Energy producing Biorefineries for Agricultural Waste Management: The Colombian Case

Laura V. Daza Serna[a], Carlos A. Cardona Alzate.[b*]
Instituto de Biotecnología y Agroindustria. Departamento de Ingeniería Química
Universidad Nacional de Colombia at Manizales, Manizales-Colombia
lvdazas@unal.edu.co [a], ccardonaal@unal.edu.co [b]

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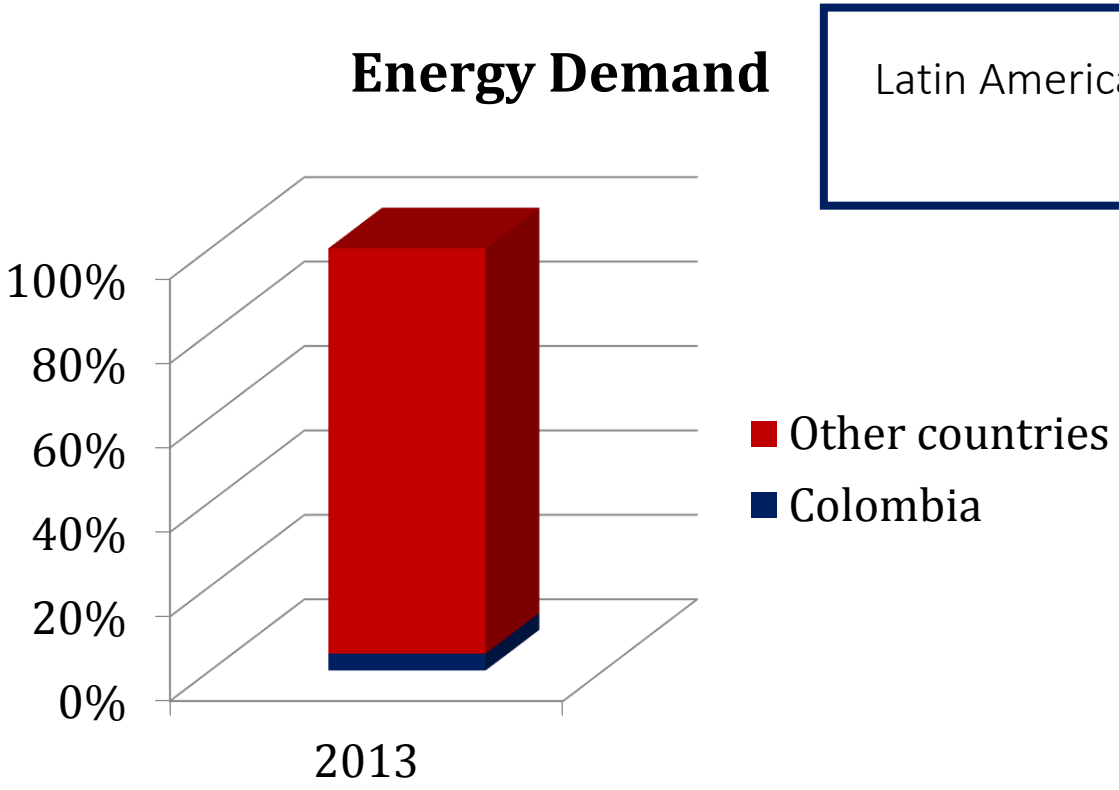
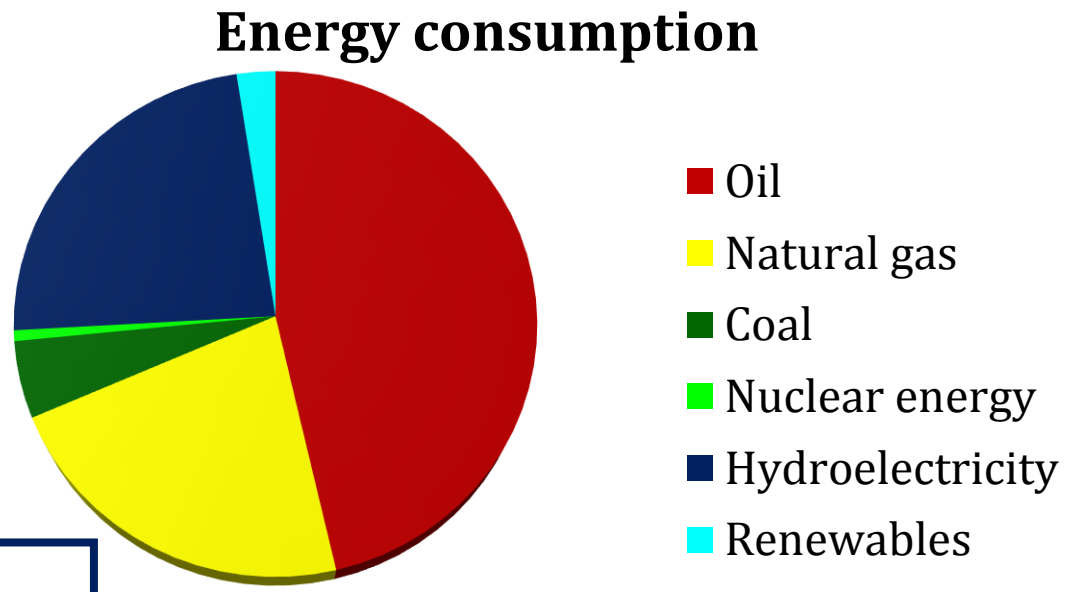
Introduction. **Latin America**
Energetic Context



