunities of the industrial sector, especially the pharmaceutical, food and biofuels segments.

Another important point to consider is that in each nation or economic bloc, the construction of a more sustainable economy has been based on distinct technological routes, policies and actions based on its skills, competences and, especially, considering the wealth of its natural resources. This trend can be observed in the cases of the European Union (which has concentrated its efforts on the circular economy system), of the United States, the United Kingdom, and China (which have prioritized high-tech innovations, in particular synthetic biology, digitization and advanced manufacturing), and of Canada and Finland (which are

structuring their systems based on “forest products”).

In this regard, there is a great potential and future prospects for the bioeconomy to be consolidated in Brazil, especially in view of the many opportunities offered by the country’s tropical biodiversity. It must be recognized that the solutions of the countries of the Northern Hemisphere will not serve as a model, given the Brazilian socioeconomic reality. However, these solutions should be used as a reference to implement collaborative actions in science and technological development, access to new markets, and the creation and implementation of national and international regulatory policies, thus making it possible to expand the economic, social and environmental benefits in this new era.

Looking at bioeconomy initiatives in countries that have tropical ecosystems with some similarities to those in Brazil, we see a limited number of action plans already implemented, with a holistic view, especially in Thailand and Malaysia. When considering the countries of the Southern Hemisphere, we must allude to the initiatives of South Africa and Australia, with innovation agendas focused on regional development. On the other hand, other countries have been leading efforts to build sustainable and green economies by incorporating topics such as bio-based products and bioeconomy into their development policies, including sustainable biomass production (food and bioenergy) and biotechnology.

In Latin America and the Caribbean, in addition to Brazil, Argentina, Colombia, Paraguay, Uruguay, Ecuador and Costa Rica have also worked to implement bioeconomy action plans. In regional terms, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has been mobilizing to organize events in the bioeconomy, with the purpose of pro-

moting the exchange of experiences between governments, the private sector and science and technology institutions, thus stimulating greater convergence of actions between nations and economic groups.

In Brazil, the bioeconomy theme was introduced by the National Confederation of Industries (CNI) in 2013 with the publication of the “Bioeconomy: Agenda for the Development of Brazil” report (CNI, 2013). This relevant initiative aimed at stimulating discussion of the issue within the country. As a consequence of the efforts made since then in the areas of science, technology and innovation, a recent action plan for the development of biotechnology has been launched (CGEE / MCTIC, 2018), and the bioeconomy is now considered a strategic issue by the federal government. It is an action plan devoted to this topic, and is expected to be implemented in the coming years (MCTIC, 2016). To this end, the strengthening of public and private mechanisms to encourage and foster entrepreneurship and innovation will be essential for Brazil to have the proper structuring and continuous actions for the construction of this new economy (CGEE, 2019). In the industrial area, there are already relevant success stories from projects led by national and multinational companies for the development of technologies and products based on Brazilian biodiversity, with emphasis on the following segments: food, medicines, advanced biofuels, cosmetics, personal hygiene, perfumery and chemicals. With the increasingly synergistic interaction of Brazilian science and technology institutions with the private sector, it will be possible to further accelerate technological development and innovation in the coming years, including the expansion of new business opportunities and more sustainable alternatives.

In Brazil, the green economy has been strengthened over the years, based on the country’s wide biodiversity, with differentiated performances of the food and bioenergy segments. In the case of bioenergy, the experience has been ongoing for over 40 years, and the sector continues to work hard to strengthen and expand production and consumption, especially of biofuels (ethanol and biodiesel) and bioelectricity. The

Renovabio Program, recently created by the federal government, is an example of the efforts being made for the production and sustainable expansion of bioenergy in the country.

In order to contribute to the strengthening of the bioeconomy in Brazil, Agropolo Campinas-Brasil has worked intensely to build a collaborative innovation platform. Between 2015 and 2018, thirteen strategic themes were identified and outlined, in a participatory manner involving all relevant players. The principal issues addressed are the opportunities, challenges, research and public policies needed for the development of the bioeconomy in the country, in the short, medium and long term. This important initiative was funded by the São Paulo Research Foundation (FAPESP), and was also supported by several public, private and governmental institutions in Brazil and abroad. The results of this relevant project are presented below.

References

- Bioeconomy Council, 2018. Bioeconomy Policy (Part III) - Update Report of National Strategies around the World, a report from the German Bioeconomy Council. Office of the Bioeconomy Council: Berlin, 2018.
- CNI, 2013. Bioeconomia: uma agenda para o Brasil. – Brasília: Confederação Nacional da Indústria - CNI, 2013.
- CGEE/MCTIC, 2018. Plano de Ação em Ciência, Tecnologia e Inovação para Biotecnologia. Brasília, DF: Centro de Gestão e Estudos Estratégicos – CGEE e Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC), 2018.
- MCTIC, 2016. Estratégia Nacional de Ciência, Tecnologia e Inovação: 2016-2022. Brasília, DF: Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC), 2016
- CGEE, 2019. Bioeconomy in the Americas – 2030 Short report. Brazil – Brasília, DF: CGEE, 2019. ■



Roadmap methodology

Rodrigo Lima Verde Leal – CPQD

Ricardo Baldassin Jr., Lilian Cristina Anefalos – Agronomic Institute (IAC)

The identification of the actions needed for the development of the Bioeconomy was carried out using roadmapping processes. Its implementation was guided by the methodology developed by the International Energy Agency - IEA (Energy Technology Roadmaps - a guide for development and implementation) and VISIONING - “create a new economy in Brazil based on BIO”.

The TIMEFRAME employed covered the short term (2018, during the project development period), medium term (projection to 2030) and long term (vision to 2050). The study was designed within the scope of three LARGE AREAS (Agriculture, Food & Health, and Bioenergy & Green Chemistry) and was focused on the development of potential PRODUCTS aiming to contribute to the reduction of GHG (Greenhouse Gases) emissions, increase the number and quality of formal jobs, and increase the value added.

The study was developed in three stages between June 2015 and June 2018, through workshops and breakout sessions held in the city of Campinas, State of São Paulo, Brazil, with wide participation of leaders, experts, policy makers and stakeholders. The roadmapping process stages are presented and described in Table 1 below.

- Stage 1 – Planning and Preparation: the activities were carried out in two distinct phases. In the first phase, workshops and breakout sessions were held with leaders, aiming to designate the members of the executive committee (general coordinators) and to identify new demands and opportunities. At this time, the following topics were preliminarily defined: scope, VISION, objectives, STRATEGIC AREAS, coordination (strategic area coordinators) and stakeholders and, consequently, the problems that required a roadmap. In the second phase, a broad workshop was held, under the coordination of the executive committee and with the participation of experts, policy makers and stakeholders, for present-

ing, discussing, reviewing and validating the elements identified in the previous phase.

- Stage 2 – Development: consisted of workshops with the strategic area coordinators, under the coordination of the executive committee, aiming at the elaboration of the Terms of Reference (ToR). During this stage the following were preliminarily identified: i) products, technologies and desired processes; ii) critical system requirements; iii) LARGE TECHNOLOGICAL AREAS; iv) DRIVERS and goals; v) scientific and technological capabilities; vi) gaps and barriers, and vii) schedules, priority routes and recommendations.

- Stage 3 – Implementation: consisted of thirteen broad thematic workshops (one for each STRATEGIC AREA), under the coordination of the strategic area coordinators and with the participation of experts, policy makers and stakeholders. The workshops aimed at presenting, discussing, reviewing and validating the outlined scenarios in the Terms of Reference. The workshops had three distinct parts. The first was composed of technical sessions, with the participation of invited experts, where contents and questions were presented and discussed, considering topics and questions preliminarily outlined in the Terms of Reference. In the second part, breakout sessions were performed, where all workshop participants were able to express their positions on panels, preliminarily defined by the area coordinators. In the third and final phase, the workshop participants discussed and revised the action plans (agenda) for the development of each STRATEGIC AREA. The implementation of the action plan activities, and consequently their revisions and improvements, were not the target of the project.

The results presented below reflect the consensus of experts, in line with the scenarios and guidelines proposed by the study, on what the main opportunities

Image provided by Embrapa Territorial

Table 1. Stages of the roadmapping process, based on IEA's methodology (IEA, 2014).

	Stage 1 - Preliminary activities		Stages 2 and 3	
	PLANNING AND PREPARATION	VISIONING	DEVELOPMENT	IMPLEMENTATION
Expert judgment & Consensus	<ul style="list-style-type: none"> Establish Steering Committee Determine the objectives and boundaries Select stakeholders and experts 	<ul style="list-style-type: none"> Conduct senior-level vision workshop to identify long term goals and objectives 	<ul style="list-style-type: none"> Conduct expert workshops to identify barriers, priorities, technologies, policies, and timelines 	<ul style="list-style-type: none"> Conduct workshops with wide audience Review of Terms of References
Data & Analysis	<ul style="list-style-type: none"> Current situation: products, consumers, suppliers and processes Future needs: market trends and projections 	<ul style="list-style-type: none"> Identify critical system requirements 	<ul style="list-style-type: none"> Technology areas assessment 	<ul style="list-style-type: none"> Monitoring, review and improvements *
			<ul style="list-style-type: none"> Elaboration of Terms of References Conduct review and consultation cycles with key stakeholders 	

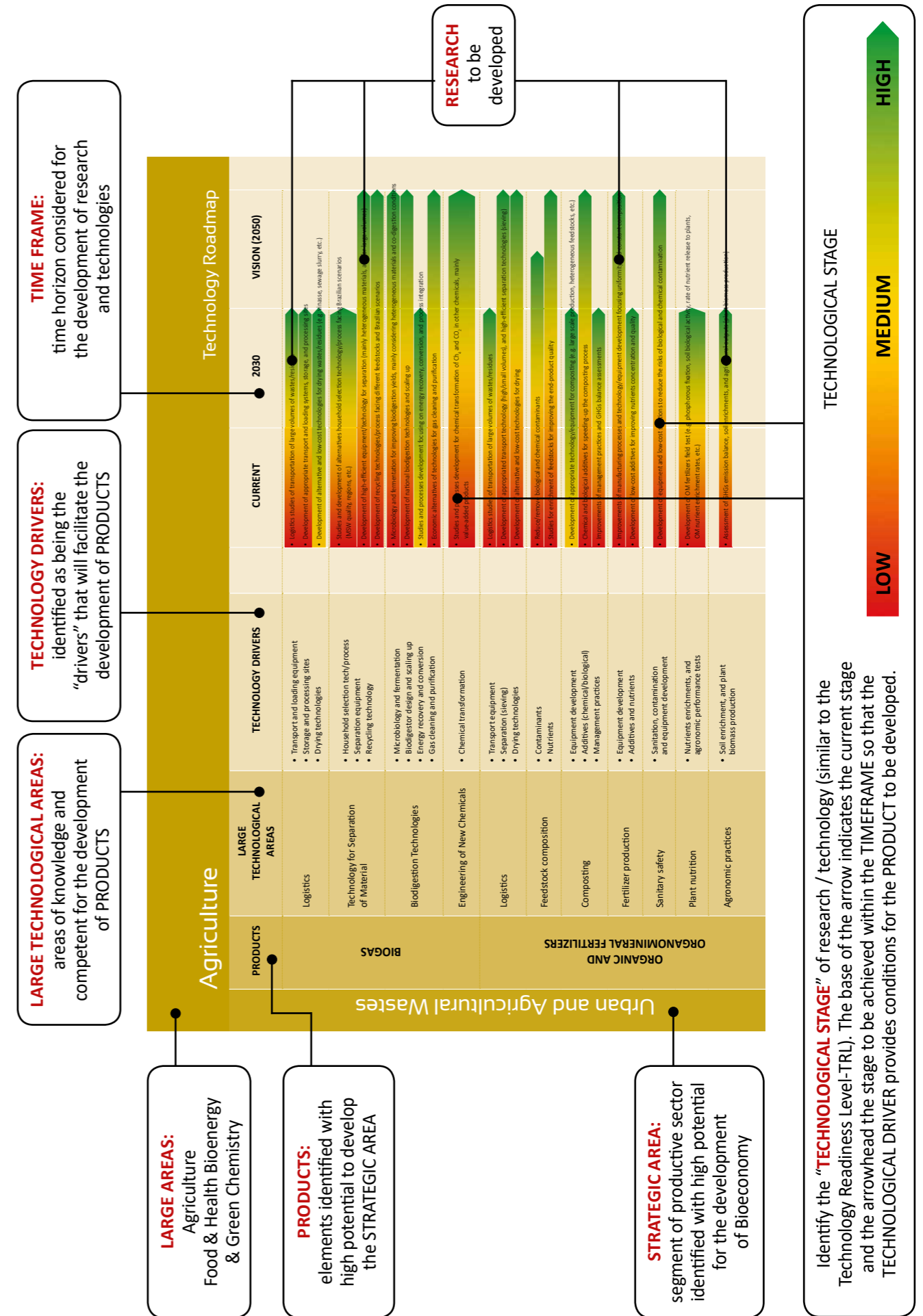
Note: * this activity was not performed.

and needs are, and the technological demands (RESEARCH) necessary to meet them. This study aimed to identify and create mechanisms to anticipate technological (and non-technological) development, as well as subsidize solid support for R&D planning and management decisions.

The technological roadmaps developed for the thirteen STRATEGY AREAS are presented in chapters II.1, II.2 and II.3, and the non-technological roadmap in chapter II.4, which is presented aggregated, since the ACTIONS identified were similar and had cross-cutting demands.

Reference

IEA. Energy Technology Roadmaps - a guide to development and implementation. International Energy Agency – IEA, Paris, France, 2014. ■



Identify the "TECHNOLOGICAL STAGE" of research / technology (similar to the Technology Readiness Level-TRL). The base of the arrow indicates the current stage and the arrowhead the stage to be achieved within the TIMEFRAME so that the TECHNOLOGICAL DRIVER provides conditions for the PRODUCT to be developed.

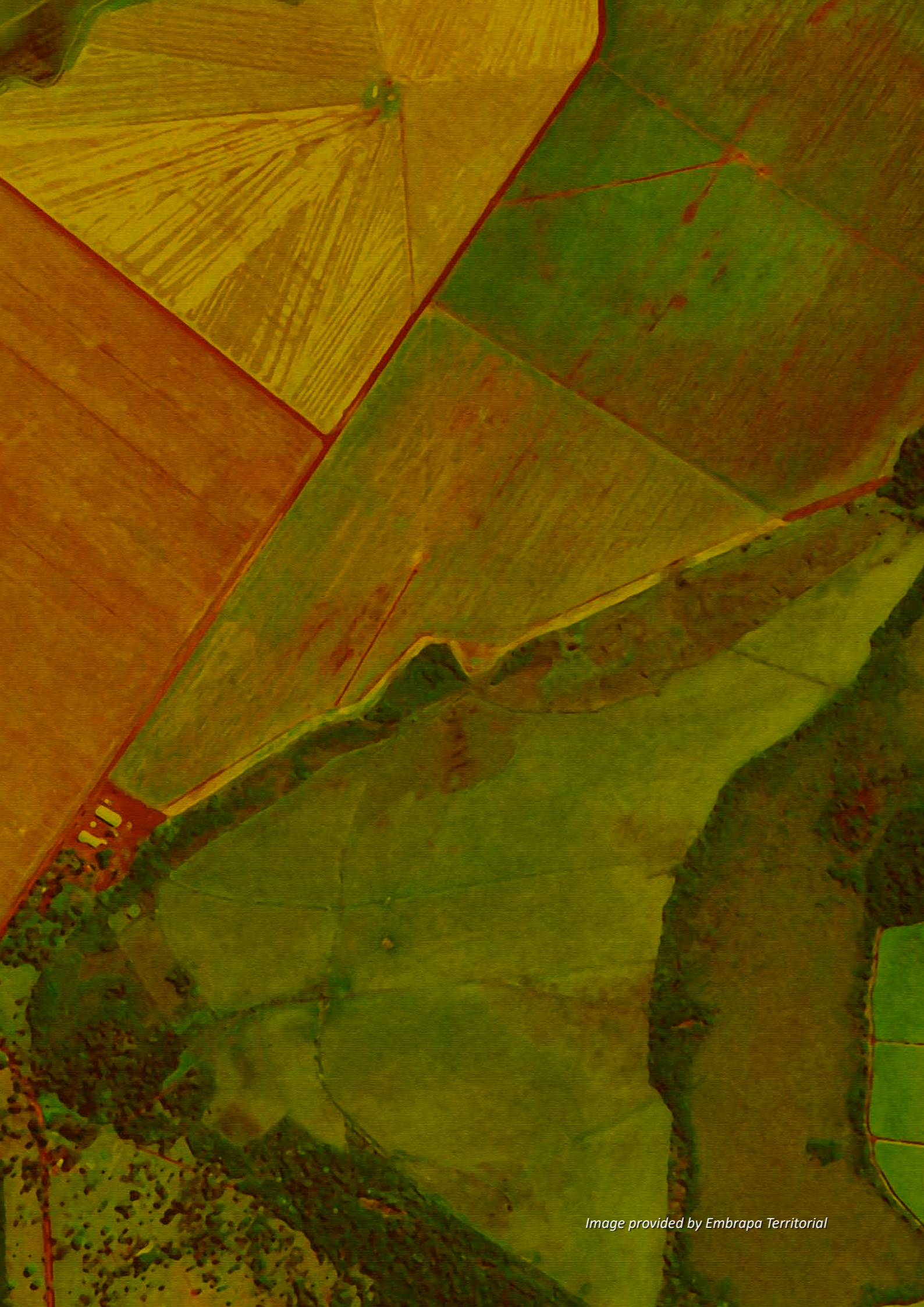


Image provided by Embrapa Territorial

Agriculture

Heitor Cantarella – Agronomic Institute (IAC)

Brazil is currently the second largest food exporter in the world (in volume), producing about four times more than domestic demand. However, this leading position was only recently achieved, since until about 50 years ago the country was a net importer of food. At that time, food shortages were pointed to as one of the main obstacles to the industrialization and overall growth of the country. To increase agricultural production and productivity, the government implemented a set of actions, of which rural credit, rural extension and agricultural research were the central points.

In the following decades the country began to reap the benefits of these initiatives. Between 1978 and 1998 grain production doubled from 38 to 76 million tons. And the results have continued to grow; by 2018 grain production reached 242 million tons!

Good results also occurred in livestock, where in the place of the then-prevailing archaic and basically subsistence production systems, today we find an environment of high production and productivity. Domestic meat production (pork, beef and chicken) jumped from 2 million tons to about 35 million tons between 1970 and 2018. Today, the leading role in the international beef and chicken markets is a reality.

