Biofuel's production and use status in "*emerging*" economies

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Agenda

LAND DEMAND FOR BIOFUELS

LCIA

- *Global Warming*

Sensitivity analysis

Policies and incentives

- *Renovabio Case*

Progress + next triennium

Overview

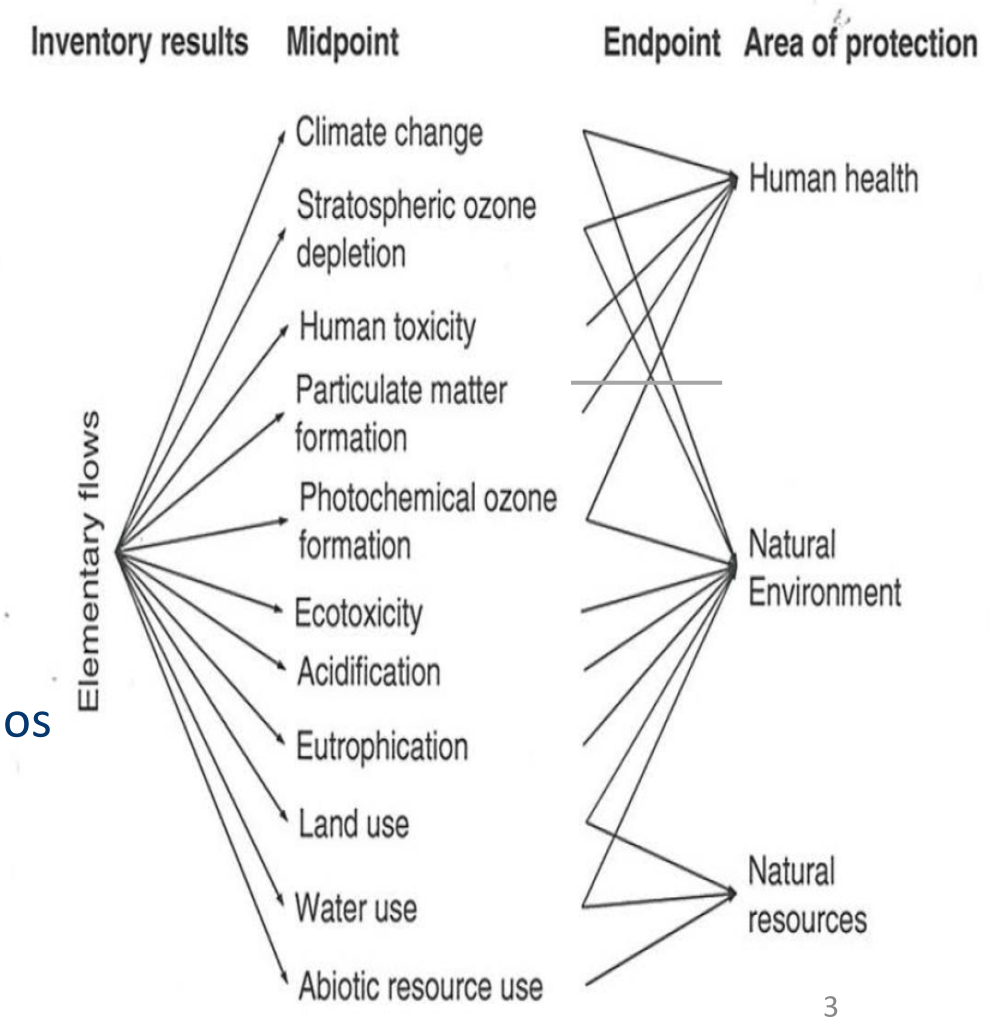
Land use for biofuels

- Land use *versus* productivity
- Food supply
- Biofuels producvity *versus* land use

Life cycle impact assessement

- Comparative analysis for ARG, BRA, COL and GUA scenarios
- Cradle-to-gate LCA
- Life cycle energy indicators

Impact methods structure:



LAND DEMAND FOR BIOFUELS

Table 1. Feedstock use for ethanol production in 2019.

	Harvested area (million ha)	Use in biofuel (million tons)	Share of all feedstocks (%)	Biofuel area (million ha)	Land under perm. Meadows and pastures (million ha)	Land use to duplicate biofuel production (%)
Brazil[1]	8.4	418	65	5.4	173.6	3.1
Argentina[1]	0.5	3.1	20	0.1	74.7	0.13
Argentina[2]	7.2	1.5	2.6	0.02	74.7	0.02
Colombia[1]	0.45	17.5	35	0.16	39.8	0.4
Guatemala[1]	0.26	18.1	69	0.18	1.8	10

[1] Sugarcane as feedstock; [2] Corn as feedstock.
Source: (EPE, 2021; Argentine Biofuels Report (June 2021); FEPA Colombia 2021; Cengicaña statistical report, 2020; FAO, 2021)

Agricultural land

Cropland + land under perm. Meadows and pastures

108 Billion ha	**237 Billion ha**	**50 Billion ha**	**4 Billion ha**

(FAO, 2021)

IEA Bioenergy

Task 39 IEA Bioenergy

LAND DEMAND FOR BIOFUELS

Table 2. Feedstock use for biodiesel production in 2019.

