Laboratório Nacional de Ciência e Tecnologia do Bioetanol

Sustainability of sugar cane bioethanol: Energy balance and GHG

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Global Sustainable Bioenergy - Latin American Vision
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Biofuels Sustainability Issues

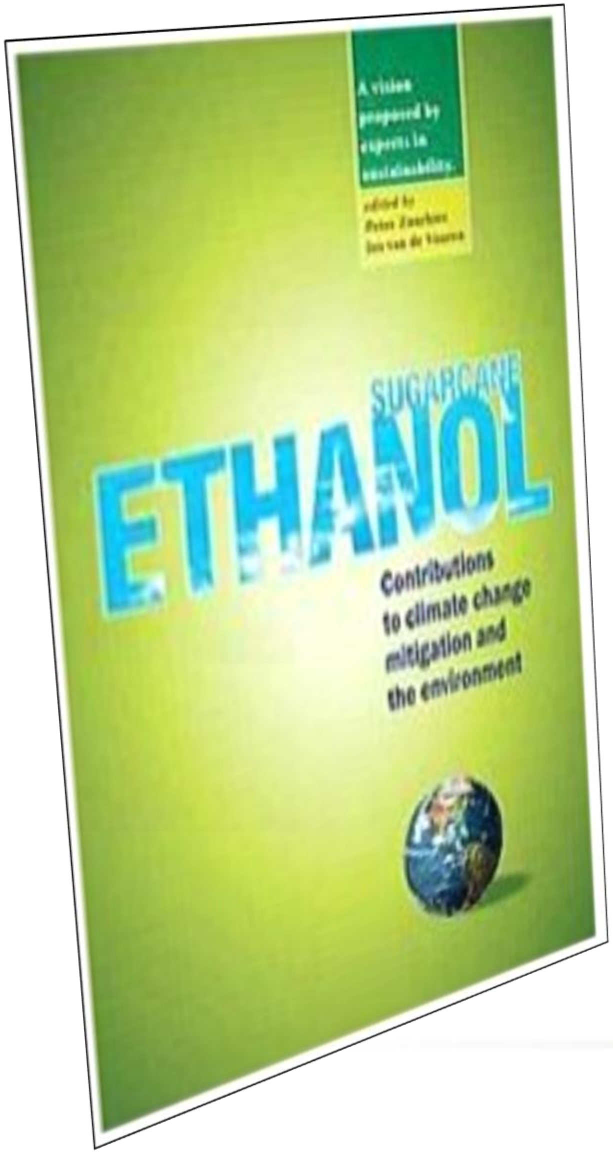
- ✓ **Economic**: displace fossil fuels ($/l eq.), GHG emission abatement ($/t CO_2 eq.)

- ✓ **Environmental:** %GHG emission reduction, local pollution, land and water use, biodiversity

- ✓ **Social:** local wealth, jobs and household income, land tenure

Biofuels are not equal and must be selected based on their sustainability characteristics and main driving forces

Sugarcane ethanol: Energy balance and GHG emissions



✓ **Macedo and Seabra (2008)**:

- **<u>2006</u>**: 44 mills (~100 Mtc/year) of Brazilian C-S Region – data from CTC Mutual Control.
- **<u>2020 Electricity Scenario</u>**: trash recovery (40%) and surplus power production with integrated commercial, steam based cycle (CEST system).
- **<u>2020 Ethanol Scenario</u>**: trash recovery and ethanol production from biochemical conversion of surplus biomass in a hypothetical system integrated to the mill.

Scenarios

Item	Units	2006 [a]	2020 electricity [b]	2020 ethanol [b]
Bagasse use		Low pressure cogeneration	Advanced cogeneration	Biochemical conversion
Electricity demand	kWh/t cane	14.0	30	[c]
Mechanical drivers	kWh/t cane	16.0	0	0
Electricity surplus	kWh/t cane	9.2 [d]	135 [e]	44 [f]
Trash recovery	% total	0	40	40
Bagasse surplus	% total	9.6	0 [g]	0 [g]
Ethanol yield	l/t cane	86.3	92.3 [h]	129

Scope

- Sugarcane production and processing, and ethanol distribution.
  - Carbon fluxes due to fossil fuel utilization in agriculture, industry and ethanol distribution; in all the process inputs; also in equipment and buildings production and maintenance.
  - GHG fluxes not related with the use of fossil fuels; mainly N_2O and methane: trash burning, N_2O soil emissions from N-fertilizer and residues (including stillage, filter cake, trash).
  - GHG emissions due to land use change.
  - GHG emissions mitigation: ethanol and surplus electricity substitution for gasoline or conventional electricity.

Energy flows in ethanol production (MJ/t cane)

	2006	2020 electricity	2020 ethanol
Energy input	235	262	268
Agriculture	211	238	238
Cane production	109	142	143
Fertilizers	65	51	50
Transportation	37	45	45
Industry	24	24	31
Inputs	19	20	25
Equip./buildings	5	4	6
Energy output	2,198	3,171	3,248
Ethanol [a]	1,926	2,060	2,880
Electricity surplus [b]	96	1,111	368
Bagasse surplus [a]	176	0.0	0.0
Energy ratio	9.4	12.1	12.1

[a] Based on LHV (Low Heating Value).

[b] Considering the substitution of biomass-electricity for natural gas-electricity, generated with 40% (2006) and 50% (2020) efficiencies (LHV).