Latin American energy demand was 854 Mtoe for 2013. **(Global Energy Statistical Yearbook)**



(BP Statistics)

Introduction. **Colombia location and biodiversity**

Source: **National Geographic**

Colombia is a country located in a tropical region. A lot of **Hydric resources**, **soils variety**, **flora** and **fauna**.

Introduction.

Different Feedstocks:1st, 2nd, 3rd generations

Introduction.

Agricultural Residues in Colombian Context

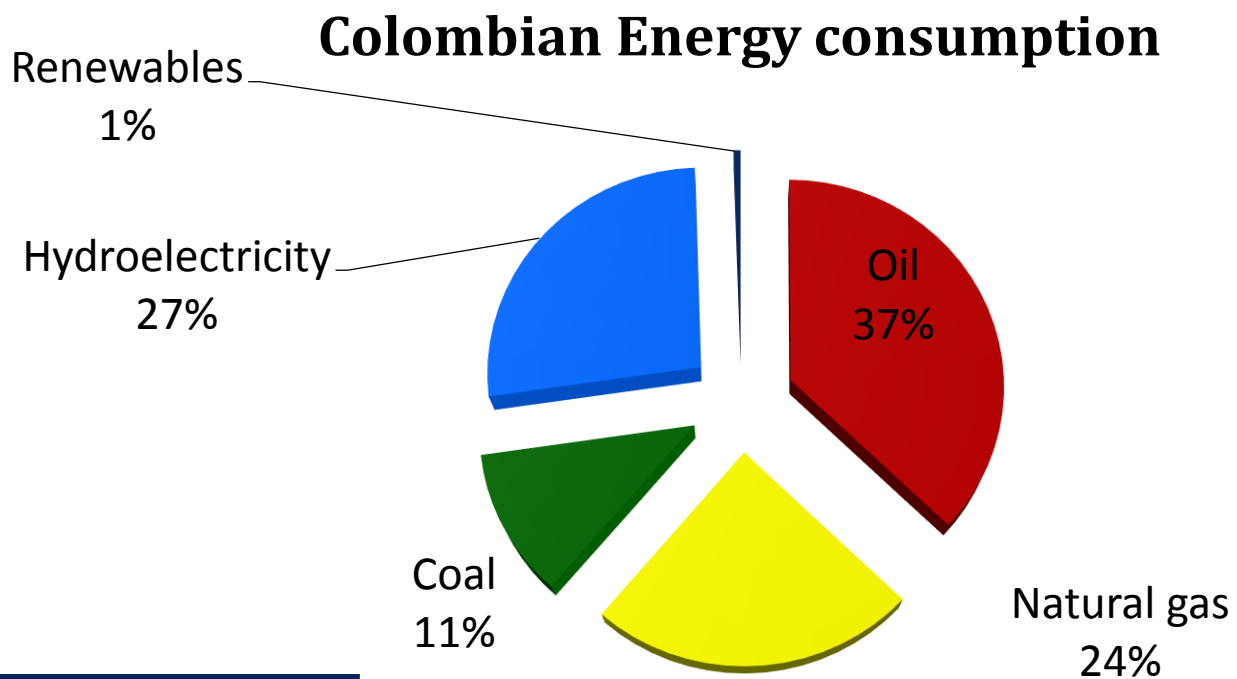
Crop	Residue	Residues Generated [ton/year]
Coffee	Coffee Pulp	301.848
	Spent Coffee	257.962
Cocoa	Cocoa Husks	59.756
Rice	**Rice Husks**	**562.964**
Plantain	**Plantain Pseudostem**	**1.699.137**
Cassava	Cassava stem	91.335