	Harvested area (million ha)	Use in biofuel (million tons)	Share of all feedstocks (%)	Biofuel area (million ha)	Land under perm. Meadows and pastures (million ha)	Land use to duplicate biofuel production (%)
Brazil[1]	35.9	3.7	42	5.7	173.6	3.3
Argentina[1]	16.6	2.2	27	3.4	74.7	4.5
Colombia[2]	0.5	0.3	21	0.02	39.8	0.05

[1] Soybean as feedstock; [2] Palm oil as feedstock.

Source: (EPE, 2021; Argentine Biofuels Report (June 2021); Fedepalma Colombia 2021; FAO, 2021)

ENERGY BALANCE FOR CROPS

Table 3. Agricultural indicators for main feedstocks used to biofuels production in Latin American countries selected in this work.

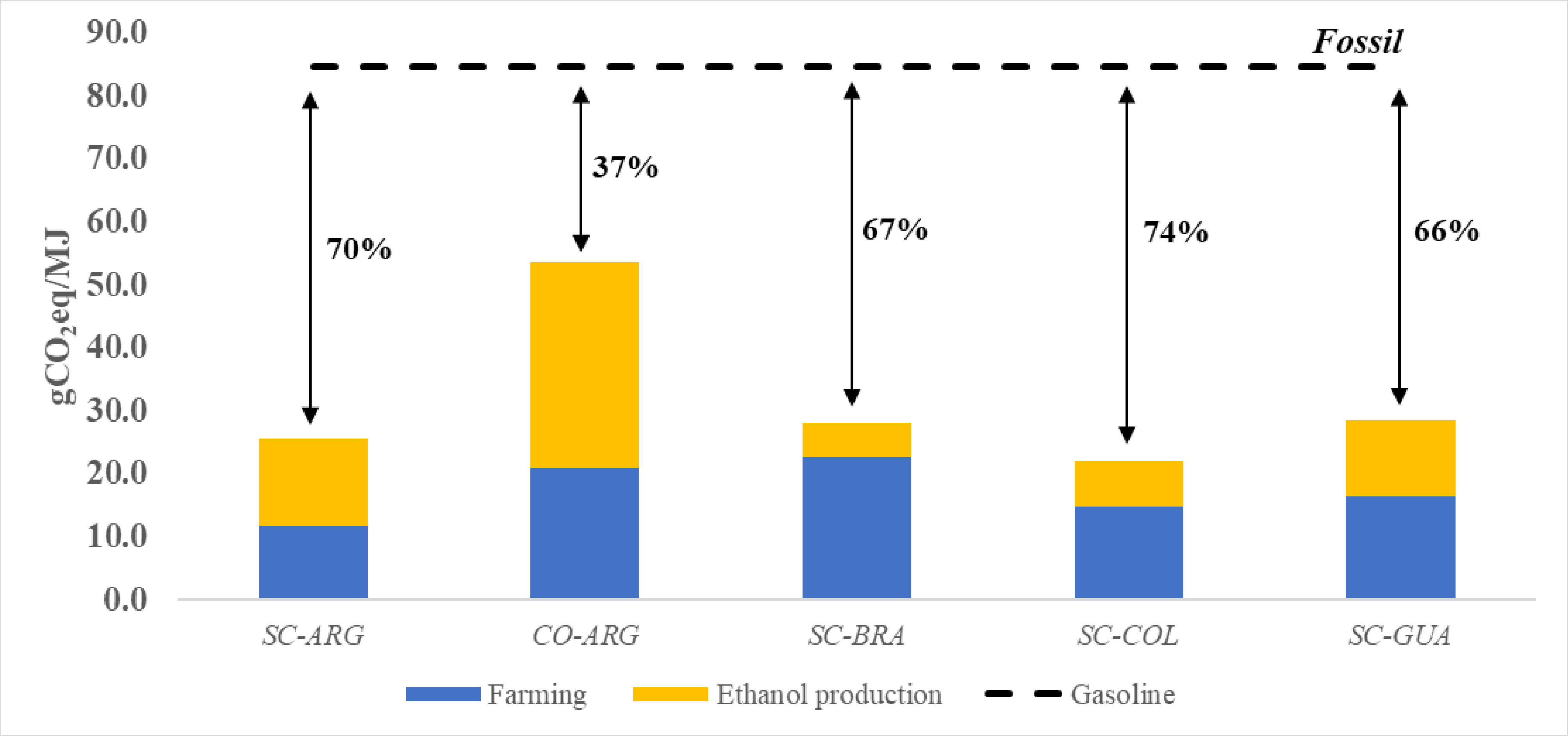
		Argentina			Brazil[d]		Colombia[e]		Guatemala[f]
Indicators	Units	Corn[b]	Sugarcane[b]	Soybean[c]	Sugarcane	Soybean	Sugarcane	Palm Oil	Sugarcane
Crop productivity	(ton/ha)	7.5	55.6	2.9	75.4	3.4	120	19.3	115.7
Crop production energy consumption	(GJ/ha)	4.4	10.8	8.5	14.5	6.8	10.6	22.1	120.2
Biomass Energy	(GJ/ha)	119.9	292.4	138.8	337.1	118.7	531.6	294	512.7
Agricultural energy ratio*	-	27.2	27.0	16.3	23.2	17.4	50.1	24.1	4.3
Biofuel productivity[a]	(GJ/ha)	22.9	25.4	50.7	137.2	22.8	29.4	42.5	21.6