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Life cycle GHG emissions ($kg\ CO_2eq/m^3$ anhydrous)[a]

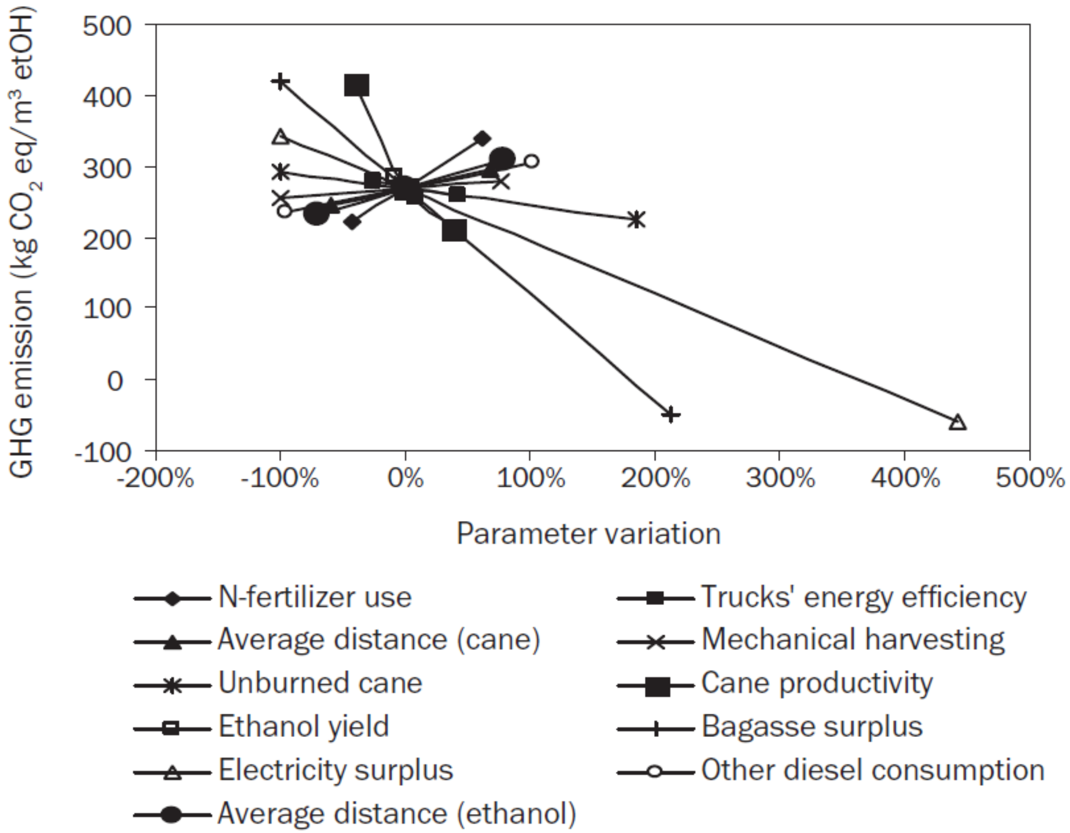
	2006	2020 electricity	2020 ethanol
Cane production	416.8	326.3	232.4
Farming	107.0	117.2	90.6
Fertilizers	47.3	42.7	23.4
Cane transportation	32.4	37.0	26.4
Trash burning	83.7	0.0	0.0
Soil emissions	146.3	129.4	92.0
Ethanol production	24.9	23.7	21.6
Chemicals	21.2	20.2	18.5
Industrial facilities	3.7	3.5	3.2
Ethanol distribution	51.4	43.3	43.3
Credits			
Electricity surplus [b]	-74.2	-802.7	-190.0
Bagasse surplus [c]	150.0	0.0	0.0
Total	268.8	-409.3	107.3

[a] Emissions for hydrous ethanol/m^3 are about 5% less than values verified for anhydrous ethanol.

[b] Considering the substitution of biomass-electricity for natural gas-electricity, generated with 40% (2006) and 50% (2020) efficiencies (LHV).

[c] Considering the substitution of biomass fuelled boilers (efficiency = 79%; LHV) for oil fuelled boilers (efficiency = 92%; LHV).

Sensitivity analysis (2006)



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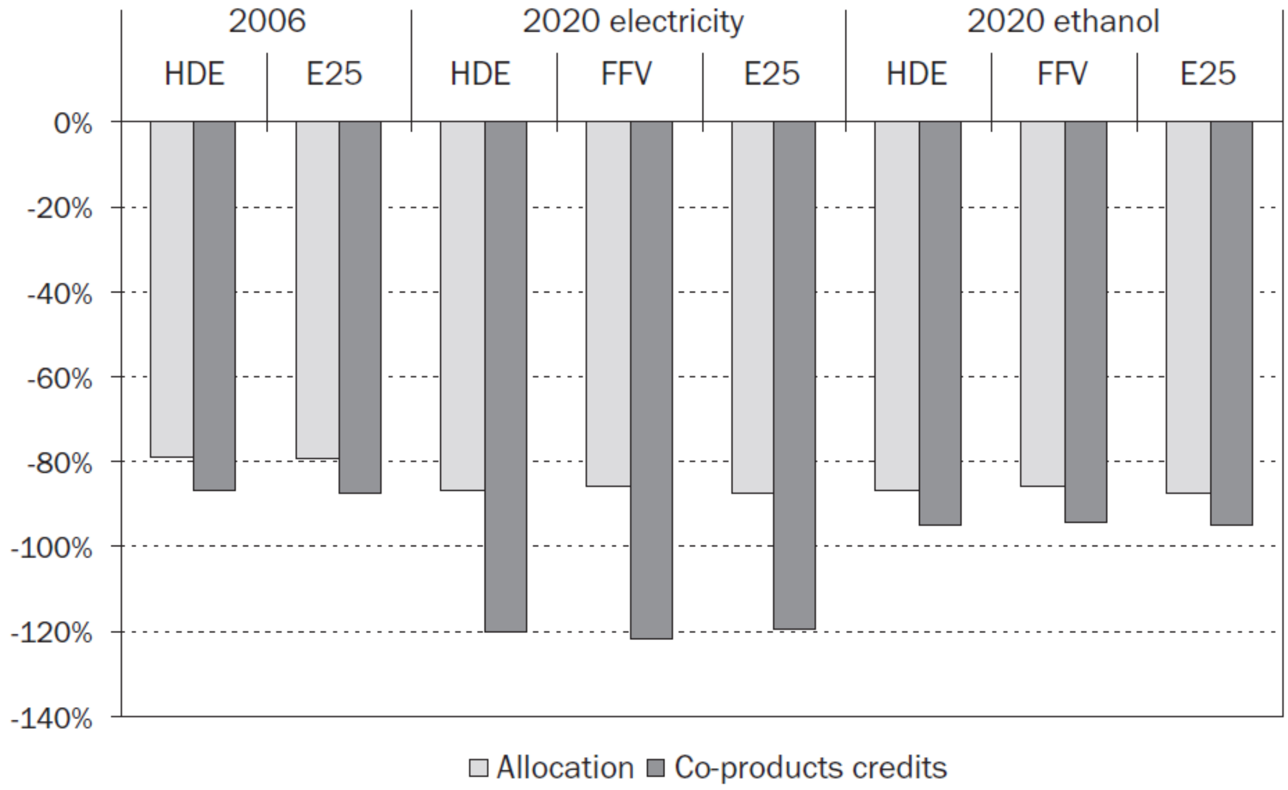
GHG emissions mitigation with respect to gasoline: allocation or co-products credits



