Sustainable Lignocellulosic Biofuels Co-production and Agro-industrial Wastes Treatment using a Multi- feed Biorefinery

Western Mexico Case Study

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Motivation

- Biorefineries for the Mexican context
- Biorefinery design
  - Biofuels co-production (bioethanol, biohydrogen and biogas)
  - Electricity-steam cogeneration
  - Multi-feed with local agro-industrial residues and wastes
- Proposal of a biorefinery for bioenergy production designed with sustainability criteria, instead of techno-economic criteria only
- Solution for
  - Restricted availability of biomass
  - Local environmental pollution
- Affordable solution at local level

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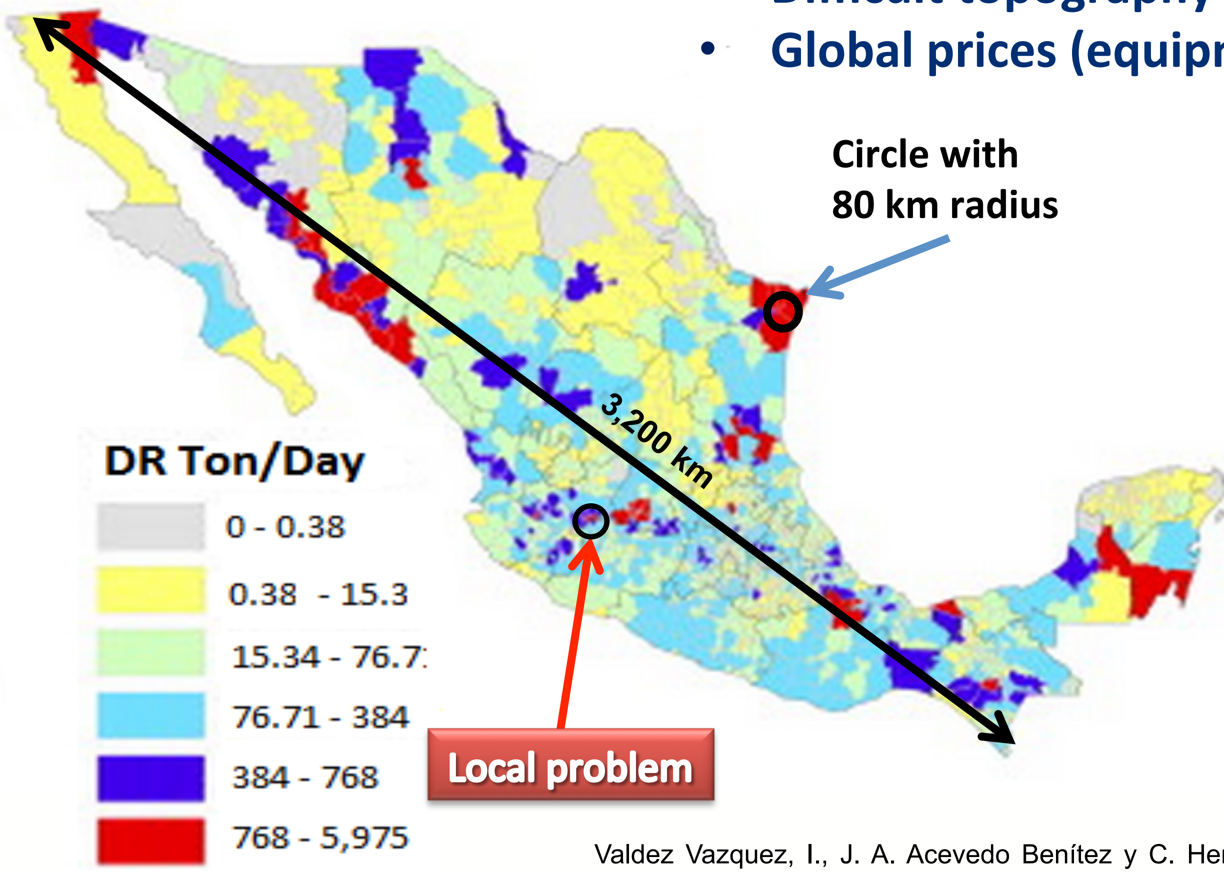
Availability of Agricultural Residues in Mexico

- Crop diversity
- "Large enough" amounts
- Scattered along vast territory
- Difficult topography ⟶ difficult collection
- Global prices (equipment, resources, logistics)

