Perspectives on Brazil's Distinctive Role and Potential in the Biofuels Field

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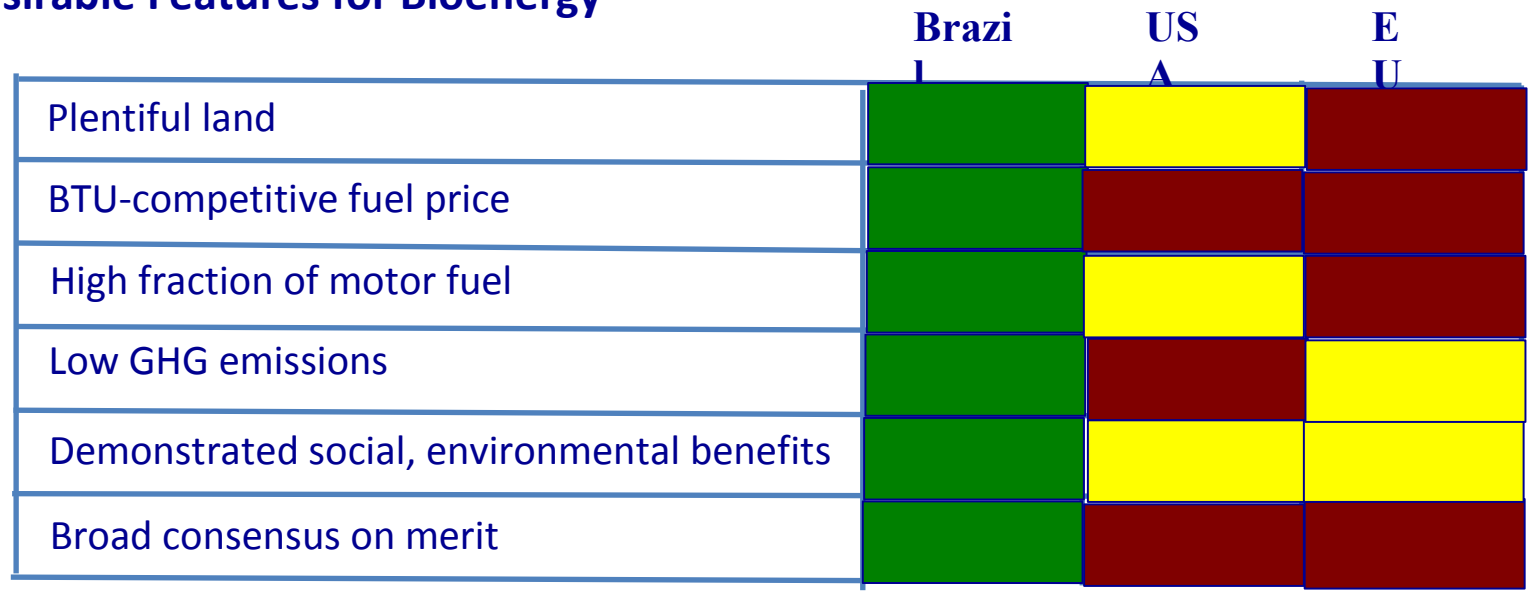
Desirable Features for Bioenergy



Realization and understanding supported by FAPESP's distinctive research program

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- Bioenergy
- Climate
- Biodiversity
- Technology transfer
- Engagement of international expertise

In the last decade, Brazil – with support from FAPESP - has developed into a global leader

in analyzing bioenergy sustainability, including all components of

Aspects of the Brazilian Bioenergy Strategic Landscape

Opportunities	Challenges	Responsive Initiatives
Intranational		
Expand domestic production	Infrastructure investment Ethanol price/GJ < global oil price	Engage international experts Drawn by positive environment, possibilities
Human resource development	Small existing expert community, takes time to develop	PAISS Engage international expertise
2nd gen ethanol	Technolog Ethanol price/GJ < global oil price	
International		
Export ethanol	Trade barriers No other exporters Negative impression of biofuels	Global analysis addressing potential & concerns: The GSB project
Export technology	Negative impression of biofuels Clear benefits for the host country	Socially-beneficial biofuels in Africa
	Limited range of sugar cane	PAISS (2nd gen transferable) Diversify feedstock focus

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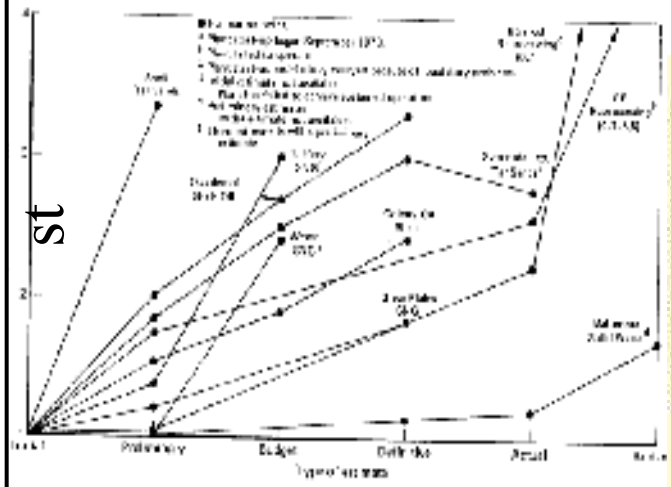
2nd Generation Ethanol

The Innovation Hump: From Initial Estimate to Nth Plant

Rand Curve

Estimated cost managed with experience, inversely related to ignorance



Rand Study, 1979

Brazil 1st Gen Ethanol Curve

Estimated cost decreases with experience

Goldemberg et al., 2004

Cost

Progress/Experience

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For 2nd Generation Cane Ethanol

- Recognize current state of technology: Cash-competitive, not investment competitive
- Anticipate mature technology
- Develop strategies to progress rapidly