Introduction. **Colombia**

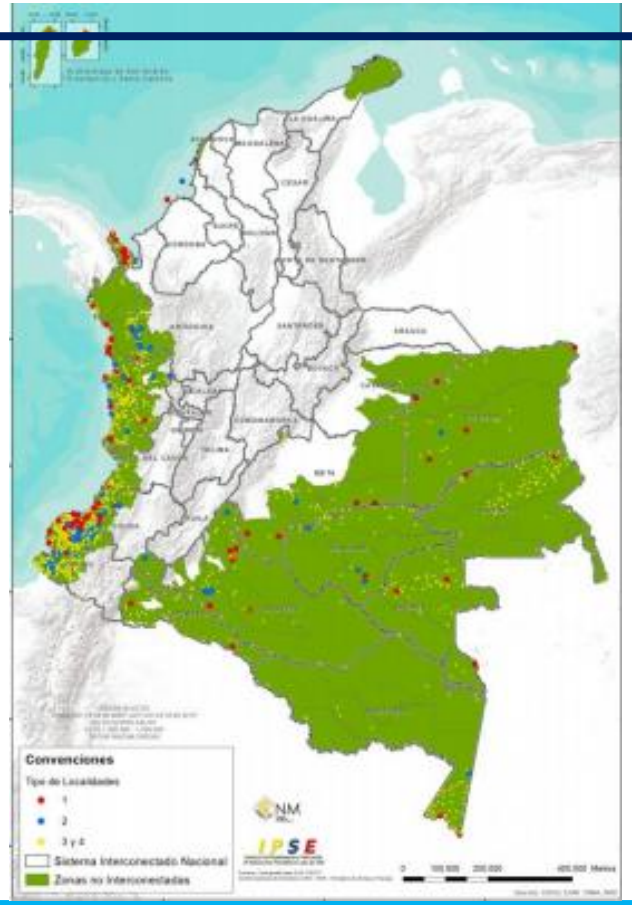
Energy Context

According to the **electricity access**, Colombian regions are classified into:

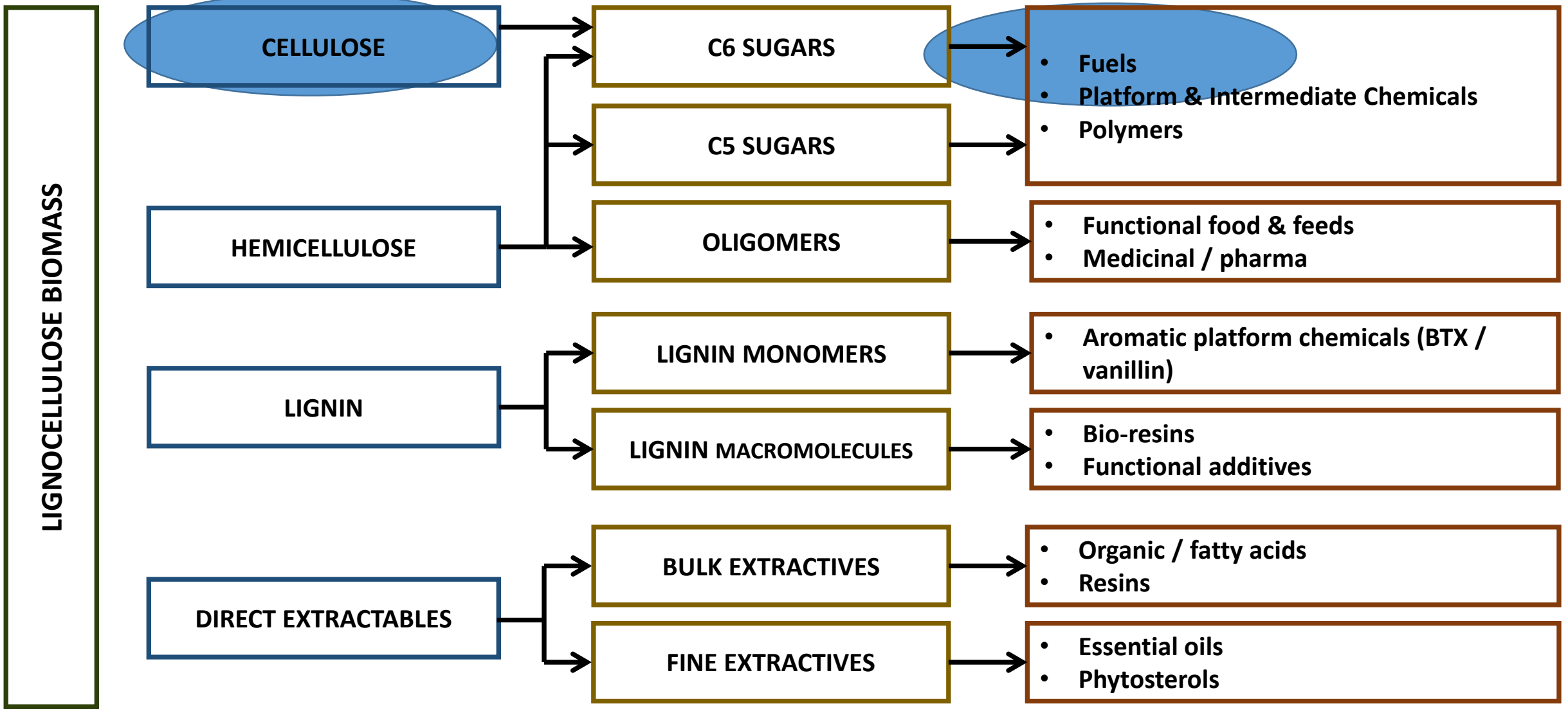
- Interconnected Zones. **48%.** (IZ). Grey Color
- Non-Interconnected Zones (NIZ). **52%.** Green Color