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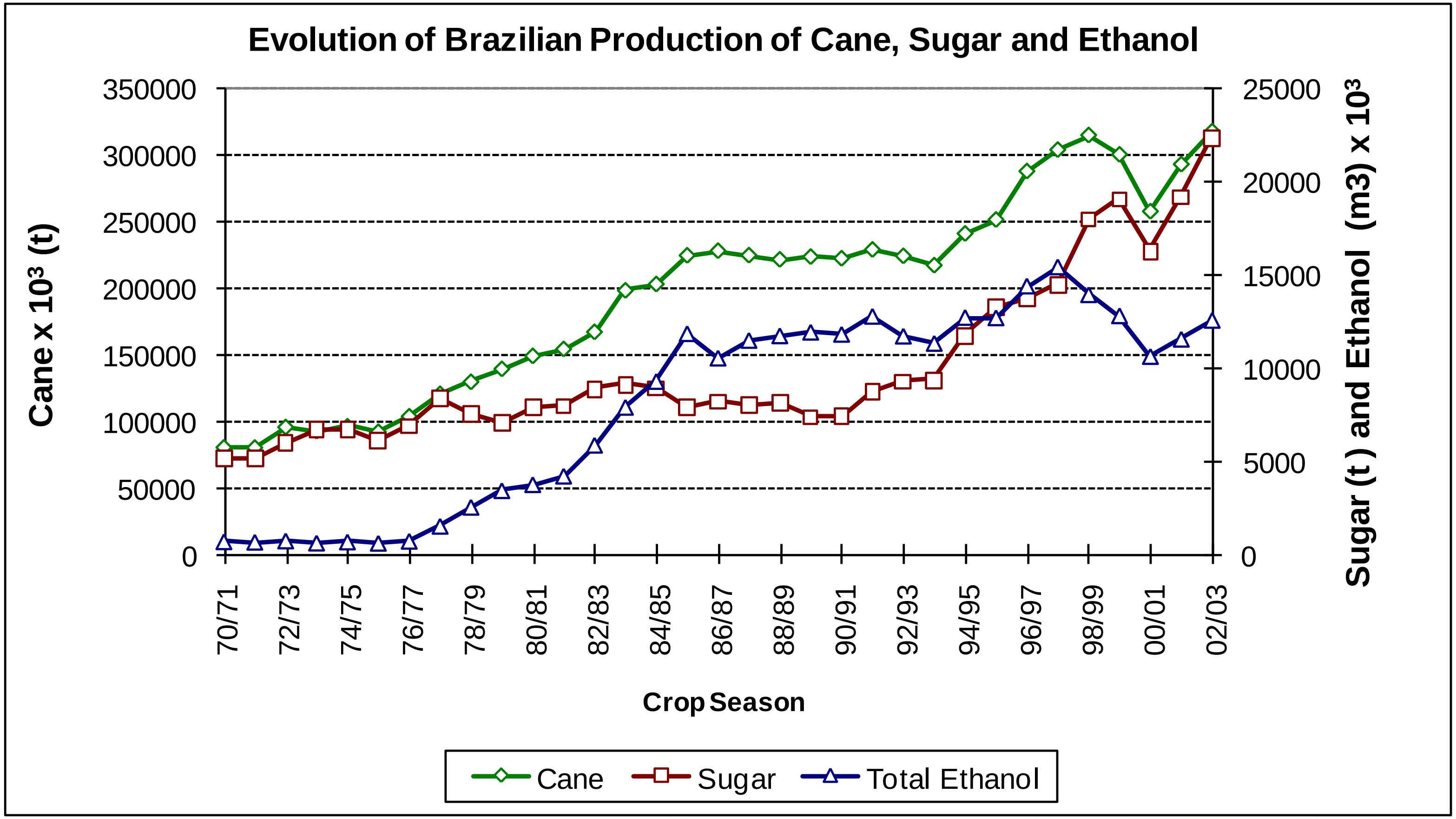
Net avoided emissions by sugarcane products

Scenario	Ethanol use	Net emissions		
		t CO_2eq/ha.y ↔	kg CO_2eq/tc ↔	t CO_2eq/m^3
2005/2006	HDE	-11,3	-155	-1,7
	E25	-11,5	-159	-1,8
2020 – Electricity	HDE	-18,1	-229	-2,4
	FFV	-16,8	-212	-2,2
	E25	-18,4	-233	-2,5
2020 – Ethanol	HDE	-20,0	-253	-1,9
	FFV	-18,2	-229	-1,7
	E25	-20,5	-258	-2,0

Source: Seabra (2008)

Direct effects of land use change for ethanol

✓ 1984-2002: 11.8 to 12.5 M m³/year → **no LUC for ethanol**.



Direct effects of land use change

- Cane expansion since 2002 was over pasturelands (mainly extensive, degraded pastures) and annual crops:
  - Data source: satellite images (Landsat and CBERS), CONAB survey (MAPA/DCAA), IBGE data and preliminary EIA-RIMA data for new units (Nassar et al., 2008; CONAB, 2008; ICONE, 2008).
- This fact in addition to cropping practices in the new areas (mechanical harvesting of **unburned cane**; **semi-perennial** crop; high level of **residues**) indicates that land use change occurs without soil carbon emissions. In many cases, the land use change may **increase carbon stocks**.