This impressive performance was driven mainly by productivity gains, reflecting the abundance of natural resources, assertive public policies, the competence and perseverance of Brazilian farmers and, most importantly, by investments in agricultural research, which made it possible to advance a scientific approach, develop appropriate technologies and innovate. In the last 40 years, the area used for the production of the fifteen major crops in Brazil has increased by 63%, but production has increased by 409%. Using 1977 technology, Brazil would need about 190 Mha to produce what it produces today with 61 Mha. In this context, the “land-saving” effect, reflecting productivity gains, is a prominent factor in national agricultural production.

If the investments in research made in the recent past have brought us to the current position of prominence, Brazilian agriculture and its international competitiveness in the coming decades will depend on continued research and scientific developments going forward. The new challenges facing Brazilian agriculture are deep and becoming more complex in light of the latest demands of society. Productivity needs to be increased by optimizing the use of natural resources within the concept of a circular economy. Attention should be given to reducing environmental impacts and greenhouse gas emissions by expanding and integrating food production and bioenergy. The modern bioeconomy, in which biomass is used in new applications, brings renewed challenges but also opportunities for agriculture. Traditional concepts of food quality should incorporate the concepts of functional and biofortified foods. The production chain becomes more complex, with new actors and new technologies added to the field, with greater use of information technology and modern specialties.

In order to explore the main opportunities for Brazilian agriculture and the scientific and technological advances required in this new scenario, seven potential areas were identified:

1. Agricultural and urban wastes: energy, nutrient recycling and fertilizers.
2. Essential oils, aromatic and medicinal plants.
3. Precision agriculture.
4. Animal system production.
5. Water.
6. Coffee.
7. Citrus.

Where are the following technological roadmaps developed for each area, so that Brazil can continue to grow, producing food sustainably, improving the living conditions of the population, and reaching new markets. ■

II.1.1 Agricultural and urban wastes: energy, nutrient recycling and fertilizers

ACADEMIA

Bioeconomy recently acquired a new meaning to characterize the use of biological resources for energy or new products, or for products meant to replace those originated from fossil resources. However, much of the traditional economy is bio-based as the feedstocks for most human activities come from agriculture, forestry and animal origin. The opportunities offered by the adequate use of agricultural and urban wastes are, perhaps, the best link between the traditional and the new bioeconomy.

Most agricultural wastes have historically been recycled in the fields to supply organic matter and nutrients to crops. On the other hand, the usual destination of urban wastes has been dumping sites or landfills by which societies get rid of their waste materials but make little use of them. But both agricultural and urban wastes need to be seen as resource-rich materials. For instance, urban wastes, in addition to recyclable plastic, metals, paper and other products, are composed of organic matter which store photosynthetic energy and organic carbon chemicals, as well as nutrients of the original plant material. The same applies to agricultural wastes.

As awareness increases in modern societies regarding the need to better use their waste resources, and as technology evolves, new opportunities arise for transforming organic wastes into energy and feedstock for a myriad of new products. At the end of this pipeline, what is left can still serve as sources of organic matter and nutrients for agriculture.

The discussions are currently focused on urban wastes from the city of Campinas and on agricultural residues generated by the sugarcane industry. The choice of the latter is due to its size and importance in the state of São Paulo and the fact that the materials are easy and less expensive to collect and use. The landfills in Campinas

have been deactivated and waste materials are being transported to another city at great cost. On the other hand, Campinas has good facilities to collect and treat sewage sludge and a structure in place to collect garden and food residues. Therefore, the search for sustainable solutions is urgent. Campinas is an example and a proxy for the mid-sized to large Brazilian cities that must solve the problem of disposing the waste they generate.

The options at hand are many, including the production of biogas and of organic and organic-mineral fertilizers with known technologies. But there are also many challenges and opportunities. What are the choices or pathways that maximize job creation, income generation, and environmental benefits? How can these resources be used to foster the creation of a new industry with novel bio-based products that can replace those that rely on the old fossil-based raw materials?

This task must be addressed by the joint efforts of research institutions, government and the private sector because each of them has information on part of the complex equation that must be linked together. That was the objective of this workshop. The potential outcomes are huge. A small but important first step was made with the creation of the Agropolo Recycling Green initiative that is already being implemented by the Agronomic Institute of Campinas and the Campinas municipal government. All efforts to expand this program and include new stakeholders will be worthwhile. ■

Heitor Cantarella, Ronaldo S. Berton

– Agronomic Institute (IAC)

Bruna de Souza Moraes – Interdisciplinary Center of Energy Planning (NIPE), University of Campinas (UNICAMP)

Raffaella Rossetto – São Paulo State Agribusiness Technology Agency, Polo Regional Piracicaba (APTA)

INDUSTRY

Brazil produces about 210,000 tons of household waste daily, according to the Brazilian Association of Public Cleaning and Special Waste Companies - ABRELPE. Of this total, 92.5% is collected but only about 40% is sent to their correct destination, a number quite distant from the guidelines contained in the Brazilian National Policy on Solid Waste from 2010.

In this context, the anaerobic biodigestion of the biodegradable organic fraction presents itself as an excellent alternative for the generation of biogas and its use, i.e. energy recycling, considering that results obtained with the capture of biogas from landfills can reach 525,000 Nm³ / h with a 50% methane content. This amount represents an electricity generation capacity equivalent to 954 MWh, enough energy to serve approximately 4.6 million families with a monthly consumption of 150 KWh.

Another option is the technological route for the purification and generation of biomethane, with 95% methane content. In this scenario, the energy equivalence with gasoline of 1 liter per m³ of biogas could reach annually around 2,420 million liters of gasoline, reducing dependence on fossil fuel.

In terms of control of greenhouse gas emissions, this process would make it possible to generate annually approximately 39.5 million tons in carbon credits, which could be used in plans to offset or reduce current Brazilian emission levels.

Another important alternative to be evaluated in the technological treatment of the biodegradable organic

matter not in landfills, but in biodigesters, is the production of organic compost, which after digestion can be used in agriculture as a soil conditioner. There already exist several studies carried out by the Brazilian Agricultural Research Corporation (EMBRAPA), as well as several cases of success in other countries, mainly in Europe and Asia. The annual production potential for this type of material is 10.5 million tons.

The biggest challenges are the continental dimensions of our country and, more importantly, the social and economic inequalities that exist throughout the country.

In view of this scenario, regional public policies need to focus on forming a consortium of small municipalities for the implementation of treatment solutions and adequate disposal of waste. This would favor the economies of scale, enabling increased CAPEX (Capital Expenditures) as well as OPEX (Operational Expenditures), thus encouraging the participation of private initiative in medium and long term projects.

Mechanisms to allow for long-term contracts, together with providing legal security, immunity to the volatility of changes in public administrations and to political tendencies, would be a very promising guide in the adoption of solutions to advance the treatment and energy use of RDU in Brazil. ■

Antonio Carlos Delbin – *Cruzeiro do Sul Engenharia e Serviços Ltda*

Agriculture

Technology Roadmap

Urban and Agricultural Wastes

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
BIOGAS	Logistics	<ul style="list-style-type: none"> Transport and loading equipment Storage and processing sites Drying technologies 	<ul style="list-style-type: none"> Logistics studies of transportation of large volumes of wastes/residues Development of appropriate transport and loading systems, storage, and processing sites Development of alternative and low-cost technologies for drying wastes/residues (e.g. vinasse, sewage slurry, etc.) 		
	Technology for Separation of Material	<ul style="list-style-type: none"> Household selection tech/process Separation equipment Recycling technology 	<ul style="list-style-type: none"> Studies and development of alternatives household selection technology/process facing Brazilian scenarios (MSW quality, regions, etc.) Development of high-efficient equipment/technology for separation (mainly heterogeneous materials, and for large volumes) Development of recycling technologies/process facing different feedstocks and Brazilian scenarios 		
	Biodigestion Technologies	<ul style="list-style-type: none"> Microbiology and fermentation Biodigester design and scaling up Energy recovery and conversion Gas cleaning and purification 	<ul style="list-style-type: none"> Microbiology and fermentation for improving biodigestion yields, mainly considering heterogeneous materials and co-digestion conditions Development of national biodigestion technologies and scaling up Studies and processes development focusing on energy recovery, conversion, and process integration Economic alternatives of technologies for gas cleaning and purification 		
	Engineering of New Chemicals	<ul style="list-style-type: none"> Chemical transformation 	<ul style="list-style-type: none"> Studies and processes development for chemical transformation of CH_4 and CO_2 in other chemicals, mainly value-added products 		
ORGANIC AND ORGANOMINERAL FERTILIZERS	Logistics	<ul style="list-style-type: none"> Transport equipment Separation (sieving) Drying technologies 	<ul style="list-style-type: none"> Logistics studies of transportation of large volumes of wastes/residues Development of appropriated transport technology (high/small volumes), and high-efficient separation technologies (sieving) Development of alternative and low-cost technologies for drying 		
	Feedstock composition	<ul style="list-style-type: none"> Contaminants Nutrients 	<ul style="list-style-type: none"> Reduce/remove biological and chemical contaminants Studies for enrichment of feedstocks for improving the end-product quality 		
	Composting	<ul style="list-style-type: none"> Equipment development Additives (chemical/biological) Management practices 	<ul style="list-style-type: none"> Development of appropriate technology/equipment for composting (e.g. large scale production, heterogeneous feedstocks, etc.) Chemical and biological additives for speeding-up the composting process Improvements of management practices and GHGs balance assessments 		
	Fertilizer production	<ul style="list-style-type: none"> Equipment development Additives and nutrients 	<ul style="list-style-type: none"> Improvements of manufacturing processes and technology/equipment development focusing uniformity and constant composition Development of low-cost additives for improving nutrients concentration and quality 		
	Sanitary safety	<ul style="list-style-type: none"> Sanitation, contamination and equipment development 	<ul style="list-style-type: none"> Development of equipment and low-cost solutions to reduce the risks of biological and chemical contamination 		
	Plant nutrition	<ul style="list-style-type: none"> Nutrients enrichments, and agronomic performance tests 	<ul style="list-style-type: none"> Development of OM fertilizers field test (e.g. phosphorous fixation, soil biological activity, rate of nutrient release to plants, OM nutrient enrichment rates, etc.) 		
	Agronomic practices	<ul style="list-style-type: none"> Soil enrichment, and plant biomass production 	<ul style="list-style-type: none"> Assessment of GHGs emission balance, soil enrichments, and agricultural outputs (plant biomass production) 		

Essential oils, medicinal and aromatic plants

ACADEMIA

Brazil occupies an important position in the world because it has the greatest plant diversity in the world, including being home to a considerable number of aromatic and medicinal species. As such, it constitutes an important socioeconomic development potential for the country as a source of dyes, vegetable oils, antioxidants, phytotherapies and essential oils.

Industrially, essential oils are used as raw materials for the hygiene, cleaning, food, pharmaceutical, cosmetic, perfumery and agricultural industries, all sectors of the economy that need constant innovations.

The effective economic exploitation and growth of the productive chain of essential oils and aromatic and medicinal plants, as well as the necessity for environmental sustainability of these natural resources, has demanded that the Brazilian scientific community develop intense research programs that focus on bioprospecting of essential oils and plant actives, biological activity, domestication and cultivation of species, processing, clean and sustainable extraction technologies, and the development of new products in the areas such as animal health, pest and plant disease control, cosmetics and perfumery.

Despite scientific advances in research, the expansion in the use, value added and innovation of products (essential oils, plant extracts) in response to market needs and environmental sustainability also requires a number of other elements: the improvement of technologies for cultivation and processing of aroma-

tic and medicinal plants; development and/or improvement of processes to obtain natural products from clean technology, meeting the principles of Green Chemistry; and development of formulations (encapsulation and emulsion) and transformation of aromatic ingredients through biotechnology.

Among the main non-technological challenges of the production chain, we can highlight the high investment in research and development required, the lack of training in good farming practices as well as of regulatory aspects (law of access to genetic heritage, protection of cultivars, registration of new agricultural products), and the lack of public policies for greater integration between the public-private sector and research funding agencies. ■

Marcia Ortiz, Juliana Rolim Salomé
Teramoto – Agronomic Institute (IAC)
Pedro Melillo de Magalhães, Ilio Montanari Junior,
Glyn Maria Figueira, Marta Cristina Teixeira
Duarte – *Chemical, Biological and Agricultural*
Pluridisciplinary Research Center (CPQBA),
University of Campinas (UNICAMP)
Sandra Maria Pereira da Silva – *São Paulo*
State Agribusiness Technology Agency, Polo
Regional Vale do Paraíba (APTA)

INDUSTRY

The Brazilian flora is considered as having one of the richest biodiversities in the world. This huge diversity in vegetable species represents a considerable potential for the sustainable development of new natural ingredients to be explored in the perfume, cosmetic and hygiene markets.

In the fragrance industry, the use of exclusive essential oils with exotic and appealing scents is one of the main ways to innovate. Furthermore, products that are of an organic, ethical and natural origin have gained more acceptance in the last few years as they are vital in guaranteeing compliance with corporate social responsibility programs.

It is worth mentioning that the Brazilian productive chain of essential oils faces great challenges especially with regard to the means for obtaining these oils, such as cultivation and/or extractivism, as well as the dispersed geographical location of plants, processing, storage, traditional and/or green extraction technologies, chemical and biological classification, product standardization, quality, and safety. It is also important to reinforce that the plant's availability, industrial production capacity (volume), and income all impact the product's

final price and are critical for the product's commercialization. Social and environmental impacts, regulation and legal aspects (access to the genetic resources), and certifications are also considered a relevant part of this process.

Another important aspect involving the productive chain of essential oils is the increasing demand for adequate management of the residues resulting from the extraction process as these byproducts may also be used for commercial purposes. Consequently, it is quite possible that new concepts and products might be developed.

The marketing perspective should also be considered as communication, legislation, customer interest, among other aspects, all deliver value to all stages of the productive chain. ■

Mauricio Cella – *Latin America Technology and*
Innovation Director, Givaudan do Brasil

Essential Oils and Medicinal and Aromatic Plants

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
ESSENTIAL OILS	Domestication and Genetic Improvement	<ul style="list-style-type: none"> Cultivars and protected varieties 	<ul style="list-style-type: none"> Biotechnological tools for pre-genetic improvement and increasing efficiency in the use of genetic resources <ul style="list-style-type: none"> Agroecological zoning, identification and systematization of candidate plants Development of gene bank Genetic selection, cloning and domestication (most productive and interesting plants) Fast and cost-effective field analysis technology for identification of specific chemical compounds 		
	Cultivation and Processing	<ul style="list-style-type: none"> Certification 	<ul style="list-style-type: none"> Cultivation technologies, propagation materials, standardization and traceability of raw materials <ul style="list-style-type: none"> Local productive systems: agroforestry systems (high tree density and “standing forest concept”) and economic agroforestry Technology for mechanized harvesting (aerial part of herbaceous and shrubby plants) Technology for raw materials traceability Drying and packaging technology (preservation of active compounds, contamination, moisture) Cultivation of plant cells and tissues in vitro Cloning of high productivity essential oil plants Standardized cultivation and domestication methodologies 		
PHYTO PRODUCTS animal health, food and pests and disease control in agriculture	Transformation and Extraction	<ul style="list-style-type: none"> Green Chemistry and Biotechnology 	<ul style="list-style-type: none"> Development and / or improvement of processes to obtain natural products using clean technology <ul style="list-style-type: none"> Inputs production by supercritical technology on industrial scale Use and destination of hydrolates Compact and modular systems for biomass bioconversion and processing in remote communities Technologies for utilization of industrial by-products Low cost moisture measurement technology for leaf, bark, root, fruits and seeds (fresh and dry) Appropriate packaging (moisture control, mechanical properties, low cost, etc.) Experimental models for clinical tests of new products Technologies and techniques for integral use of plants 		
	Product Technology	<ul style="list-style-type: none"> Formulation Fractionation, Purification and Identification 	<ul style="list-style-type: none"> Development of products containing essential oils or active extracts of aromatic and medicinal plants <ul style="list-style-type: none"> Product development: additives, antimicrobials, antibiotics, natural preservatives, new products from plant residues, others Use of bark and seed residues in the production of phyto products Low cost studies and technology for in vitro and in vivo testing In vitro screening of biological activity (fast and low cost) Use of nanoparticles in biodefensives and herbal medicinal products Optimization of technologies: formulation, encapsulation and emulsion Technology for concentration and fractionation of complex matrices Product development based on plants/substances generally recognized as safe (GRAS) Development of biodegradable packaging from plants Natural herbicide for no-till crop production Pest control products for stored products Faster and more cost-effective analytical methods 		

Precision agriculture

ACADEMIA

The concept of precision agriculture (PA), while not new, could only be made feasible on a large scale with the advent of geolocation techniques through the Global Navigation Satellite System (GNSS) together with the end of the US Department of Defense's selective availability in 2000 to the Global Position System (GPS) signal. It has become a revolutionary milestone, as it allows us to treat the agricultural field according to its spatial variability and to monitor agricultural operations.

What, then, is the role of PA in a world increasingly concerned with sustainable and low-cost production? Is it possible to design complex, large-scale systems that can simultaneously respond to demands for greater sustainability and low costs?

PA offers the potential to automate and simplify information gathering and analysis. It allows management decisions to be made and implemented quickly in small areas within larger fields. In addition, PA allows small and large landowners to better understand why this particular management system should be implemented in a particular part of the field, thereby allowing for management optimization. Consequently, PA shows potential to increase the quantity and quality of agricultural output while optimizing input usage (water, energy, fertilizers, pesticides, etc.), optimizing profits and reducing environmental impacts.

Although a wide range of enabling technologies for PA are available, there are still many gaps that need to be filled. Growers frequently face problems when trying to use PA tools that were designed by huge enterprises

for specific crops and production systems. Thus, proper equipment and techniques need to be developed for use with specific Brazilian crops and production systems. On the other hand, small landholders often do not adopt a PA approach because the currently available technology was created for large or high-tech (intensive) farmers from other parts of the globe. Thus, it is also mandatory that technology be developed looking to the particularities of the Brazilian small growers who generally are very low-technology practitioners.

Within this scope, and considering PA advances worldwide, the three main technological processes identified to address the local precision agriculture development needed to provide a rapid return on investment to growers are: soil spatial characterization, crop monitoring and site-specific pest management. ■

.....
Lucas Rios do Amaral, Paulo Sérgio Graziano Magalhães, Luiz Henrique A. Rodrigues – School of Agricultural Engineering (FEAGRI), University of Campinas (UNICAMP)

INDUSTRY

Precision agriculture has seen a booming growth over the past 10 years and will continue expanding with the introduction of new technologies that can make ever faster, cheaper and more precise measurements that in turn lead to better decision making and crop management.

