AFOLU Lab

Biofuels Technology Vision 2050
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Outline (condensed version)

- Global biofuel overview
- Understanding biofuels technologies in Brazil
- Other MAPS countries
- Conclusions
Global Biofuel Overview
Biofuel routes

Notes:
1. Parts of each feedstock, for example, crop residues, could also be used in other routes.
2. Each route also gives coproducts.
3. Biomass upgrading includes any one of the densification processes (pelletization, pyrolysis, torrefaction, etc.).
4. Anaerobic digestion processes release methane and CO2 and removal of CO2 provides essentially methane, the major component of natural gas; the upgraded gas is called biomethane.
5. Could be other thermal processing routes such as hydrothermal, liquefaction, etc.

* Commercial products

• Potential GHG emissions reduction helps to select …

Source: Chum et all (2011)
# Cane Ethanol is an Intense-Residue Fuel

<table>
<thead>
<tr>
<th>Feedstock / biofuel / Process</th>
<th>Total Energy MJ ha⁻¹ year⁻¹</th>
<th>Biofuel Energy MJ ha⁻¹ year⁻¹</th>
<th>Energy Yield (biofuel/feedstock)</th>
<th>Energy Balance (biofuel/fossil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Ethanol</td>
<td>61,065.0</td>
<td>31,180.9</td>
<td>0.51</td>
<td>1.8</td>
</tr>
<tr>
<td>Palm Oil HVO</td>
<td>300,960.0</td>
<td>151,165.3</td>
<td>0.50</td>
<td>3.5</td>
</tr>
<tr>
<td>Palm Oil FAME</td>
<td>300,960.0</td>
<td>149,103.9</td>
<td>0.50</td>
<td>3.3</td>
</tr>
<tr>
<td>Rapeseed HVO</td>
<td>73,975.4</td>
<td>43,382.5</td>
<td>0.59</td>
<td>2.6</td>
</tr>
<tr>
<td>Rapeseed FAME</td>
<td>73,975.4</td>
<td>42,790.9</td>
<td>0.58</td>
<td>2.4</td>
</tr>
<tr>
<td>Soybean FAME</td>
<td>55,960.0</td>
<td>18,182.1</td>
<td>0.32</td>
<td>1.8</td>
</tr>
<tr>
<td>Sugar beet Ethanol</td>
<td>280,604.9</td>
<td>152,544.1</td>
<td>0.54</td>
<td>1.8</td>
</tr>
<tr>
<td>Sugarcane Ethanol (68.7 ton ha⁻¹ year⁻¹)</td>
<td>370,293.0</td>
<td>133,574.4</td>
<td>0.36</td>
<td>11.1</td>
</tr>
<tr>
<td>Sugarcane Ethanol (82.4 ton ha⁻¹ year⁻¹)</td>
<td>444,351.6</td>
<td>160,289.3</td>
<td>0.36</td>
<td>12.4</td>
</tr>
<tr>
<td>Waste vegetable or animal oil FAME</td>
<td></td>
<td></td>
<td>0.98</td>
<td>3.1</td>
</tr>
<tr>
<td>Wheat Ethanol (straw CHP)</td>
<td>76,586.8</td>
<td>40,688.0</td>
<td>0.53</td>
<td>5.4</td>
</tr>
<tr>
<td>Wheat Ethanol (natural gas CHP)</td>
<td>76,586.8</td>
<td>40,688.0</td>
<td>0.53</td>
<td>1.4</td>
</tr>
</tbody>
</table>

- Ethanol is produced from fermentable sugars but cane residues (bagasse and molasses) are integrally used in the industrial process.
- Other crops already have the majority of its energy accounted either in the biofuel or in the avoided ILUC-credit (feed co-product).
- Sugarcane is the only crop with potential to increase its energy share dedicated to biofuels.

Note: due to the area under renovation, some methodologies assume 5/6 of the current yield (5 years planted and harvested and 1 year planted). It is included in the table both the current yield and the 5/6 of the current yield.