Direct effects of land use change

Reference crop	Carbon stock change[a] (t C/ha)	Emissions (kg CO_2 eq./m^3)		
		2006	2020 electricity	2020 ethanol
Degraded pasturelands	10	-302	-259	-185
Natural pasturelands	-5	157	134	96
Cultivated pasturelands	-1	29	25	18
Soybean cropland	-2	61	52	37
Maize cropland	11	-317	-272	-195
Cotton cropland	13	-384	-329	-236
Cerrado	-21	601	515	369
Campo Limpo	-29	859	737	527
Cerradão	-36	1,040	891	638
LUC emissions[b]		-118	-109	-78

[a] Based on measured values for below and above ground (only for perennials) carbon stocks.
[b] Considering the following LUC distribution – 2006: 50% pasturelands (70% degraded pasturelands; 30% natural pasturelands), 50% croplands (65% soybean croplands; 35% other croplands); 2020: 60% pasturelands (70% degraded pasturelands; 30% natural pasturelands); 40% croplands (65% soybean croplands; 35% other croplands). Cerrados were always less than 1%.

Expansion includes only a very small fraction of lands with high soil carbon stocks, and some degraded pasturelands, leading to increased carbon stocks.

INDIRECT effects of land use change

In the Brazilian context, most scenarios (based on Internal Demand plus some hypotheses for exports) indicate a total of ~ 60 M m^3 ethanol in 2020, or 36 M m^3 more than in 2008. Such expansion corresponds to a relatively small requirement for new cane areas (~5 M ha), which must be considered combined with probable release of areas due to the progressive increase of pasture productivities. Within Brazilian soil and climate limitations, the strict application of the environmental legislation for the new units, and the relatively small areas needed, the expansion of sugarcane until 2020 is not expected to contribute to ILUC GHG emissions.

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Other analyses

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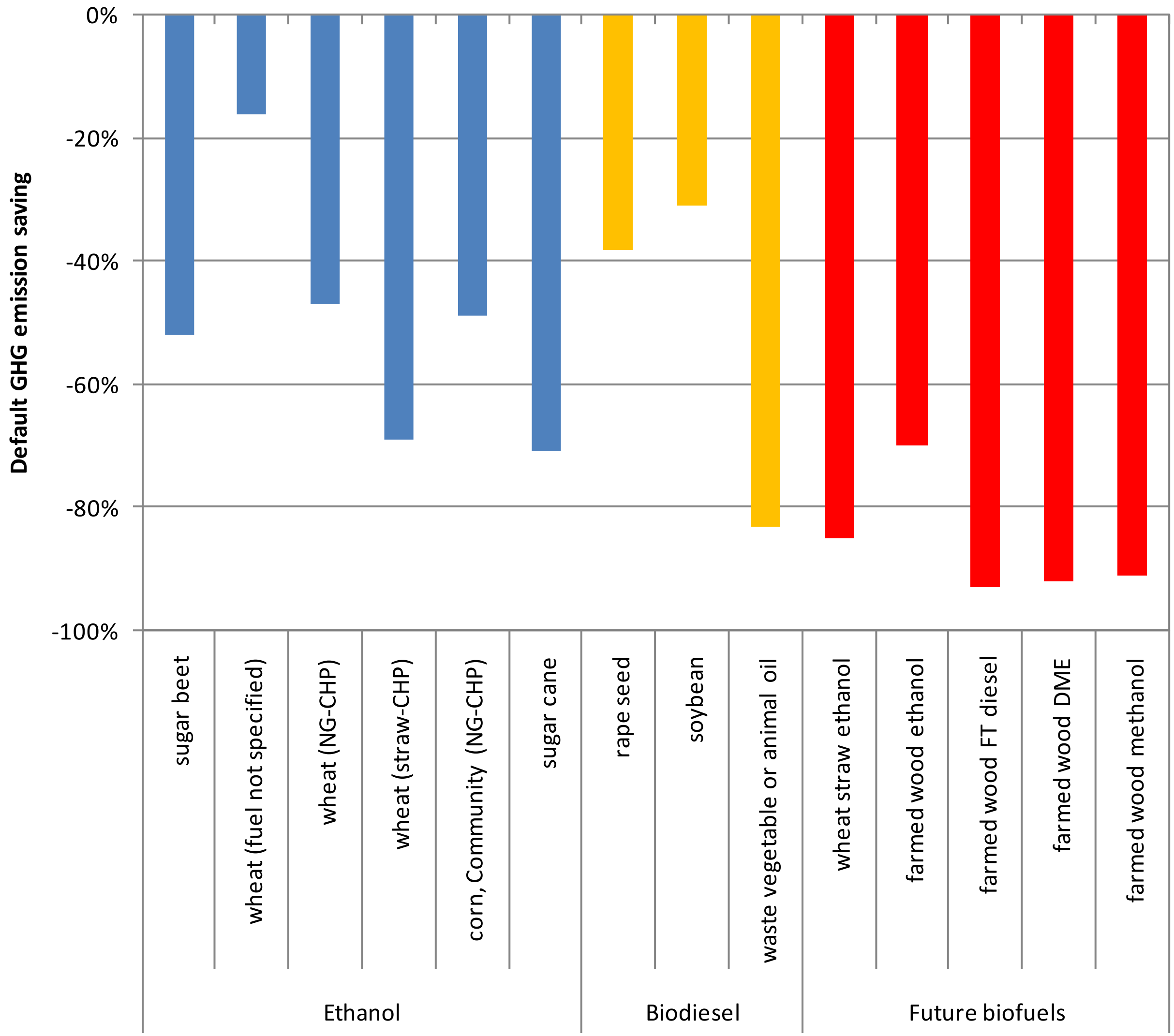
EU Directive

Sugar cane ethanol	Default GHG emissions (g CO2eq/MJ)
Cultivation (e_{ec})	14
Processing (e_p – e_{ee})	1
Transport and distribution (e_{td})	9
Total	24
Default GHG emission saving	71%