2nd Gen Cane Ethanol: Anticipating Mature Technology

Back of the envelope

- Feedstock costs generally dominate economics of fuel production
- $60/dry ton = $4/GJ = $23/barrel = ~25% that of petroleum
- Compared to processing petroleum, processing biomass has some advantages (more reactive chemical constituents, much greater amenability to biotechnology) and thus may not be inherently more expensive
- **Cost competitive fuel production is reasonable to expect**

More detailed

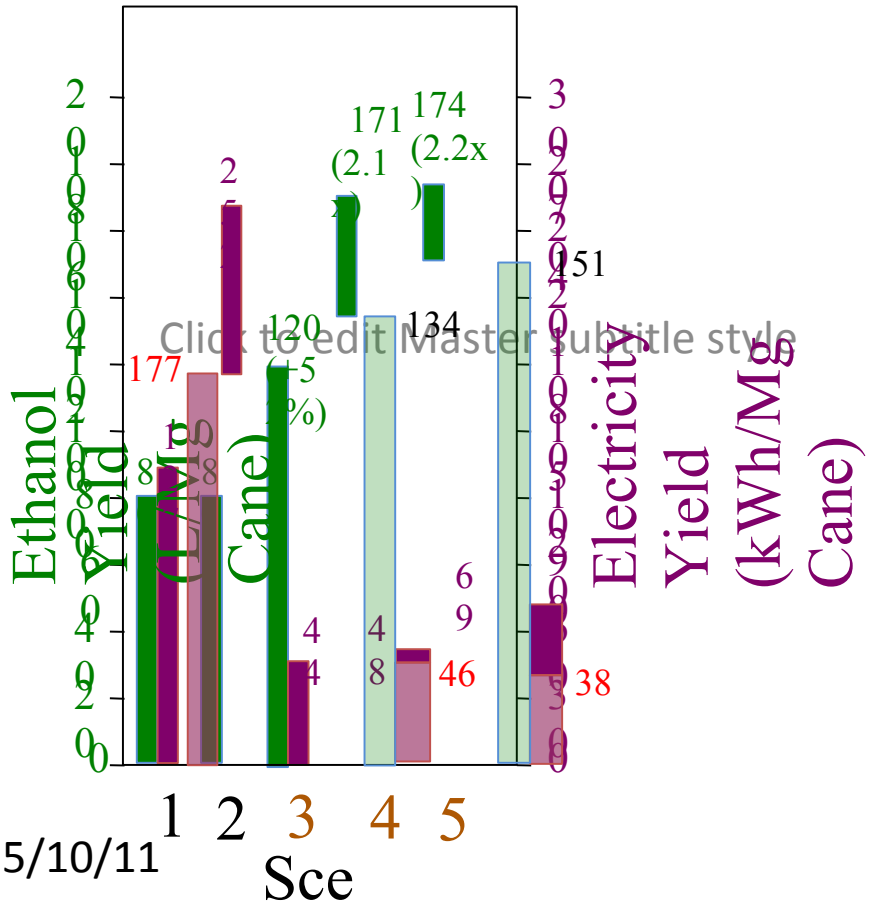
Analysis presented at BBEST meeting, Campos Do Jordão. August, 2011, by Mascoma Corp. & Dartmouth College in consultation with many Brazilian colleagues

Seed funding provided by FAPESP

Scenarios examined

1) Gen 1 ethanol with cogen (bagasse only)
2) Gen 1 ethanol with cogen (+ trash)
3) Gen 1 + Gen 2 ethanol with cogen (bagasse only)
4) Gen 1 + Gen 2 ethanol with cogen (+ trash)
5) Scenario 4 + increased thermal integration

Ethanol and Electricity Yields



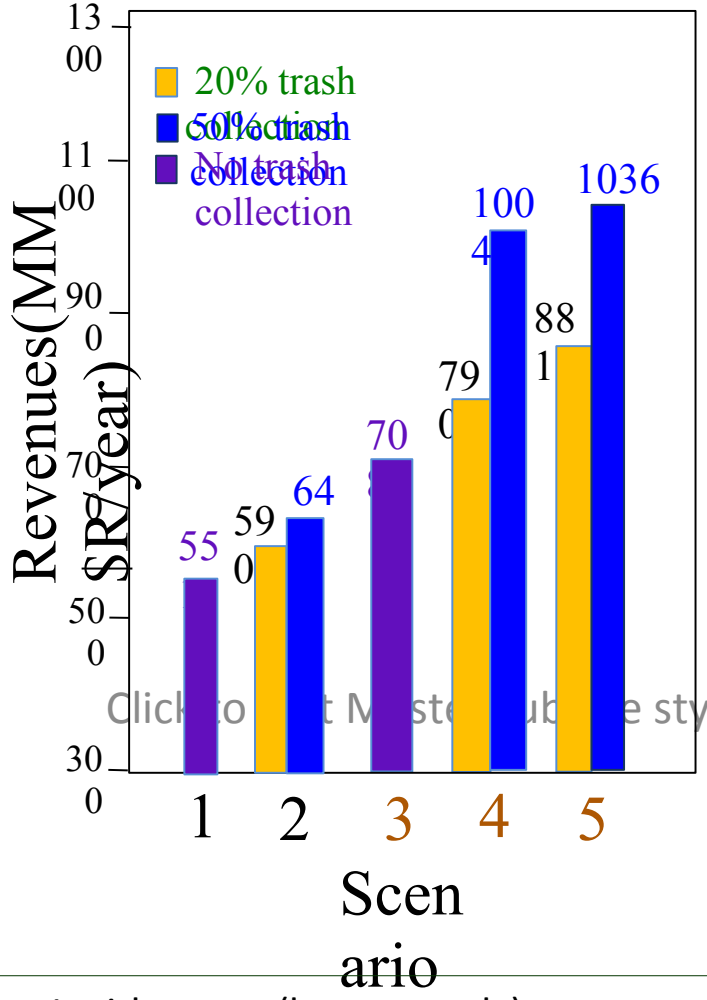
Electricity yield with 20% trash collection
Added electricity yield with 50% trash collection
Ethanol yield with 20% trash collection
Added ethanol yield with 50% trash collection