Source: Agroicone, adapted from BIOGRACE Biofuel Calculations Tool (Version 4b public).
Cost trajectory is also quite relevant...

Biofuel production costs (2010 – 2050)

Note:
Costs reflect global average retail price without taxation. Regional differences can occur depending on feedstock prices and other cost factors.

Source: IEA (2011)
Biofuel Technologies in Brazil
Sugarcane ethanol

Yields
- Field yield: 79.5 ton of sugarcane/ha;
- Industrial yield: 6,500 l of ethanol/ha;
- Energy yield: 139,640 MJ/ha
- Cogeneration - Surplus electricity export (boiler 65 bar/480ºC): 80 kWh/1 ton of processed sugarcane (bagasse) and 150 kWh/t (bagasse and straw)
- Water use: 137 liters of water to produce 1 kg of sugarcane (78 liter/MJ for sugarcane ethanol).

Production Costs
- Electricity auction from biomass (sugarcane bagasse): R$ 133 /MWh (1 USD = R$ 2.40)

Environmental Issues
- It avoids about 80% of GHG emissions comparing to pure gasoline (considering CHP of bagasse only). If CHP is supplemented with trash, reduction be higher than 100%.
- Energy consumption: 12,329.7 MJ/ha (inputs + mechanized operations) and 2,611.1 MJ/ha (industrial phase)
- It spends 1.8 m³ of water to process 1 ton of sugarcane in industrial phase (Brazilian refineries spend about 0.9 m³ of water to produce 1 m³ of petroleum).

Investments
- Agricultural and industrial equipment for greenfield mill (4 million ton of sugarcane processed per year)
  - Only Ethanol: R$ 739 millions
  - Ethanol (60%) Sugar (40%): R$ 817 millions
- Cogeneration greenfield plant (3 million ton of sugarcane processed per year): R$ 2,312/kW

Social Issues
- Workers per hectare in 2012:
  - Sugarcane: 0.058
  - Soybean: 0.013
  - Corn: 0.12
- Average income in 2012:
  - Sugarcane: R$ 992/month
  - Soybean: R$ 1,802/month
  - Corn: R$ 234/month
  - Minimum wage: R$ 622/month
- For each generated employment in petroleum sector it generates 152 employments in sugarcane sector.

Sugarcane Agroecological Zoning

Because of possible conflicts between sugarcane ethanol expansion and conservation targets, the Brazilian government and the private sector agreed to develop a national policy that would orient sugarcane expansion and protect environmental interest.¹

The sugarcane agroecological zoning restricts expansion over natural vegetation and in biomes considered strategic for conservation, among others.

Although sugarcane has expanded over pastureland (69%) and other crops (31%)¹¹, the zoning gave great visibility for long term sugarcane sustainability.

Main Criteria

- Exclusion of areas with native vegetation;
- Exclusion of areas at the Amazon Biome, Pantanal biome and Upper Paraguay river Basin;
- Indication of areas with agricultural potential without full irrigation;
- Indication of areas with slope inferior to 12% (suitable for mechanization);
- Respect to the safe nourishing;
- Prioritize degraded or pasture areas.

Results: Suitability Land

- High suitability under agriculture (Ac), Livestock (Ag) and Pastureland (Ap): 19.3 millions ha;
- Average suitability (Ac + Ag + Ap): 41.5 millions ha;
- Low suitability (Ac + Ag + Ap): 4.2 millions ha;
- Total suitable land for sugarcane expansion: **65 millions ha**

Biodiesel program goals

Combined Social and biofuels program with focus on smallholders in Northeast, especially jatropha and castor bean did not delivered expected outcomes. As seen in the graphs, the bulk of biodiesel production comes from soybean produced in the Center West, mainly by large scale, commercial farmers.