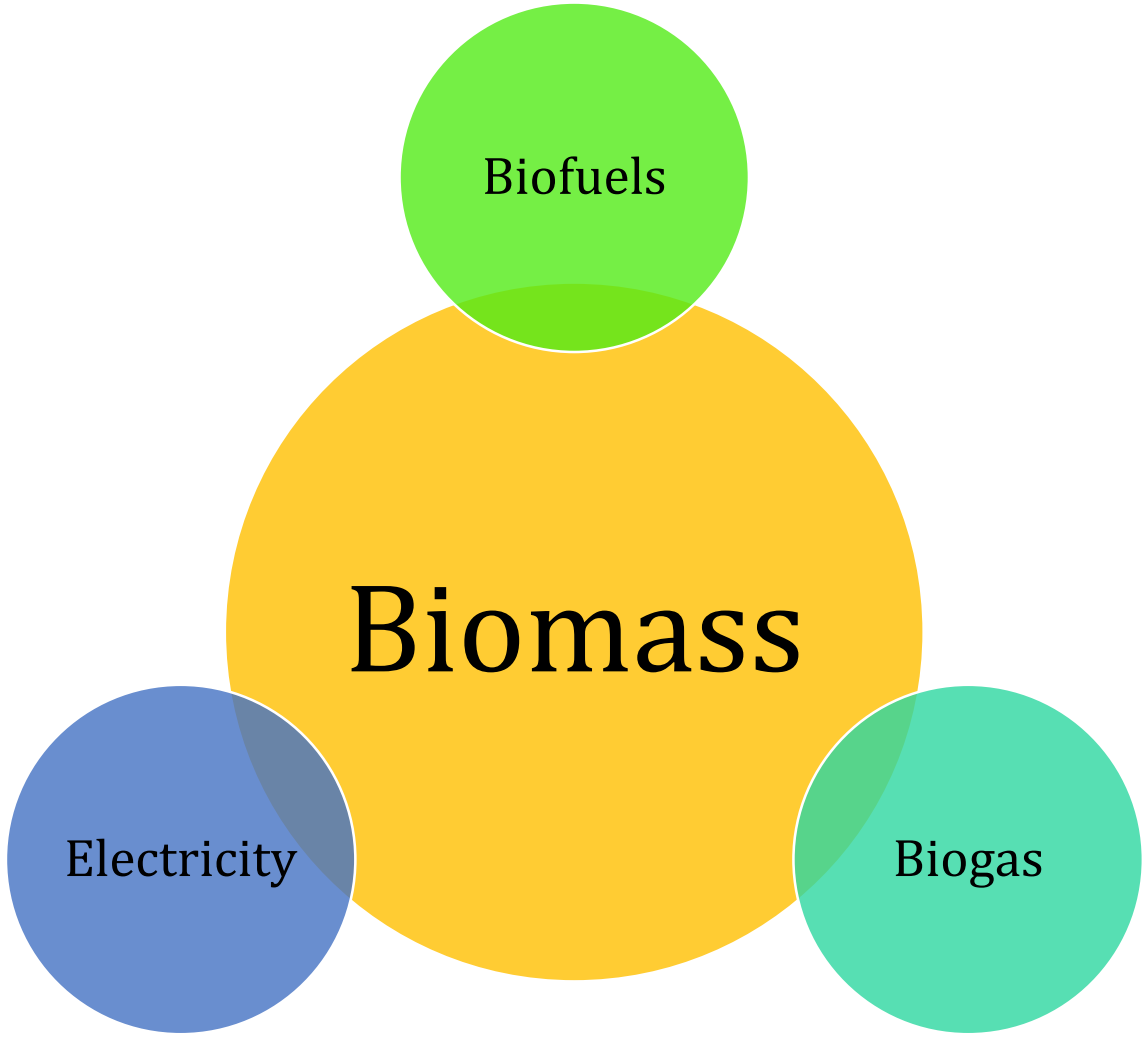
(BP Statistics)