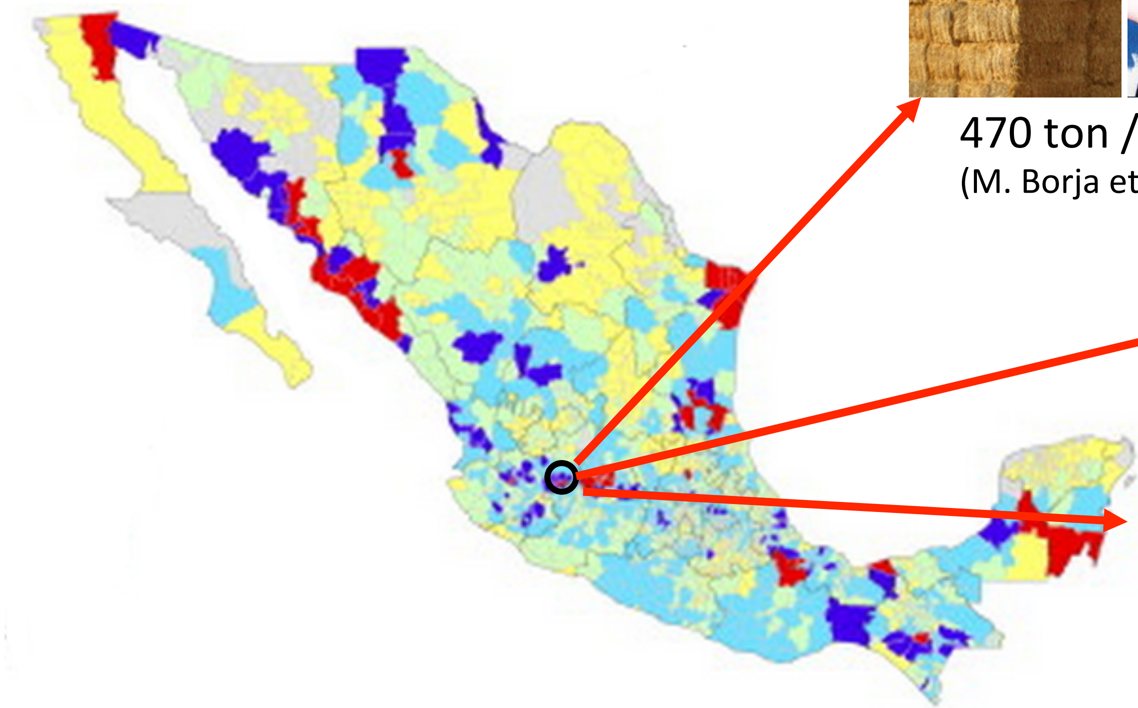


Crop	PCRI	Prod Mton/ year	Res prod Mton/year
Wheat	1.5	3.4	5.1
Corn	1.5	21.9	32.9
Sorghum	1.5	5.5	8.2
Sugarcane	0.15	50.6	7.6
Coffee Cherry (pulp)	0.24	1.5	31.5
Agave (bagasse)	0.12	1.2	1.5

Valdez Vazquez, I., J. A. Acevedo Benítez y C. Hernández Santiago. (2010) Distribution and potential of bioenergy resources from agricultural activities in México. Renewable & Sustainable Energy Reviews. 14(7): 2147-2153 p

Local Problem in a Western Region in Mexico

- **Wheat straw and composted wheat straw**
- **Wastes from tequila and diary industries with high COD**



Wheat straw

470 ton /day
(M. Borja et al. 2013)

Cheese whey

230 ton /day
(D.A. Lugardo et al. 2013)

Vinasses

3,900 ton /day
(A. Lopez-Lopez et al. 2010)

Design Basis

- Economies and feedstock availability suitable for 500 ton/day
- Increasing biorefinery sustainability by
  - Reducing direct operation/capital cost
  - If biofuels production already efficient, alternative: improving process tasks not related to biofuels production
    - Efficient process water usage
    - CO_2 reutilization
    - Heat and electricity co-generation

A. Sanchez, G. Magaña, D. Gomez, and M. Solis. (2014) Bidimensional sustainability analysis of lignocellulosic ethanol production processes. *Method and case study. Biofuels, Bioproducts and Biorefining*, 8:670–685.

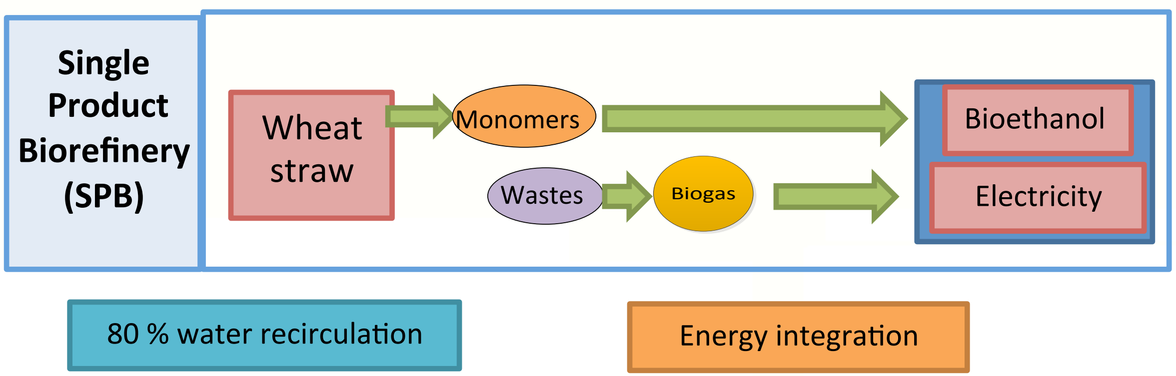
Design Strategy based on Bidimensional Sustainability Criteria

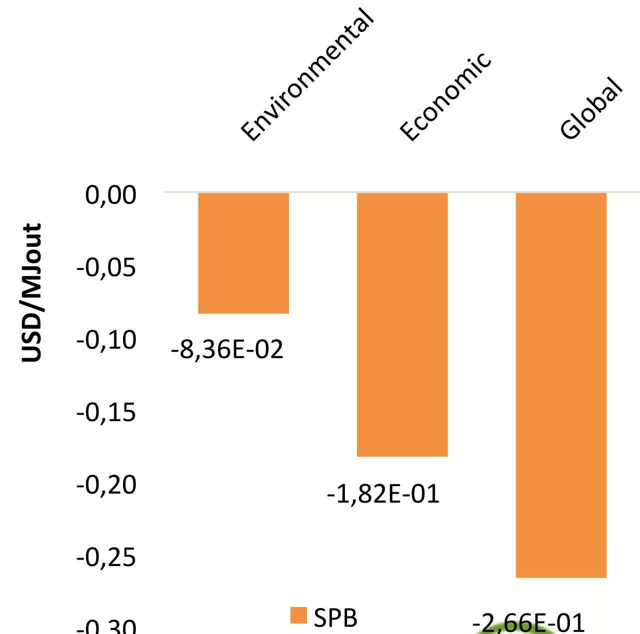
- Design a multi-feed biorefinery for 500 ton wheat straw (compost)/day dry basis