Based on: [a]Legeveld et al. (2018), [b]IPAAT (Institute for the Promotion of Sugar and Alcohol of Tucumán, 2021), [c]Ministerio de Agricultura, Ganadería y Pesca de Argentina. Informe biocombustibles (Junio 2021), [d]Brazilian National Supply Company (2021), [e]Colombian National Federation of Oil Palm Growers (FEDEPALMA, 2021), [e]Colombian Sugarcane Research Center (CENICANA, 2021), and [f]Guatemalan Sugarcane Research and Training Center (CENGICANA, 2021).

* The ratio between Biomass Energy and Crop production energy consumption.

Ethanol

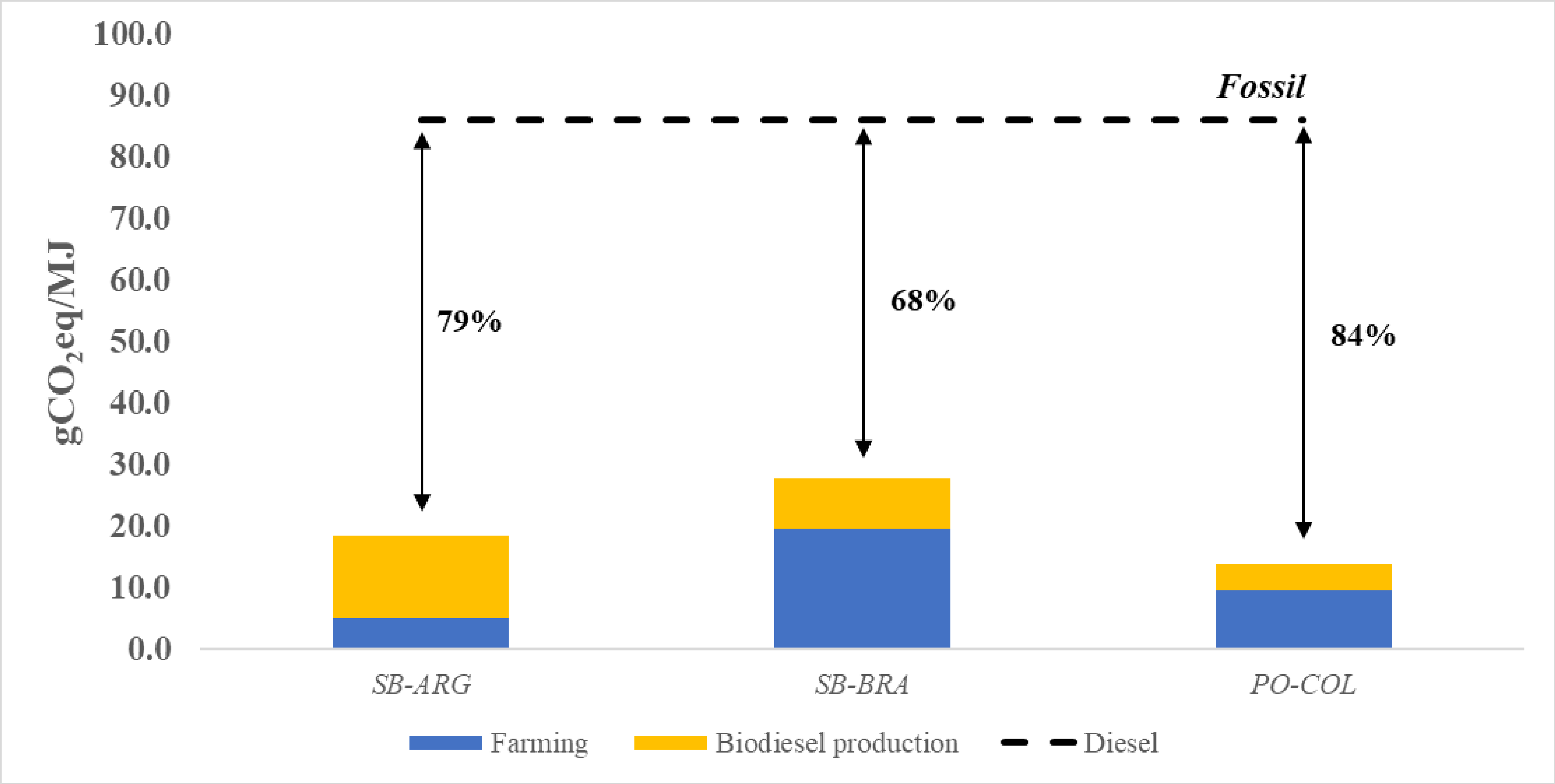
Figure 1. Climate change impact (GWP 100) for ethanol production in comparison with gasoline use for the countries investigated in this study. (Recipe Midpoint (H))



