Bioeconomy World Tour: Bioeconomy Innovations – Challenges and Opportunities

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Ning Li, Beijing Genomics Institute (China)
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Marc Palahí, European Forest Institute

Chairs: Eduardo Trigo, Ministry of Science, Technology and Innovation of Argentina, Hannelore Daniel, German Bioeconomy Council
Bioenergy and the bioeconomy
The São Paulo Research Foundation,
FAPESP

Glaucia Mendes Souza
President
FAPESP Bioenergy Research Program
State of São Paulo, Brasil

42 Million people
32% of Brazil's GDP
45% of Brazilian science
13% of State budget to High Education and R&D
80+ Research Institutions

3 State Universities
3+1 Federal HE institutions
52 State Tech Faculties
45% of the PhDs graduated in Brazil (5,754 in 2013)
22 Research Institutes (19 state/3 federal)
Research Grants and Scholarships funded by FAPESP since 1992

Health Sciences, Biological Sciences, Agricultural, Veterinary Sciences and Biomedical Engineering

<table>
<thead>
<tr>
<th>BIOECONOMY</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,552</td>
<td>Ongoing research grants</td>
</tr>
<tr>
<td>40,212</td>
<td>Completed research grants</td>
</tr>
<tr>
<td>5,076</td>
<td>Ongoing scholarships in Brazil</td>
</tr>
<tr>
<td>53,249</td>
<td>Completed scholarships in Brazil</td>
</tr>
<tr>
<td>399</td>
<td>Ongoing scholarships abroad</td>
</tr>
<tr>
<td>2,640</td>
<td>Completed scholarships abroad</td>
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<tr>
<td>104,128</td>
<td>All Research Grants and Scholarships</td>
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</table>

Dispêndio Total em P&D (% PIB)
SCOPE-FAPESP
Reporting a global assessment of Bioenergy & Sustainability
137 experts from 24 countries

Bioenergy now
Bioenergy expansion
Energy security
Food security
Environmental and climate security
Sustainable development and Innovation
The much needed science

Developed and developing regions
Numbers, cases, issues, solutions

779-page Ebook
Download at http://bioenfapesp.org
Bioenergy Contribution in 2050: Five Low-Carbon Energy Scenarios
Bioenergy Contribution in 2012:
Liquid biofuels - over 100 Billion L – 4.2 EJ
Biopower – 1 EJ

Share of total primary energy supply in 2012

- Oil: 31.4%
- Coal: 29%
- Natural Gas: 21.3%
- Nuclear: 4.8%
- Hydro: 2.4%

Bioenergy:
- Traditional Bioenergy: 6.5%
- Modern Bioenergy: 3.5%
- Geothermal/solar/wind: 1.1%

Source: IEA Energy Statistics
World Road Transport Liquid Biofuels Demand

2010

800 million cars

50 countries, including many developing countries, now have biofuels mandates with blends of 5-27%, many driven by climate change

2050

2.1 billion cars

Advanced automotive technology has expanded the use of ethanol Biofuels could contribute to up to ~30%
Electricity, hydrogen, CNG/LPG to ~20%

3% Biofuels

27%
Advanced Research Centers:
10-year contracts, researchers from universities and from company

FAPESP+Peugeot-Citroen: biofuel engines

Natura: cosmetics and biodiversity

Glaxxo-Smith-Kline, GSK: Green Chemistry and Target Discovery

British Gas, BG: natural gas from renewable sources
Integrated new biorefinery systems are on the way: no carbon waste!

<table>
<thead>
<tr>
<th>Specialty cellulose</th>
<th>Lignin</th>
<th>Vanillin</th>
<th>Bioethanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction materials</td>
<td>Concrete additive</td>
<td>Food</td>
<td>Car care</td>
</tr>
<tr>
<td>Cosmetics</td>
<td>Animal feed</td>
<td>Perfumes</td>
<td>Paint/varnish</td>
</tr>
<tr>
<td>Food</td>
<td>Agrochemicals</td>
<td>Pharmaceuticals</td>
<td>Pharmaceutical industry</td>
</tr>
<tr>
<td>Tablets</td>
<td>Batteries</td>
<td></td>
<td>Biofuel</td>
</tr>
<tr>
<td>Textiles</td>
<td>Mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filters</td>
<td>Oil field chemicals</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Opportunities to diversify our use of biomass!
Since 2003, Brazil’s use of sugarcane ethanol has avoided 242 million tons of carbon dioxide emissions. This represents a 76% reduction in emissions in relation to gasoline. Mechanization of harvesting, balanced conditions between sugarcane producers and millers, waste recycling to reduce demand for chemical fertilizers, improved land use by implementing crop rotation between sugarcane cycles, production of bioelectricity through co-generation, significant improvements in energy balance of sugarcane ethanol, reduction in the use of water with recycling through fertirrigation, reduction of pollution in the urban areas, agroecological zoning and permanent protection areas.