**Soybeans**

Yields
- Field yield: 2.8 ton of soybean/ha;
- \( \frac{4}{5} \) Meal (80%); Oil (20%)
- Industrial yield: 680.7 l of biodiesel/ha;
- Energy yield: 11,450 MJ/ha
- Water use: 1,408 liters of water to produce 1 kg of soybean (40 liter/MJ for soybean biodiesel)

Economic issues
- Production cost: USD 0.85/l of biodiesel (without freight and taxes);
- Average price in biodiesel auctions (2012): USD 1.01/l of biodiesel (tax included);
- + CAPEX: USD 23.4 milicos (33 millions liters of biodiesel per year)
- Biodiesel is not price competitive with fossil diesel.

GHG emissions
- In field: 8 g CO\(_{2}\)eq/MJ
- Soybean processing: 8.2 g CO\(_{2}\)eq/MJ
- Biodiesel production: 4.5 -11 g CO\(_{2}\)eq/MJ

**Palm Oil**

Yields
- Field yield: 10.9 ton of palm oil (fruit)/ha; Palm Oil (20 – 50%):
- Industrial yield: 4,207 l of biodiesel/ha;
- Energy yield: 138,855 MJ/ha

Economic issues
- Production cost: USD 0.74/l of biodiesel (nominal value in 2006: R$ 1.231/l of biodiesel)
- Investment: USD 500 millions (processing 25 ton of palm oil per hour)

GHG emissions
- Whole process: 19.7 g CO\(_{2}\)eq/MJ

New Investments
- Petrobrás: will implement a biodiesel plant in Pará State (capacity 230 millions liters of biodiesel per year)
- Vale: will implement 2 biodiesel plants in Pará State (80,000 hectares of palm oil tree)

Source: ABIOVE (2014)

Feedstock

Soybeans | Tallow | Cotton Oil | Others
---|---|---|---
2008 | 80% | 20% | 0%
2009 | 80% | 20% | 0%
2010 | 80% | 20% | 0%
2011 | 80% | 20% | 0%
2012 | 80% | 20% | 0%

Land use change GHG emissions

- LUC GHG emission are highly dependent on local characteristics
- Changing from annual to perennial tends to be a carbon sink in all regions
- Any conversion of natural vegetation is a net emitter. Expansion of biofuels over natural vegetation should be restricted, independent of the crop.
- Sugarcane SOC is similar to perennial crop. Additional research is needed to establish proper conversion factors.

Source: EPA (2009)
• Sugarcane is usually planted once every 5 years, technologies to reduce N application are under development.
• Water impacts of biofuels crops must be analyzed regionally, considering the net balance with the previous land use.
• Careful and local studies should precede sugarcane expansion in water stressed regions.

## Development status of the main Brazilian biofuel industrial tech

<table>
<thead>
<tr>
<th>Basic and Applied R&amp;D</th>
<th>Demonstration</th>
<th>Early Commercial</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>Biogas</strong> from sugarcane bagasse and straw gasification</td>
<td>• <strong>Ethanol 2\textsuperscript{nd} Generation</strong> from sugarcane bagasse and straw hydrolysis</td>
<td>• <strong>Biodiesel</strong> from sugarcane and palm oil</td>
<td>• <strong>Ethanol 1\textsuperscript{st} Generation</strong> from sugarcane juice fermentation</td>
</tr>
<tr>
<td></td>
<td>• <strong>Biojet Fuel</strong> from sugarcane (DSHC) and algae (HEFA)</td>
<td>• <strong>Biogas</strong> from vinassee (sugarcane residue)</td>
<td>• <strong>Electricity</strong> from sugarcane bagasse combustion</td>
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<tr>
<td></td>
<td></td>
<td>• <strong>Biogas</strong> from landfill (urban residue anaerobic digestion)</td>
<td>• <strong>Biodiesel</strong> from soy oil and animal tallow transesterification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• <strong>Ethanol 1\textsuperscript{st} Generation</strong> from corn in flex mill (sugarcane/corn)</td>
<td>• <strong>Biogas</strong> from manure anaerobic digestion</td>
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<tr>
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<td></td>
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</tr>
<tr>
<td></td>
<td>• <strong>Biodiesel</strong> from algae</td>
<td></td>
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</tr>
</tbody>
</table>