The four major factors shaping *agricultural knowledge* will come from the development of: i) new agronomic technologies, ii) 4.0 technologies iii) non-controllable variables that continue to challenge farming practices around the world, and iv) the integration of the three previous factors.

Although new precision agricultural tools will continue to be developed and improved (especially in a) high resolution spatial soil characterization, b) advanced crop monitoring, and c) site-specific pest management), nowadays many actors are working on the integration of different tools that already exist to come up with more meaningful and complete solutions, easy to use and deploy in farmers' operations.

A typical framework to develop integrated solutions in agricultural knowledge will be:

1. Diagnosis: Using many different sensors and field communication technologies to make an assessment of the crop/field conditions.
2. Predictive systems: Once the assessment is made, create algorithms to simulate the evolution of the crop/field conditions in the future.
3. Prescriptive systems: Based on the simulation results, decide what will be the agronomic prescription needed for the crop/field.

4. Operation: Apply the recommended prescription to the crop/field.
5. Operation assessment: Assess the quality of the executed operation.
6. Diagnosis: Re-assess the crop/field conditions to assure the effectiveness of the prescription.

These are the main steps of a control cycle in a crop production season. This control cycle is done manually today with the assistance of some tools, but will become more and more automatic, so that it can be done once a week and eventually once a day. This is the highly integrated system of systems everyone is striving for.

There is no doubt that Brazil is one of the best places in the world for Bioeconomy from a natural resource point of view (abundance of biodiversity, sun, water and land). It has the potential to be a world leader in agricultural technology and agricultural products.

Agricultural Knowledge is set to emerge as one of the coolest jobs in the world. ■

.....
Tsen Chung Kang – New Business Research Director - Jacto Máquinas Agrícolas SA and Professor at Fatec Shunji Nishimura

Agriculture

Technology Roadmap

Precision Agriculture

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
SOIL SPATIAL CHARACTERIZATION	Spectroscopy Sensing Technologies	• Soil characterization	• Development of technologies for soil property characterization by spectroscopy (reflectance diffuse on the visible and near infrared region of the spectra, and other approaches such as laser induced breakdown, x-ray spectroscopy, mid-infrared, and impedance)		
		• Soil classification	• Development of technologies for soil classification by sensors (Apparent Electrical Conductivity sensors- ECa and Magnetic Susceptibility- MS), with further sensors application to assist soil sampling for fertility mapping, classification mapping, variable-rate irrigation, management zone delineation, etc.		
		• Remotely Piloted Aircrafts technology	• Development/improvement of RPA technologies for quantification and provision of auxiliary data		
		• Ion selective sensors	• Development of technologies for soil nutrient availability by ion-selective, as an alternative to spectroscopy (e.g. for quantifying some specific elements in the soil, such as nitrate and potassium detections, and soils samples enriched with plant nutrients)		
CROP MONITORING	RPA imagery and Spectroscopy Data Communication and Transfer Data Analysis	• Wireless sensing stations	• Development of Wireless Sensor Networks (WSN), mainly considering large scale agricultural production systems (large areas and poor infrastructure) such as in Brazil		
		• Data communication and transfer	• Debottleneck Data Communication & Transfer		
		• Data interpretation/modelling	• Development of real-time data interpretation and modeling systems based on diverse sensor signals in order to predict a future occurrence, as well as indicate a certain management practice to be adopted in the proper time		
		• RPA for monitoring and provide auxiliary data	• Development/improvement of RPA technologies for monitoring and provision of auxiliary data		
SITE- SPECIFIC PEST MANAGEMENT	Modelling Sensing technologies Data Management and Support Decision Tools	• Intelligent insect traps	• Development of intelligent insect trap technologies for monitoring and predicting (pest/disease monitor)		
		• Pest alerts by modelling	• Development of pest alerts and/or disease infestation by modeling based on weather forecasts and/or sensing readings		
		• Autonomous site-specific manage	• Development of autonomous site-specific management systems in order to indicate a certain management practice to be adopted at the appropriate time		
		• RPA for variability identification and provide auxiliary data	• Development/improvement of RPA technologies for variability identification and provision of auxiliary data		

Animal system production: low carbon livestock

ACADEMIA & INDUSTRY

World leadership in beef exports, based on the world's largest cattle herd and on its predominant and extensive animal production systems, has required from Brazil new strategies to overcome its challenges in order to reach new markets, increase quality and productivity, and ultimately provide greater profitability throughout the supply chain. Recently, several factors have contributed to the increased competitiveness of Brazilian beef, including advances in animal breeding and management techniques, nutrition, and marketing. Despite the advances, the biggest obstacle is the still low productivity, because despite having more than twice as many animals as the USA, the Brazilian slaughter rate is still low.

In the context of animal breeding, weight, or weight gain, and reproductive efficiency are characteristics considered in selection criteria of almost all beef cattle programs, because this information is easy to obtain and has a high accuracy and correlation with the carcass weight. Young animal carcasses with higher muscle deposition and cover fat tend to bring better prices. Although this is a necessity, these features are not yet widely considered in cattle breeding programs.

In beef cattle production systems, diet represents a strong determinant of animal performance through the quality and quantity of nutrients ingested. As feed represents the most economically important item within meat production systems, and being one of the main factors responsible for fluctuations in profitability, improvements in the efficiency of feed use as well as its nutrients should always be pursued. An alternative to improve profitability in beef production is the breeding selection using characteristics of feed efficiency combined with fertility and precocity of the animal. However, the difficulty in measuring individual

feed intake in beef cattle has made selection based on these traits neglected to this day. Another reason for this shortcoming in breeding programs is that it has always been assumed that efficiency would be closely correlated with the gain rate. Recent results from cattle efficiency studies make clear the need to emphasize reducing inputs to increase efficiency and maximize profitability of the production system as a whole. This becomes even more relevant when the reduction of the use of natural resources as well as the reduction of the generation of pollutants (manure, methane, etc.) per unit of meat produced are a necessity, both economically and for the positive marketing of beef.

The possibility of improving production efficiency, coupled with sustainable actions, by exploiting the genetic variation in residual feed intake (RFI), and the possible variation in greenhouse gas emission (GHG), depends not only on the existence of genetic variation of this trait in young animals, but also on the magnitude of the genetic correlations with the principal economic factors for beef cattle. This trait needs to be extensively studied and should combine carcass and meat quality characteristics in order to obtain better quality and more affordable meat.

However, limited knowledge regarding the biological control mechanisms and the prohibitive costs of obtaining large-scale RFI have resulted in little progress in implementing these characteristics in breeding programs. In addition, many discussions have taken place regarding the RFI phenotype being diet-specific. There is certainly limited information on RFI repeatability as well as associated characteristics measured at different stages of the production cycle, which is extremely necessary for the selectors to adopt this feature on a large scale. It is essential to understand the relationship of diet performance by grazing intake and feedlot

intake for selecting more efficient animals, and thus meet consumer demands for higher quality and sustainable beef production.

It is also essential to stimulate research and increase efforts on training and extension in order to expand existing knowledge and technologies. New research should be integrated for improving the quality of life in rural areas, adding value, soil quality and environmental restoration, conservation and protection.

Given the unprecedented increases in food and energy costs, and the overall volatility in production costs, it is urgent to identify sustainable alternatives to reduce the cost of beef production (mainly in high quality beef systems). There are pros and cons to many different approaches to improving food efficiency, and many strategic benefits to industry in adopting RFI as a preferred metric. It has great advantages and the poten-

tial for improvement in response to genetic selection and in response to improvement in specific aspects of nutrition. By improving and refining knowledge of the physiological factors of RFI variation, it can improve management strategies and genetic selection, sustainably increasing performance and productivity. ■

Renata Arnandes, Linda Monica Premazzi,
Flávia Maria A. Gimenes – *Animal Science Institute (IZ)*
Antônio Batista, Ana Eugênia de
C. Campos – *Biological Institute (IB)*
César de Almeida Franzon – *Director of*
Market Development, CRV Lagoa

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
ANIMALS PRODUCED IN LOW CARBON EMISSION PRODUCTION SYSTEM	Production systems	• Production systems	<ul style="list-style-type: none"> Development of integrated production systems: crop-livestock (ICL), crop-livestock-forest (ICLF) and livestock-forest (ILF) <ul style="list-style-type: none"> Definition and implementation of productivity and sustainability indicators for integrated systems (plant and animal components) Identification of pests and diseases in integrated production systems Grass-legume consortium Regional technical-economic feasibility studies of the different integrated production systems 		
		• Recovery of degraded areas	<ul style="list-style-type: none"> Development of techniques and technologies for the recovery of degraded areas <ul style="list-style-type: none"> Biological fertilization for improving microbiome biodiversity and soil restructuring Integrated production systems 		
	Animal feed and nutrition	• Additives and supplements	<ul style="list-style-type: none"> Development of nutritional additives and supplements for animal nutrition <ul style="list-style-type: none"> Study and development of new nutritional additives: reduction in enteric methane emission and increased animal performance Use of agricultural residues, agroindustrial by-products and new raw materials for ruminants feed (bagasse, grain processing by-products, bran, sugar cane filter cake, algae, etc.) Ruminal microbiota modulation to maximize dietary nutrient utilization Use of plant extracts as animal supplementation for nutraceutical purposes (e.g. antimicrobials) Use of fibrolytic enzymes in fibrous raw materials 		
		• Forage	<ul style="list-style-type: none"> High quality forage development: lower fiber content and higher digestibility 		
	Genetic	• Animal genetic improvement	<ul style="list-style-type: none"> Genetic improvement <ul style="list-style-type: none"> Genotype and phenotype database construction Assessment and obtention of appropriate genetics for different regions and production systems (e.g. high productive efficiency, disease resistant, low carbon emissions, etc.) Improvement of breeding biotechniques Low cost genotyping analysis 		
Animal health	• New products	<ul style="list-style-type: none"> Development of new veterinary products <ul style="list-style-type: none"> Generation of molecular data (genomes, transcripts) of endo and ectoparasites and creation of a database for prospecting immunogenic molecules by in silico analysis Development and testing (in vitro / in vivo) of vaccines (endo / ectoparasitoses) and preventive measures Development of models of production systems with minimal use of microbials Development and testing of plant extract antibiotics with antimicrobial properties Development and testing of natural products (antiparasitic, therapeutic, biological control and other drugs) for animal health improvement 			

II.1.5

Sustainable use of water

ACADEMIA

Brazil holds about 12% of the world's surface freshwater. However, the availability of water resources in the country is irregular and is concentrated in the Amazon River Basin, which has about 78% of the country's total flow.

In the remaining 22%, primarily near metropolitan regions, the situation of the streams and bodies of water is worrisome because most are polluted. In these environments, even if the volumes are sufficient to meet the demand, consumption is made unfeasible by physicochemical parameters, such as the presence of heavy metals. This will have a major impact on human health, the economy and the environment over the coming decades, potentially undermining the population's water supply, power generation and industrial and rural activities, as well as fauna and flora.

In order to avoid situations of water scarcity and irreversible damage to the environment, it will be crucial to intensify and modernize water resource management processes in the country, taking into account sustainability aspects at different levels of water users in order to ensure the quality and sustainability of the amount of water required for agricultural, urban and industrial use. To achieve this, it will be necessary to undertake directed research, improve skills and develop processes and technologies in the following areas: water management, irrigation, reuse of agricultural effluents and reduction of diffuse loads.

In this context, challenges to achieving water sustainability include technological and non-technological aspects.

Regarding technology, we highlight the techniques and/or technologies for using treated sewage in agriculture (treatment systems, logistics systems, appli-

cation techniques and environmental and biological monitoring), irrigation and crop management (reduction of input use, no-till, adoption of water deficit irrigation, precision irrigation, higher intensity irrigation management techniques and in different degrees), and water resource management (catchment and reservoir, qualitative-quantitative monitoring, data transmission, management software watersheds and decision-making tools).

It is noteworthy that there exists scientific and technological knowledge related to water sustainability and management in Brazil and abroad, as well as the scientific and technological capacity to develop products and processes, generate knowledge and qualify human resources at federal, state, municipal and non-governmental levels (initiative and social organizations). However, further advances require greater organization, prioritization and integrated planning of the water resources in the country.

In the non-technological context, the highlights are actions that encourage rational and sustainable use of water in all sectors, expand capacitation and seek to integrate and share sector information, as well as minimize conflicts in the exploitation of natural resources (soil and water). ■

Regina Célia de Matos Pires – *Agronomic Institute (IAC)*
José Teixeira Filho – *School of Agricultural Engineering (FEAGRI), University of Campinas (UNICAMP)*

INDUSTRY

It is commonly stated that up to 70% of the water supply is used to irrigate different crops. The hydrologic cycle that shows that a significant part of all water consumed by agriculture returns to nature is not always well or widely understood; the consumptive use of water concept must be better explained, to change the perception that irrigation is a "villain" when it comes to water consumption. Even though only 20% of the total arable land in the world is irrigated, it is responsible for more than 40% of the overall food production. As populations grow, irrigation becomes an important tool to guarantee food security in the world.

The irrigation industry in Brazil is fully aligned with sustainability, concentrating mainly in two areas. The first one is related to the equipment itself; companies are always developing better products and systems, aiming at higher water application efficiency. The second one refers to water management, which includes sensors, softwares, and agronomical knowledge (soils and crops) that indicate when and how much water should be applied at any given time.

A recent development in the industry is the growing number of startups involved in water management for irrigation. These companies are internet based and ad-

vise growers regarding the correct amount of water to be used. The utilization of drones to monitor the water application efficiency in the field is another growing trend, including infra-red thermometry techniques, helping to evaluate and correct eventual problems in the irrigation systems.

Drip irrigation, generally utilized in vegetables and row trees (coffee, citrus, fruits), is becoming common in sugarcane and commodity crops such as soybeans and corn. The high efficiency associated with drip systems (up to 95%) is another advance to minimize the water usage on such large scale crops.

The combination of equipment and management techniques is part of the future of irrigation. The intelligence (agronomical know-how) connected with sophisticated hardware (higher efficiency) will allow us to minimize the amount of water applied while maximizing production. ■

Marcus Henrique Tessler – *Netafim*

Agriculture

Technology Roadmap

Sustainable Use of Water

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
WATER QUALITY AND QUANTITY agricultural, urban and industrial uses	Water Resources Management	<ul style="list-style-type: none"> Water Resources Management and Risk Reduction Monitoring: Quality and Availability 	<ul style="list-style-type: none"> Development of water resource management and risk models <ul style="list-style-type: none"> Integrated database: soils, hydrological data, satellite images and climate data Groundwater exploration map Adequacy of water resource management models in river basins, scenario simulation and decision making: impacts of water quality and availability (GHG emissions, local productive activities, quality of life) and climate change - short, medium and long term perspectives Development of technologies and models for monitoring water quality and availability <ul style="list-style-type: none"> Development and implementation of national technology for real-time monitoring of water quality in water bodies (including diffuse loads) and water use - reliability, durability and low cost Identification of strategic monitoring points (water and climate) Development of models and systems for forecasting and extreme events alerts 		
	Irrigated agriculture	<ul style="list-style-type: none"> Water management technologies Management and decision making tools Digital agriculture and field connectivity 	<ul style="list-style-type: none"> Development of technologies for management and control of water use in agriculture <ul style="list-style-type: none"> Agronomic technologies: water-efficient genetic materials, deficit irrigation, water and nutrient efficiency in irrigated agriculture Irrigation technologies: precision irrigation, low cost technology packages and energy consumption (small farmers and horticulturists), sensors and connectivity (accessibility and low cost) Water management and use models for different crops: performance and efficiency of available irrigation methods, water use optimization and nutrient management models 		
	Diffuse loads	<ul style="list-style-type: none"> Characterization and modeling 	<ul style="list-style-type: none"> Management and impact of agricultural activities on the generation of diffuse loads <ul style="list-style-type: none"> Studies of the impacts of agricultural activities on river basin mass flows (hydrological regimes and balances, allocation of water resources, erosion dynamics, changes in water quality, others) Impact assessment on water and soil quantity and quality as a function of land use change and pollutant dispersion Development of models to prevent and mitigate the effects of diffuse loads on the environment Development of techniques and protection / barrier devices to contain diffuse loads, including incorporating degraded area restoration and soil conservation techniques 		
	Effluent use in agriculture	<ul style="list-style-type: none"> Effluent use and efficiency improvement 	<ul style="list-style-type: none"> Development of technologies for adoption and monitoring of reused water use in agriculture <ul style="list-style-type: none"> Development of filtration technologies and treatment of contaminants (microorganisms and drug residues) for fertigation uses New techniques and technologies for the application of wastewater in agriculture;; National technologies and systems for monitoring soil and water quality in different environments Sanitary studies of the use of effluents in fertigation, including the use of urban effluents Feasibility study of the use of effluents in agriculture, including logistics and environmental aspects 		

II.1.6

New Bioeconomy Industry: Coffee

ACADEMIA

The Brazilian coffee agribusiness has a total turnover of around of 5.2 billion dollars, in a production chain that goes from nurseries to retailers. In the state of São Paulo, coffee is one of the top ten agricultural activities, involving around 1 billion dollars per year. The national coffee production is supported by a strong regulatory system headed by federal government agencies, in areas including trading policies and funding to support rural producers and processors during crisis, as well as strategic interests for boosting the sector. In the last 30 years coffee production has increased significantly, from 27 million bags in 1990 to 50 million bags in 2018, supplying a very well-structured and booming market. The coffee plantation area has been reduced by half a million hectares, due to the development and introduction of more productive cultivars, which are suitable for dense cultivation, resistant to biotic and abiotic factors, and allied with appropriate plant nutrition, in addition to the adoption of topnotch management crop practices and the use of new harvesting and pre-treatment technologies. The growth in Brazilian coffee production is the result of the well-developed national breeding programs.