Despite many ups and downs, ethanol has been successful in sustainably displacing gasoline without subsidies through technology improvements.
Newly created biomass and bioenergy centers

SP BIOEN
RESEARCH CENTER
USP - UNICAMP - UNESP

Biomass Systems and Synthetic Biology Center

http://bioenfapesp.org
SCOPE-FAPESP
Bioenergy & Sustainability Policy Brief

BIOENERGY AND SUSTAINABILITY

Bioenergy, a renewable energy source, has the potential to move the planet into a more sustainable future. Today fossil fuels supply almost 82% of the world’s energy demand. The resulting greenhouse gas emissions (GHG) impact Earth’s systems and human health and wellbeing.

Currently bioenergy contributes approximately 10% of the world’s primary energy supply. Bioethanol and biodiesel provide about 3% of the world’s transportation fuels, but biofuels could provide up to 30% by 2050 with projected improvements in technology. Bioenergy-developed knowledgeably and implemented considering local and regional needs - can help:

- increase resilience in food supply both locally and globally
- decrease pollution
- preserve biodiversity
- improve human health
- rehabilitate degraded land
- mitigate climate change
- provide economic and business opportunities

http://bioenfapesp.org/scopebioenergy/index.php
big data and synthetic biology for a better life

Ning LI
Read

Epigenetic level
- BS/RRBS
- MeDIP/ChIP-Seq

DNA level
- Whole genome Resequencing
- Exome/All-In-One/Target region seq

RNA level
- Transcriptome seq
- RNA-Seq / miRNA seq/ lncRNA seq

Protein level
- Proteome profiling
- Quantitative proteomics
- Target proteomics

Metabolite level
- Metabolites identification
  - non-targeted metabolomics
  - targeted metabolomics

Interpret

Protein-DNA Interaction

DNA modification

DNA

Non-coding RNA regulation

Transcriptional Complex

preRNA

mRNA
- gene fusion,
- RNA editing, etc.

Non-coding RNA:
- miRNA, siRNA, piRNA, lncRNA, etc.

Apply

Metabolites

Protein

Metabolite

Certifications: ISO9001  ISO14001  OHSAS18001  ISO27001  ISO17025

BGI has 13 MS sequencers, including Triple Quadrupole Mass Spectrometer (QMS), MALDI mass spectrometer, Orbitrap and Q-TOF mass spectrometer (as of June 2014).

The platform is used for industrial-scale proteomics, metabolomics research and targeted molecule detection.

Certifications: OHSAS18001  ISO14001  ISO9001

BGI’s total peak performance of computing is up to 248 Tflop, the total memory capacity 46.3 TB and the total storage capacity 22.7 PB (as of May 2014). BGI has several supercomputing centers, located in Shenzhen, Hong Kong, Beijing, Wuhan, and Hangzhou. It has established the TH-BGI Bioinformatics Union Lab with the National Supercomputing Center in Tianjin.
Generated 586 Plant & animal reference genomes

<table>
<thead>
<tr>
<th>Technology</th>
<th>Classification</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>de novo</td>
<td>Animal</td>
<td>407</td>
</tr>
<tr>
<td></td>
<td>Plant</td>
<td>179</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>586</td>
</tr>
</tbody>
</table>

Importance of the species:
- Taste good species: agriculture: rice, potato, cabbage, chicken, pig…
- useful species: Industrial: Silkworm, Palm Oil tree, Macaque…
- Cute species: digital library: G10K, i5K, 1KBird…

Technological difficulties: Highly repetitive, Heterogeneity, Polyploidy: wheat, Oyster…
Interpret

<table>
<thead>
<tr>
<th>‘Omics’ data</th>
<th>Environments</th>
<th>Mode of inheritance</th>
<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Single Gene" /></td>
<td><img src="image2.png" alt="Single Gene" /></td>
<td>Single Gene</td>
<td><img src="image3.png" alt="Different combinations" /></td>
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<tr>
<td><img src="image4.png" alt="Multiple Gene" /></td>
<td><img src="image5.png" alt="Multiple Gene" /></td>
<td>Multiple Gene</td>
<td><img src="image3.png" alt="Different combinations" /></td>
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<td><img src="image6.png" alt="Single Gene" /></td>
<td><img src="image7.png" alt="Single Gene" /></td>
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<td><img src="image3.png" alt="Different combinations" /></td>
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<tr>
<td><img src="image8.png" alt="Multiple Gene" /></td>
<td><img src="image9.png" alt="Multiple Gene" /></td>
<td>Multiple Gene</td>
<td><img src="image3.png" alt="Different combinations" /></td>
</tr>
</tbody>
</table>

**X Omics condition + Y environment condition = Z phenotype**
BGI Diagnostics aims to apply high genetic research capacity and a well-developed global network to solving current health issues worldwide.