- Increasing electricity production: treatment of 50% whey and 10% vinasses available in the region

- Design MPB as sustainable as our most sustainable biorefiniery design (SPB)

SPB Benchmark





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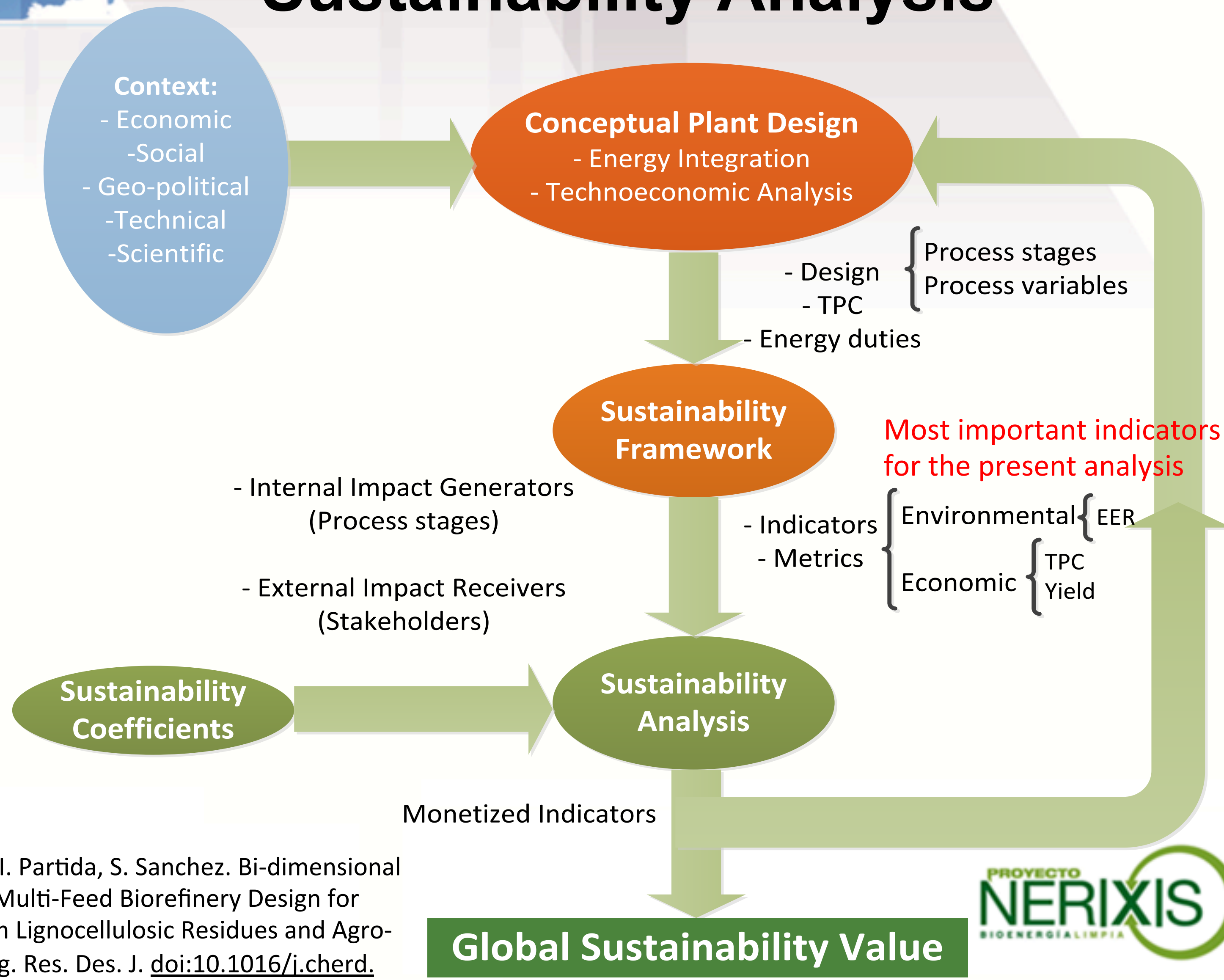
Conceptual Design and Bidimensional Sustainability Analysis



A. Sanchez, G. Magaña, M.I. Partida, S. Sanchez. Bi-dimensional Sustainability Analysis of a Multi-Feed Biorefinery Design for Biofuels Co-production from Lignocellulosic Residues and Agro-industrial Wastes. Chem Eng. Res. Des. J. doi:10.1016/j.cherd.2015.10.041