0%
-20%
-40%
-60%
-80%
-100%
Default GHG emission saving
sugar beet
wheat (fuel not specified)
wheat (NG-CHP)
wheat (straw-CHP)
corn, Community (NG-CHP)
sugar cane
rape seed
soybean
waste vegetable or animal oil
wheat straw ethanol
farmed wood ethanol
farmed wood FT diesel
farmed wood DME
farmed wood methanol
Ethanol
Biodiesel
Future biofuels

EU Directive

- ✓ "Biofuels should be promoted in a manner that encourages greater agricultural productivity and the use of degraded land."
- ✓ "The Commission should develop a concrete methodology to minimise greenhouse gas emissions caused by indirect land-use changes."
- ✓ $e_l = (CS_R – CS_A) × 3,664 × 1/20 × 1/P – e_B$
  - The bonus of **29 gCO2eq/MJ** shall be attributed if evidence is provided that the land:
    - (a) was not in use for agriculture or any other activity in January 2008; and
    - (b) falls into one of the following categories:
      - (i) severely degraded land, including such land that was formerly in agricultural use;
      - (ii) heavily contaminated land.

CARB

Table B. GHG Emissions Summary for Sugar Cane Ethanol

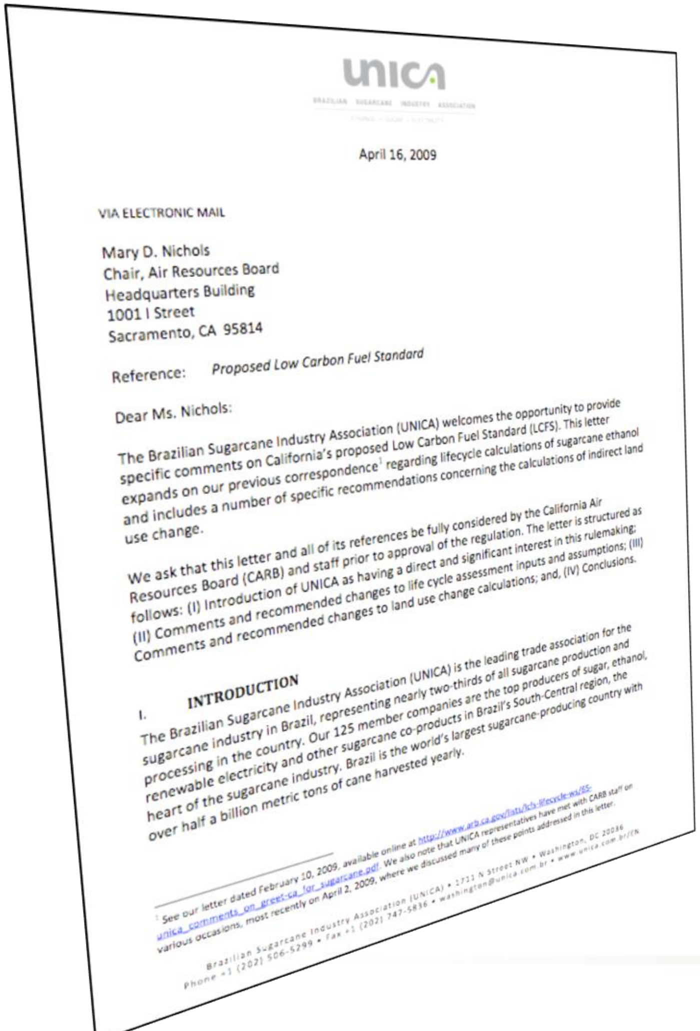
Sugar Cane Ethanol Components	GHGs (g CO_2e/MJ)	% Emission Contribution
Sugar Cane Farming *(incl. straw burning)*	9.9	37.2%
Ag Chemicals Production and Use Impacts	8.7	32.7%
Sugar Cane Transportation	2.0	7.5%
Ethanol Production	1.9	7.1%
Ethanol T&D	4.1	15.4%
Total Well-to-Tank	26.6	100%
Total Tank-to-wheel	0	0%
Total Well-to-Wheel	**26.60**	**100%**
Inclusive of Tailpipe Emissions and Land Use Change	**73.40***	

LUC: **46 g CO2e/MJ**

CARB

Pathway Description	WTW GHG* Emissions (gCO_2e/MJ)
Baseline Pathway Brazilian sugarcane using average production processes	27.40
Scenario 1 Brazilian sugarcane with average production process, mechanized harvesting and electricity co-product credit	12.20
Scenario 2 Brazilian sugarcane with average production process and electricity co-product credit	20.40

*These values do not include contributions from Land Use Change. This analysis is available in report titled "Proposed Regulation to Implement the Low Carbon Fuel Standard - Initial Statemer Reasons (ISOR)" from the website: www.arb.ca.gov/fuels/lcfs/lcfs.htm.



unica
BRAZILIAN SUGARCANE INDUSTRY ASSOCIATION

April 16, 2009

VIA ELECTRONIC MAIL

Mary D. Nichols
Chair, Air Resources Board
Headquarters Building
1001 I Street
Sacramento, CA 95814

Reference: *Proposed Low Carbon Fuel Standard*

Dear Ms. Nichols:

The Brazilian Sugarcane Industry Association (UNICA) welcomes the opportunity to provide specific comments on California's proposed Low Carbon Fuel Standard (LCFS). This letter expands on our previous correspondence[1] regarding lifecycle calculations of sugarcane ethanol and includes a number of specific recommendations concerning the calculations of indirect land use change.

We ask that this letter and all of its references be fully considered by the California Air Resources Board (CARB) and staff prior to approval of the regulation. The letter is structured as follows: (I) Introduction of UNICA as having a direct and significant interest in this rulemaking; (II) Comments and recommended changes to life cycle assessment inputs and assumptions; (III) Comments and recommended changes to land use change calculations; and, (IV) Conclusions.

I. INTRODUCTION

The Brazilian Sugarcane Industry Association (UNICA) is the leading trade association for the sugarcane industry in Brazil, representing nearly two-thirds of all sugarcane production and processing in the country. Our 125 member companies are the top producers of sugar, ethanol, renewable electricity and other sugarcane co-products in Brazil's South-Central region, the heart of the sugarcane industry. Brazil is the world's largest sugarcane-producing country with over half a billion metric tons of cane harvested yearly.