It is committed to raising genetic health awareness and reducing the rate of major disease by offering an array of accurate, reliable and affordable genetic tests and molecular diagnostics services.
BGI Agro carries out genomics guided plant germplasms development and application, plant variety improvement and modern agriculture industrialization promotion.

- It has a lab area of over 8000 square meters, over 1200 mu breeding field, well equipped with advanced experimental instruments.

- BGI Agro has 4 production bases: Baguang & Dapeng base in Shenzhen, Luoyang base in Henan province and Laos’s base.
Apply

Big data, Synthetic Biology, Bio-manufacturing

**BENCH**
- Omics Analysis
- Gene/Genome Design & Synthesis
- Chassis Design

**BOTTLE**
- Cost effective bio-manufacturing
What Bio-manufacturing needs from Synthetic Biology

- DNA synthesis and assembly techniques

- Knowledge

Genome  Transcriptome  Proteome  Metabolome
Microarray based DNA synthesis

- Parallel Chip synthesis
- 12k /94k oligos synthesized simultaneously

- Pooled Assembly
- Enzymatic Error Correction
- 1,00s parallel synthesis

- Next-Gen Sequence Verification
- Low cost

- High yield/run
- High efficient assembly
- Low cost
- Fast turn around time
The future of Bio-manufacturing

Read by Sequencing

Write by Synthesis
China National Genebank

By the end of 2015:
• Store 30 million copies of the traceable biospecimens;
• Build 1EB accessible genetic information database.

• The China National Genebank (CNGB) was initiated in 2011 and is the first national genebank in China integrating a large-scale bio-repository and an omics database.
• The mission is to collect, preserve and exploit genomics resources, and to build a network fostering global communication and collaboration on biodiversity conservation and genetic resources utilization.

CNGB has preserved thousands of genomes, representing 80% of the finished large genome projects in the world.
The total storage capacity is 52 PB and the peak computing performance 227 T FLOPS.

8.4 million human, plant, animal and microbe samples

40+ reference genome database
52PB data storage
Peak performance 227T

60+ organization in consortia
40+ collaborative institutions

Biological Bank

Bioinformatics Bank

Consortium Network
BGI (Headquarters)
Hotline: 400-706-6615 / 400-605-6655
Tel: 86-755-36307888
Fax: 86-755-36307273
Address: Building 11, Beishan Industrial Zone,
Yantian District, Shenzhen (518083)
Website: http://www.genomics.cn/
Email: info@genomics.cn
From Burgers to Biomes: Food Agriculture and the Bioeconomy

Jack A. Bobo  |  Senior Vice President
40% Land

Jack A. Bobo  |  Senior Vice President  |  Intrexon
70% Aral Sea Today

Water

Jack A. Bobo | Senior Vice President | Intrexon
Greenhouse gas emissions from agriculture and deforestation

25%
Global Fisheries

85%

Aquabounty
Young Entrepreneurs  Investors

April 6th – 8th April, Imperial College London
Scientist as Storyteller

Personalize
Acknowledge
Connect
Build Trust

Only then can we talk about the science

Jack A. Bobo  |  Senior Vice President  |  Intrexon
Jack A. Bobo  
Senior Vice President  
jbobob@Intrexon.com  
www.dna.com
Background

- 1994 – Democracy
- 1996 - White Paper on Science & Technology
- 2001 - National Biotechnology Strategy
  - Number of mini-agencies created
  - Based on technology commercialisation
- 2014 Bio-economy Strategy

Population: 54.96 million
GNI/capita: $12,240
Unemployment: 25.5%
9th largest producer of GMO’s
a) The **full pipeline**, from research to commercialisation, needs to be considered to ensure sustainable ‘through-flow’ and desired outcome.

b) **Coordination** between academic and science council researchers, public and/or private sector institutions is vital to ensure teamwork, efficiency, and to avoid fragmentation of effort.