GLOBAL WARMING POTENTIAL

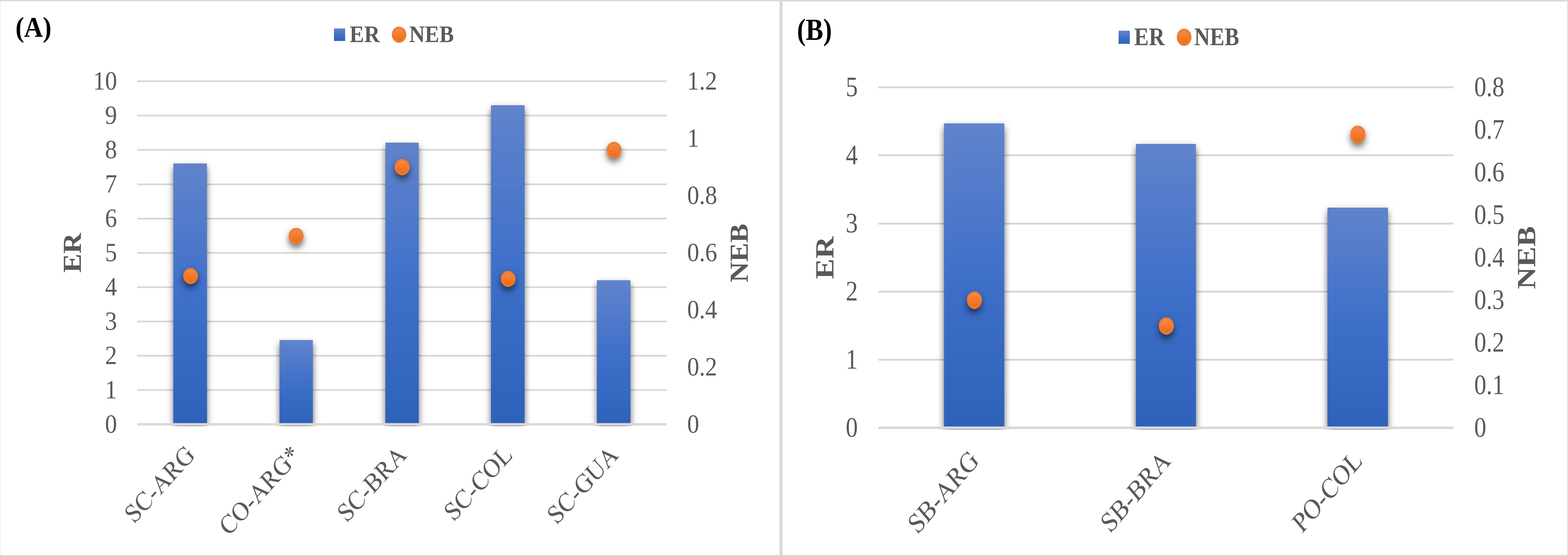
Biodiesel

Figure 2. Climate change impact (GWP 100) for biodiesel production in comparison with diesel use for the countries investigated in this study. (Recipe Midpoint (H))



LIFE CYCLE ENERGY INDICATORS

Figure 3. Energy ratio and Net energy balance for ethanol (A) and biodiesel (B) production in selected countries.