[1] See our letter dated February 10, 2009, available online at http://www.arb.ca.gov/lists/lcfs-lifecycle-ws/65-unica_comments_on_greet-ca_for_sugarcane.pdf. We also note that UNICA representatives have met with CARB staff on various occasions, most recently on April 2, 2009, where we discussed many of these points addressed in this letter.

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Table 9: GTAP Modeling Results for Sugarcane Ethanol Land Use Change with Alternative Scenarios

1.	Shock size	*1.5 billion gallons*
2.	Elasticity of substitution among primary factors in livestock production	*0.2 everywhere but 0.4 in Brazil*
3.	Crop yield elasticity w/ area expansion	*0.9*
4.	Adjustment for sugarcane and TRS yields	*16.66%*

Total land converted (million ha)	0.60
Forest land (million ha)	0.01
Pasture land (million ha)	0.59
Brazil land converted (million ha)	0.35
Brazil forest land (million ha)	-0.07
Brazil pasture land (million ha)	0.42
ILUC carbon intensity (gCO2e/MJ)	**25.3**

Table 10: Carbon Intensity Using Land Use Change from Table 9 and Alternative Scenarios for Carbon Uptake

Alternative Scenarios	**ILUC carbon intensity (gCO$_2$e/MJ)**
1. Departing Scenario (Table 9)	25.3
2. Departing Scenario + Carbon Uptake of Forest Gained (array EMISSCTR) + Carbon Uptake of Crops from GTAP Efs-ef_tables.xls (18Mg CO2e/ha)	12.4
3. Departing Scenario + Carbon Uptake of Forest Gained (array EMISSCTR) + Carbon Uptake of Crops Rest of World from GTAP Efs-ef_tables.xls (18Mg CO2e/ha) + Carbon Uptake for Sugarcane Brazil from Table 8 (244Mg CO2e/ha).	-9.4
4. Departing Scenario + Carbon Uptake Forest Gained (array EMISSCTR) + Carbon Uptake Crops from Table 8 (160Mg CO2e/ha)	-10.7

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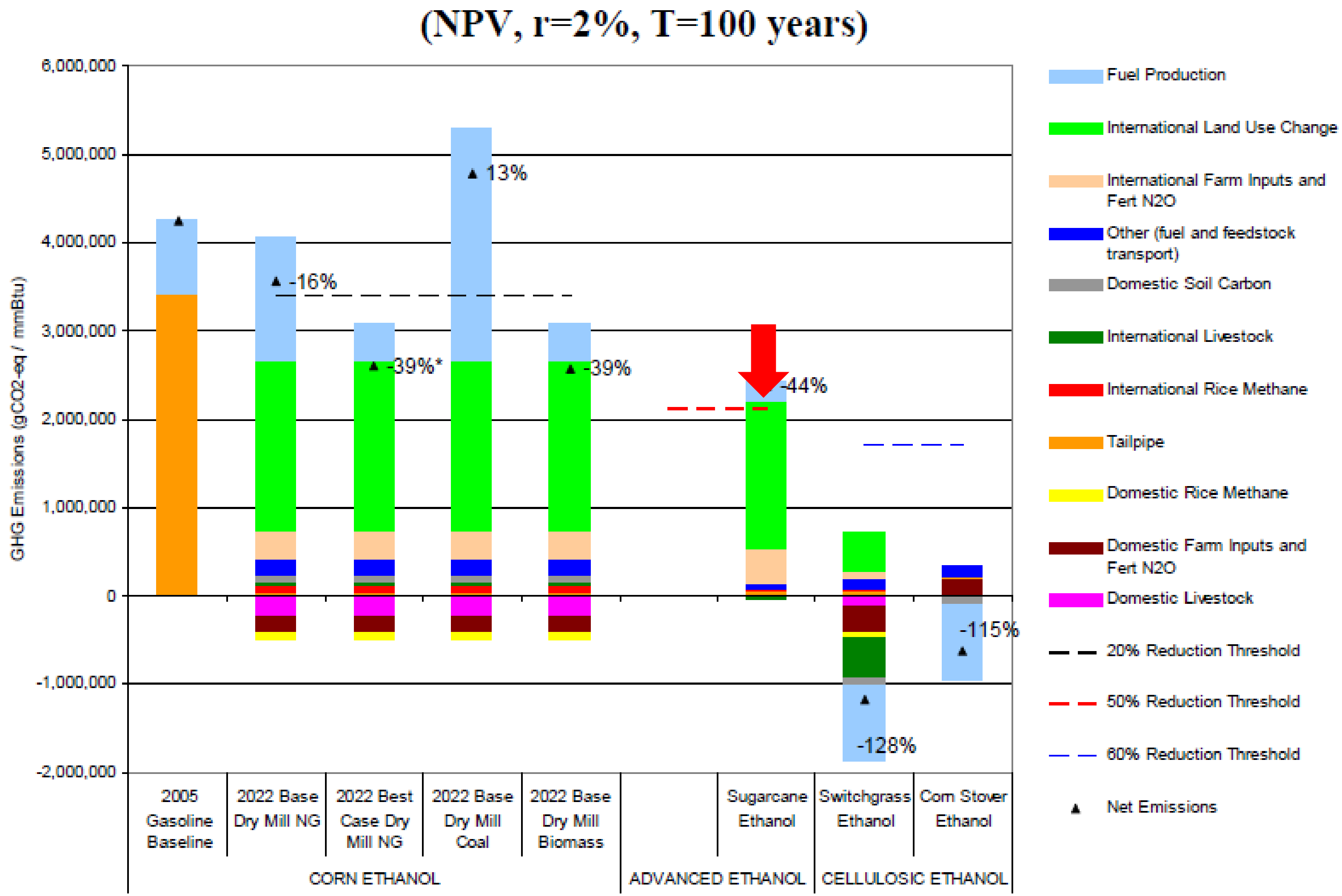
US EPA