Introduction. **Chemical and Biochemical Transformations**

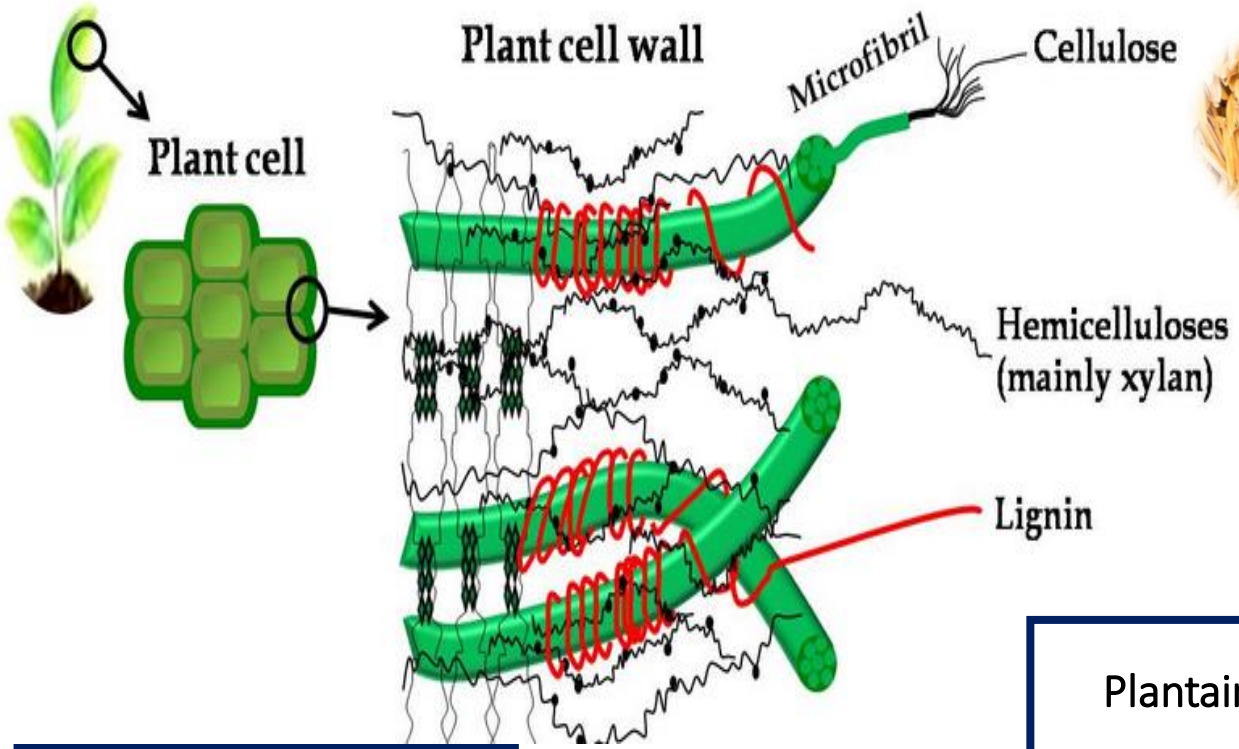


Introduction. **Biorefineries just for energy**



Introduction. 2nd Generation Raw Materials

Rice Husks (RH). 0.23 ton/ton rice



Plantain Pseudostem (PP) 50% of total plantain biomass

Lignocellulosic Biomass

Methodology

Experimental Characterization

-Extractives
- Cellulose
- -Hemicellulose
- -Lignin
- Ash

Techno-Economic Evaluation

Based on reported kinetics and experimental data for 10,000 kg/h

Hierarchization → Sequentiation → Integration*

Methodology

Methodological Approach

Process synthesis following a knowledge-based approach (Hierarchy, sequence and integration concepts)