Parameters

· 0.15 kg dry bagasse /kg wet cane (70% moisture)
· 0.1 kg dry harvested trash/kg wet cane
· Future trash scenario: 50% collection
· Current trash scenario: 20% collection
· Gen 2 ethanol yield: 78% of theoretical
· Electricity Price $R 131.38/MWh
· Ethanol Price $R .94/L
· 6MM ton cane crushed/ year scale

Lynd et al., BBEST

Revenues



2nd Generation ethanol offers decisively more coproduct revenue as compared to electricity

	Incremental Coproduct Revenue (MM$R/year)
Cane trash → electricity (Scenario 2 - scenario 1)	94
Cane trash → 2nd gen EtOH (Scenario 4 - scenario 1)	453
Revenue multiplier	**4.8**

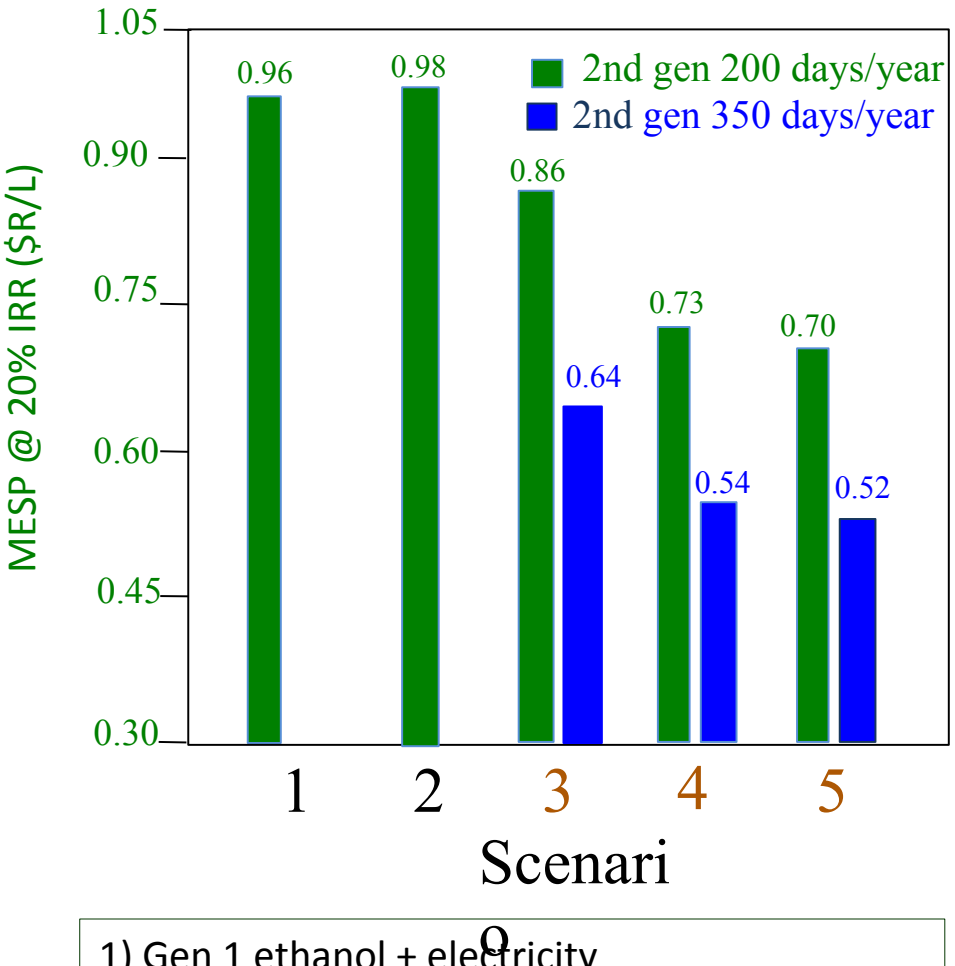
	Incremental Coproduct Revenue (MM$R/year)
20% trash	39
50% trash	239
	6.1

1) Gen 1 with cogen (bagasse only)
2) Gen 1 with cogen (+ trash)
3) Gen 1 + Gen 2 with cogen (bagasse only)
4) Gen 1 + Gen 2 with cogen (+ trash)
5) Scenario 4 + increased thermal integration

Parameters
- 6 million Mg cane/year
- $R 40.55 /Mg cane (70% moisture)
- $R 56.77/Mg trash (15% moisture)
- $R 131.38/MWh
- Exchange Rate 1.62 BRL / USD