In parallel to the development and implementation of suitable agronomic techniques, modern society has changed its lifestyle. The new demands of consumers include detailed information about the product, highlighting certification of purity, roast point declaration, sensory analysis, cultivar characteristics, rural

production identification (i.e. quality assurance), and [the] full traceability throughout the entire production chain. The requirement for higher quality has led to improvements in the pre-treatment and processing of raw coffee, including carbonic fermentation, use of selected microbial strains during the sun drying process, and the storage of green coffee in barrels, among others. Today the majority of coffee consumption is in the form of a drink, however interest is growing in the exploration of raw coffee and the processing of by-products, mainly for formulation of energy drinks, cosmetics, additives in personal care products, building materials, bioenergy, and natural antibacterials. There are well-developed technologies (in some cases, in progress) to improve the efficiency of the coffee production system and make feasible the full conversion of the coffee bean, improving the sustainability of the entire production chain. However, it is crucial to strengthen relations between the actors along the production chain, increase investments and accelerate efforts in research, training and technology transfer. ■

.....
Júlio Cesar Mistro, Maria Bernadete Silvarolla, Terezinha de Jesus Garcia Salva, Julieta Andrea Silva de Almeida, Oliveira Guerreiro Filho, Gerson Silva Giomo – *Agronomic Institute (IAC)*

INDUSTRY

Coffee plantations have expanded to some traditional areas previously used for pasture and to plant soybeans, corn, and sugarcane, indicating the opportunities, the great potential and the strength of this crop in several Brazilian regions. Brazil is the largest coffee producer worldwide and the majority of our production is commercialized as a commodity. This scenario emphasizes the necessity of improvements in marketing, mainly by taking into account high quality coffee beans.

We are moving towards a segmentation of the activities along the coffee production chain, aimed at improving efficiency and adding value, and supported by continuous new practices and techniques from the field all the way to the consumers' coffee cup. New management techniques (plant spacing, nutrition, etc.), aligned with mechanization technologies and new cultivars, have allowed for increased productivity. New post-harvest concepts have added new flavors to Brazilian coffees, and opened new markets that favor unique coffees with unique characteristics.

Advances in genetic breeding is the key to sustaining the growth of national coffee production, making it possible to obtain higher yield cultivars, higher quality grains, and cultivars better able to tolerate pests and diseases. The need for traceability has posed a new challenge for the sector, making many companies verticalize the entire production process, thus ensuring greater control of coffee quality, from beans to coffee cups. The application of new controlled fermentation techniques has brought sensory improvements (more complex flavors and aromas), thus making it possible to add value to products and access new consumers.

More elaborate processes for the preparation of coffee have also been adopted, including the use of peeled cherries, honey and carbonic maceration. Solid coffee residues have a great potential to increase income much higher than the current composting, among others, highlighting the production of soluble fiber for the chemical or animal nutrition industry, as well as second generation ethanol. Another important alternative that can be developed includes the use of low quality coffee beans, such as green, sweeping and black coffee, in the nutrition, mineral, cosmetic and chemical industries.

Certainly a greater penetration of coffee in the pharmaceutical and food and beverage industries should also occur in the coming years. Given this scenario, it is evident that increasing the supply of new cultivars, processes and technologies will be crucial for the growth of the sector, primarily because it makes it possible to increase the financial return to the producer and thus encourage new investments. ■

.....
André Cunha – *coffee producer in Cristais Paulista, São Paulo State, and Vice President of the Alta Mogiana Specialty Coffee Association (AMSC)*
Tuffi Bichara – *coffee producer in Monte Alegre do Sul, São Paulo State*
Daniella Pelosini – *coffee producer in Pardinho, São Paulo State*

PRODUCTS		LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
NEW CULTIVARS <i>Coffea arabica</i> and <i>C. canephora</i>	Genetic improvement	<ul style="list-style-type: none"> • Marker-assisted selection • Cultured leaf segments and Somatic embryogenesis • Clonal and hybrid cultivars 	<ul style="list-style-type: none"> • Plant selection assisted by genomic markers as a tool to reduce cultivar development time 			
			<ul style="list-style-type: none"> • Multiplication of hybrids / individuals through culture leaf segment and application of somatic embryogenesis 			
			<ul style="list-style-type: none"> • Development of new clonal and hybrid cultivars through classical breeding using male-sterility in F1 seed production as a tool to reduce cultivars development time 			
RAW MATERIALS AND PRODUCTS FOR FOOD, BEVERAGE AND PHARMACEUTICAL USES	Co-products processing	<ul style="list-style-type: none"> • Microbiology • Extraction • Disinfection / Drying • Formulation • Coffee extract • Processing 	<ul style="list-style-type: none"> • Development of biotechnological processes to obtain inputs and products from the metabolism of microorganisms: non-mechanical pulping of grains, grains treatment (pre and post beneficiation) to improve physical and sensory quality, etc. 			
			<ul style="list-style-type: none"> • Development of extraction technology for active compounds and obtaining flour from coffee pulp and husk for different applications (e.g. use in the pharmaceutical and food and beverage industries: antioxidants, lipids, pectins, caffeine, flavorings, waxes, food fibers for human and animal consumption, abrasives, etc.) 			
			<ul style="list-style-type: none"> • Development of processes and equipment for coffee pulp and husk disinfection / drying- conservation and new uses (e.g. teas and other alternative products) 			
			<ul style="list-style-type: none"> • Development of new products based on coffee flour from shell and pulp (insoluble fiber) 			
			<ul style="list-style-type: none"> • Development of process for obtaining coffee extract from pulp and husk with potential use in energetic beverages, functional foods and veterinary antibiotic 			
			<ul style="list-style-type: none"> • Development of processes for harnessing low commercial value defective grains to obtain chemical compounds for the food and pharmaceutical industries 			
COFFEE BEAN WITH COMMERCIAL ADDED VALUE	Green coffee bean treatment	<ul style="list-style-type: none"> • Fermentation • Alternative treatment 	<ul style="list-style-type: none"> • Controlled fermentation as a tool for producing coffees with differentiated sensory profiles 			
			<ul style="list-style-type: none"> • Alternative treatment of benefited grain by physical and / or chemical processes aiming at improving quality and increasing commercial value (e.g. treatments with water, enzymes, steam and coffee waxes) 			

New Bioeconomy Industry: Citrus

ACADEMIA

The world citrus industry represents a remarkable agricultural system from farm to table, producing oranges, mandarins, limes (acidic or sweet), grapefruits, pummelos and other related fruits in more than 140 countries. It supplies the fresh fruit market as well the processing plants of either frozen concentrated orange juice (FCOJ) or not-from-concentrated (NFC) juice. The total citrus production in the world ranks first among all other cultivated tropical to temperate fruits.

This industry is also of great relevance in Brazil, producing approximately 20 million tons of fruit yearly and providing more than 80% of global exports of orange juice, which demonstrates its significant capability and competitiveness in the agribusiness.

Indeed, the total Brazilian orange crop production forecast of 388 million boxes (40.8 kg per box) for the 2019-2020 season points out the increasing productivity (>1050 boxes per ha) attained by citrus growers year by year, and which is unmatched by any other growing area in the world. Despite such success, the potential yield of trees is still limited by biotic (pests and diseases) and abiotic (drought and excess temperature) stresses, which in several cases depends on genetic characteristics of the rootstock and canopy varieties. Taken together, these have also caused unevenness in fruit quality (acid and sugar content) and

irregular distribution in fruit maturation, which also impacts production costs.

Comprehensive research opportunities exist in the field of citrus including: genotyping and breeding of new potential varieties that are resistant/tolerant to abiotic and biotic stress, highlighting the occurrence of huanglongbing (HLB); characterization of physiological processes and factors determining environmental tree responses; metabolite profiles; and soil and horticultural management of orchards, including irrigation and fertilization.

The consolidation of a scientific and technical network developed in recent years has still to be further fostered for the development of a range of projects oriented by a joint council, established within drivers for identified technological areas, and developed in the short and long term, which is inherently necessary for a perennial crop. ■

.....
Dirceu de Mattos Jr, Marcos Antonio Machado,
Mariângela Cristofani-Yaly – *Sylvio Moreira*
Citrus Center, Agronomic Institute (IAC)

INDUSTRY

The global citrus consumption, either as fresh fruit or juice, moved agriculture and industry to invest heavily in the production chain to satisfy consumers' demand for a nutritious food.

Despite differences between the two commercialization markets, the overall citrus industry relies on the availability of high quality fruit, which has been limited due to the increased pressure imposed by pests and climate change in the orchards, consequently causing increased production as well as consumer costs. Moreover, the consumption of orange juice, a major product in the Brazilian citrus industry, has been declining by about 4% per year as a result of inaccurate information on the health benefits to consumers, high prices, and competition from other beverages such as other fruit juices, punches and carbonated drinks.

Taking these factors all together, it becomes clear that there is a need to increase productivity of high quality citrus fruits in the orchards in order to sustain this highly important agribusiness. This will be made possible by integrating agricultural and industrial visions regarding production strategies in the field. New citrus varieties with superior horticultural characteristics and tolerance/resistance to biotic and abiotic stresses are required in the modern citrus industry, as well as employing better management practices in areas such as planting to orchard maintenance.

Such practices include management of plant architecture, water and nutrients, growth promoters, chemical and biological molecules for crop protection, and harvesting. These in turn must be associated with the capacity to track the aforementioned activities, as a major tool for certifying the environmental and social sustainability of the production chain, which is driven by public opinion concerning food security.

For these visions to lead to the development of innovative processes and products, the efforts of scientists, producers and industry must be coordinated within priority themes, and be addressed by creating outstanding work programs that include evaluation, monitoring and validation of research. The productive sector must then promote and sustain this type of initiative, so that the results can be achieved and transferred in an objective and effective way. ■

.....
Ricardo Franzini Krauss – *General Manager of*
Sucorrico Citrus and Agricola Industrial Ltda

PRODUCTS		LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
HIGH QUALITY CITRUS	GERMPLASM OF CITRUS & SCALING UP OF NEW ROOTSTOCKS	Genetic improvement	<ul style="list-style-type: none"> New hybrid genotypes 	<ul style="list-style-type: none"> Research for improvement of citrus rootstocks focused on obtaining new hybrid genotypes from controlled crossing of elite cultivars <p><i>~300 genotypes available</i></p>	<p><i>~600 new genotypes</i></p>	<p><i>At least 10 % become cultivars (genotypes used for commercial proposal)</i></p>
		Genetics and Genomics	<ul style="list-style-type: none"> Genotyping tools 	<ul style="list-style-type: none"> Development of genotyping tools with pre-defined molecular markers (SSR, microsatellites), or GBS (genotyping by sequencing), for the selection of hybrids <p><i>Less than 100 genotypes available</i></p>	<p><i>Over than 500 genotypes</i></p>	<p><i>Data base of genomics and genetic markers</i></p>
		Bioinformatics	<ul style="list-style-type: none"> New tools for genotyping 	<ul style="list-style-type: none"> Development of new tools for genotyping, whether for genome or transcriptome analysis, or for genetic mapping <p><i>Tools available</i></p>	<p><i>New tools for big data</i></p>	<p><i>Data base available</i></p>
	FRUIT QUALITY	Biochemistry, chemistry and metabolism	<ul style="list-style-type: none"> Chemical and nutritional traits versus management 	<ul style="list-style-type: none"> Construction of interaction models correlating chemical and nutritional traits versus management <p><i>Basic industrial traits (color, °Brix, ratio)</i></p>	<p><i>Physical and chemical traits</i></p>	<p><i>Physical, biochemical and nutritional traits characterized</i></p>
		Healthy management	<ul style="list-style-type: none"> Chemical and nutritional traits versus HLB 	<ul style="list-style-type: none"> Construction of interaction models correlating chemical and nutritional traits versus HLB <p><i>Unknown mechanism of HLB on fruit quality</i></p>	<p><i>Known mechanism</i></p>	<p><i>Control of HLB on fruit quality</i></p>
		Crop management	<ul style="list-style-type: none"> Chemical and nutritional traits versus rootstocks 	<ul style="list-style-type: none"> Construction of interaction models correlating chemical and nutritional traits versus rootstocks <p><i>Basic industrial traits (color, °Brix, ratio)</i></p>	<p><i>Physical and chemical traits</i></p>	<p><i>Physical, biochemical and nutritional traits characterized</i></p>
	STRESS EVENTS AND NEW CONTROL APPROACHES	Plant physiology	<ul style="list-style-type: none"> Stress temperature and fruit quality 	<ul style="list-style-type: none"> Construction of interaction models correlating stress temperature and fruit quality <p><i>Unknown effects</i></p>	<p><i>Known mechanisms</i></p>	<p><i>Full integration of information and construction of interaction models between different factors involved in the fruit development processes</i></p>

Food & Health

Luis Fernando Ceribelli Madi – Institute of Food Technology (ITAL)

In the last 50 years, food science and technology have evolved in a fantastic way, and so today's food products and beverages are safer and more nutritious. On the other hand, the general population has difficulty seeing this positive evolutionary process, having the perception that the food of the past, "Grandma's cooking", was healthier and more nutritious: pure myth! Which is more valuable: perception or reality?

In this regard, the communication process will be one of the most relevant and strategic themes for the coming years, considering that in the next ten years the transformations will be even more disruptive. According to several experts, the changes that will take place until 2030 will be much greater than those that have occurred in the last 50 years, not only in the production processes of food and beverages, but also in their distribution and consumption.

Science and technology will be increasingly fundamental to guide the evolution of the sector, but it will also require communications that are more connected with social media and meet the demands of society, especially generations X, Y (millennials) and Z: connectivity will be the key element to achieve sustainable growth.

In line with these demands, ITAL has been working, through the *ITAL Series Brasil Trends 2020* (<http://ital.agricultura.sp.gov.br/publicacoes/#acesso-livre>), in partnership with the private and public sectors, seeking to identify opportunities and challenges for the food and beverage sector for the coming years. *Brasil Food Trends 2020*, launched in May 2010 at FIESP (Federation of Industries of the State of São Paulo), was the first such study and observed the "convenience"

and "practicality" trends as the most important for the Brazilian consumer. The most recent study, *Industrialized Food 2030*, sought to follow, step by step, all the recent transformations, in line with the efforts in research, development and innovation for the benefit of the consumer and society.

Through this series of studies, it was possible to observe that, now in 2019, the themes "healthiness" and "well-being" are priorities and food has become a strategic tool to create a healthier population.

By 2030, it is expected that the themes "sustainability" and "ethics" will be in the foreground, especially in light of the recent events related to climate change worldwide.

In order to explore the main opportunities for the Brazilian food and beverage sector and the scientific and technological advances required in this new scenario, three potential areas were identified:

- Ingredients and functional food processes.
- New packaging for food and beverages.
- Processing technologies for food and beverages.

In the following chapters, the technological roadmaps developed for each area are presented, so that Brazil, and its food and beverage sector, can be able to take advantage of existing opportunities and promote the necessary transformations. ■

Ingredients and functional processed foods

ACADEMIA

Over the last decade, the development of new ingredients with functional properties has been expanding the functional products market more than the food and drink sectors as a whole. The market for ingredients and functional foods will continue to grow in the coming years because consumers increasingly seek health benefits through their daily diets. However, it is uncertain whether this growth will be similar to that observed in recent years because there are important limiting factors that can interfere with this growth, such as conservative regulatory systems and a lack of proper communication with the consumer.

The growth of the functional foods market will create new products with high aggregated value, increase the number of formal jobs and cause a GHG reduction due to the increase in industrial productivity. Brazil, being one of the largest food producers in the world and having great biodiversity, a considerable infrastructure of science and technology, and a developed industry, has the opportunity of assuming an increasingly relevant role in the development of new functional ingredients. One example is the isolation of bioactive compounds from waste and by-products of the food production chain, as well as from its biodiversity. Another example is the creation of a multidisciplinary center to support and validate the scientific proof of functional properties, with a unique alignment with international standards.

For that to happen, it will be necessary to invest in RD&I, mainly in areas such as: encapsulation; nutritio-

nal genomics; identification, extraction and purification of bioactive compounds; nanotechnology; organic synthesis; fermentation; gut microbiome; and synthetic biology. It will be also necessary to improve the access of small and medium-sized companies to the necessary technologies for food processing and quality analysis. There will also be a need to develop studies focused on the identification of validated biomarkers of exposure, effective use of emerging “omics technologies”, identification of biomarkers, and molecular procedures to demonstrate the efficacy and safety of bioactive compounds.

However, the most important need is for Brazil to create a reliable business environment, to construct and implement a national plan for the development of ingredients and functional food, and also to construct a marketing strategy to explain to consumers and society as a whole the real benefits of functional foods, helping them to feel less confused. We must focus on studies to create quantitative data regarding technological as well as non-technological issues that need to be solved. These studies will provide input for new decision points in the medium term. ■

Airton Vialta, Luis Madi – *Institute of Food Technology (ITAL)*

INDUSTRY

The industry of functional and nutraceutical food ingredients arrives at the beginning of the 4th industrial revolution with a new scenario, one that could not be more challenging. Humans now live longer, doubling, or even tripling, the limit of the longevity barrier. Human consumption needs have gone from the prosaic needs of shelter and food to needs of self-esteem: the market is focused on the individual, individual recipes, specific ingredients, personalization taken to its most egoic. How will a food and beverage industry meet these capricious and selective needs, confronted by the expectation that in some fifteen years it will have to feed and nourish 10 billion mouths?

The answer is technology, or in the methodical application of food science expanded by nanotechnology, genomics, molecular biology and their near miracles. By intervening in the basics of the engineering of life, where it is developed and begins to structure itself, right there we must observe, manipulate, learn and imitate mother nature and its artificial constructions and architectures to create and develop this truly challenging force of universal entropy: life itself in its desire to sustain itself.

With artificial intelligence, the Internet of things (IoT: machines teaching machines with only human monitoring) directing and showing with their infinite creative capacity how to integrate this immense mutant algorithm, constantly fed by a huge database, which at each moment becomes more complex and filled with puzzles to be solved, will lead to solutions that today are so challenging.

The workshop discussions not only elucidated and organized the main research and industry current demands, but also, in a rational and systematic way, pointed out paths that will need to be empirically tested, as there is so far no ready recipe!

Although complex computational models can hypothetically test dozens or even hundreds of hypotheses, these will always be hypotheses to be qualified, tested by the fire of reality, which changes every second.

Although consensus has not always been reached, there has always been an open debate of ideas, a commitment to the collective issues and to the time that urges and devours inappropriate solutions.

Finally, the importance of science and technology has been contextualized and detailed in the chapters of this work, and can be appreciated and serve as a basis for the next challenges that await our species in terms of nutrition, healthiness, sustainability and permanence in face of the disproportionate scarcity of natural resources in the times to come.