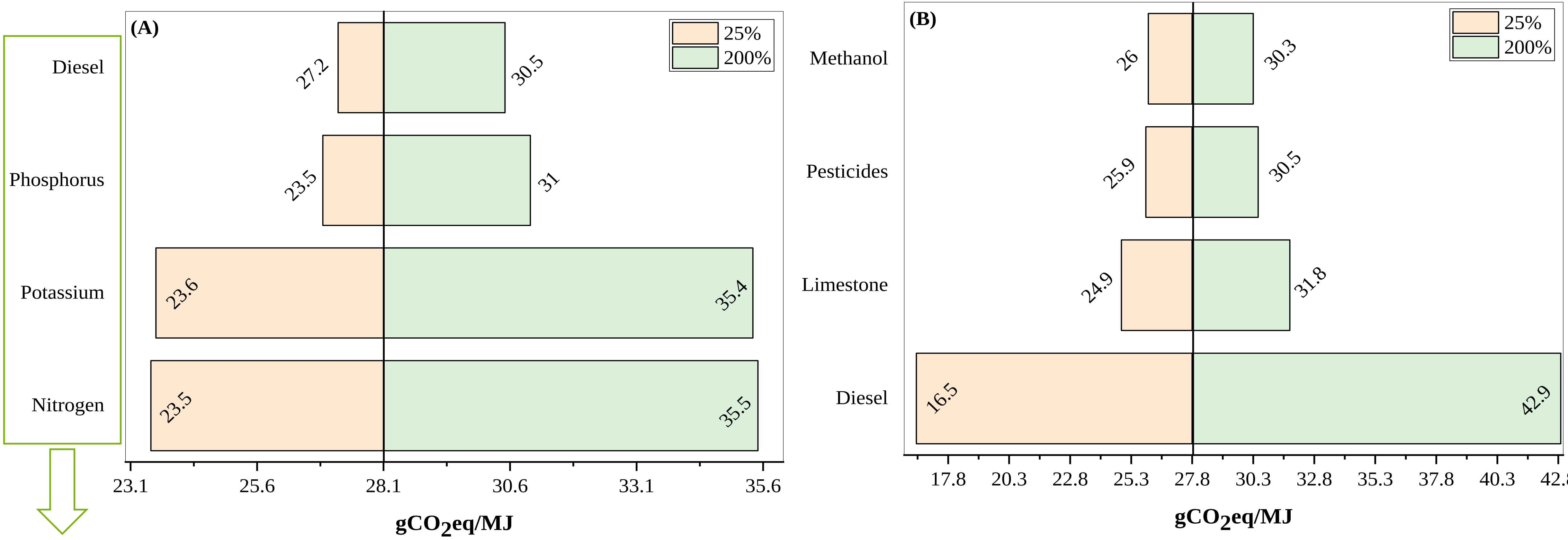
***CO-ARG** provided by *Hilbert et. al (2018)*

Other values were calculated based on LCI

$$\left.\begin{matrix} NEB > 0 \\ ER > 1 \end{matrix}\right\} \textit{Energetically sustainable}$$

SENSITIVITY ANALYSIS (GWP)

Figure 4. Sensitivity analysis for global warming potential (GWP100) impact category in Brazilian ethanol (A) and biodiesel (B) production.



LCIA analysis

25 and 200% of the inventory values GWP Global Warming Potential)

RENOVABIO CASE

Ethanol

Scenarios	Annual Production (Billion L)	GHG emissions ethanol (Gg CO_2 eq)	GHG emissions Gasoline[2] (Gg CO_2 eq)	Emissions avoided by replacing gasoline by ethanol (CBIO)[3] (%)	tons CO_2eq	Credits evaluated by CBIO value (Million US$)[4]
Argentina[1]	1.07	910	1989	54.2	1079	10.8
Brazil	35.3	20961	65427	68	44286	446.2
Colombia	0.45	210	834	74.8	624	6.2
Guatemala	0.27	0	499	0	0	0

[1] ethanol from corn and cane; [2]GHG for gasoline 87.4 gCO_2 eq/MJ ;[3]Assuming all countries has a public policy like Renovabio; [4]1 CBIO = US$ 10.

Biodiesel

Scenarios	Annual Production (Billion L)	GHG emissions Biodiesel (Gg CO_2 eq)	GHG emissions Diesel[1] (Gg CO_2 eq)	Emissions avoided by replacing diesel by biodiesel[2] (%)	tons	Credits evaluated by CBIO value (Million US$)[3]
Argentina	2.4	1284	6013	78.6	4729	47.3
Brazil	5.9	5483	16508	66.8	11025	110.2
Colombia	0.6	283	1706	83.4	1423	14.2

[1]GHG for diesel 84.3 gCO_2 eq/MJ ;[2]Assuming all countries has a public policy like Renovabio; [3]1 CBIO = US$ 10.

MASS AND ENERGY BALANCES

Ethanol from Sugarcane

Table 3. Sugar and ethanol mill operating conditions.

Parameters	value	unit
Sugarcane processed	4	Million ton/year
Operation time	200	days
Amount of bagasse	280	kg/t_c
Steam consumption (3 bar, saturated)	442	kg/t_c
Milling electricity consumption	16	kWh/t_c
Sugar plant electricity consumption	18	kWh/t_c
Ethanol production	46	l/t_c
Sugar production	59	kg/t_c
Cogeneration system		
Boiler pressure	60	Bar
Boiler temperature	480	°C
LHV bagasse (50 wt% moisture)	7.5	MJ/kg
Pumps isentropic efficiency	85	%
Generator electric efficiency	92	%
Cogeneration boiler efficiency (%LHV)	75	%
Backpressure turbine isentropic efficiency	75	%

Biodiesel from soybean

Table 4. Biodiesel plant operating conditions.