Lynd et al., BBEST

Minimum Ethanol Selling Price (MESP) for 2nd Gen Cane Ethanol



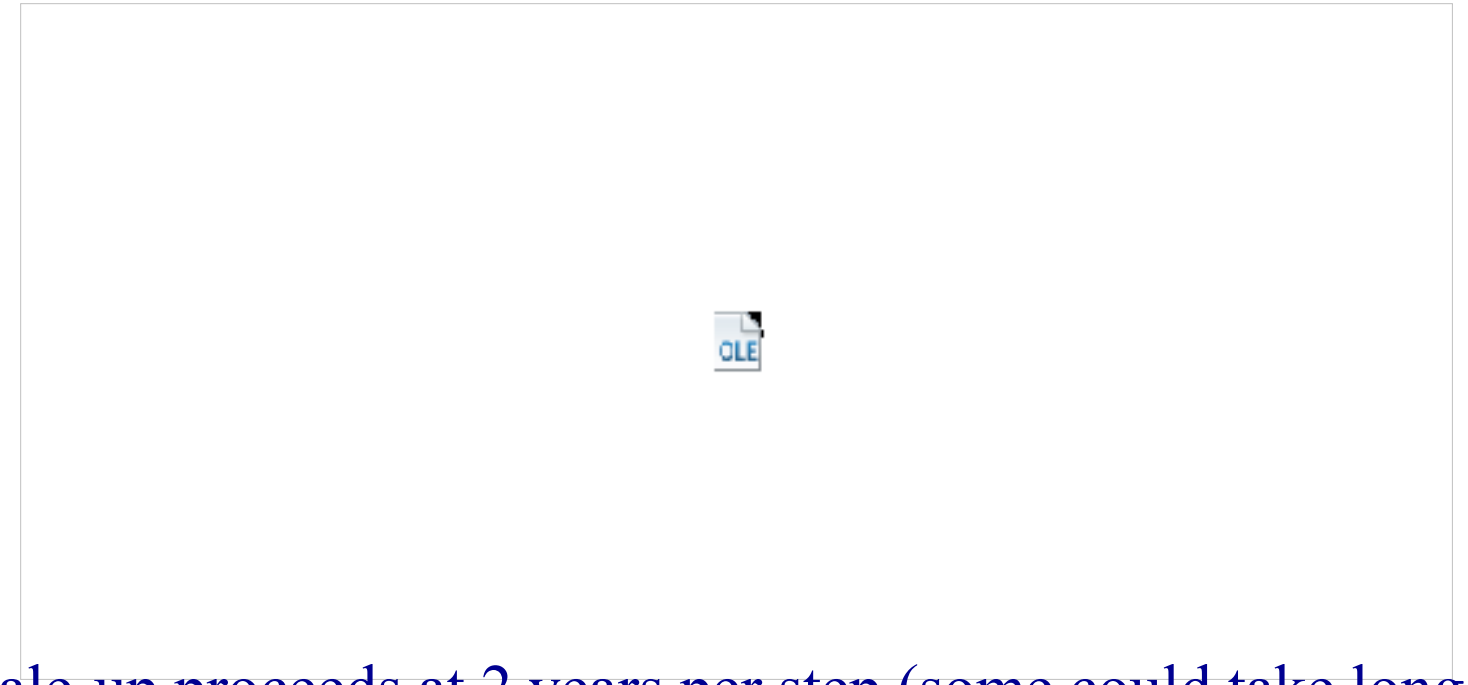
1) Gen 1 ethanol + electricity
2) Gen 1 ethanol + electricity (+ trash)
3) Gen 1 + 2 ethanol + electricity (bagasse only)
4) Gen 1 + 2 ethanol + electricity (+ trash)
5) Scenario 4 w/increased thermal integration

Parameters

- 6 million Mg cane/year
- $R 40.55 /Mg cane (70% moisture)
- $R 56.77/Mg trash (15% moisture)
- $R 131.38/MWh
- 20% IRR
- 100% equity financing, 20-year SL depreciation
- 34% income tax rate
- Exchange Rate 1.622BRL / USD

2nd Gen Cane Ethanol: Develop Strategies to Progress Rapidly

Potential scale-up steps



If scale-up proceeds at 2 years per step (some could take longer) it would take 12 years
to reach a billion liters of capacity

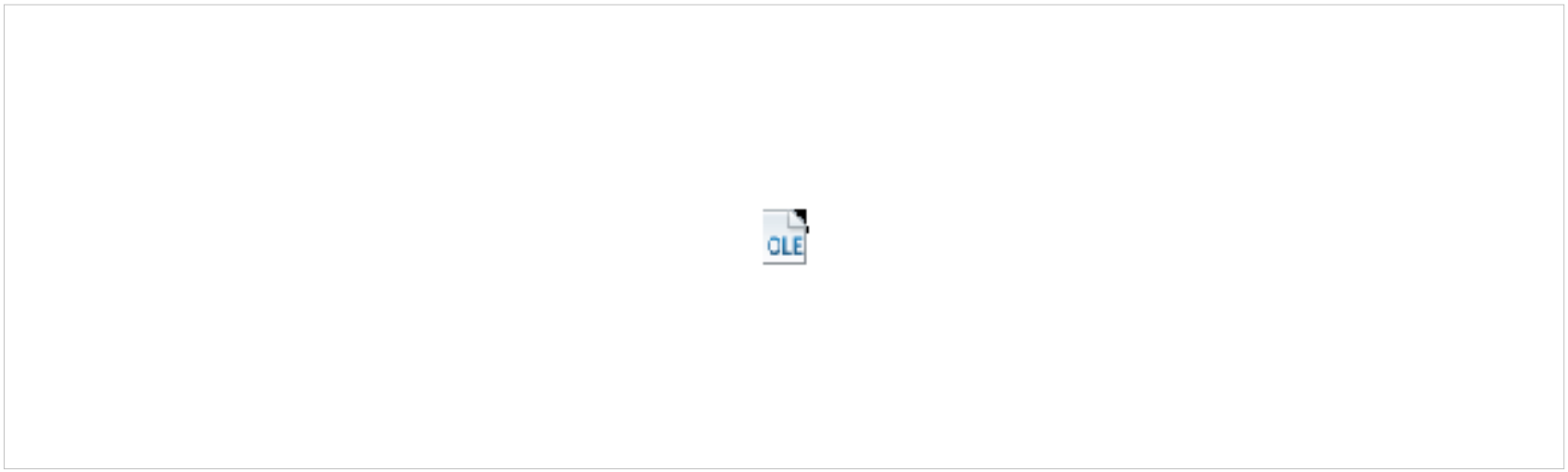
Both commercial and governmental objectives would be served by proceeding faster