The real needs to promote basic and applied research, qualification of labor for new technologies, infrastructure financing, availability of qualified interdisciplinary forums were pointed out, where, by confronting the proposals and debating ideas, we will arrive at the necessary solutions. ■

Eduardo Carità – *Director of Technology and Innovation, Funcional Mikron*

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS		CURRENT (2018)	2030	VISION (2050)
INGREDIENTS, PROCESSING AND PRODUCTS	New parameters and processing technologies	• Processes		• Development of unconventional methods for food and beverage processing: high pressure, ohmic heating, electrical pulse, irradiation, microwave, membranes and others		
		• Automation		• Increase the level of automation in food and beverage processing technologies		
	Microencapsulation	• New techniques		• Development of new techniques and technologies for microparticles production		
		• New materials		• Development of new structure wall materials		
	Nanoencapsulation	• Scaling up		• Increase capacity to scale up the particles production		
		• Analytical		• Increase analytical capacity		
	Nutritional genomics	• Ohmic technology		• Development of ohmic technologies		
		• Human microbiome		• Improve knowledge regarding human gut microbiome		
Synthetic biology	• Microorganisms		• Development of more efficient microbial chassis			
	• Engineering		• Increase engineering approach to biology			
Organic synthesis	• Microorganisms		• Development of analytical technologies			
	• Organic catalysts		• Development of organic catalysts			

Food and beverage packaging

ACADEMIA

Society has posed a major challenge for the packaging industry: to match safe, affordable food for the entire population with long shelf life based on safe and sustainable packaging, in line with circular economy concepts. In this sense, there are significant problems to be overcome, especially in the scientific and technological fields.

In Brazil, given the diversity of existing raw materials, their important role in loss reduction and food safety, their impact on the environment and their participation in the economy, it is crucial to intensify efforts in the development of packaging technologies to meet the demands of the food and beverage value chain as well as those of end consumers.

This scenario creates great opportunities for research and for new business in the areas of innovative materials, processes and technologies such as sensors, smart tags, tracking systems, two-dimensional coding and a variety of communication technologies. In this regard, the main opportunities and major innovation potentials for the packaging sector have been identified: technologies that ensure food safety, high-performance packaging, renewable material packaging, and smart and active packaging (aggregation of functionality).

Renewable materials, such as biopolymers and advanced materials from nanocellulose, have a growing share of the packaging market, but still face major challenges in replacing fossil-fueled food packaging, particularly in terms of functionality and cost requirements. The diversity of chemical components available in biomass should be researched to replace conventional packaging production materials and processes.

Active and intelligent packaging must overcome the limitations of conventional packaging in food preser-

vation and control, and in communication with the distribution and marketing chains, as well as including consumer interaction. Active components and new technologies should be added to existing packaging, which will require multidisciplinary knowledge.

Technological developments in food preservation processes, the need to address current (and future) environmental issues, and the growing launch of new products have required constant modification of existing packaging as well as the development of new materials to be transformed into high performance food packaging.

As a consequence of the development of new materials, new manufacturing processes and new conditions of use, it is essential to assess the potential for chemical contamination of food via packaging in order to ensure consumer safety. Thus, the development of new food safety material, process and technology assessment protocols is a major challenge to be overcome.

In addition to technological challenges, economic and regulatory issues must also advance to enable the development, production and large-scale use of safer and more sustainable packaging in the food and beverage industry worldwide. ■

.....
Eloisa Garcia, Sílvia T. Dantas, Aline B. Lemos, Ana Paula R. Noletto, Anna Lucia Mourad, Beatriz M. C. Soares, Claire Sarantópoulos, Leda Coltro, Marisa Padula – *Packaging Technology Center (CETEA), Institute of Food Technology (ITAL)*

INDUSTRY

The current text is a result of an impressive collaboration across a number of players from the packaging industry value chain, including from academia, technology institutes, regulatory agencies and major industries in different sectors (chemical, conversion, pulp and paper and food additives, among others) that have all discussed and proposed actions to deliver the most sustainable, safe and efficient packaging.

The food industry in Brazil and around the globe has the important challenge to feed the growing world population with healthy and safe food. This will only be possible if we, as key owners of packaging technology development, deploy resources with a focus on obtaining solutions that make it possible to effectively reduce food waste, which is by far the most crucial challenge we will face in the coming years. Food waste is mostly associated with deterioration processes, which involve chemical, biochemical and physical reactions as well as microbiological growth and biological attacks. Packaging provides product protection against these environmental actions and reactions, significantly reducing losses of in natura and manufactured foods. An adequate performance of packaging systems is especially required in countries like Brazil, considering its climate and geographic extension. High performance packaging is what determines food and beverage expiration dates, consequently affecting the food industry logistics and therefore strategies for allocating food processing assets. Besides preventing deterioration and degradation, proper packages also play an important role in assuring food safety after employing conservation processes, whether thermal, high pressure, oxidative, or any other.

It is an effort that goes from the farmers up to the retailers and consumers, including the implementation

of the circular economy concept to make it more effective. The use of Life Cycle Analysis (LCA) to determine the carbon footprint for the most relevant food chains must be determined and the best solutions implemented to mitigate GHG emissions, based on in-depth technical aspects. Packaging for the food and beverage industry in Brazil must rely on a holistic approach among the key players in the packaging value chain for a fruitful dialogue and intense collaboration in the development and implementation of effective solutions.

Novel packaging to deliver proper functionality for each of the different world populations will be required. This will require correct proportions, innovative designs and new functionalities to enhance customer experience, including easy opening and release, new reclosing mechanisms, new packaging designs and enhanced food safety (e.g. tracers for shelf life and temperature shifts control with designs for tamper evidence). More efficient methods of fabrication and design for self-recycling should allow consumers to better manage their food waste as well as providing the most appropriate disposal method for the packaging itself.

Along with the challenges comes a wide variety of opportunities for the industry to develop technologies in both products and processes. The increasing demand for high performance materials will certainly continue to accelerate and provide the necessary critical mass for the development of new polymeric materials (fossil or bio based), new converting processes, and innovative recyclable solutions to excel at delivering efficient packaging for the food and beverage industry. ■

.....
Jorge Caminero Gomes – *R&D / TS&D Fellow, Dow*

PRODUCTS		LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT (2018)	2030	VISION (2050)		
MATERIALS AND PACKAGES FROM RENEWABLE SOURCES	BIOPOLYMERS	Molecular biology	• Technological Route/Source	<ul style="list-style-type: none"> Production of monomer precursors through direct fermentation (in one stage) Production of monomer from their precursors 				
		Biotechnology (fermentation and enzymology)		<ul style="list-style-type: none"> Direct use of biomass 	<ul style="list-style-type: none"> Technological platforms for production of monomer precursors through conventional biomass biorefineries 			
		Analytical chemistry		<ul style="list-style-type: none"> Direct biopolymer production by microorganisms 	<ul style="list-style-type: none"> Technological platforms for production of monomer precursors through biorefineries of biomass from wastes of the food and biofuel chain 			
		Catalysis						
		Plant breeding	• Enhancement of properties	<ul style="list-style-type: none"> Development and application of additives from renewable sources Development of thermoplastic blends and/or multilayer structures Molecule functionalization 				
		Genetic, Metabolic, Materials and Computational engineering		<ul style="list-style-type: none"> Biopolymers with good intrinsic properties Production of composites and nanocomposites based on biopolymers 				
		Life cycle assessment		<ul style="list-style-type: none"> Post-Consumer recovery and recycling 	<ul style="list-style-type: none"> Reverse logistics including post consumption biopolymers management Recycling technology for biopolymers in their own chain or by compatibilization Biodigestion applied to urban solid waste management 			
				• Assessment of environ. impacts	<ul style="list-style-type: none"> Application of Life Cycle Assessment – LCA for mensuration and interpretation of environmental aspects 			
			NANOCELLULOSE	Biotechnology	• CNF and CNC production	<ul style="list-style-type: none"> Production using wood cellulose 		
		Macromolecules chemistry		<ul style="list-style-type: none"> Chemical and enzymatic pretreatments for fibrillation optimization 		<ul style="list-style-type: none"> Production using cellulose from other sources of biomass (agricultural waste, for instance) Production in integration with biorefineries for the processing of hemicellulose and lignin Toxicological studies for the assessment of possible occupational and environmental hazard effects caused by nanoparticles of cellulose and creation of safety protocols 		
Nanoscale analysis								
Nanotechnology	• Development of applications in packaging	<ul style="list-style-type: none"> Characterization of particles regarding intrinsic properties, examining the potential of different cellulose sources (e.g. particle size and distribution, shape, degree of branching, specific surface area, composition, surface charge, surface chemistry, crystallinity, purity and contamination, etc.) Functionalization of nanoparticles to enhance compatibilization with hydrophobic resins (laboratory scale and pilot plant) Application of nanocellulose for improvement of paper and cardboard (commercial scale) Assessment of materials and packages for food contact safety 						
Materials, Chemical and process engineering		<ul style="list-style-type: none"> Application of nanocomposites with functionalized particles on a commercial scale Development of manufacturing processes for nanocellulose based packages (coating, extrusion, injection, blow and/or specific processes such as electrospinning) Reverse engineering: production of particles and manufacturing process development aiming at required properties by markets/specific applications 						
Life cycle assessment								

PRODUCTS		LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)	
ACTIVE	Food chemistry		<ul style="list-style-type: none"> Oxygen absorber incorporated to packaging material 	<ul style="list-style-type: none"> Control of absorber activation, in order to avoid premature reaction Technology for the incorporation of absorbers in packages, including variations in concentration and distribution Selection/development of oxygen barrier structures for absorber application Prospection of oxygen absorber actives (oxidable polymers, charges, nanoparticles, etc.) Shelf life lab. studies of meat products in packages containing absorbers, incl. assessment of storage temperature effects (constant and variable) 			
				<ul style="list-style-type: none"> Field studies to confirm active packaging effects on the increase of quality and shelf life of different meat products, incl. assessment of storage temperature effects (constant and variable) 			
	Food microbiology			<ul style="list-style-type: none"> Techniques of incorporation of indicator active agents to material or packages 			
	Food biochemistry - Physical-chemistry		<ul style="list-style-type: none"> Antimicrobial packaging 	<ul style="list-style-type: none"> Identification of target microorganisms Prospection of effective antimicrobial actives over the microbial flora of interest Studies on mechanisms of inhibition and on the influence of food compositions and/or external factors Microencapsulation of active components Studies on the kinetics of the actives release Lab and field studies to prove efficiency/repeatability of systems for each category of product and conditions of storage/distribution of interest 			
	Nanotechnology						
	Polymer blends						
	Mass transfer		<ul style="list-style-type: none"> Active packaging for control of fresh produce 	<ul style="list-style-type: none"> Prospection of ethylene and carbon dioxide absorbers (polymers, inorganic loads, nanoparticles, etc.) Selection/development of packaging structures for absorber application Development of film family with different ranges/characteristics of absorption to be used with fruits of varied physiologies Shelf life lab studies of different types of fruits in packages with absorbers, incl. assess. of storage temperature effects (constant and variable) Field studies for assessment of active package effects over the increase in quality and shelf life of different types of fruits, incl. assessment of storage temperature effects (constant and variable) 			
				<ul style="list-style-type: none"> Technology of absorber incorporation in packages, including variations in concentration and distribution 			
	INTELLIGENT & INTERACTIVE	Transport		<ul style="list-style-type: none"> Freshness indicator 	<ul style="list-style-type: none"> Prospection of active agents with potential to be used as freshness indicators on each potential application (biocins, natural preservatives, etc.) 		
		Information technology (TI)			<ul style="list-style-type: none"> Studies to identify potential compounds resulting from deterioration to be used as indicators in different food categories Printed electronics for chemical sensors production Nanotechnology for production of simple gas chemical sensors (sensitive, selective and reversible) Technology for remote control of degradation reactions (sensor and data transmission) Lab and field studies to prove efficiency and repeatability of systems for each food category and conditions of storage/distribution Studies with consumers in order to understand their comprehension of the technology 		
Telecommunication			<ul style="list-style-type: none"> Intelligent packaging for monitoring and traceability 	<ul style="list-style-type: none"> Technologies for production of reading systems free of flaws (as in products with high level of water content and high speed of load movement) 			
				<ul style="list-style-type: none"> Encapsulation of RFID tags for returnable packages Integration of RFID tags and sensors Development of printing materials (ink viscosity, ink deposition, etc.) 			

PRODUCTS		LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
HIGH PERFORMANCE PACKAGES	ADEQUATE MATERIALS FOR NON-CONVENTIONAL TECHNOLOGIES FOR FOOD PROCESSING	Physical-chemistry Chemical degradation & microbiological inactivation modeling Food chemistry Food microbiology Shelf life estimation	<ul style="list-style-type: none"> Performance facing non-conventional technologies for food processing 	<ul style="list-style-type: none"> Development of non-conventional processes for food and beverages Studies on the migration potential from packaging systems to food when submitted to conservation processes, taking into account food processing conditions, distribution temperature and shelf life Studies on formation of polymer degradation compounds, their risks and migration potential to food Practical studies on packaging physical mechanical and barrier properties, aiming at creating protocols to guide specifications by process type, product characteristics and technology 		
	MATERIALS WITH ENHANCED PERFORMANCE	High performance polymers and additives Nanocomposites development Structural design	<ul style="list-style-type: none"> Nanomaterials for packaging application 	<ul style="list-style-type: none"> Prospection and selection of nanoparticles Development of nanocomposites Development of coatings using nanomaterials Practical assessment of expected performance of material/structure Toxicological studies for the evaluation of possible occupational and environmental hazards from nanoparticles, and establishment of safety protocols Assessment of migration potential Toxicological and consumer exposure studies 		
	HIGH BARRIER PACKAGES	High performance polymers and additives Mass transfer Nanocomposites development Shelf life estimation Food chemistry	<ul style="list-style-type: none"> Materials with enhanced performance Assessment of environmental aspects 	<ul style="list-style-type: none"> Prospection and development of additives Development of new materials in terms of chemical nature and/or by control of molecular architecture Development of high performance adhesive systems Development of printing systems and ink formulation Compatibilizers for multi-materials recycling Application of economic analysis of innovation in high performance materials and its positive and negative impacts on food packaging systems Investigation and quantification of food loss and waste in Brazil Application of Life Cycle Assessment (LCA) for mensuration and interpretation of environmental aspects of food loss and waste in Brazil 		

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
FOOD PACKAGING SAFETY ASSURANCE					
		<ul style="list-style-type: none"> Compliance with current packaging legislation and its updates 	<ul style="list-style-type: none"> Development of formulations prioritizing substances with no or low toxicological restrictions Legislation concepts as functional barriers, no migration that can reduce the number of material testing w/o compromising consumer safety Develop and establish mechanisms in Brazil and MERCOSUR for continuous updating of the legislation 	<ul style="list-style-type: none"> Modeling applied to migration estimates for simple and multilayer structures 	<ul style="list-style-type: none"> Development of analytical methods
	Analytical and Organic Chemistry	<ul style="list-style-type: none"> Toxicological assessment of migrating substance 	<ul style="list-style-type: none"> Development and validation of alternative methods to evaluate substance toxicity (for example, TCC, QSAR, and others) Knowledge of reproductive methods for toxicological assessment in short term 	<ul style="list-style-type: none"> Studies to evaluate substances coming from packages, being intentionally added substances (IAS) or non-intentionally added substances (NIAS) Development of bioassays and in-silico toxicological assessment of compounds of interest to assess toxicity and potential of action as endocrine disruptor 	
	Materials science and Physicochemical		<ul style="list-style-type: none"> Establishment of protocols for assessment of packages for new food preservation processes (ex: high pressure processing irradiation, micro-waves, ozonization, etc.) 		
	Food Engineering	<ul style="list-style-type: none"> Protocols for the approval of materials and innovative processes 	<ul style="list-style-type: none"> Establishment of protocols for safety assessment in active packages whose agent migrates to food 		
	Toxicology		<ul style="list-style-type: none"> Establishment of protocols to assess set-off migration potential Establishment of protocols for new material and input certification (ex: inks with UV and EB curing, adhesives) 		
	Statistics				
	Computer Science	<ul style="list-style-type: none"> Studies regarding the presence of NIAS in packaging materials 	<ul style="list-style-type: none"> Development of analytical methods for detection and quantification of NIAS Toxicological studies applied to the analysis of multicomponent migrants Studies to establish the exposure of consumers' to NIAS and the associated risks 		
		<ul style="list-style-type: none"> Consumers' exposure to substances from packages 	<ul style="list-style-type: none"> Development of statistical and computational tools to assess consumer exposure, including when diet varies 	<ul style="list-style-type: none"> Exposure studies to establish procedures in order to compile data about food ingestion by Brazilian consumers and define consumption factors 	<ul style="list-style-type: none"> Establishment of chemical substances of interest in relation to expected migration from packages for different types of food

Food and beverage processing technologies

ACADEMIA

Some specialists consider that food processing is responsible for humanity existing until today (food safety effect). Since primitive times, natural sources such as the sun, ice, fire and salt have been applied to preserve foods. Heat, cold and salt are still widely used alone or combined with other technologies to transform and preserve foods. The uses of modern food processing technologies, be they emerging, innovative, or non-conventional, are nowadays the focus of several industries. Studies have been made worldwide on new technologies to ensure food safety and to preserve sensory and nutritional aspects, as well as to reduce costs. Manufacturers of processing equipment are also searching for machines that use less energy or alternative sources of energy in order to achieve goals related to sustainability.

At the same time, consumers are seeking products with a better nutritional profile and greater convenience. As a result, this scenario will lead to the growth of the food processing area in the coming years in order to meet the increasing demand for processed foods. This framework will also lead to the development of better alternatives than the traditional food processing technologies. In this study, the conventional heat treatment and the non-conventional microwave, high pressure and plasma processes were considered.

Conventional heat treatment is a consolidated process widely applied in the food processing sector. Its appli-

cation is increasing, including in association with the non-conventional technologies. Microwave has great potential for industrial application and is a reality in countries with highly developed industrial and technological standards, but Brazil is not keeping pace with those countries. High Pressure Processing (HPP) also has great potential but requires more research to reduce the high production and maintenance costs. With the continuous and gradually increasing demand for HPP equipment, new manufacturers will continue to appear. Plasma is a promising technology for application in food but needs more scientific research to have a proper development. One example is the need to improve understanding of the creation and destruction of plasma species responsible for each application.

For non-conventional technologies, especially plasma, there will be a need to invest in clarification both for consumers and for the authorities; it will be necessary to explain what these non-conventional technologies are and what their benefits are. It will also be necessary to develop a national plan for the development of the food and beverage sector. ■

Maria Isabel Berto, Michele Berteli, and Izabela Dutra Alvim – *Institute of Food Technology (ITAL)*

INDUSTRY

Every day, in different ways, we appreciate how central food is to our lives. Food not only provides essential nourishment, but also gives us pleasure, opportunities for some of our best social interactions, and an enduring connection to diverse global cultures and traditions.