**Note:**
I. Hydro-processed Esters and Fatty Acids; II. Catalytic hydrothermolysis; III. Direct Sugar to Hydrocarbon; IV. Alcohol to Jet; V. Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene; VI. hydrotreated depolymerized Cellulosic to Jet

Source: Agroicone
### Development status of the main Brazilian biofuel agricultural tech

<table>
<thead>
<tr>
<th>Basic and Applied R&amp;D</th>
<th>Demonstration</th>
<th>Early Commercial</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>Sugarcane GMO Varieties</strong></td>
<td>• <strong>Sugarcane GMO Varieties</strong> (Drought Resistance).</td>
<td>• Sugarcane High Fiber Content Varieties;</td>
<td>• Sugarcane Mechanized Harvesting (No Burn).</td>
</tr>
<tr>
<td>- Cell Wall with Self-hydrolysis;</td>
<td></td>
<td>• Trash recovery;</td>
<td>It is already used for electricity cogeneration, beyond that, it might be</td>
</tr>
<tr>
<td>- Insect Resistance;</td>
<td></td>
<td>“The next step”</td>
<td>used for improving ethanol 2\textsuperscript{nd} generation production</td>
</tr>
<tr>
<td>- High Sugar Content</td>
<td></td>
<td>• <strong>Wood chips.</strong></td>
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<tr>
<td></td>
<td></td>
<td>These technologies are already used for electricity cogeneration, beyond that,</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>they might be used for improving ethanol 2\textsuperscript{nd} generation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>production</td>
<td></td>
</tr>
<tr>
<td>• <strong>Capim-elefante</strong> (<strong>Pennisetum purpureum</strong>).</td>
<td>Similar to switch grass. It might be used for electricity cogeneration and ethanol 2\textsuperscript{nd} generation production</td>
<td>• <strong>Sweet Sorghum.</strong> Used as supplementary feedstock in sugarcane mill</td>
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<tr>
<td>• <strong>ETC</strong> (Controlled Traffic Structure)</td>
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<tr>
<td></td>
<td></td>
<td>Implementation of no-till system</td>
<td></td>
</tr>
</tbody>
</table>

Source: Agroicone
Mechanized harvesting

**Sugarcane Harvesting in São Paulo**

<table>
<thead>
<tr>
<th>Year</th>
<th>Mechanized (No Burn)</th>
<th>Manual (With Burn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
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<tr>
<td>2008</td>
<td></td>
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<td>2009</td>
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<td>2010</td>
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<tr>
<td>2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
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</tr>
</tbody>
</table>

Source: CANASAT (2013)

Agro-environmental Protocol\(^V\): Sugarcane plants are committed to eliminate burning (pre-harvesting) in areas with slope up to 12% (mechanizable) in 2014. In areas above 12%, the burning practice must be eliminated by 2017.

**Yield**
- Manual Harvesting: 8 ton/worker/day
- Mechanized Harvesting: 446 ton/harvester/day

**Harvesting Cost**
- Manual: R$ 7.05 – 11.64/ton
- Mechanized R$ 5.41 – 8.65/ton

**GHG emission**\(^{III,IV}\)
- Manual Harvesting: 2,192.7 kg CO\(_{2}\)eq/ha
- Mechanized Harvesting avoids: 310.7 kg CO\(_{2}\)eq/ha
- Mechanized Harvesting avoids (considering soil carbon stock): 1,484 kg CO\(_{2}\)eq/ha