US EPA

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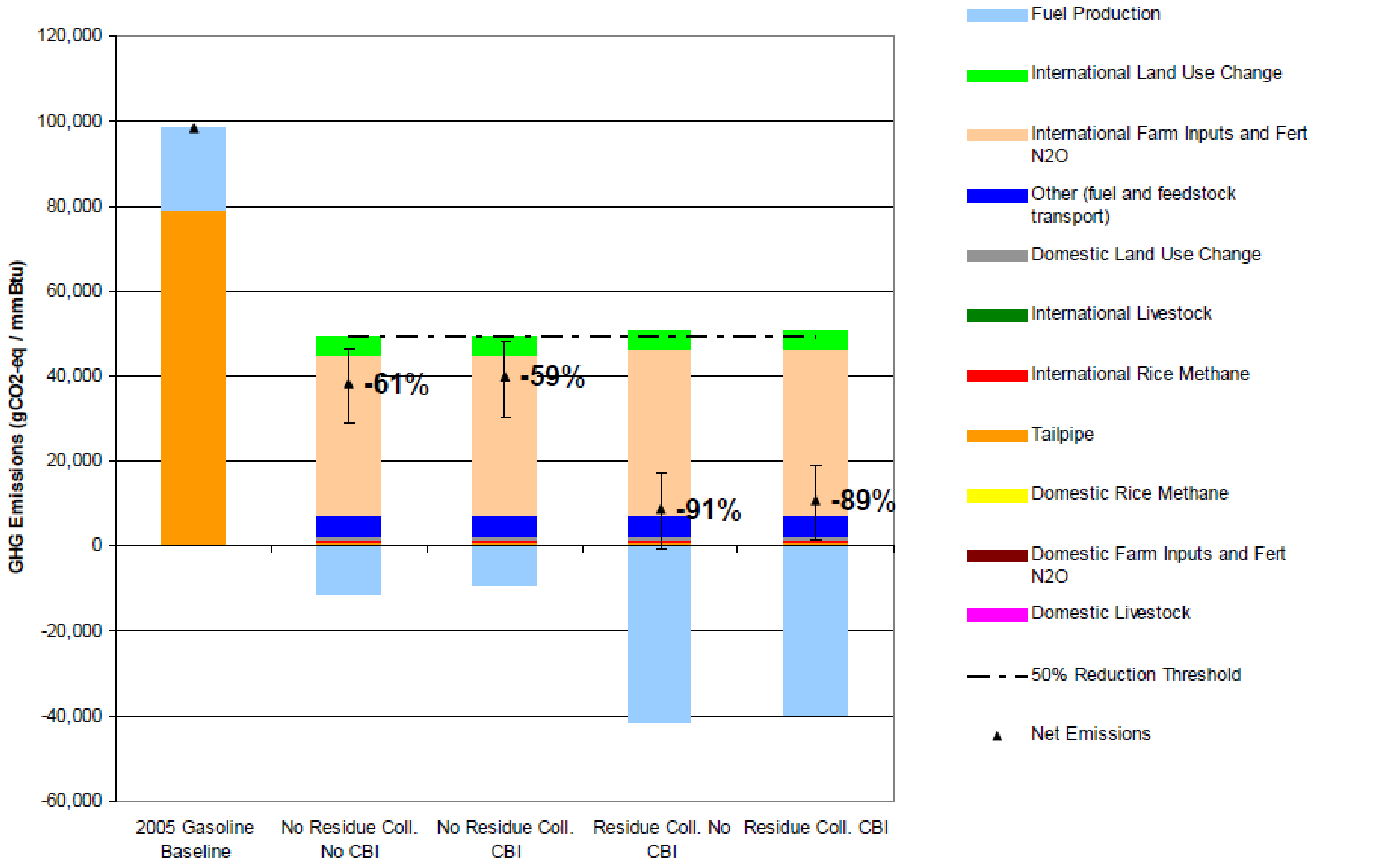

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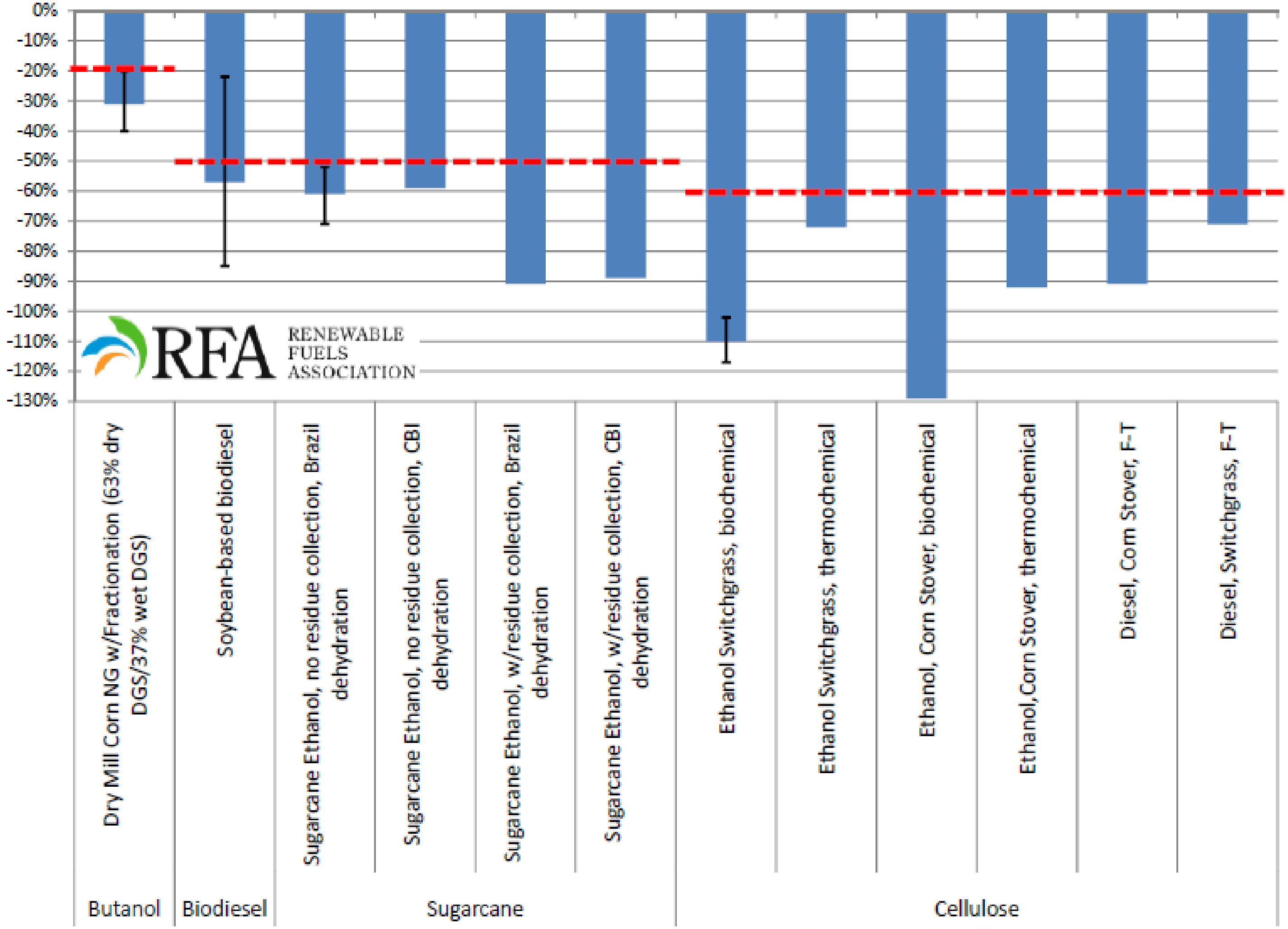
RFS2 Final Rule: Butanol, Advanced, and Cellulosic Biofuels GHG Reductions