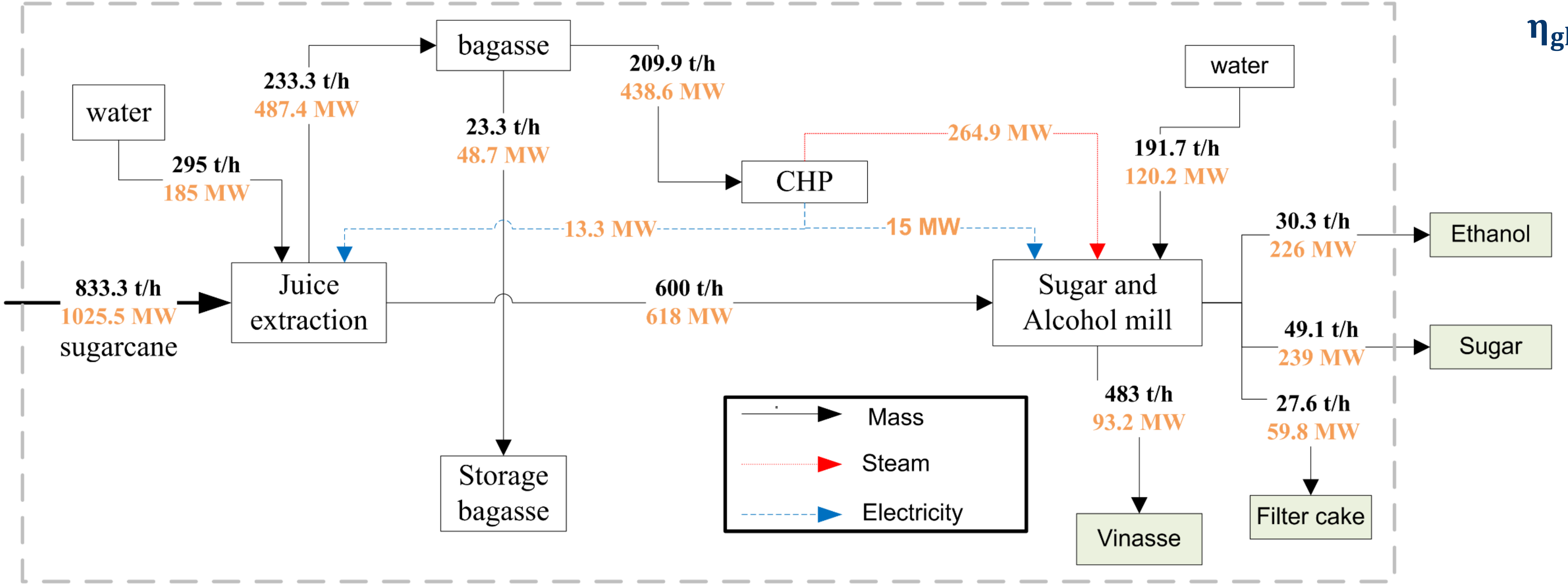
Parameters	value	unit
Soybean processed	6300	ton/day
Amount of soybean meal	790	$kg/t_{soybean}$
Yield of soybean oil	180	$kg/ t_{soybean}$
Extraction electricity consumption	29.9	$kWh/t_{soybean}$
Refining electricity consumption	12.6	kWh/t_{oil}
Transesterification electricity consumption	0.8	kWh/t_{oil}
Glycerol production	21.7	$kg/t_{soybean}$
Biodiesel production	181	$kg/t_{soybean}$

Additional information → **LCI**

Source: (Ocampo Battle et al., 2021; Brondani et al., 2015)

MASS AND ENERGY BALANCES

Ethanol from Sugarcane



Only Ethanol

$\eta_{global} = 22.1\%$

$$\eta_{global} = \frac{\text{energy in products}}{\text{energy in raw material}}$$

→ (Ethanol, sugar, Bioelectricity, glycerin)