**Obstacles:**
- loss of jobs.
- Adaptation to new technology and soil computation (followed by loss in yield)

**Challenges:**
- Training of actual labor
- Better technologies for trash recovery
- Access to areas with high slope

**Trash Recovery**\(^VI\)
- It represents 1/3 of sugarcane energy content (2,500 MJ/ ton of sugarcane);
- It would double the sugarcane biomass supply;
- A part of trash should continue to be left in the field due to its agronomic benefits: soil and water losses reduction and carbon storage;
- Currently, Brazil recovers about 5%,
- The ethanol with trash recovery emits 95 – 120% of GHG less than gasoline (scenario for 2020)\(^VII\) because of credit from electricity surplus
Controlled Traffic Structure (ETC)

Opportunities and goals
- It allows no till production system;
- It reduces machines traffic in sugarcane fields from 60% to 10%
- It reduces soil compaction; soil erosion and fuel consumption
- Productivity gains and longevity;
- It works in fields with greater slope;
- Lower investments and costs for mechanization;

Technical specifications
- Machine width (in transport): 3m
- Spacing between planting row: 1.5 m
- Capacity of stored weight: 20 ton
- Machine weight: About 20 ton
- Working speed: 2-8 km/h
- Free span: 2m
- Stability angle: 40°
- Track gauge: 12m

Source: CTBE (2014)
Lignocellulosic ethanol plants being built in Brazil. Expected to start in 2014

**GranBio**

- Investment: R$ 350 millions;
- Ethanol 2G production (expect): 82 millions liters per year

**raigen**

- Investment: R$ 200 millions;
- Ethanol 2G production (expect): 40 millions liters per year

**CTC**

- Investment: R$ 80 millions;
- Ethanol 2G production (expect): 3 millions liters per year

39 projects of 2G (16) biorefinery (22) and gasification (1) were approved in 2013 in Brazil. Total investment was higher than R$ 3,3 bi.

- Sugarcane Bagasse Composition
  - Water: 50.0%
  - Cellulose: 20.0%
  - Hemicellulose: 15.8%
  - Lignin: 10.0%
  - Protein: 1.7%
  - Ash: 2.5%

- Yield
  - 1 ton of sugarcane produces 276 kg of bagasse (50% moisture)
  - 1 ton of bagasse (50% moisture) produces
    - 209 kg of hexose (glucose) = 123 l of ethanol
    - 126 kg of pentose (xylose + arabinose) = 63 l of ethanol
  - 4,096 l of ethanol (2G) per hectare
    (currently, there is no efficient yeast for pentose fermentation, however, for the hexose, the process is already consolidated)

- Water use: 5.4 liter of water to produce 1 liter of ethanol
  (using biochemical process and switch grass as a feedstock)

- US Market Price: 2.5 RIN per gallon of cellulosic ethanol

- Production Cost
  - Ethanol 2G plant (only): USD 1.548 per liter
  - Ethanol 2G plant (1G plant integrated): USD 0.425 per liter

(Ethanol 2G plant with 1G plant integrated might reduce costs by using and selling the electricity generated, therefore, the trash recovery will be necessary to become economic feasible)

Supplementary feedstock and Sugarcane varieties

Sweet sorghum
- Genetic breeding
- It is planned to be used as a supplementary feedstock in sugarcane mills;
- To produce ethanol (1G and 2G), electricity and sugar
- Reduction of idle capacity of mills from 66 to 62% making it competitive with
- Yield:  
  - Field: 60 ton/ha;
  - Ethanol production (1G): 3,000 – 3,600 liters/ha;
  - Ethanol production (2G): 1,079 liters/ha

Energy cane
- Genetic breeding;
- It will be used for biochemical and lignocellulosic ethanol production;
- 3 times more productive than conventional;
- 50% of sugar content;
- 4 times for biomass production
- 3 times for longevity;
- it can be harvested in any season

GMO Varieties
- Drought resistance: currently, they are in field testing. These varieties might avoid about 10 - 50% of yield reduction caused by hydric stress
- Cell wall with self-hydrolysis: these varieties are expected to perform a pre-hydrolysis for ethanol 2nd generation production
- Insect resistance: varieties resistant to sugarcane borer (Diatraea saccharalis)
- High sugar content: increasing yield, it is possible to raise production in the same area