Almost all food and drink require some sort of processing for consumption. For example, we all cook our potatoes or rice prior to consuming them. Processing makes foods safe and gives them a consistent nutritional quality; it also offers consumers wider availability and convenience.

Current dietary recommendations are based on decades of nutritional science, during which the link between consumption of specific nutrients and foods and the risk of developing non-communicable diseases has been investigated. International bodies, such as the World Health Organization - WHO¹, and many organizations recommend that a healthy balanced diet contains plenty of, among other things, vegetables, fruits, whole grains and lean protein, and is limited in free sugar, salt and saturated fat. Therefore, the nutrient quality of a product is what determines its health impact.

Food processing allows us to enjoy safe, nutritious, tasty, affordable and convenient foods all year round. Additives are used to maintain and/or improve the safety and freshness (preservatives), nutritional value (vitamins, minerals), taste (spices, sweeteners), texture (emulsifiers, stabilizers, thickeners) and appearance (colors) of foods, besides contributing to the reduction of food waste. (It should be noted that the use of additives is strictly regulated by governmental bodies to ensure their safe use in foods and beverages.)

All foods - whether home-made, artisanal or packaged – can be high in nutrient density and low in calories. Several studies, such as those developed by Howard, Adams and White² and by Trattner, Elswailer and Howard³, have shown that freshly prepared foods are not by definition more healthy than processed foods. It all depends on the nutritional quality of the recipes used.

The nutritional composition of the food, and more importantly the composition of the diet, is what really matters. No single food will deliver all required nutrients. A healthy balanced diet should contain a variety of foods to deliver nutrients at the recommended levels.

References

- ¹ WHO – healthy diet. <https://www.who.int/news-room/fact-sheets/detail/healthy-diet>
- ² Howard, S., J. Adams, and M. White, *Nutritional content of supermarket ready meals and recipes by television chefs in the United Kingdom: cross sectional study*. *BMJ : British Medical Journal*, 2012. 345: p. e7607. <https://www.bmj.com/content/345/bmj.e7607>
- ³ Trattner, C., D. Elswailer, and S. Howard, *Estimating the Healthiness of Internet Recipes: A Cross-sectional Study*. *Front Public Health*, 2017. 5: p. 16. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5304340/> ■

Fernanda de Oliveira Martins

– *Senior Nutrition & Health Manager (Unilever)*

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS		CURRENT	2030	VISION (2050)
PROCESSED FOOD AND BEVERAGE	Conventional heat treatment	<ul style="list-style-type: none"> Processes improvements Automation 		<ul style="list-style-type: none"> Optimization and improvements of thermal process <ul style="list-style-type: none"> Assessment of thermal process parameters and food/beverage changes: safety (destruction of microorganisms), nutritional, sensorial and functional characteristics, optimal binomial time/temperature conditions, etc. Development of customized technologies: suitable packaging, ingredients and equipment Automation and processing monitoring: development of sensors, thermocouples, probes, and process control software 		
	Microwave technology	<ul style="list-style-type: none"> Pilot plant Clean technology and process National technologies 		<ul style="list-style-type: none"> Implementation of microwave pilot plant for technology development <ul style="list-style-type: none"> Assessment and improvements of microwave irradiation and food effects: inactivation kinetics, electric field homogeneity, optimal microwave irradiation for each product, etc. Improvements on dielectric properties data 	<ul style="list-style-type: none"> Development of clean technologies and energy sources 	<ul style="list-style-type: none"> Development of national microwave technology
	High Pressure Processing (HPP)	<ul style="list-style-type: none"> Processing New applications 		<ul style="list-style-type: none"> Low-cost and faster operation for food processing <ul style="list-style-type: none"> Technology development and improvements: higher processing capacity, reduce maintenance and operational costs, suitable packaging, new low-cost prototypes, low-cost materials, etc. 	<ul style="list-style-type: none"> Development for new application: Fruits and Vegetables 	
	Plasma	<ul style="list-style-type: none"> Plasma technology Kinects and modeling 		<ul style="list-style-type: none"> Plasma technology development: Lab and Pilot scale 	<ul style="list-style-type: none"> More comprehensive understanding of the plasma effects <ul style="list-style-type: none"> Assessment of plasma effects on food/beverages: nutritional, sensorial and functional qualities, chemistry kinetics and antimicrobial actions, safety assurance, generation of radicals, shelf of life improvements, etc. Process modeling and scaling-up 	<ul style="list-style-type: none"> Plasma technology development: Demonstration and Industrial scale

Bioenergy and Green Chemistry

Luís Augusto Barbosa Cortez – University of Campinas (UNICAMP)

Historically, Brazil's energy matrix has counted on an intense participation of renewable energy sources. Currently, renewable sources account for about 42% of the energy matrix, with biomass being of significant importance. Brazil is today a reference in modern bioenergy production and use, with sugarcane ethanol responsible for about 40% of the energy consumption of the light vehicle fleet, in addition to biodiesel from vegetable oils, bioelectricity generation (roughly 8.5% of total electricity), and planted eucalyptus used as firewood.

Regarding the generation of electricity in Brazil, recently there has been a noteworthy and important growth of renewable sources such as wind, solar and biomass, as well as natural gas. In addition to the energy matrix, biomass can still play an important role in green chemistry, replacing fossil sources. In fact, this is already happening, and the so-called Brazilian green plastic is already a well known point of reference. As a result, Brazil is one of the countries with the best prospects globally for bioenergy and modern green chemistry.

Despite these important advances, the coming decades will bring new challenges and new questions, such as how will the energy and chemical sectors cope with global warming and the end of the petroleum age?

In order to explore the principal opportunities for Brazil, considering its scientific and technological advances, three potential areas were identified:

1. Advanced biofuels: aviation and maritime;
2. Valorization of biomass for chemicals;
3. Enzymes and Green Chemistry

These three areas are part of important global markets and can be considered strategic for the Brazilian domestic economy and for its insertion into international markets. Brazil is very well positioned to become a major supplier for these markets as it possesses considerable scientific knowledge, an abundance of fertile land and a number of companies that can make these opportunities possible.

With the current need to reduce GHG emissions and minimize global warming, new windows of opportunity have opened. These opportunities must be seized by both the Brazilian government, through the formulation of policies for sustainable development, and by the private sector, aiming at their globalization.

In the following chapters, the technological roadmaps developed for each of these areas are presented, showing how they will contribute to the growth of the Brazilian economy and develop sustainable technology and products, thus helping to mitigate the effects of global warming, thereby improving conditions for Brazilians while reaching new markets. ■

Advanced biofuels: aviation and other heavy transport

ACADEMIA

The economy of Brazil and especially that of the state of São Paulo, strongly depends on the transport of raw materials and feedstocks, intermediate and finished products, end-of-life output (waste) and residues, and last but not least, people. Economic development, as reflected in GDP per capita for instance, is inherently flanked by increased transport, and thus sustainable economic development requires sustainable transport of people, resources and products.

Biofuels can play a role in sustainable transport, in combination with electric transport, depending on regional situations and the mode of transport. In Brazil, a substantial portion of human transport relies on light vehicles, which is already sustainably supplied by the mature 1st generation bio-ethanol industry with a well-recorded history of technical, market and financial development, as well as by an emerging 2nd generation bio-ethanol industry. For heavy road transport (people and freight), Brazil has implemented a biodiesel mandatory measure, with some advances but also with many criticisms.

In general, the aviation, marine and heavy road transport sectors have less alternatives regarding energy sources, not only in Brazil but worldwide. They require sustainable biofuels with high energy densities, good availability and competitive pricing, and, especially for aviation, more critical specifications (ASTM and others). The fuel volumes in each of these three heavy duty sectors are comparable with 10-12% of total transport energy.

Worldwide, flights produced 859 million tonnes of CO₂ from the 275 million tonnes of jet kerosene consumed in 2017. This is approximately 2% of human produced CO₂, and 12% of global transport emissions. Global

passenger-kilometers have increased by 4-5% annually, and historic improvements in aircraft fuel efficiency, operations and infrastructure have contributed a combined 1.5% CO₂ emission reduction per year. Since 2010, the aviation industry worldwide has implemented actions and ambitious targets for total carbon emission by 2020 and 2050 (ICAO-target).

In the marine sector, given the relatively low quality of common marine fuels (compared to aviation fuels), not only are carbon emissions important. In particular, sulphur dioxide (SO₂), nitrogen oxide (NO_x) and particulate matter (PM) emissions are critical, due to their contribution to air pollution. Total shipping emissions ranged from 714 to 932 million tonnes of CO₂ between 2015 and 2019 from around 265 million tonnes of fuel. Similar to flight results, this is approximately 2% of human produced CO₂. But additionally, another 10.4 million tonnes of SO₂, 19 million tonnes of NO_x and 1.4 million tonnes of particulate matter were emitted. Together aviation and shipping demanded around 12 million barrels of oil equivalent per day in 2017, and by 2040 fuel demand may reach up to 19.2 million barrels of oil equivalent per day, demonstrating that emission levels could increase significantly in the coming decades. Legislation is emerging that limits and targets marine air pollutant emissions, mainly sulphur emission, both in territorial zones and in more remote places. The long term maritime strategy proposes to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008, while, at the same time, pursuing efforts towards phasing them out entirely (IMO-strategy).

A recent study regarding truck transport predicts the sustained key importance of diesel engines for the heavy duty segment over the medium and even long

term, with an upcoming role for gas fuel (LNG, CNG). In general, diesel engines have improved in terms of emissions of CO₂, NO_x and particulate matter (PM), however, truck and bus emissions have risen at a rate of 2.2% annually since 2000. Emission standards for diesel HDVs are being implemented in many places, mainly in the United States, European Union, and Japan. However, for further emission reduction, the heavy duty sector relies on substantial improvements in liquid and gas biofuels and more restrict legislation.

In general, the environmental impact will continue to be the key driver for the development of these three sectors in the coming years, even though guided by different perspectives, but with biofuels as one of the central pillars. For aviation, in Brazil and worldwide, ICAO-targets (carbon neutral growth in 2020, and halved 2005 GHG emission profiles in 2050, as well as a secure supply of affordable biofuels) should reign. In the marine sector, IMO (International Marine Organization) is engaged in addressing air pollutants and GHG emission regulations for international shipping. In Brazil, standards and targets are not yet formalized for air pollutant emissions, but soon will be related to SECA (Sulphur Emission Control Areas) and NECA (Nitrogen Emission Control Areas), as has been observed worldwide. With respect to heavy road transport, the

improvements in Brazil will be guided by the biodiesel mandatory measure (percentage increase of biodiesel in fossil diesel over the years), in progress since 2008, and other national related biofuels and GHG emission programs and legislation.

Based on these perspectives, the technological roadmap presented below was developed with a focus on the development of advanced biofuels for the aviation, marine and heavy road transport sectors. ■

Telma T. Franco – School of Chemical Engineering (FEC), University of Campinas (UNICAMP)

Luuk van der Wielen – Bernal Institute, University of Limerick e Delft University of Technology (TU Delft)

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)
AVIATION & MARINE BIOFUELS	Feedstock production	<ul style="list-style-type: none"> • Croptimisation 	<ul style="list-style-type: none"> • Pilot and demo plantations with integral and improved water, nutrient, energy and carbon management • Double-cropping system, co-production (energy crops and feed/cattle), pasture intensification • Improved harvest systems (including low-impact equipment), and utilization of harvest residues including sewage, vinasse, and other agro-industrial (mill) co-products • Debottleneck biomass storage 	<ul style="list-style-type: none"> • Domestication and optimization of (new) energy crops (e.g. energy cane and macaúba) 	
	Conversion Technology & Biofuel Use	<ul style="list-style-type: none"> • Optimization of existing technologies 	<ul style="list-style-type: none"> • 1G processes/technologies optimization • Improvements in hydro-processed esters and fatty acids (HEFA) and other hydrogenation technology/catalysts • Use of biogas (CBG and/or LBG) in plant/processes, and in other transportation (road, marine, ship) to replace fossil diesel • Development/improvements on thermochemical processes/technologies: HTL (incl. catalytic), pyrolysis, gasification/syngas and other • Solutions, processes and technologies for debottlenecking biomass pretreatment • Development of new robust strains, strains (incl. GMO), and catalysts sugar/syngas/lignin/ethanol/alcohols to hydrocarbon conversion • Development of platforms other than yeasts, bacteria (algae and cyanobacterias) • Use of alternative wastes (e.g. MSW) to produce transport fuels, including other value-added co-products and by-products 		
		<ul style="list-style-type: none"> • Integral biorefinery development 	<ul style="list-style-type: none"> • Technologies/processes to coproduct valorization, and combined production of fuels/chemical/food/energy • Development of cascading systems (e.g. biocrude to marine to kerosene – lower to higher biofuels specification) • Development of integral oil and sugar/lignin biorefineries (e.g. macaúba and other oil crops) 		
		<ul style="list-style-type: none"> • Fleet (engine/equip) redesign 	<ul style="list-style-type: none"> • Engine upgrading/redesign for operating with high blends (>50%), biofuel (100%), dual fuel (e.g. diesel-gas) and alternative fuels • Advanced marine engine development (EUR VI) and Marine biofuel specification for “Bio-HFO” and biocrude 		
		<ul style="list-style-type: none"> • Flanking technologies 	<ul style="list-style-type: none"> • H₂/hydrogenation technology combined with fertilizer production (NH₃), including further energy integration • Modular scalable technology for small sites (<100.000 t/year) • Continuous/in-line blending for high blends, and blending logistics 		
		<ul style="list-style-type: none"> • Breakthrough, alternative and disruptive development 	<ul style="list-style-type: none"> • Solar biofuels (CO₂/syngas + electric/PV/direct light) • Solar planes, hybrid propulsion including mixed solar/electric 		
	Modeling & Strategic Analysis	<ul style="list-style-type: none"> • Data & scenario analysis and decision support tools 	<ul style="list-style-type: none"> • Quantitative and non-quantitative analysis of integral advanced biofuels value chains, including feedstock/technology evaluation, and integrated systems models (water, energy, nutrients)- Virtual Biorefinery • Landscape and logistics-effect of scale (distributed/modularity, hub, and central systems manufacturing), including macro-economic and LCA models, uncertainty and risk analysis, other • Database (reliable and high quality data), big data management and imaging 		

Biomass valorization for chemicals

ACADEMIA

The chemical industry is the fourth most important industrial sector in Brazil and is among the ten largest chemical industries in the world. However, over the past 10 years it chemical industry has experienced a marginal net growth, and historically Brazil has had a trade deficit in the chemical industry, importing more than exporting and is strongly dependent on petroleum. Nowadays, the production of chemicals from biomass is related to the production of biofuels and can represent from 15 to 30% of total chemical production, depending on the chemical segment.

The economy of the state of São Paulo is diversified and the leader in several industrial segments from agricultural production (e.g. sugarcane and citrus) to high-tech products (e.g. aircraft). Regarding fuels and chemicals, the four petroleum refineries in the State of São Paulo are responsible for 39% of all production in Brazil.

Thus, taking into account the chemical industry opportunities and trends and the Brazilian experience in agriculture and renewable technologies and products, Brazil and especially the state of São Paulo, is the right place for an industrial revolution of the chemical industry based on renewable feedstock.

Although there is a worldwide effort to convert renewable sources into chemicals, part of the Brazilian chemical industry already has this expertise, mainly using sugar from sugarcane as raw material. The main Brazilian biochemicals include organic acid (acetic, citric, lactic and lactates), amino acids (glutamate and lysine), material for polymers (polyethylene and polypropylene) and solvents (ethyl acetate). However,

the transformation of biomass into chemicals, mainly into value-added chemicals, still faces several challenges and barriers.

Motivated by this scenario, the workshop discussions identified the necessary actions for the development of bio-based chemicals divided in four frameworks: immediate, short term, medium term (2030) and long term (2050).

In the immediate timeframe, it will be necessary to implement policies and legislation to encourage the production of bio-based chemicals and intensify industry-academia partnerships with a focus on the development of new processes (breakthrough and incremental processes).

In the short term, the emphasis should be on the development of new processes and products, and the production of bio-chemicals such as surfactants, bioplastics and pharma products. Although they are for specific uses, these bio-chemicals can be produced with current technology at competitive prices and can be used as a demonstration of the potential of the bio-based economy. During this period, new processes and different feedstocks should be intensively evaluated and tested, since the portfolio of chemicals that can be produced from biomass is very large and the process gaps are even larger.

Breaking down biomass into its basic components still needs to be solved. Although the separation of the biomass fractions is well known (Kraft Process), it is still expensive to be used in many commodity chemicals. It will be necessary to develop new processes that first separate the main biomass components at a low cost,

and then use C5 sugars and lignin as feedstock to produce commodity chemicals. Although the use of C6 sugars is well known and the use of C5 sugars offers many options, the use of lignin is still limited. Since lignin is rich in aromatics the possibilities of its use for added-value chemicals is high, however, considering the current processes that aim to valorize lignin several challenges will need to be overcome, including severe process conditions of temperature and pressure, long reaction times, high cost of noble metal catalysts, and the use of environmentally unsuitable solvents).

In the medium and long term, cheap new biochemicals should be available in the market, and some relevant technologies should be evaluated and tested: conversion of ethanol into higher alcohols, in-situ removal of acetone, ethanol and butanol in ABE fermentation technology, using carbonates as construction materials, hydrodeoxygenation of lignin-derived pyrolysis oil, and the development of new bioplastics with different physical properties. The technology for the production of these chemicals already exists but still needs to be made economically viable. In addition to the development of new technologies, it is necessary to develop fully integrated assessment support tools for industry to make the use of feedstock and energy more efficient.