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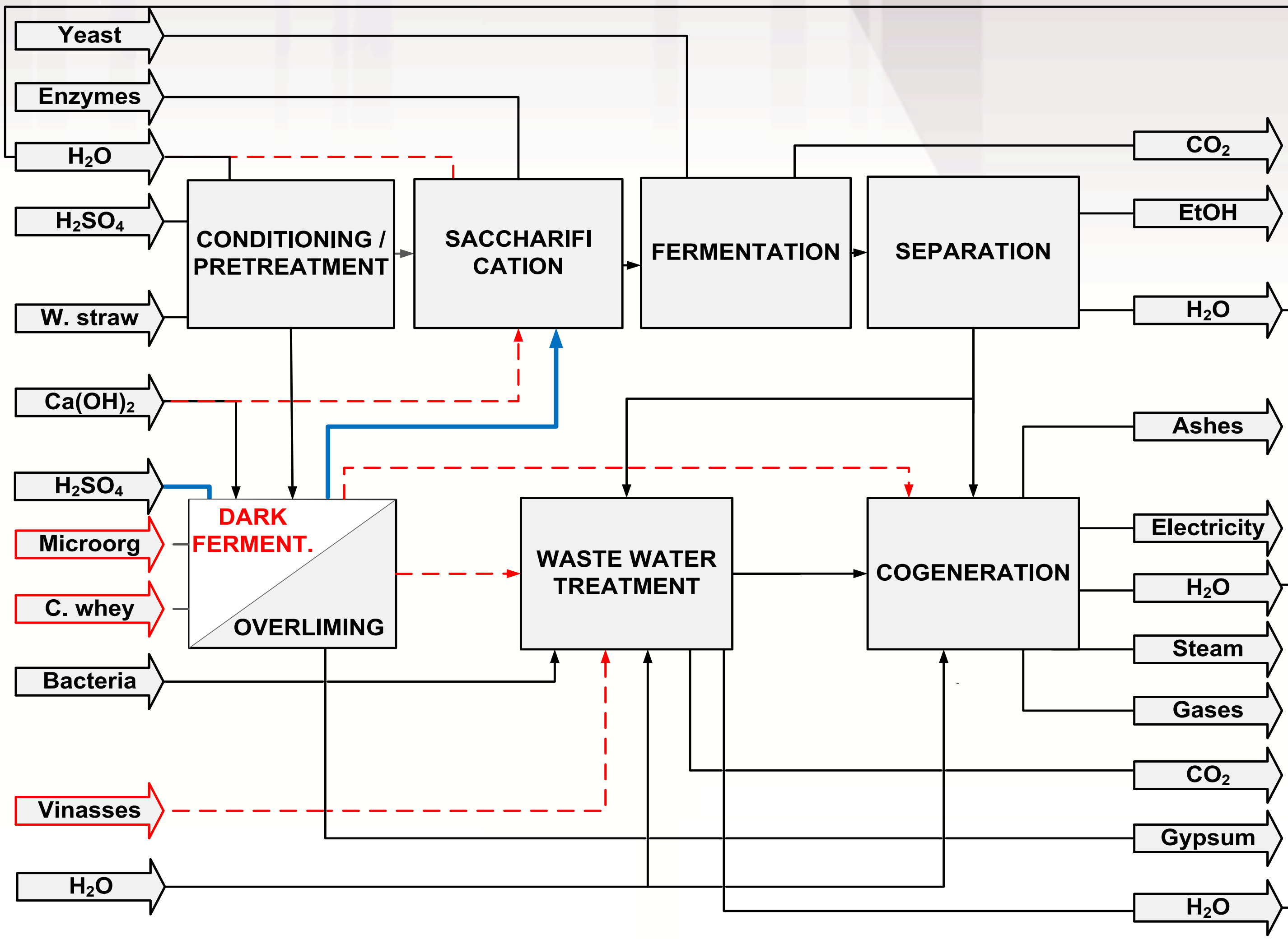
Multi-feed Coproduction Scheme



Biorefinery Complexity Index

MPB10 BCI=38

SPB BCI= 29

BOTH DESIGNS → MPB10 - - → SPB →

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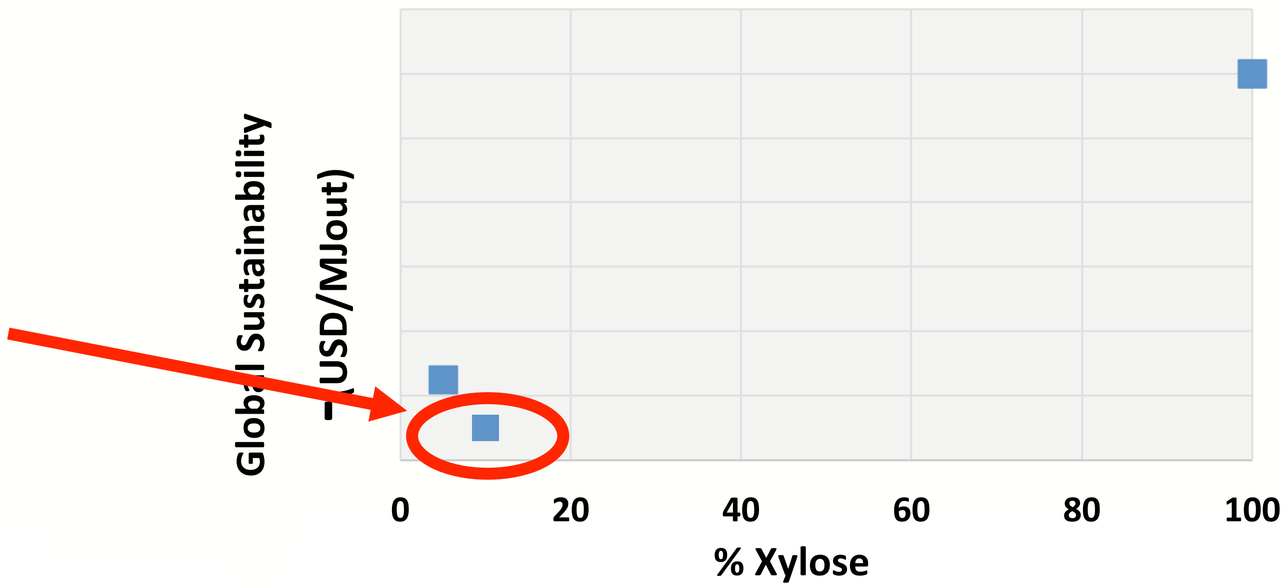
Design Strategy based on Bidimensional Sustainability Criteria