2nd Gen Cane Ethanol: Develop Strategies to Progress Rapidly

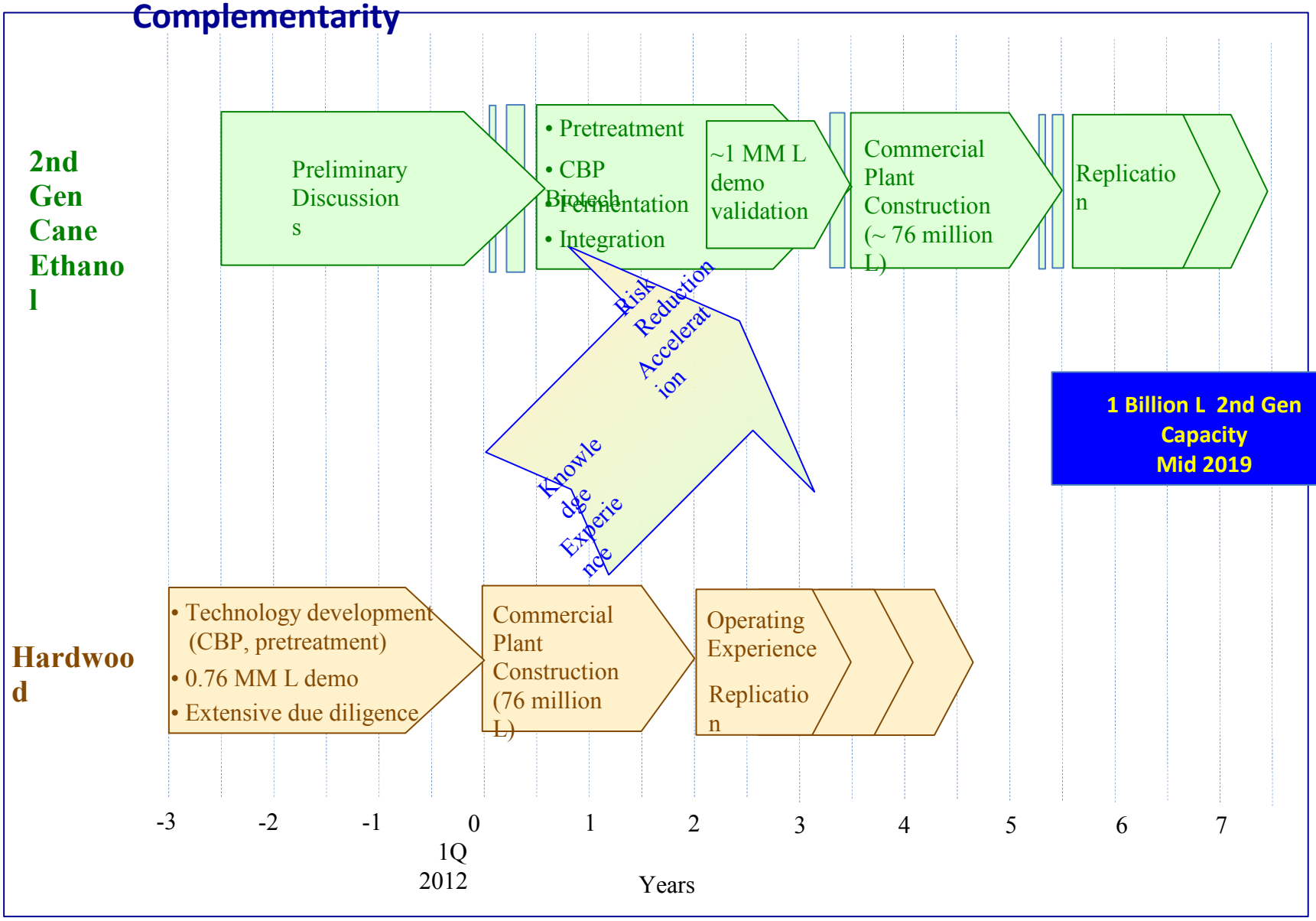
Take advantage of experience with other feedstocks

Do lab, demo 1 simultaneously – as Mascoma Corp. has done for hardwood ethanol

Eliminate Demo 2 – as Mascoma Corp. is doing for hardwood ethanol



Hardwood and 2nd Gen Cane Ethanol Timelines & Complementarity



Global analysis addressing potential & concerns: The GSB project

Notwithstanding concern over land-use issues, there appear to be many "levers" that could enable large-scale bioenergy production within existing managed land without decreasing food production, and with neutral or positive environmental impacts

Pasture intensification	10% of global pasture land ⍰ global petroleum	Richard Hamilton, Ceres
Underutilized managed land	Degraded Brazilian pasture ⍰ ¾ global gasoline	This presentation
Double crops	US implementation ⍰ current US + Brazilian ethanol	Richard et al., 2011
Changed animal feed rations	US implementation ⍰ 50% US gasoline	Dale et al., 2010
Burned & damaged lands	Global implementation ⍰ Global gasoline	Giglio et al., 2010 + preliminary calculation
Use crops that grow where food crops can't (e.g. CAM)	Powerful multiplier for other strategies	Somerville et al., 2010
Dietary choice & higher supply chain efficiency	US implementation ⍰ Global gasoline	Extensive analysis, in-preparation