Regarding non-technological aspects, the construction of bio-based technoparks can stimulate development of joint projects seeking a more efficient integration of utilities and feedstock. Public policies to stimulate the bio-based chemical industry should be implemented, including encouragement of public-private partnerships, fiscal incentives for bio-based chemicals, increased education and training and financial support for research and new business (startups). ■

Gustavo Paim Valença – School of Chemical Engineering (FEC), University of Campinas (UNICAMP)

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT	2030	VISION (2050)	
DROP-IN PRODUCTS	Chemical catalyst design	• New materials	• New characterization tools • Development of materials and industrial application • Product based development			
		• New theoretical methods	• Development of new computation packages • Use of the new computation capabilities			
		• Hydrodeoxygenation catalyst (HDO)	• Development of new catalysts • New characterization tools • Development of hybrid chemical and biological processes			
		• Coupling catalysts	• Industrial application of solid catalysts (chemical routes) • Exploitation of catalysts combinations • Development of new analysis and design techniques of catalysts			
		• New polymerization	• Development of new specific catalysts • Exploitation of new process conditions			
		• New theoretical methods	• Development of computation packages • Application of artificial intelligence			
	Enzyme technology	• New pretreatments	• Use of new enzyme combinations • Use of new physical and chemical processes			
		• Immobilization	• Development of new supports • Development of more efficient attachment to support			
		• New enzymes	• Development of new GMO • Computation development of new enzymes			
		Microorganism	• Genetic engineering	• Development of specific microorganism for biomass • Exploitation of Brazilian biodiversity		
			• Immobilization	• Development of new supports • Development of more efficient attachment to support		
			• New pretreatments	• Use of more specific microorganisms		
	SIMILAR PRODUCTS (physical and chemical properties)	• Robust microorganism	• Collection and identification of existing robust microorganisms			
		Nanotechnology	• New theoretical methods	• Development of packages taking into account size reduction		
• New applications/ new materials			• Enhanced physical properties • Development of precision applications • Development of more resilient systems • Exploitation the use of nanocompounds from biomass			

Enzymes and Green Chemistry

ACADEMIA

The global enzyme market is growing fast, and new demands and opportunities are overtaking its traditional uses. The new applications of enzymes most prominently include as active ingredients in food (for example, in smart / personalized foods), in the degradation process of lignocellulosic materials (for example, for the production of 2nd generation bioethanol), and as green catalysts in the production of pharmaceuticals, replacing chemical catalysts. Several scientific studies have confirmed that industrial biotechnology can provide a range of options for competitive industrial performance in diverse sectors – chemicals, food and feed, healthcare, detergents, paper and pulp, textiles, and energy – and enhance economic growth, while at the same time saving water, energy, raw materials as well as reducing waste production and GHG emissions. However, industrial biotechnology is still a relatively new field and therefore not yet fully developed, thereby producing several areas of knowledge yet to be explored. And though these areas present several technical bottlenecks to be overcome, they also offer tremendous opportunities for further research that can lead to break-through innovations and new business opportunities.

On the other hand, as a concept applied to industrial processes, green chemistry can contribute to minimizing the environmental impacts of any existing chemical process, not necessarily solely bio-based processes. The keyword in green chemistry is reduction, primarily as related to environmental pollution, and to energy consumption and waste generation, as well as the use of toxic compounds, non-renewable sources and raw materials. Although the twelve principles of green chemistry are nearly thirty years old, they have become

much more referenced in the last few years. But despite being an excellent guide for the sustainable production of chemicals, the green chemistry principles still face several challenges.

Based on this scenario, and with the expectation of bio-based sustainable development in Brazil, the workshop discussions have highlighted the main processes and technologies needed for the development of several products, such as enzymes and (bio)products.

Concerning enzymes, the discussion focused on their use as biocatalysts in industrial processes and as final products for different applications (food, health, environmental, etc). Some issues that guided the presentations and debates were, among others, the substitution of catalysts for enzymes, creating cleaner and better processes; the possibility of improving the catalytic properties of the enzymes currently used; the reduction of the enzymatic load as a result of the use of improved performance enzymes; the creation of new applications/markets for current enzymes; the design of new enzymes for current/new applications; and the availability of technologies to achieve these goals.

Concerning green chemistry, the discussions focused on the existence of industrial chemical processes, biomass-based or not and biotechnology-based or not, in which the use of less toxic components and processes less harmful to the environment were targets. In this case, the presentation and debates were guided to identify, among other things, the existence of company actions in this direction; the existence of technologies supporting these achievements; and whether a green process is necessarily more expensive than a conventional process, or whether it can be even simpler and cheaper.

The results of these discussions identified that the needs for the production of enzymes are related to two main processes: (i) *recombinant DNA technology and enzyme engineering* - a powerful strategy to either increase enzyme efficiency for a given reaction or to enable enzymes to perform different reactions; and (ii) *bioprocess engineering and microbial physiology* – important disciplines necessary for industrial enzyme production and purification.

Regarding the green production of chemicals, fuels and plastics, bio-based or not, three main processes were identified: (i) *green processing and green technologies* – key issues to improving environmental friendliness; (ii) *process intensification* – crucial element to decrease costs and to increase the overall conversion and yields, mainly in large biorefinery sites such as in Brazil; and finally (iii) *advanced tools to indicate whether a process is green* – to ensure the sustainability of processes and products.

Concerning non-technology issues, Brazil has universities and public research organizations that have reasonably strong scientific capabilities. These could certainly be harnessed to address the products, technologies and processes involved, through incentivizing public-private research partnerships, and/or incentivizing private companies directly. In addition, for the realization of sustainable and green processes, eco-

nomic and green considerations should take the lead. Global knowledge regarding catalysts and solvents, for instance, is fairly mature, but should be directed more towards dedicated processes. Green processes will require high-end solutions in terms of (bio)catalyst, reactor and process design, and incentives (e.g. tax incentives) for the development and establishment of more advanced and cleaner processes that can stimulate their adoption by companies. ■

.....
Andreas Gombert – School of Food Engineering (FEA), University of Campinas (UNICAMP)

Isabel Arends – Delft University of Technology (TU Delft)

Bioenergy & Green Chemistry

Technology Roadmap

Enzymes & Green Chemistry

PRODUCTS	LARGE TECHNOLOGICAL AREAS	TECHNOLOGY DRIVERS	CURRENT (2018)	2030	VISION (2050)
ENZYMES Active ingredient in food and consumer applications / Lignocellulose degradation / Engineering for potential new future applications / Green biocatalysts in production of pharmaceuticals	Recombinant DNA Technology & Enzyme Engineering	<ul style="list-style-type: none"> New enzymes 	<ul style="list-style-type: none"> Improve enzyme efficiency 	<ul style="list-style-type: none"> Improve enzymes ability to perform different reactions <ul style="list-style-type: none"> Development of biotechnology methods to improve GM microbes (CRISPR, RNAi, etc.), low cost High-Throughput Screening (HTS) robotics, artificial intelligence design of enzymes and metabolic pathways, robust software for protein modeling, cofactor-free enzymes, high stable enzymes, microbes from Amazonia, 3D printing (enzymes), in silico design of new enzymes catalyzing unnatural reactions, easy design of any catalytic activity Debottlenecking gene/DNA synthesis, enzyme development time consuming, low enzymes ability to work at high substrate/product concentration 	
	Bioprocess Engineering & Microbial Physiology	<ul style="list-style-type: none"> Bioprocesses Microbial physiology 	<ul style="list-style-type: none"> Development of novel bioprocesses Microbial physiology <ul style="list-style-type: none"> Development of methods to bring biomolecules faster into industrial applications (e.g. screening technologies, molecular cloning, metagenomics), cheaper technology to make and store liquid sucrose solutions, complex microbial ecosystems engineered for bioprocess development, wider variety of non-conventional microbes being used for commercial purposes, minimal multipurpose microbial catalyst, high level production of any enzyme Debottlenecking long and non-competitive timeframe (from laboratory to industrial scale plant), enzyme production costs, low yields, and high residence times, widespread use of CO₂ as carbon source in microbial cultivations; valorization of Brazilian biomass (full use of local feed streams) 		
(BIO)CHEMICALS, (BIO)FUELS, (BIO)PLASTICS, AND BIOBASED PLATFORM CHEMICALS	Green processing/ green technologies	<ul style="list-style-type: none"> Sustainable processing Lignin Catalysts 	<ul style="list-style-type: none"> Chemoenzymatic processes for sustainable processes <ul style="list-style-type: none"> Development of non-toxic biobased solvents, integrated processes for lignocellulose (pretreatment-processing-DSP) Lignin valorization <ul style="list-style-type: none"> Development of lignin derived buildings blocks, organosolv lignin modification to produce materials (binders), solvents for lignin processing New catalysts for new processes <ul style="list-style-type: none"> Development of new and better heterogeneous catalysts for biomass conversion (e.g. production of a new class of plastics), non-noble metal catalysts replacing noble metal catalysts for H₂O based reactions, efficient catalytic methods for lignin (e.g. to BTX, phenol, etc.) 		
	Process Intensification	<ul style="list-style-type: none"> Reactors Down-stream processing 	<ul style="list-style-type: none"> New reactors <ul style="list-style-type: none"> Development of microchannel reactors, membrane reactors (e.g. for industrial application and continuous processing), microreactors, etc. Development of integrated downstream processing <ul style="list-style-type: none"> Development of process intensification models and simulators, advanced process control (including artificial intelligence), 3D printing (reactors and DSP), membrane technology on an industrial scale Debottlenecking continuous operations, aqueous streams, biomass pretreatment, process design (scaling-up and scaling-down), high CAPEX, overall conversion, processes combination 		
	Advanced tools to indicate whether a process is green	<ul style="list-style-type: none"> Life Cycle Analysis (LCA) 	<ul style="list-style-type: none"> LCA applied by companies <ul style="list-style-type: none"> Development of integrated LCA tools (energy efficiency, CO₂ storage, emissions, etc.) to indicate whether a process is green, to support decision making, and for different scales and processes (from very small to large industrial scale) 		

Non-technological roadmap

Rodrigo Lima Verde Leal – CPQD

Ricardo Baldassin Junior, Lilian Cristina Anefalos – Agronomic Institute (IAC)

Facing the great challenges in RD&I, especially those in the field of bioeconomy, in order to better understand the technological gaps in a more consistent way, and to propose robust technological routes, non-technological aspects also need to be considered and presented as crucial factors for overcoming the technological barriers.

There is a conjunction of efforts by science and technology institutions, in different areas of knowledge, in researching and developing incremental, or even disruptive, technological solutions, although it is essential to also consider socioeconomic, environmental and institutional aspects as critical factors for effective adoption of technological solutions. This point corroborates the need to strengthen the important role of society, the various actors in civil society, the industry as a whole and, especially, the government in the RD&I processes. In many cases, non-technological issues become the main obstacles to innovation. For example, the regulatory aspects that need to be met in order to obtain authorization for the commercialization of new products, either due to the high levels of the prerequisites imposed (either by the inexistence of metrics, norms and standards), or to mechanisms to regulate the offer of new products in the domestic and international markets.

In this context, the expansion of business towards a more globalized economy has become a major challenge for business relationships, especially for innovative companies, which need to differentiate themselves from their competitors, particularly at the global level.

Thus, cultural and structural aspects have incorporated key elements to the non-technological problems of innovation. This is because, besides requiring global quality solutions to meet specific local requirements,

within the scope of cities, states and the country there is a need to be easily absorbed by a much broader and more diversified consumer market.

In Brazil, given the complexity and richness of its tropical ecosystems, associated with its territorial dimension and structural diversity, the development of bioeconomy incorporates non-technological specificities that need to be properly understood and equalized. Therefore, in addition to technological demands, the methodology also considered the construction of non-technological roadmaps. For this, non-technological components were identified and analyzed in a broader scope, but with less detail in relation to technological ones.

In this sense, during the planning stage (elaboration of the Terms of Reference) and thematic workshops, the specialists were encouraged to address, with full autonomy, the non-technological limitations.

The main themes were related to sustainability, institutional economy, research funding, cost, capacity and training, technology and knowledge transfer, and entrepreneurship.

Given the coexistence and transversality of the elements identified in the STRATEGIC AREAS, as well as in the PRODUCTS, the non-technological demands have been grouped and are presented in an aggregated form. Furthermore, given the wide distribution in the TIMEFRAME (2018-2050) and the different levels of technological maturity observed, such aspects will not be identified. ■

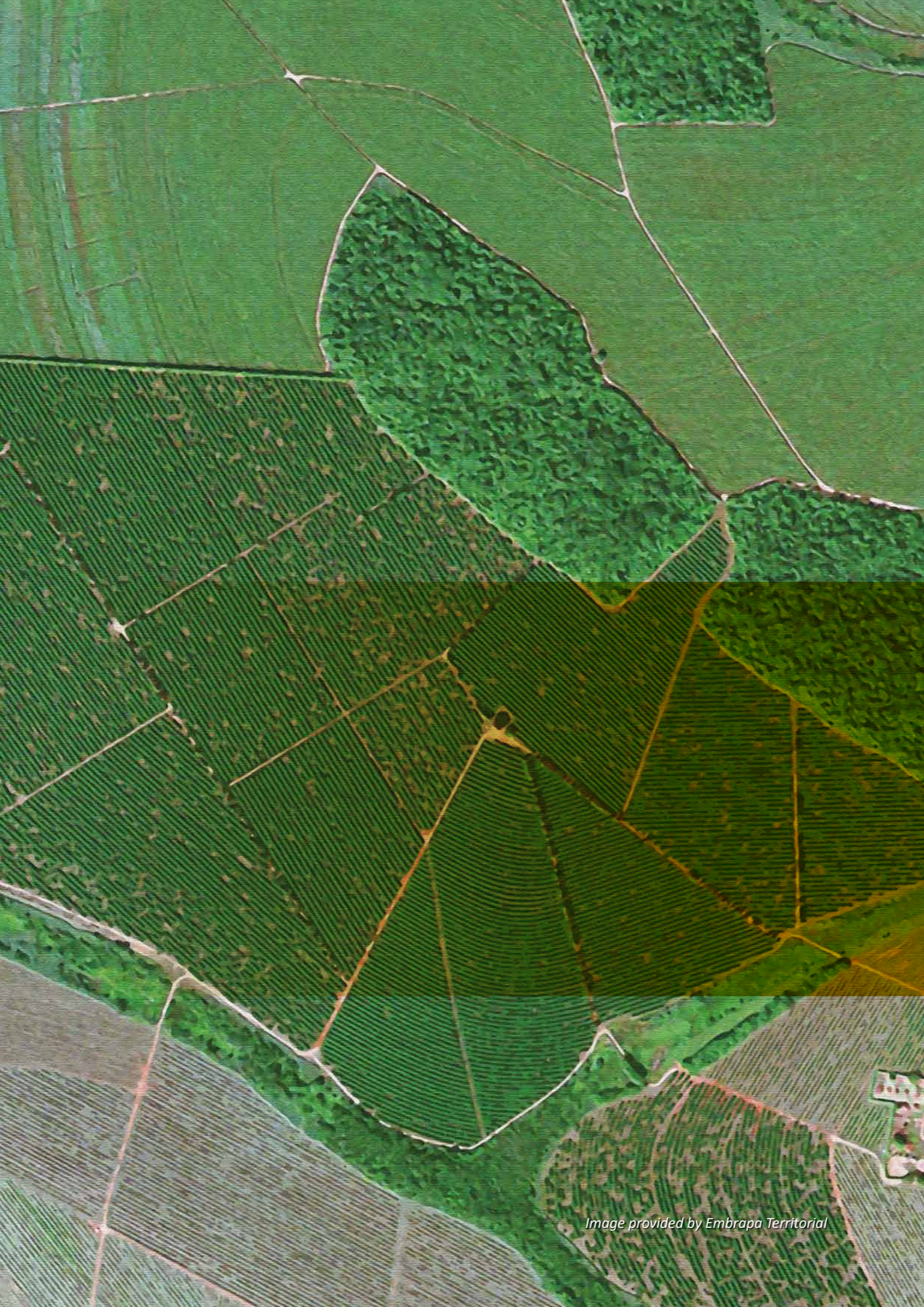
Image provided by Embrapa Territorial

Agriculture, Food & Health, Bioenergy & Green Chemistry

Non technology roadmap

Bio-Based or Biological Products

LARGE AREAS	DRIVERS	TODAY	2030	VISION (2050)
ECONOMIC	<ul style="list-style-type: none"> Tax incentives 	<ul style="list-style-type: none"> Develop and introduce tax incentive mechanisms to increase the competitiveness of green technologies and boost the market for sustainable bioproducts <ul style="list-style-type: none"> Environmental sustainability: carbon emission trading, carbon footprint, carbon tax, etc. Incentive for R&D and the formation of public-private partnerships (PPPs) in strategic themes: reduction of production costs, logistics, use of residues and agricultural and agro-industrial by-products, reduction of losses in the food production chain, pilot plants for the development of processes, integration processes, green technologies, development of national technologies, etc. Innovation in small and medium-sized enterprises (SMEs) and creation of startups and spin-offs 		
TRAINING AND CAPACITATION	<ul style="list-style-type: none"> Specialized education 	<ul style="list-style-type: none"> Improving skills, including in researchers, and training of professionals in strategic areas and themes <ul style="list-style-type: none"> Bioeconomy, Biotechnology, Bioinformatics, Nanotechnology, Modeling and Simulation, Biorefinery, Process Integration, Precision Agriculture, Big Data, Industry 4.0, Robotics, Internet of Things (IoT), Information Technology (IT), Artificial Intelligence (AI), Green Chemistry, Product Development, Entrepreneurship and Business 		
TECHNOLOGY TRANSFER	<ul style="list-style-type: none"> Productivity and sustainability Adding value Byproducts and residues recovery 	<ul style="list-style-type: none"> Connect and intensify existing technical assistance programs and facilitate technology transfer <ul style="list-style-type: none"> Agriculture: increased productivity, reduced use of agricultural inputs, water and energy, adoption of sustainable management techniques and exploitation of biodiversity, recovery of degraded areas, multiple cropping, no-tillage systems, etc. Food and beverage industry: new processes and products with a focus on adding value to small and medium-sized enterprises (SMEs) Bioenergy and chemicals: use and conversion of biomass and agricultural and agro-industrial by-products 		
ENTREPRENEURSHIP	<ul style="list-style-type: none"> New Business 	<ul style="list-style-type: none"> Expand efforts to stimulate and support technology-based entrepreneurship <ul style="list-style-type: none"> Training: business, management and planning, marketing Infrastructure to support innovation: sharing of public R&D infrastructure, business incubator, technology parks, etc. Financial support and investment: public financing (payable and non-repayable funds) and investment access channels (angel investors, seed funds, equity crowdfunding, venture capital, private equity) Markets: business acceleration programs, government procurement markets, opening of new markets 		
REGULATION	<ul style="list-style-type: none"> Control mechanisms 	<ul style="list-style-type: none"> Establish parameters and implement mechanisms to control the production, quality and impact of biological and bio-based products <ul style="list-style-type: none"> Environmental: sustainability criteria and standards, quantification and qualification of impacts, monitoring tools, exploitation of biodiversity (e.g. access to genetic heritage) Laboratory and clinical trials: evidence of efficacy and safety Production and marketing: standardization, certification and registration of products, traceability, designation of origin International markets: harmonization of national legislation with international standards and protocols (environmental, efficiency and safety and production) 		



Part III

Guidelines for Bioeconomy Development in Brazil

Image provided by Embrapa Territorial



Image provided by Embrapa Territorial

Technological innovation is strongly dependent on support mechanisms and adequate public policies, which, depending on the segment, need to act along the entire value chain, from scientific research to the consumer market. Nowadays, given the advance of globalization and the intense commercial relations between countries, it is imperative that these instruments are in harmony and in line with global directives.