- Reducing xilose to alcoholic fermentation means
  - reducing bioethanol production
  - Increasing hydrogen/biogas production
- A.M. Lopez-Hidalgo et al. 2013: at least 0.07 $kg_{xylose}/kg_{lactose}$ for optimal hydrogen and organic acids production with *E. coli WHDL.* (60% higher than WSH alone @ 28°C)
- Design parameter: minimum xilose/whey ratio for improved H2 and biogas enhancers production in BF

10% of xylose from pretreatment for H_2 production

=

0.3 $kg_{xylose}/kg_{lactose}$



A.M. Lopez-Hidalgo, Z.D. Alvarado-Cuevas, A. Sanchez, L.G. Ordonez-Acevedo, and A. De Leon-Rodriguez. (2013). Production of biohydrogen by fermentation using a mixture of cheese whey and wheat straw hydrolysate. In Proceedings of CIAB 2. Iberoamerican on Biorrefineries Congress, Jaen, España.

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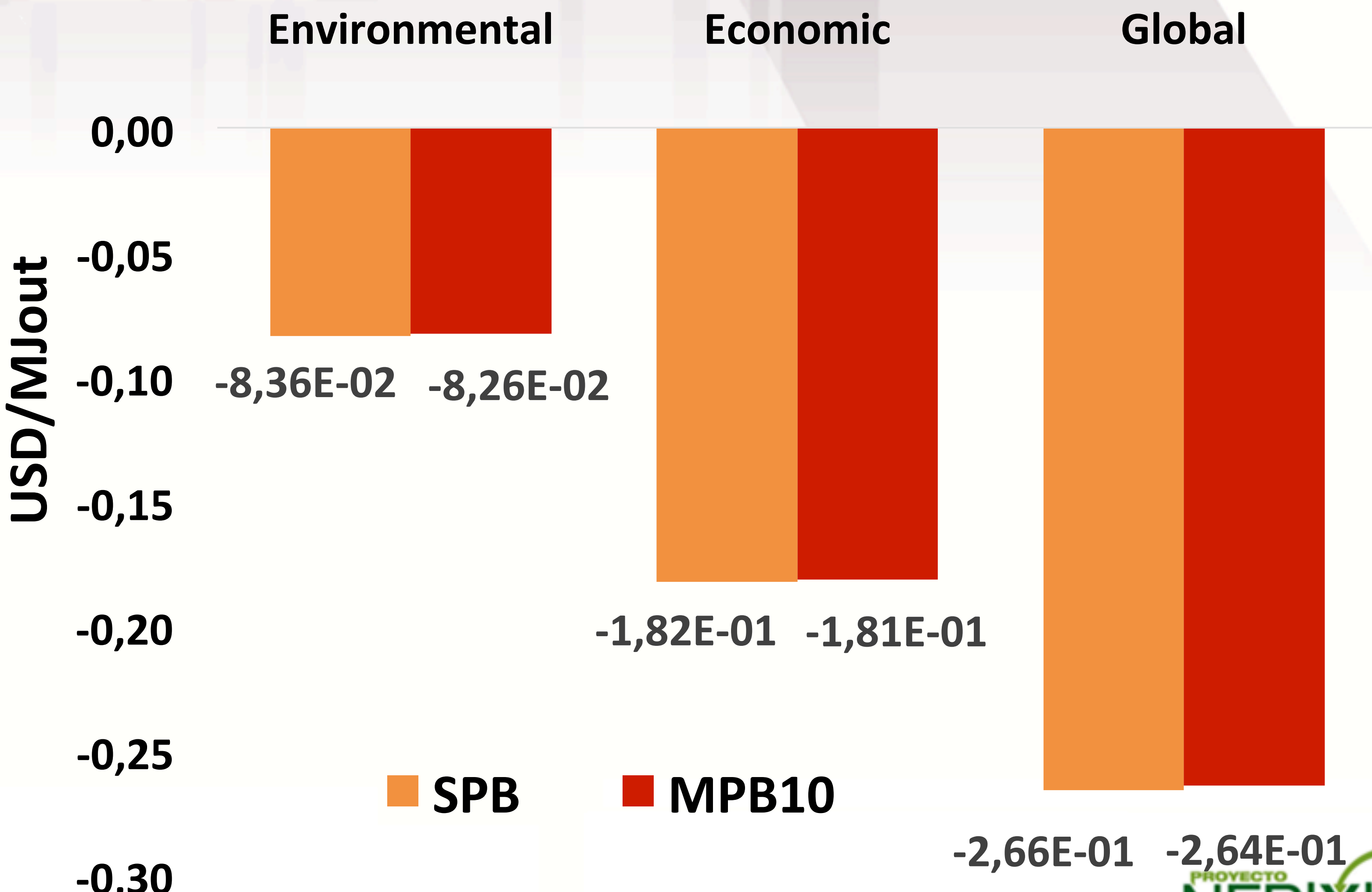
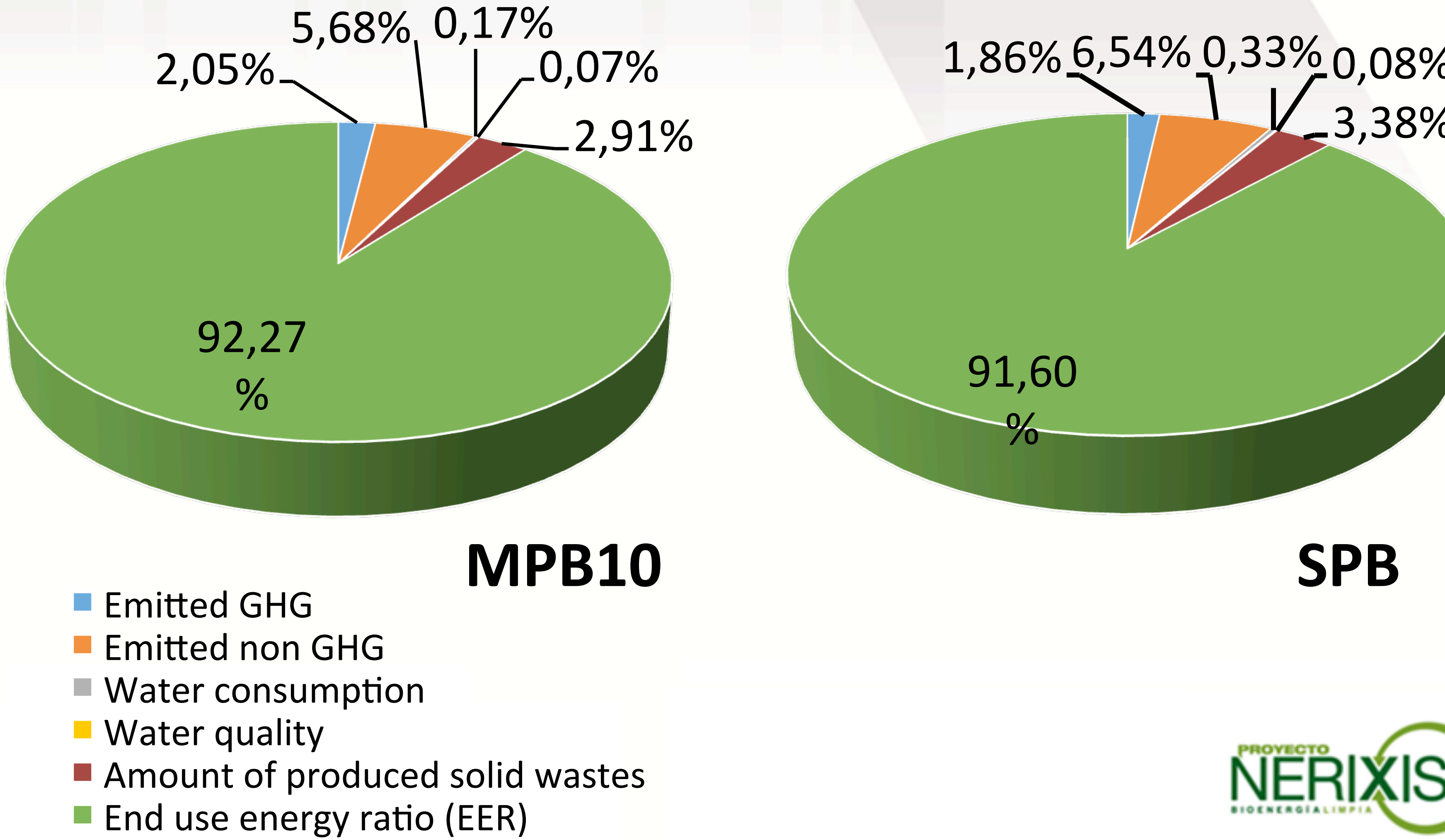
Results