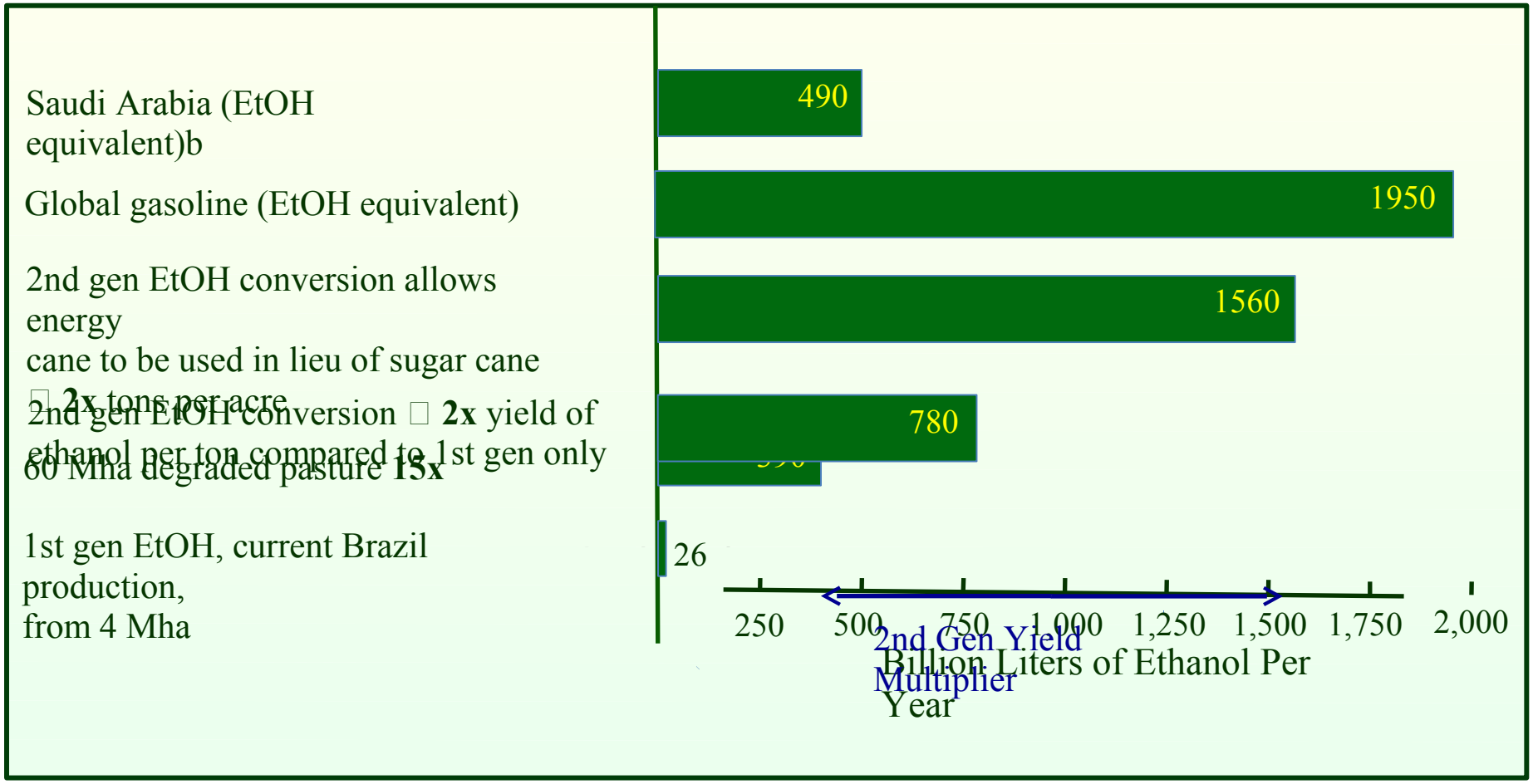
These levers

Appear to have gigantic fuel production potential, with application of single levers in single countries significant relative to global fuel demand in several cases

Have seldom been considered in analyses of "food vs fuel" and energy futures

Merit more detailed analysis at a global scale

Example: 60 Mha degraded pasture could be used to grow sugar cane with no significant impact on environment and biodiversity (Brazlian Ministry of Agriculture)



b12.5 million barrels/day, 72 L gasoline/bbl, 1.5 L ethanol equivalent/L gasoline

Global Sustainable Bioenergy: Feasibility & Implementation Paths "GSB Project" (www.engineering.dartmouth.edu/gsbproject/)

Initiated June, 2009. "Bottom-up effort", no request for proposals, no initial sponsorship.

Working hypothesis: It is physically possible to gracefully reconcile large-scale bioenergy production (≥ 23% of primary energy supply in 2050, consistent with IEA Blue Map Scenario) with feeding humanity, meeting other needs from managed lands, and preserving wildlife habitat and environmental quality.

Staged Structure

Stage 1. Continental Conventions

- Gather input on framing stages 2 and 3
- Continental and common resolutions
- Recruit participants & funds

Stage 2. Address working hypothesis, unconstrained by current realities.

Stage 3. Analyze implementation paths, recommend policies

GSB Project: Approach and Differentiation

	Most Bioenergy Projects & Analyses	GSB Project
Focus	Most probable	Most desirable
Expert opinion	Reflected, often sharply divided	Informed, seek new understanding & consensus
Point of reference	Current reality	Future vision
Value	√	√