Biojet Fuel and renewable diesel

Feedstock and their relative position according to costs and technical efforts to be converted to aviation biofuel (For illustrative purposes only)

Routes:
- Lipid Conversion
- Biochemical Conversion
- Thermochemical Conversion

Process:
- HEFA – hydroprocessed Esters and Fatty Acids
- CH – Catalytic hydrothermolysis;
- DSHC – direct fermentation of Sugars to Hydrocarbons;
- ATJ – Alcohol to Jet;
- FT – Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene;
- HDCJ – hydrotreated depolymerized Cellulosic to Jet

Feedstock
There are several choices for feedstock. Considering the crop yield and energy balance, sugarcane and forestry are the most productive sources.

Commitment
50% reduction in net CO₂ emissions over 2005 levels by 2050

Costs
Currently, the production cost is considerably higher than conventional (petroleum-based)

Amyris process is capable of reducing 80 to more than 100% of GHG emissions, considering trash recovery. Hydrogenation is still a major challenge regarding costs and logistics.

Both company have demonstration plants in Brazil. Amyris produces biojet fuel and renewable diesel from sugarcane juice and GMO yeast. Solazyme produces similar biofuels from sugarcane juice processed by algae.

Source: Cortez et al (2013)
Others MAPs Countries
**Horizontal Expansion: Land availability**

**Yield and land gap**

Note:
Suitable means that at least 60 percent of possible yield can be attained for any of the 5 rainfed crops (wheat, oil palm, sugarcane, soybean, maize).

Suitable ha per cultivated ha area based on non-protected, non-forest suitable area where the population density of the grid cell is <25/km², <10/km², or <5/km².


**Land use in MAPS countries in 2011**

<table>
<thead>
<tr>
<th>Country</th>
<th>Total Area (million ha)</th>
<th>Forest Area (million ha)</th>
<th>Agricultural Area (million ha)</th>
<th>Cattle herd Million</th>
<th>Stock rate (head/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Crop*</td>
<td>Pasture</td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td>128.52</td>
<td>67.84</td>
<td>4.50</td>
<td>17.00</td>
<td>5.66</td>
</tr>
<tr>
<td>Chile</td>
<td>75.60</td>
<td>16.26</td>
<td>1.77</td>
<td>14.01</td>
<td>3.75</td>
</tr>
<tr>
<td>Colombia</td>
<td>144.17</td>
<td>60.39</td>
<td>4.00</td>
<td>39.78</td>
<td>23.49</td>
</tr>
<tr>
<td>Brazil</td>
<td>851.48</td>
<td>517.32</td>
<td>79.03</td>
<td>196.00</td>
<td>211.28</td>
</tr>
</tbody>
</table>

Source: FAOSTAT (2014) *Crop = temporary and permanent crops, market and kitchen gardens and fallow

- Land use in Peru and Chile is close to their agricultural land potential, whereas there is still significant space for sustainable agricultural expansion in Brazil and Colombia, (45.5 and 4.9 million hectares, respectively).
- All countries are still far from their yield potential (crops), meaning that vertical expansion and land optimization might be a solution for all.
- A closer look on pastureland:
  - Significant areas in all countries
  - Very low productivity (even lower than Brazil)
- Agricultural expansion over pastureland seems to be the most appropriate recommendation.
- Intensification of pastureland might be less expensive and lower water impact (Brazilian experience).
- Suitability for crops is not guarantee.
- Public policy might play an important role.
### Sugarcane Vertical expansion: technology simulation

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>Production (million ton)</td>
<td>Area (Thousand ha)</td>
<td>Yield (ton/ha)</td>
<td>Ethanol (million liter)</td>
</tr>
<tr>
<td>Peru</td>
<td>10.3</td>
<td>81.1</td>
<td>127.0</td>
<td>220.1</td>
</tr>
<tr>
<td>Colombia</td>
<td>20.8</td>
<td>227.7</td>
<td>91.3</td>
<td>362.4</td>
</tr>
<tr>
<td>Brazil</td>
<td>588.9</td>
<td>8,485.0</td>
<td>69.4</td>
<td>23,500.0</td>
</tr>
</tbody>
</table>