Global Sustainability Values



Environmental Indicators
Contribution to Global Sustainability



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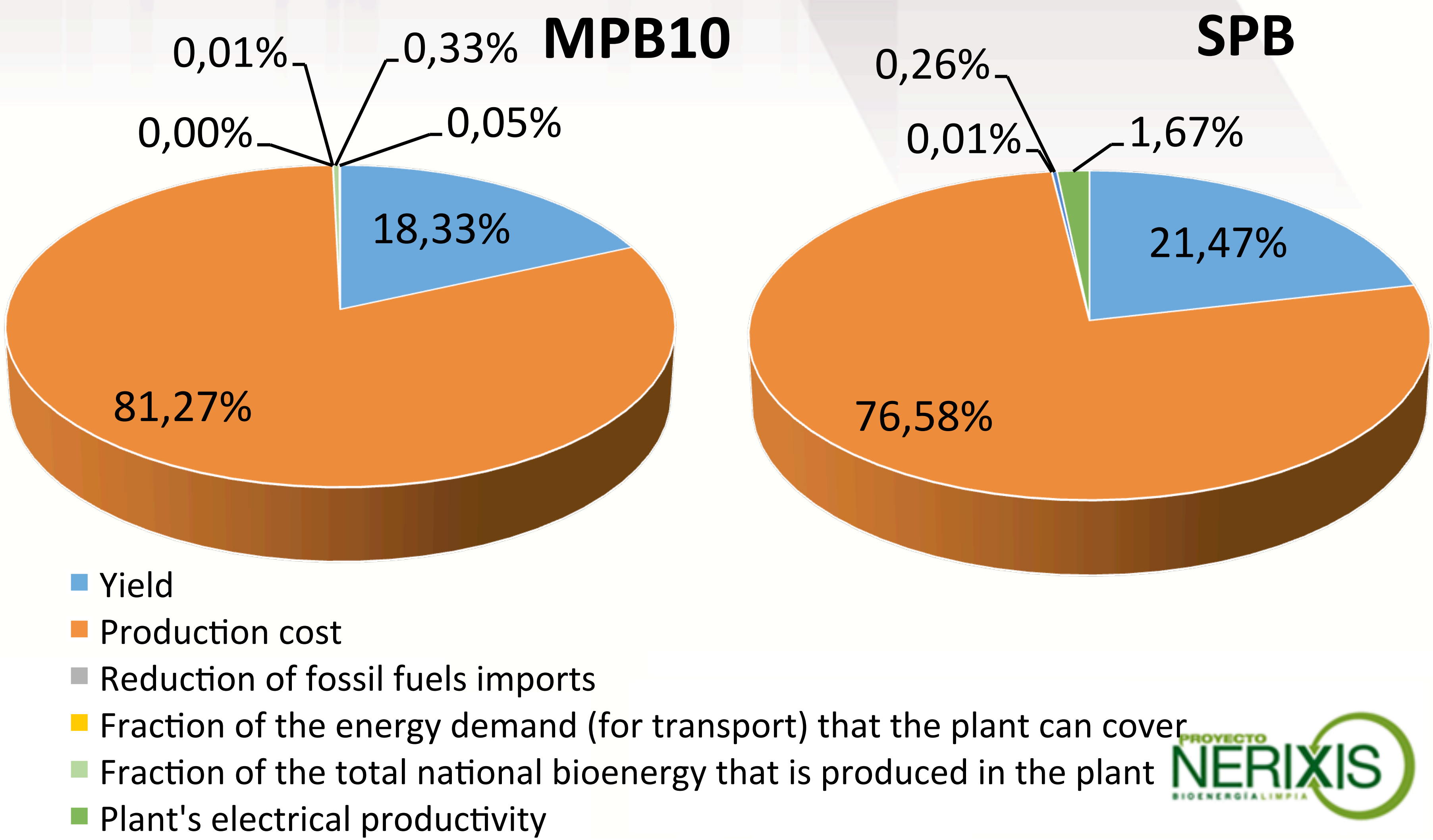
Economic Indicators Contribution to Global Sustainability