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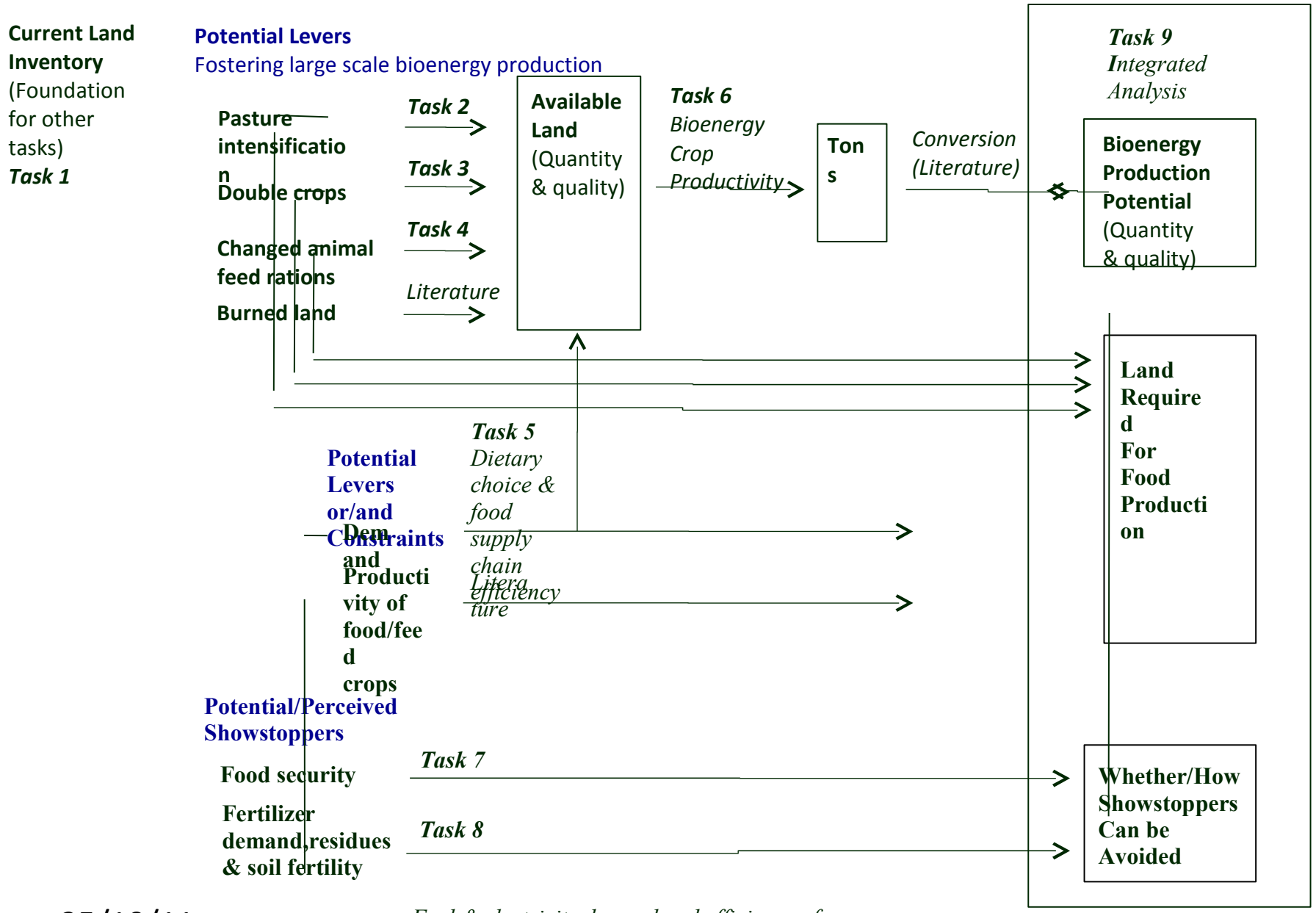
While there is a natural reluctance to consider change, we must do so since humanity cannot expect to achieve a sustainable and secure future by continuing the practices that have resulted in the unsustainable and insecure present.

Statement made on behalf of the GSB Stage 1 Organizing Committee, Issues in Science and Technology, Summer, 2009

Emergent GSB Structure



After the GSB project held meetings in every continent, Brazil – more than any other country and led by FAPESP – has stepped forward with support and participation

Socially-Beneficial Biofuels in Africa

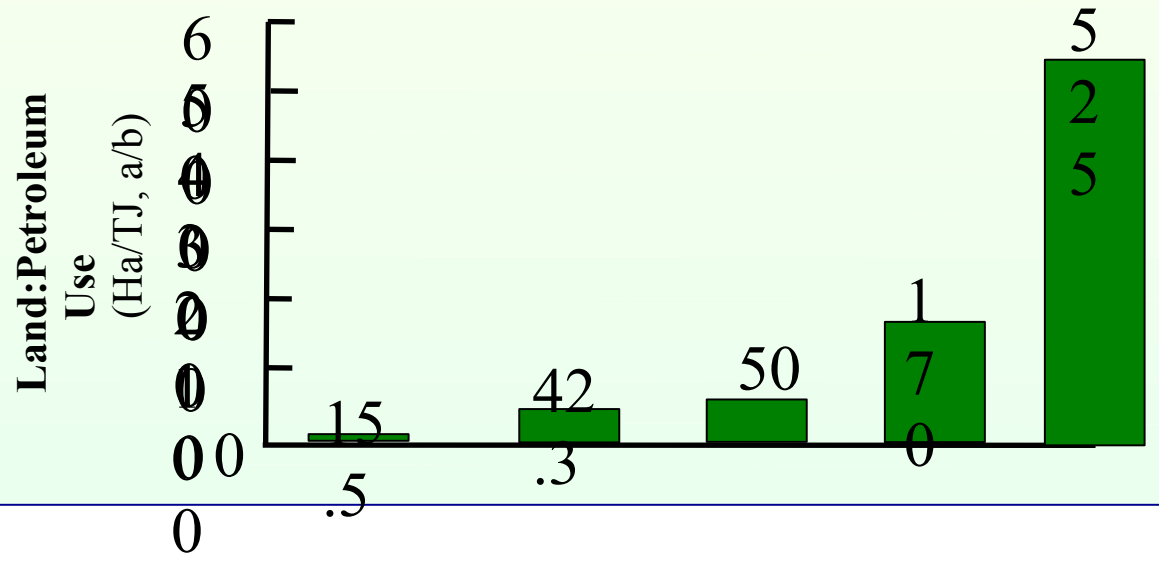
Potential: Assessments of biomass production potential consistently identify Africa and South America as the two continents with the greatest capacity

Need: Greatest incidence of food insecurity and poverty

Significance: Africa is often seen as particularly impacted by food vs fuel issues

Bioenergy in Africa: Modest Production from Plentiful Land Large Petroleum Displacement

	European Union	North America	Asia	South America	Africa
a. Total land (ha capita-1)	0.9	6.0	0.8	4.5	3.1
b. Petroleum Use (TJ capita-1 yr-1)	0.0581	0.142	0.016	0.0265	0.0059



Food Security & Biofuels

Why are people hungry?