All products

$\eta_{global} = 52.4\%$

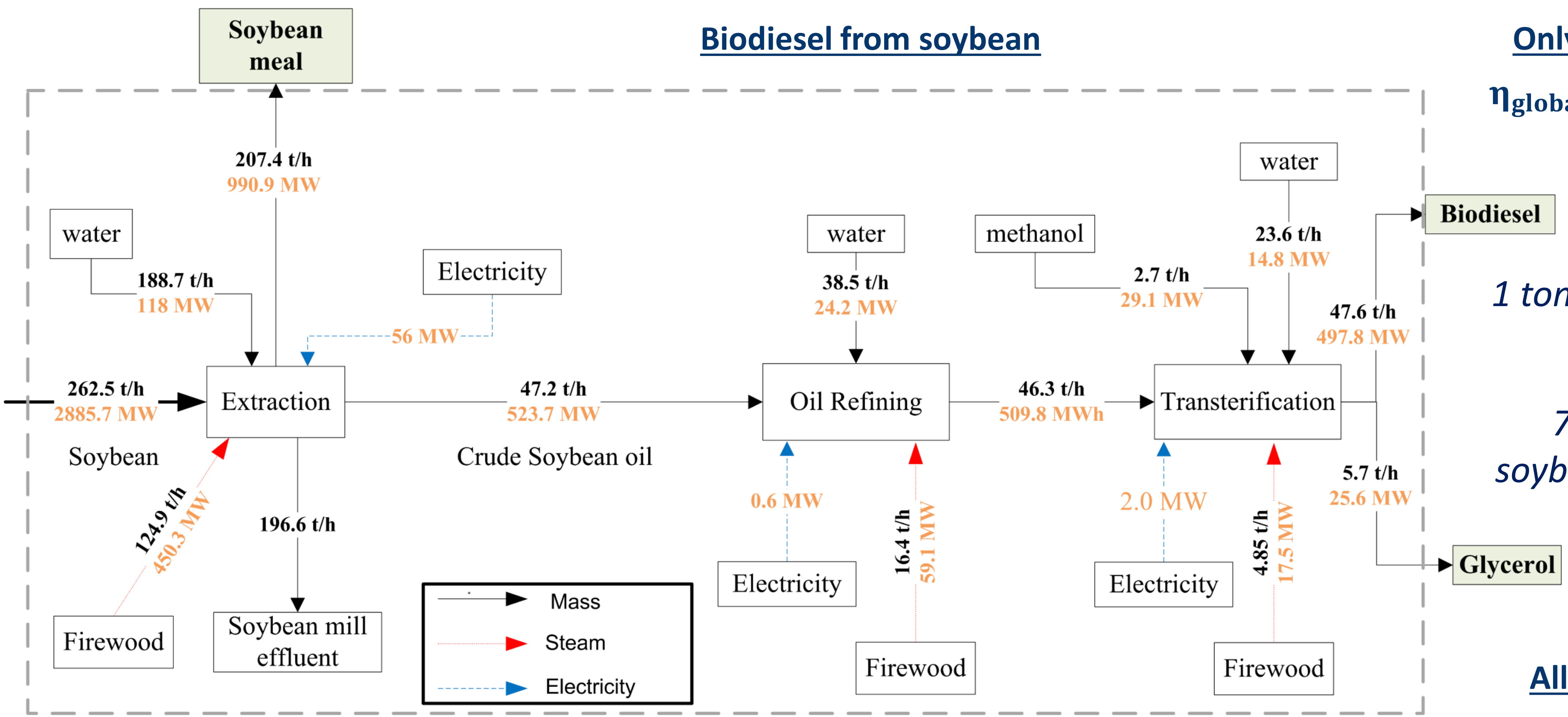
ADVANCES IN ETHANOL MILLS

Table 6. Water and electricity Production in ethanol plants.

Parameters	1990	Today
Steam conditions (P e T)	• 22 bar • 350°C	• 65 – 100 bar • 480 – 520°C
Water consumption (m^3/TC)	21	(1-3) 15
Steam consumption (kg/TC)	500	300
Mechanical energy for the drivers (kWh/TC)	16	18
Electricity for the mil (kWh/TC)	12	16
Surplus electricity (kWh/TC)	0	150*

*Considering feed bagasse and straw in the boiler. Source: Leal et al. (2014), Pina et al. (2015)