**Notes:**
- Electricity Surplus: Total electricity cogenerated in sugarcane mill discounted the self consumption.
- In 1G + Trash Recovery (A) and 1G + 2G + Trash Recovery (B) scenarios the following assumptions were considered:
  - Technical coefficients from CTBE; 2G only considered hexose fermentation.
  - TRS (sugar content) = Peru 108 kg/ton of sugarcane, Colombia 132 kg/ton, Brazil 140 kg/ton.
- Chile: There is no significant sugarcane production.

- **Peru (Current):** produced 220.1 million liters of ethanol and consumed 85 million liters. Supply seems not to be a restriction to increase the 7.8% mandate blend. The electricity surplus (77 GWh) can supply only a small amount of total demand (33,204 GWh). If all sugarcane is used for biofuel production (no sugar), the ethanol production might reach 628.3 (Scenario A) and 837.5 million liters (Scenario B) and the electricity surplus might supply 5.02% (Scenario A) and 2.03% (Scenario B).

- **Colombia (Current):** produced 362.4 million liters of ethanol and consumed 366.0 million liters. In a mandate blend of 8 - 10%, production will have to increase to keep current blend mandate. The electricity surplus (204 GWh) can supply only a small amount of total demand (48,704 GWh). The ethanol production in “Scenario A” might reach 1,560 million liters and 1,982 million liters in “Scenario B”. The electricity surplus might supply 6.91% (Scenario A) and 2.79% (Scenario B).

- “A” and “B” scenarios focus on the use of already existing sugarcane residues. Improvements in agricultural phases could boost the above potential.

- Because of climate conditions, sugarcane yield is higher in Peru and Colombia, but sugar content is lower, so those countries tend to have competitive advantages in technologies that focus on biomass (and not sugar).

Final conclusions
Final conclusions (i)

- Biofuels economic and environmental indicators varied significantly: need to focus at regional opportunities.
- Sugarcane ethanol is the only biofuel currently produced in large scale that will keep being relevant and competitive in 2050.
- Brazil example:
  - More than 40 years of large scale biofuels production
  - Achieved more than 50% of light vehicles consumption; 5% for biodiesel
  - **Demand policies:** Upper limit and FFV (ethanol) lower limit (biodiesel). Tax policies has become controversial.
  - **Production policies:** different types of support along history. Currently subsidized credit for investments in agricultural and industrial phases can be highlighted. Strong programs for RD&I.
  - **Environmental policies:** zoning are the main policies, as well as national environmental legislation.
  - **Private initiatives:** support to zoning, anticipation of legislation (burning phase-out), adoption of sustainability schemes.
  - Current technologies reduces 70% of GHG emissions, or more…
- Technology pathways:
  - Mechanized harvest, trash recovery, no till
  - 2G, electricity surplus, new fuels (bioQAV, etc) are linked to additional biomass availability.
  - New feedstock, enhanced varieties.
  - Some focus on biomass, not sugar
Final conclusions (ii)

- The conclusions for other MAPS countries depends on regional characteristics.
- Land expansion for agricultural based biofuel seems not being viable in Chile, and relatively restricted in Peru.
- Colombia still has available land for expansion, however, concerns can be raised related on possible water impacts.
- Significant yield gap remains, signalizing opportunities for land optimization.
- Vertical and horizontal are should not be understood as opposite.
- Peru and Colombia have an even higher potential of lignocellulose production per hectare than Brazil?
- Land use planning and local analysis, especially for water impacts when using irrigated systems.
- Optimal choices of technologies pathways might not be unique for all countries.
- Similarly to technology improvements, public and private policies are evolving rapidly. Defining the correct policies has as much, or even more, power than developing the most efficient technology.'
Thank you

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