Poverty

All hungry people are poor

All wealthy people have access to food

Perpetuated and exacerbated when growing crops for sale - in excess of subsistence requirements - is not a viable enterprise, leading to a *loss of resilience* when crops fail

Household level – Poor subsistence farmers have no reserves of food or cash

Regional level – No excess productive capacity

The problem

Food Security

Poverty

No skills

No opportunity

Growing crops for sale not viable

Low crop productivity
- Exhausted soil
- Lack of capital
- No access to latest seeds, techniques
- Collapsed ag. extension
- Poor farmers not rewarding private sector customers

Infrastructure poorly developed
- Storage & transport
- Energy

Poor farmers can't compete without benefits available to famers in developed countries
- Established markets
- Price supports
- Futures pricing
- Crop insurance
- Counter cyclical payments

Food aid Needed in emergencies but perpetuates dependency, administered more to benefit producers than recipients

Remedies

Economic development

Jump start agriculture

The problem

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Remedies

Economic development

Jump start agriculture

Biofuels

Have marked potential to positively impact both

Food Security and Biofuels

Lynd & Woods, "A New Hope for Africa", Nature, June 2011.

Supported by a consortium of organizations including FAPESP

It has widely been assumed that increased production of energy from biomass requires a sacrifice in food security, especially for the world's poor. Yet closer scrutiny suggests that modern bioenergy – in the form of fuel, electricity or heat – could be developed in ways that increase food security

Consideration of the impact of bioenergy on African food security has tended to focus on land competition and to overlook bioenergy's marked potential to promote rural development.

However, potentially productive land is rather plentiful in much of Africa whereas lack of development is the most important underlying cause of hunger.

Africa has about 12 times the land area of India, similar land quality, and 30% fewer people - yet India produces enough food to feed itself and Africa does not. The green revolution bypassed Africa primarily due to serious organizational and institutional weaknesses, not geographically-limited capacity (A. Temu, ICRAF)

Although each situation is different, Africa might hope to replicate aspects of Brazil's success.

Food Security and Biofuels

Lynd & Woods, "A New Hope for Africa", Nature, June 2011.

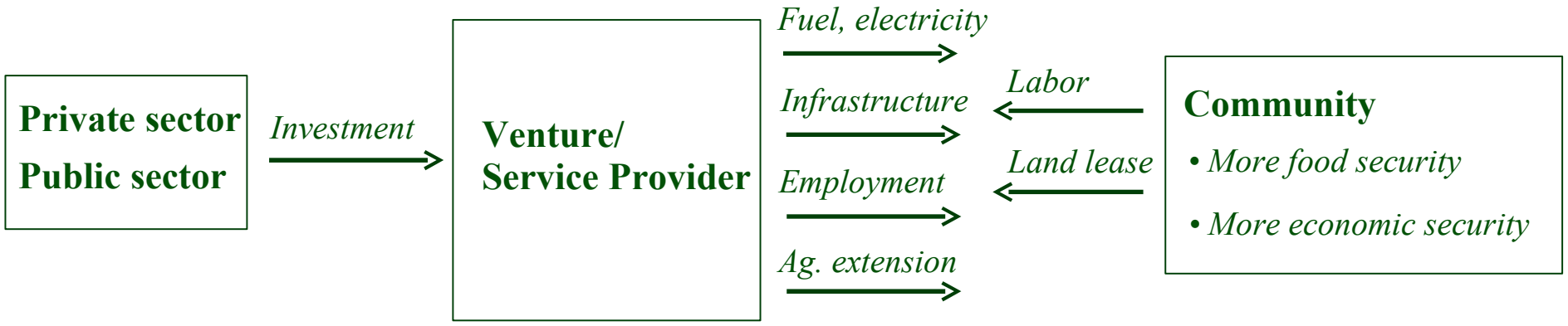
We suggest that proposed bioenergy projects in Africa be expected to demonstrably improve food security at a local level.

- Honors the centrality of food security
- Moves the discussion from the abstract to the specific
- Is perhaps not hard to achieve
- Merits further thought & analysis

Food Security and Biofuels

Intriguing question: How might an enterprise be configured with the dual goals of producing bioenergy and enhancing local food security?

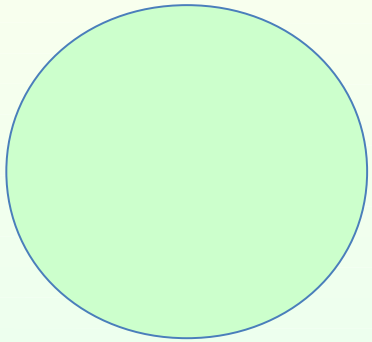
Human perspective



Land perspective

Without bioenergy
(modern)

• *All land devoted to food (and energy), low productivity*



With bioenergy
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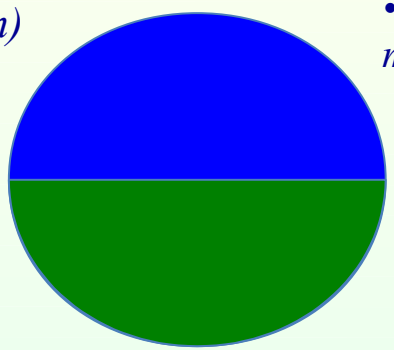

• *Some land used for modern bioenergy,*

• *More food from less land*

It is clear that this is physically possible. Do we have the imagination to make it happen?

Potential Factors Limiting Bioenergy in Africa

Technology

Investment

Articulation of a vision for socially-beneficial Biofuels in Africa

- Arguably the most important
- Accessible to the GSB

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Challenges

Infrastructure investment

Ethanol price < global oil price

Small existing expert community, takes time to develop

Technology

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Trade barriers

No other exporters

Negative impression of biofuels

Negative impression of biofuels

Clear benefits for the host country

Limited range of sugar cane

Responsive Initiatives

Engage international experts

Drawn by positive environment, possibilities

PAISS

Engage international expertise

Global analysis addressing potential & concerns: The GSB project

A new, positive example: Socially-beneficial biofuels in Africa

PAISS (2nd gen transferable)

Diversify feedstock focus

FAPESP is already leading several of these initiatives, and will likely play a meaningful role in all

Each initiative multiplies the value of the others

This combination of initiatives is not happening elsewhere…

… positioning Brazil to be a, quite possibly the, global leader in the biofuels field

- ***Intellectual***
- ***Commercial***
- ***Technical***