MASS AND ENERGY BALANCES



Only Biodiesel

$$\eta_{global} = 17.2\%$$

1 ton soybean

780 kg soybean meal

All products

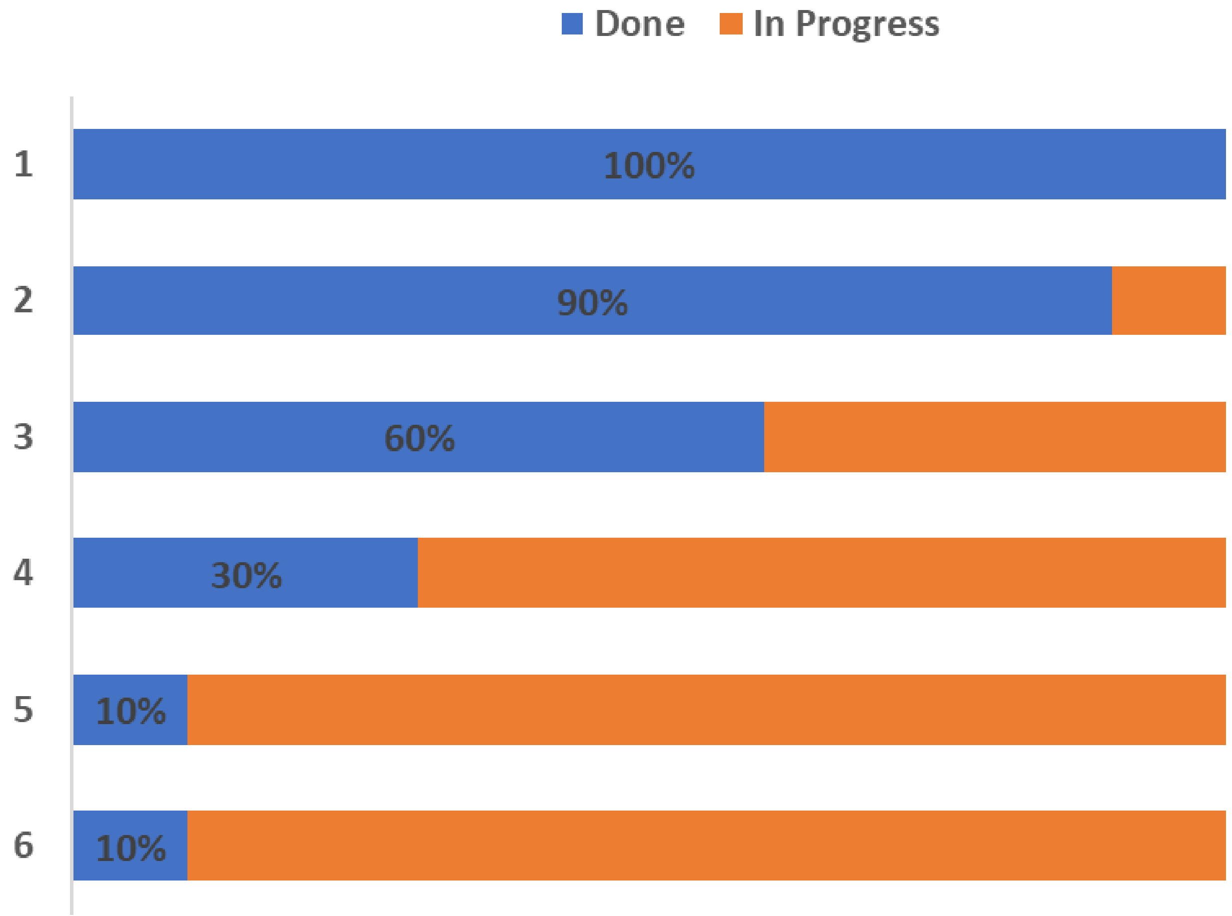
$$\eta_{global} = 52.5\%$$

TAKE HOME MESSAGES

- Land demand for biofuels has a lower impact on countries with large areas, while smaller countries should look for the possible impacts caused by land expansion such as food supply;
- Enhancing the feedstocks productivity can improve the biofuels productivity and breaks the expansion of land demand, which means that the efforts on research focused on new feedstocks phenotypes development should be intensified;
- Although farming activities and natural gas utilization are responsible for the most significant portion of GHG emissions, biofuels production remains extremely attractive to replace fossil fuels;
- The adoption of a biofuels policy like Brazilian Renovabio shown to be a great incentive to increase the biofuels production as well as the blend mandates levels;
- Appropriate public policies for biofuels can help grow the biofuels production chain, create jobs, enhance the producers' profits, and mitigate GHG emissions.

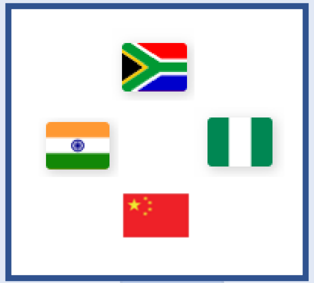
Progress

1. Life cycle assessment – Base case scenarios;
2. Paper I – Writing Phase;
3. Mass and Energy balances;
4. Exergy analysis;
5. Paper II – EXA and TEA: Outline
6. Life cycle assessment – LNBR collaboration;

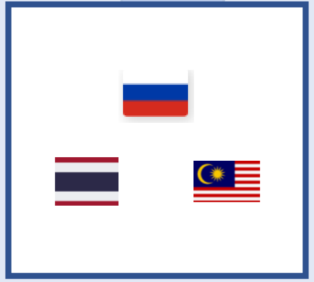


NEXT STEPS AND TRIENNIUM PLAN

Group II



Group III



Feedstocks and conversion process data

SYSTEM ANALYSIS

Techno-economic assessment (TEA), and Life-cycle(LCA), Exergy Analysis

Integrated methodologies approach

Key performance indicators *(KPIs)*

Capital Costs (CapEx)
- Purchase cost
- Installation cost
- Engineering and construction costs
- Financing

Operating Costs (OpEx)
- Raw materials
- Utilities
- Labor
- Waste treatment

Emission Inventory (LCI)
- Upstream
- Logistics
- Conversion process

Specific chemical exergy

Multiple Criteria Decision Analysis (MCDA)

Comparison of biofuels production impacts between all selected countries

PAUL SCHERRER INSTITUT

PSI

***Group I** has already been evaluating in the triennium 2019-2021* (Brazil, Argentina, Colombia, and Guatemala)

Thank you for your attention!

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