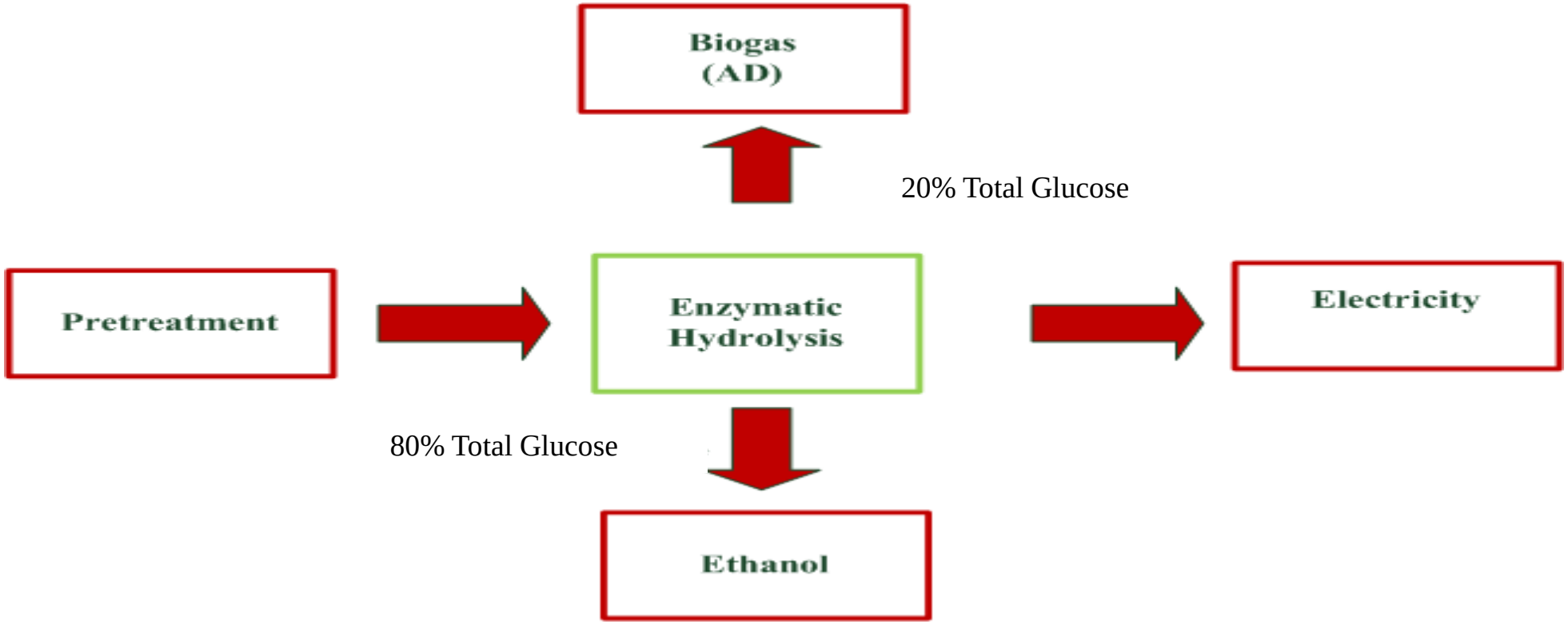
Mass and Energy Balances

Generated in *Aspen Plus V8.2* (AspenTech) after flowsheet modelling

Economic Analysis

Calculated using *Aspen Process Economic Analyzer* at the Colombian conditions

Methodology. **Process Scheme**



Methodology. **Used Technologies**

Process	Used Technology	Reference
Lignocellulosic pretreatment	Diluted Sulfuric Acid 2% (v/v). 121 °C, 15 psi, verified experimentally in this work	Esteghillian et al .
Enzymatic Hydrolysis	Cellulases cocktail. 50°C, pH 4.8 Sodium citrate buffer, , verified experimentally in this work	Morales-Rodriguez et al.
Ethanol Production	Fermentation by Saccharomyces cerevisiae yeast. 30°C. Separation by distillation train and dehydration by molecular sieves, , verified experimentally in this work	Birol et al Pitt et al
Biogas Production	Anaerobic digestion using diluted glucose 2 g/L as substrate. 35°C, verified experimentally in this work	Kalyuzhnyi and Davlyatshina.
Electricity Production	Combustion turbine, not verified experimentally	Rincón et al.

Results. **Experimental Characterization RH.**

Feature	This Work	Literature	Reference
Moisture	11± 0.5%	11.7 %	Srinivas and Reddy [36]
Extractives$^{(db)}$	7 ± 1%	3.35 %	Quintero et al [37]
Cellulose$^{(db)}$	40 ± 2%	26.45 %	
Hemicellulose$^{(db)}$	16 ± 3%	27.29 %	
Lignin$^{(db)}$	26 ± 7%	28.03 %	
Ash$^{(db)}$	11 ± 1%	14.89 %	