In Bioeconomy, the role and importance of these elements are enhanced. Based on the recommended concepts, combined with their wide diversity and magnitude, and in addition to economic gains, they are of paramount importance to ensure environmental and

social gains, both locally and globally.

During the workshops, in addition to the construction of the roadmaps the participants had the opportunity to point out and discuss the main elements and actions that should comprise an “Agenda for the development of Bioeconomy in Brazil” for each of the 13 strategic areas. Despite the peculiarities of each area and the need to carry out studies and develop specific structures, there was a great convergence of the central themes of the agendas, based on 7 major themes. Table 1 presents a summary of the agenda, with the themes to be developed, the main actors involved and the time horizon for the effective implementation of each.

Table 1. *Agenda for Bioeconomy development in Brazil*

WHAT needs to be done	WHO should be in charge	WHEN needed to be implemented
1. National Strategy Plan	Ministry of Science, Technology and Innovation (MCTI), Ministry of Agriculture, Livestock and Supply (MAPA), and State Government	Short term (2-5 years)
2. Communication Plan	Federal / State Governments, Class Entities, Science and Technology Institutions, and Private Companies	Short term (2-5 years)
3. Education and Training	Science and Technology Institutions	Long term (20-30 years)
4. Technology Transfer and Extension	Federal / State Government Agencies, and Science and Technology Institutions	Medium term (10-20 years)
5. Innovation and Entrepreneurship	Federal / State Government Agencies, Science and Technology Institutions, ST&I Funding Agencies, and Private Companies	Medium term (10-20 years)
6. RD&I Support and Incentives	Public and Private ST&I Funding Agencies, and Private Companies	Medium term (10-20 years)
7. Regulation	Federal / State Government Agencies, with collaboration from Science and Technology Institutions and Class Entities	Medium term (10 years)

1. National Strategy Plan

The development and implementation of a National Strategy Plan in Bioeconomy in Brazil is a crucial factor to obtain direct public support and incentive policies, thereby establishing guidelines for research and favorable and attractive conditions for the private sector to invest in.

Similar to what is observed in the countries that direct efforts on the theme (IACGB, 2020a), the strategy plan should focus on global challenges (environmental, social and economic), as well as defining the strategic lines of action (such as the target productive sectors, raw materials, technologies, processes and products of interest). In this regard, directing financial support, science, education and regulation to support and maximize innovation, in line with current industrial policies and national development strategies. Although Bioeconomy is present in the Science, Technology, and Innovation plans of the Federal Government (CGEE/MCTIC, 2018, MCTIC, 2016), its participation is still not very significant and the efforts directed toward the development of the theme are dispersed and ineffective.

In this regard, the discussions held during the workshops converged on the vision of expanding the Brazilian bio-based economy reducing greenhouse gas emissions (environmental goal), increasing the quality and quantity of formal jobs (social goal) and creating new products with high added value (economic goal). Given the size of Brazil, the richness of its tropical ecosystem biodiversity, and the wide regional and cultural diversity, coupled with the fact that several advances related to the green economy already coexist in Brazil, (especially in the food and bioenergy segments), it will be essential to outline development actions regionally. This is particularly true in view of the existing R&D infrastructure and knowledge and of local vocations.

As it is a topic of global interest and impact, it will be necessary to develop internationally recognized standards and metrics for sustainable exploration and production, especially regarding the environmental and social impact. To this end it is of paramount importance that Brazilian strategies for the development of the Bioeconomy be expanded and that they seek to achieve the Sustainable Development Goals (SDGs) set by the United Nations.

2. Communication Plan

Communication takes on a vital role and presents great challenges in the development of Bioeconomy, not only in Brazil, but worldwide.

It is also necessary to inform consumers about the Bioeconomy, because for most people the topic is still abstract and uncertain, or even full of myths. The new terminologies and their concepts and meanings need to be properly contextualized and presented to avoid misunderstandings while enabling a holistic view of the theme. Related topics, such as circular economy, green economy, ecological economy, blue economy, blue growth and even sustainability, need to be clarified.

Raising awareness of the advantages and benefits, especially environmental and social, that bio-based products can have compared to fossil-based products is another major challenge, particularly in view of the need to convey the message clearly and simply, through transparent and credible mechanisms. Currently, while conventional products are well established and widely accepted by consumers, bio-based products need to be constantly explained and justified.

Given the breadth of the theme and the diversity of the markets, it is necessary to differentiate the approaches for the different target audiences and their sustainable lifestyle patterns, as well as to create new formats and alternative and innovative means of communication.

Finally, considering that the Bioeconomy is a global movement, it is essential to establish global collaboration mechanisms to broaden the understanding and share the cases of success / failure in communication.

3. Education and training

It is crucial to update and modernize higher education, as well as direct and enable the training of researchers and professionals in strategic areas and themes.

Curriculum grids need to be constantly updated, and learning and research in new areas of knowledge need to be prioritized, with emphasis on the following: bioeconomy, biotechnology, bioinformatics, nanotechnology, modeling and simulation, biorefinery, process integration, precision agriculture, big data, Industry 4.0, robotics, Internet of Things (IoT), information technology (IT), artificial intelligence (AI), green chemistry, product development, marketing, entrepreneurship and business.

Connecting and expanding the efforts of the institutions in the training and qualification of young entrepreneurs (i.e. improving entrepreneurial education) is a fundamental factor for innovation, as proven by the leading countries in the field.

4. Technology transfer and extension

In Brazil, the business sector is comprised mainly of small and medium-sized companies, most of which are unaware of or have limited access to deeper knowledge and new technologies. This is a very important issue and a great challenge for the development of the Bioeconomy.

There are several representative institutions and federal and state bodies dedicated to the subject, but given the dimension, plurality and complexity of the theme, it will be necessary to create agendas for integrated and collaborative actions between these institutions and agencies, thus minimizing the use of human and financial resources and enhancing the results.

The incorporation of technologies in the agricultural sector and in the food industry, even those already consolidated, has a high potential for innovation and increased competitiveness.

5. Innovation and entrepreneurship

In the last few decades, innovation and high-tech entrepreneurship have assumed prominent positions in the development strategies of the major economies, being the principal elements responsible for the significant economic and social improvements observed in countries and cities such as India, Hong Kong, Israel, South Korea, Singapore and Taiwan, where many of the main technological hubs in the world are located.

In all the initiatives, there exist common factors: the strong participation of the State in the creation of innovative environments, the presence of Science and Technology Institutions and the large number of qualified professionals in the region. Long-term public policies, strongly centered on education (including extensive reforms to the educational system), formed the basis for the construction of these environments.

In Brazil, in 2019 about 53 million Brazilians, almost four out of ten of all adults, either owned a business or were involved in the creation of a business, which represents one of the highest rates of entrepreneurship in the world, ahead of countries such as China, the United States, the United Kingdom, Japan and France (GEM, 2020). On the other hand, Brazil occupies only the 71st position in the Global Competitiveness Ranking (WEF, 2019) and the 62nd position in the Global Innovation Index (Cornell University, INSEAD and OMPI, 2020), a position that is incompatible with its stature, added to the fact that the country is the 3rd

largest agricultural exporter and the 9th largest economy in the world.

The numbers relating to Brazilian entrepreneurship show the need to invest in further entrepreneurial education, not only aiming to transform the simplest businesses, of low complexity and low added value, into more complex and innovative businesses, but more importantly, to create new high-tech businesses focused on the global market. To achieve this, it will be necessary to structure and implement long-term public policies to encourage the adoption of new technologies, stimulate innovation and foment the development of qualified professionals. In addition, it will be essential to improve mechanisms for encouraging collaboration between Science and Technology Institutions and private companies, reducing bureaucracy, and connecting and expanding local entrepreneurial initiatives (business incubators, clusters, innovation hubs, technology parks, etc.), thus enabling construction and consolidation of innovative ecosystems in the country.

6. RD&I support and incentives

In general, the promotion of and incentives for RD&I need to focus on the development, demonstration, and implementation of bio-based solutions.

Increasing investments in RD&I is necessary and a great challenge, considering that public and private investments in Brazil represent only 1.27% of GDP (0.67% public and 0.60% private – IBGE, 2014), while in OECD countries they represent on average 2.38% of GDP, and above 4.5% of GDP in countries like Israel and South Korea (OECD, 2018).

Given the limitation of public resources, in addition to increasing efficiency it is necessary to develop and implement new mechanisms to encourage private investments in R&D, mainly in partnerships with Science and Technology Institutions. However, the major bottleneck to be overcome is the fact that the Brazilian business environment is not very attractive as it does not adequately reward private investment in innovation (World Bank, 2017). This in addition to the macroeconomic aspects, is caused by the high cost and time it takes to be granted patents, the difficulty of companies, especially small ones, in accessing public resources and services for innovation, the instability of resources destined to science and technology (S&T), mainly at the federal level, and the low expressiveness of economic subsidy mechanisms for innovation (FIESP -CIESP, 2018).

The maintenance and improvement of public R&D infrastructures need to be prioritized, as they play a crucial role in scientific and technological cooperation, both between Science and Technology Institutions and

Science and Technology Institutions in partnerships with companies. In view of the growing demand and complexity of research, public R&D infrastructures contribute to reducing the risks and costs of scientific and technological advances and, consequently, of innovation. In this regard, it is crucial to direct actions and investments to enhance the advances in the Bioeconomy.

Brazil has more than 300 Science and Technology Institutions (MCTIC, 2019), a broad and diversified infrastructure for R&D, and world-class facilities and technologies, such as the Sirius, the largest and most complex scientific infrastructure ever built in the country and one of the first sources of 4th generation synchrotron light in the world. It is part of the infrastructure of the Brazilian Synchrotron Light Laboratory (LNLS), which in turn is part of the Brazilian Center for Research in Energy and Materials - CNPEM (LNLS, 2020).

However, one of the great challenges for Brazil is the creation of cooperative arrangements for innovation in line with national industrial policies. The high level of bureaucracy for sharing public R&D infrastructures, and in some cases, their infeasibility, is a challenge to be overcome. Another bottleneck is the inexistence, or the limited number, of pilot scale and demonstration plants, essential environments for validation, proof of concept and scale up of technologies and processes. For example, for the production of biofuels and biochemicals, the need for and importance of platforms for bioprocesses (fermentative processes, biomass pretreatment, downstream, purification, chemical conversion, etc.), as well as for biorefinery arrangements, is significant. Among the existing environments, one that stands out is the Pilot Plant for Process Development of the Brazilian Biorenewables National Laboratory (LNBR), part of CNPEM (LNBR, 2020).

7. Regulation

Regulation plays a vital role in economic development. It is responsible for setting standards, in addition to monitoring, inspecting, controlling and evaluating results. Given the great complexity and magnitude of the Bioeconomy, the subject poses great challenges for the public and private sectors, both in the construction of the regulatory framework and in its implementation and compliance. Transparency, effectiveness, cooperation, and good governance are issues to be pursued.

As it is a topic of global interest and impact, it will be essential that the regulations and, especially, indicators, metrics, quality and impacts are in line with both the market and the global guidelines. In this sense, it is necessary for Brazil to participate actively with the agencies and institutions that lead global initiatives in

Bioeconomy, in particular the Economic Commission for Latin America and the Caribbean (ECLAC), a United Nations (UN) body (ECLAC, 2019), and the International Advisory Council on Global Bioeconomy (IACGB) (IACGB, 2020b).

In view of the high potential for generating new products, it is essential that regulatory instruments are agile and effective, on the one hand, reducing bureaucracy and costs and simplifying procedures, and on the other hand guaranteeing the safety of consumers and the environment.

During the workshops, the main topics pointed out that demand regulation, or its improvement and harmonization with international instruments, were: norms and standards of quality, safety and product certification; *in vitro* and *in vivo* tests and trials; registration and validation of new products (including new molecules and materials); access and exploitation of genetic resources and biodiversity; traceability and certification; sustainability and environmental impact; and data transfer, privacy and security.

Within the scope of the market, it will be necessary to implement local and global mechanisms that make it possible to increase the competitiveness of bioproducts compared to conventional products, mainly those of fossil origin. These mechanisms include, among others, the removal of subsidies and the introduction of carbon taxation. Other metrics will need to be incorporated into the bioproducts market to increase its competitiveness, such as the generation of green jobs, the restoration and preservation of natural environments, the improvement of income and quality of life of rural / local communities, sustainability indexes, etc. In this new economy, traceability will assume a key role, an area where Brazil still faces major challenges to be overcome.

Finally, it will be necessary to expand the financing mechanisms for international cooperation initiatives, both in the scope of scientific and technological research and in the development of business and markets, giving special attention to cooperation between developed countries and the productive sectors of developing economies.

Reference

- CGEE/MCTIC, 2018. Plano de Ação em Ciência, Tecnologia e Inovação para Biotecnologia. Brasília, DF: Centro de Gestão e Estudos Estratégicos – CGEE e Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC), 2018.
- ECLAC, 2019. Towards a sustainable bioeconomy in Latin America and the Caribbean: elements for a regional vision. Natural Resources and Development series, N°193.

A. G. Rodríguez, M. Rodrigues and O. Sotomayor (Ed.). Santiago: Economic Commission for Latin America and the Caribbean - ECLAC, 2019

FIESP-CIESP, 2018. O desafio de posicionar o Brasil na rota do desenvolvimento. São Paulo: Federação das Indústrias do Estado de São Paulo-FIESP, Centro das Indústrias do Estado de São Paulo-CIESP, 2018.

GEM, 2020. Global Entrepreneurship Monitor - Empreendedorismo no Brasil: 2019. Simara Maria de Souza Silveira Greco (Coord.). Curitiba: Instituto Brasileiro de Qualidade e Produtividade - IBQP, 2020.

IACGB, 2020a. Global Bioeconomy Policy Report (IV): A decade of bioeconomy policy development around the world. A report from the International Advisory Council on Global Bioeconomy. Berlim: International Advisory Council on Global Bioeconomy – IACGB, 2020.

IACGB, 2020b. Expanding the Sustainable Bioeconomy – Vision and Way Forward. Communiqué of the Global Bioeconomy Summit 2020. Berlim: International Advisory Council on Global Bioeconomy – IACGB, 2020.

IBGE, 2014. Sidra – Sistema IBGE de Recuperação Econômica, Indicadores de Desenvolvimento Sustentável, Tabela 905 - Investimentos nacionais, Valor e Percentual em relação ao PIB, em Pesquisa e Desenvolvimento - P&D, segundo os setores de aplicação. Available at: <https://sidra.ibge.gov.br/tabela/905>

LNBR, 2020. Available at: <https://lnbr.cnpem.br/pt-br/instalacoes-abertas/planta-piloto/#>

LNLS, 2020. Available at: <https://www.lnls.cnpem.br/sirius/>.

MCTIC, 2016. Estratégia Nacional de Ciência, Tecnologia e Inovação: 2016-2022. Brasília, DF: Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC), 2016

MCTIC, 2019. Relatório FORMICT: Ano Base 2018 - Política de Propriedade Intelectual das Instituições Científicas e Tecnológicas e de Inovação do Brasil. Brasília, DF: Ministério da Ciência, Tecnologia, Inovações e Comunicações - MCTIC, 2019

OECD, 2018. OECD.Stat – Main Science and Technology Indicators, GERD as percentage of GDP. Available at: https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB

Universidade Cornell, INSEAD and OMPI, 2020. Índice Global de Inovação 2020 – Quem financiará a inovação?. Soumitra Dutta, Bruno Lanvin, and Sacha Wunsch-Vincent (Ed.). Geneva: Universidade Cornell, INSEAD, and Organização Mundial da Propriedade Intelectual – OMPI, 2020.

WEF, 2019. The Global Competitiveness Report 2019. Klaus Schwab (Ed.). Switzerland: World Economic Forum - WEF, 2019

World Bank, 2017. A Fair Adjustment: Efficiency and equity of public spending in Brazil – Volume I: Overview. World Bank Group, 2017. ■

About the images used in the book

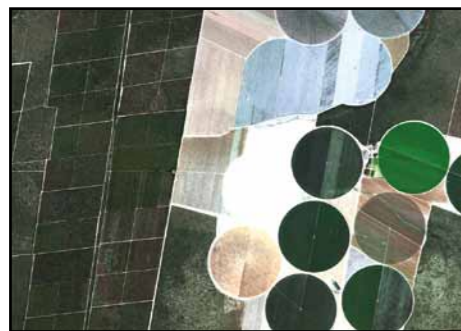
A The images used in this book were provided by the Brazilian Agricultural Research Corporation - EMBRAPA, according to the Image Use License Agreement - Contract 3356649 / SEI 21190.001244 / 2019-16, according to Letter number 18/2019-CNPM / SAT (13 November, 2019).

The original images were treated digitally and graphic filters to obtain texture and watercolor effect were applied.

Original files:



File name: *geoeye_agspec_soja_faz_cacadinha_ms_2*
Format: *jpg*
Size: *1240 x 952 pixels*
Resolution: *300 dpi*
Bit intensity: *24*



File name: *geoeye_ba_luizeduardo*
Format: *jpg*
Size: *1240 x 877 pixels*
Resolution: *300 dpi*
Bit intensity: *24*



File name: *geoeye_eucalipto_sp_sao_luiz_paraitinga*
Format: *jpg*
Size: *1240 x 764 pixels*
Resolution: *300 dpi*
Bit intensity: *24*



File name: *geoeye_sp_cosmopolis*
Format: *jpg*
Size: *1240 x 977 pixels*
Resolution: *300 dpi*
Bit intensity: *24*



File name: *geoeye_sp_itajobi*
Format: *jpg*
Size: *1240 x 877 pixels*
Resolution: *300 dpi*
Bit intensity: *24*



File name: *geoeye_sp_itirapina*
Format: *jpg*
Size: *1240 x 877 pixels*
Resolution: *300 dpi*
Bit intensity: *24*



File name: *geoeye_sp_sertaozinho*
Format: *jpg*
Size: *1240 x 877 pixels*
Resolution: *300 dpi*
Bit intensity: *24*