c) Focus on areas of **comparative advantage** and/or **national priority**. In SA - health & agric, but harness indigenous knowledge towards the development of products and empowering communities.

d) The absence of local medium to large biotechnology companies creates a challenge both for investors to ‘exit’ their investments, and to ‘scale up’ industry-relevant start-ups.

e) Under-investment in technology commercialisation seriously hampers start-ups from being competitive globally (local market size is usually insufficient for sustainable commercialisation).
The Bio-economy Strategy

Technical, opportunistic

Planned, consulted, coordinated, process focus

1) Developing World perspective
2) Sustainable livelihoods - Jobs, Jobs, Jobs
3) Poverty, inequality, unemployment
The Strategy

Input

- 3 thematic docs that outline landscape and strategic priorities
- An 'implementation plan' that reviews & provides interventions across the value chain
- Steering committees: govt, industry, science councils, academia
Some enabling priorities

- Future skills
- Technology Service Platforms
- Entrepreneurialism
- Seed funding (poc)
- Rapid advance off-take
- VC seeded
- Marketing & promotion

- Coordination
Some competitive advantages

- Human genome
  - Clinical trials, precision/genomic medicine
  - SHIP; H3D; ICGEB; BTRI (precision cancer); CPGR; UCT; WITS;
- Indigenous biodiversity mainstreaming (Cape Floral Kingdom)(CSIR; Universities)
- Indigenous knowledge (ATM; cosmeceuticals; neutraceuticals; infusions)

Some National priorities

- Agricultural sector, agroprocessing (related to access to land, the job multiplier of Agric, and rural development)
- Infectious disease burden (SA creating capabilities for manufacture and expanded trialling).
Implementation:

Detailed plans for each thematic area identified in the Strategy

**Ag:** New crop & plant and commercialisation; Crop/plant improvement, molecular breeding and genome engineering; Animal improvement, health and aquaculture; Biocontrol agents and Biofertilisers; Food safety and food nutrition; Agro-processing and agro-engineering; Natural Resource Management and Climate Smart Agriculture; Indigenous African Knowledge (IAK)-Based Agriculture

**Health:** New or improved drugs, therapeutics and drug delivery systems; New vaccines and other biologicals; New or improved diagnostics; New medical devices.

**Industry & Environment:** Bio-based chemicals and biologics; Biomaterials; Bio-energy; Biomining; Waste and Waste-water.
• SA researchers amongst most productive (publications & citations) per $.
• Very strong international collaboration.
• Proximity of world class institutions and genomically diverse populations.
• A key gateway into Africa.
• A land of unparalleled beauty!
Marc Palahí, Director

Building the European bioeconomy: a forest perspective

Global Bioeconomy Summit 2015
25-26 November 2015, Berlin

www.efi.int
European forests: our most important bio-infrastructure

- Covering 40% of EU land
- Delivering 50% of renewable energy
- Capturing 9% of CO$_2$ emissions
- Representing 25% of EU Biomass supply
- Resources for 25% of EU Bioeconomy

Key for the sustainability of: biodiversity, water and soil
Towards a cross-sectoral forest-based bioeconomy

**Enforcing drivers**
- mature markets for current products
- changing competitive advantages
- emerging economies & shifting production
- long lasting economic slump

**Enabling drivers**
- climate and energy policies
- technological advances and new products
- production synergies & resource efficiency
- services megatrend & industrial internet
- forest resource base and potential

www.efi.int
Wood construction: the beginning of the timber age?

Cross Laminated Timber (CLT) production: (> 15 % annually)

=> 28% less primary energy
=> 45% less carbon emissions
Substituting concrete by 1 m³ of wood
= saves 1 tonne of CO₂

Erkki Oksanen / Luke
Wood-based textile fibres for a growing population

- Only 5% of world textile’s are wood-based, but expected to grow at 10% per year
- The textile market to triple by 2050: from 80 Mt to 250 Mt
- The share of cotton (now 30%) to decrease due to competition for arable land and water
First biorefinary producing wood-based diesel

• UPM’s biorefinery: 100,000 tonnes of second generation biodiesel for transport
• Decreasing transport emissions up to 80% compare to fossil fuels
• 25% of Finland’s biofuel target
Concluding remarks

• A coherent, well coordinated International Bioeconomy policy framework
  • sustainability and resource efficiency
  • regulatory and market failures
  • long-term predictability for investments

• A new scale of research and innovation investments and cooperation

• An effective science-policy-society interface: reflective governance
We cannot solve our problems with the same thinking we used when we created them

- Albert Einstein
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