Results. **Experimental Characterization PP.**

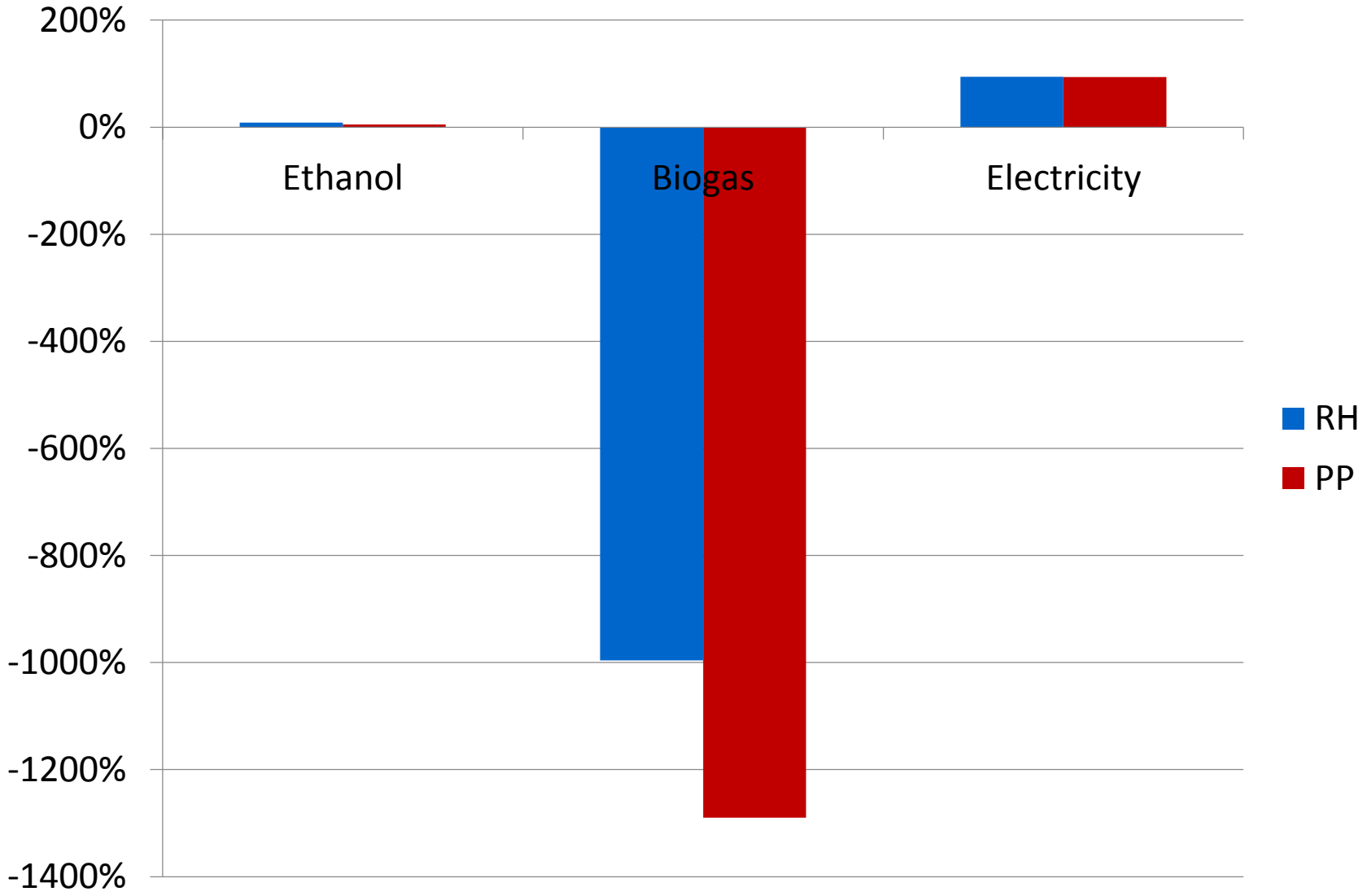
Feature	This Work	Literature	Reference
Moisture	83 ± 3%	85 %	Pérez [23]
Extractives$^{(db)}$	19 ± 1%	8.1 %	Cordeiro et al[38]
Cellulose$^{(db)}$	41± 7%	40.2 %	
Hemicellulose$^{(db)}$	19± 5%	25 %	
Lignin$^{(db)}$	14± 4%	14.6 %	
Ash$^{(db)}$	8± 0.1%	15.6 %	

Results. **Techno-economic results**

Production Prices				
	RH	**PP**	**Market price**	**Source**
Ethanol (USD/kg)	0.88	0.91	0.96	Fedebiocombustibles*
Biogas (USD/m^3)	5.37	6.81	0.49	Gas Natural Fenosa*
Electricity (USD/kWh)	0.0097	0.0099	0.16	EPM *

*Local information

Results. **Profit margin**



Conclusions

The results showed that it is possible to take advantage of agricultural wastes under biorefinery scheme but considering additional products such as biogas through sugars platform is not interesting. Sugars as raw material for metanogenesis makes very expensive the raw material for biogas,

The problems with the AD stage is that it is really difficult to reach the productivities of electricity and ethanol. Moisture content represents one bottleneck for waste valorization of plantain residues, considering the increases in costs associated to drying process and low available dry matter to be transformed.

Conclusions

In this work a biorefiney scheme at high scale was firstly proposed to diversify the needings supply in energy for those isolated zones where these residues are produced and not totally managed. However , for rice husk and plantain it is obvious that the energy solution will be just the generation. Gasification in these cases is going to be the best option, working very good and with good profits even at small scales.

Acknowledgments

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THANK YOU