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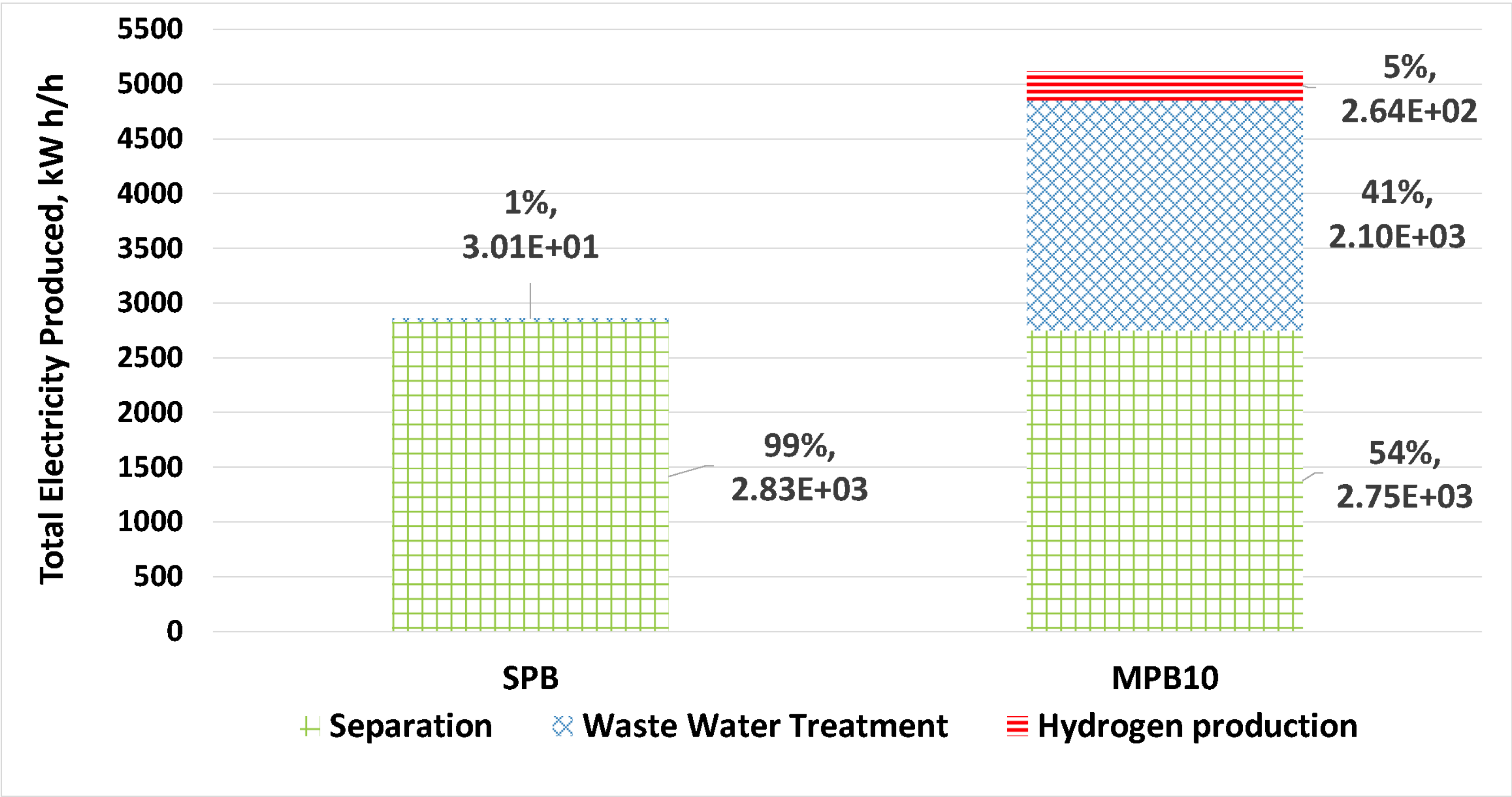
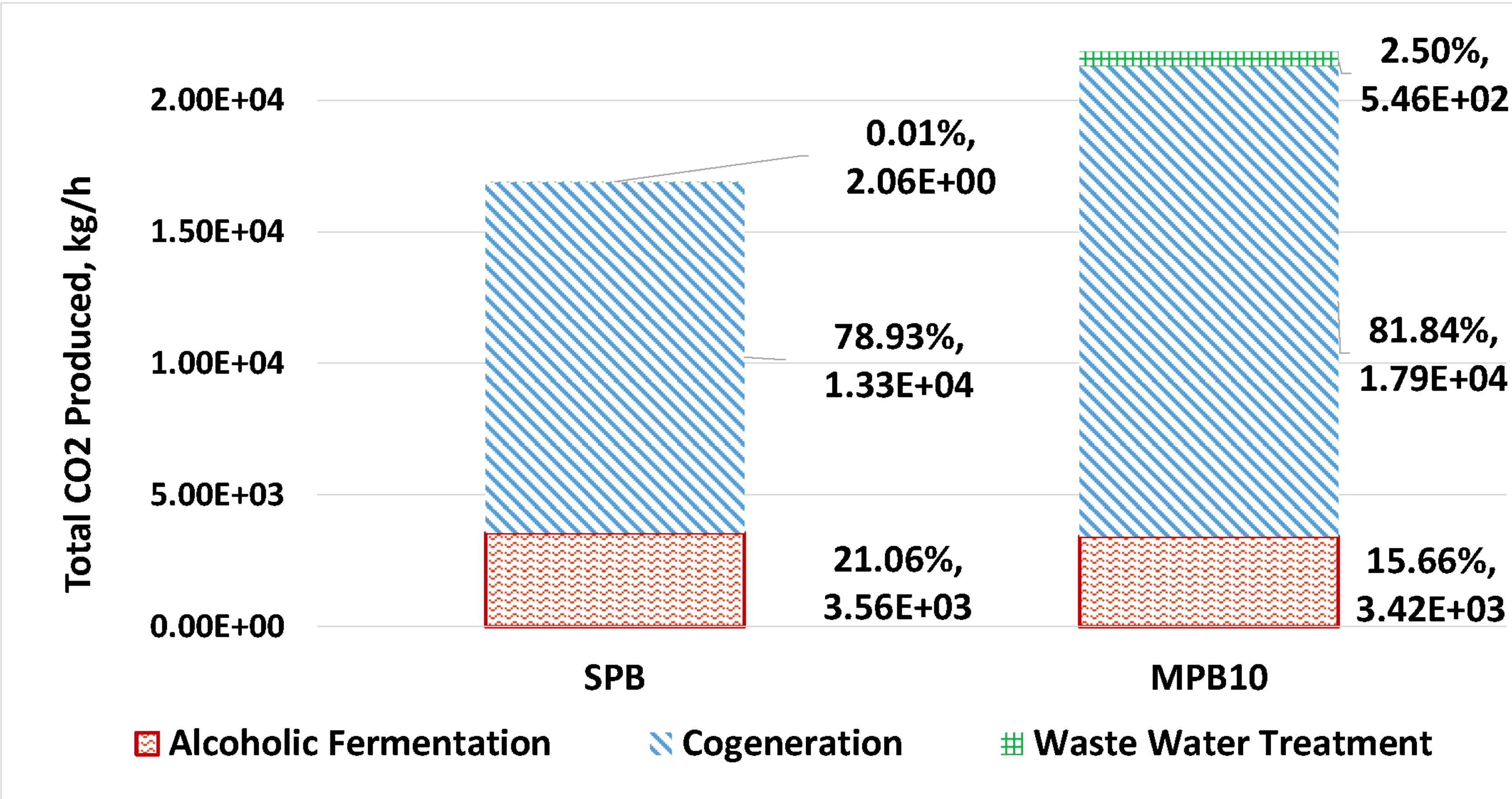
Process Stages Contribution to Electricity Generation



Process Stages Contribution to CO_2 Production



Conclusions

Conclusions

- Higher process complexity (MPB10 BCI=38 vs SPB BCI= 29)
- MPB10 with
  - Lower water consumption (50% lower)
  - Fewer solid wastes (15% lower)
  - Similar EER (6% higher)
  - Higher energy yield (18% higher)
  - Higher electricity productivity (40% higher)
  - Only 4% lower bioethanol production than SPB and the added benefit of solving a severe environmental pollution problem.

•However, SPB TPC per etOH (1.20 USD/L) and per energy unit (0.141 USD/MJ_{out}) produced are 30% and 5% smaller than MPB10 (1.56 USD/L, 0.148 USD/MJ_{out})

•Nevertheless

- An alternative for limited biomass availability
- An important environmental pollution problem is solved. Not accounted in the design criteria!

•Design criteria beyond techno-economic parameters?

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THANK YOU

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AGARED

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