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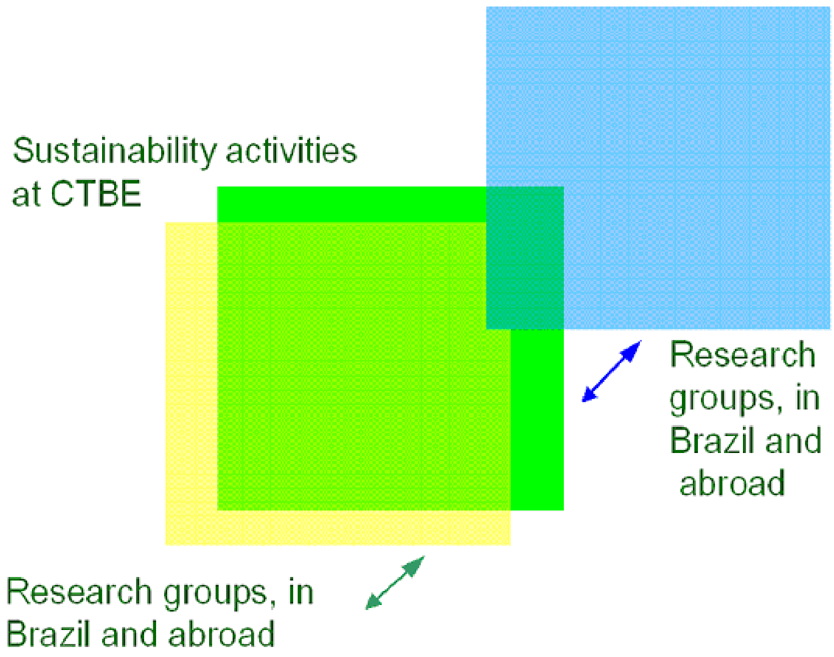
CTBE's proposal on GHG emissions analysis

- ✓ Database consolidation:
  - Sugarcane production and processing;
  - Advanced technologies;
  - National parameters for LCA studies (fertilizers, electricity, fossil fuels, etc.);
  - Experimental results on CH_4 and N_2O emissions in sugarcane production chain;
  - Above and below ground Carbon stocks for different crops (and native vegetation).
- ✓ LCA studies for fossil fuels and biodiesel in Brazil;
- ✓ Work on current models to evaluate land use change (e.g., BLUM-ICONE);

CTBE's proposal on GHG emissions analysis

- ✓ Ethanol LCA studies:
  - Well-to-wheels analysis;
  - Focus on energy balance (fossil vs renewable) and GHG emissions;
  - Two and three regression levels;
  - Use of GREET model defaults in the short-term (when necessary);
  - Development of dedicated spreadsheets for analyses;
  - Methodology analysis:
    - Co-products credits;
    - System boundaries;
  - LUC and ILUC analysis;
  - GHG emissions mitigation.

Strategy



- ✓ **On modeling of LUC**: **ICONE**, aiming at improving the BLUM model (Brazilian Land Use Model) and on getting (and on speeding-up) specific results.

- ✓ On evaluating **carbon stocks and gaseous emissions**: **Delta CO2** (close-related with Cerri's research group), aiming at building an adequate data basis regarding Brazilian conditions.

Project	GHG emissions along the life-cycle of ethanol produced from sugarcane – and avoided emissions regarding gasoline
Action	GHG emission balances should be done regularly
Aims (synthesis)	Enhancement of the GHG balances, considering: (a) more accurate parameters and (b) changes in the production process (tendencies and technology disruption)
CTBE's role	Balances should be done by an expert of CTBE on regular basis
Partnerships	CTBE is open for discussion At least one research group abroad should be partner
Availability of information	Data basis should be organized in order to be publicly available
Dissemination	Papers should be published at high level journals Attendance at conferences and workshops
Results to be achieved after one year	- Compiled database on: sugarcane production and processing; fertilizers production and distribution; fossil fuels production and distribution (preliminary results). - Analysis of different allocation methodologies for co-products evaluation, considering different co-products (sugar, yeasts, lysine, bagasse, electricity, etc.) - Ethanol LCA studies considering the adoption of different commercial technologies in the ethanol fuel chain (e.g., co-production of biodiesel and ethanol).

Thank you for your attention!

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