Centro de Ciência e Tecnologia do Bioetanol

IEA Bioenergy Conference

Alternatives to Use Sugarcane Residues to Reduce GHG Emissions

Manoel Regis L.V. Leal
Arnaldo S. Walter
Joaquim E. A. Seabra
Marcelo V. Galdos
Tassia P. Pereira

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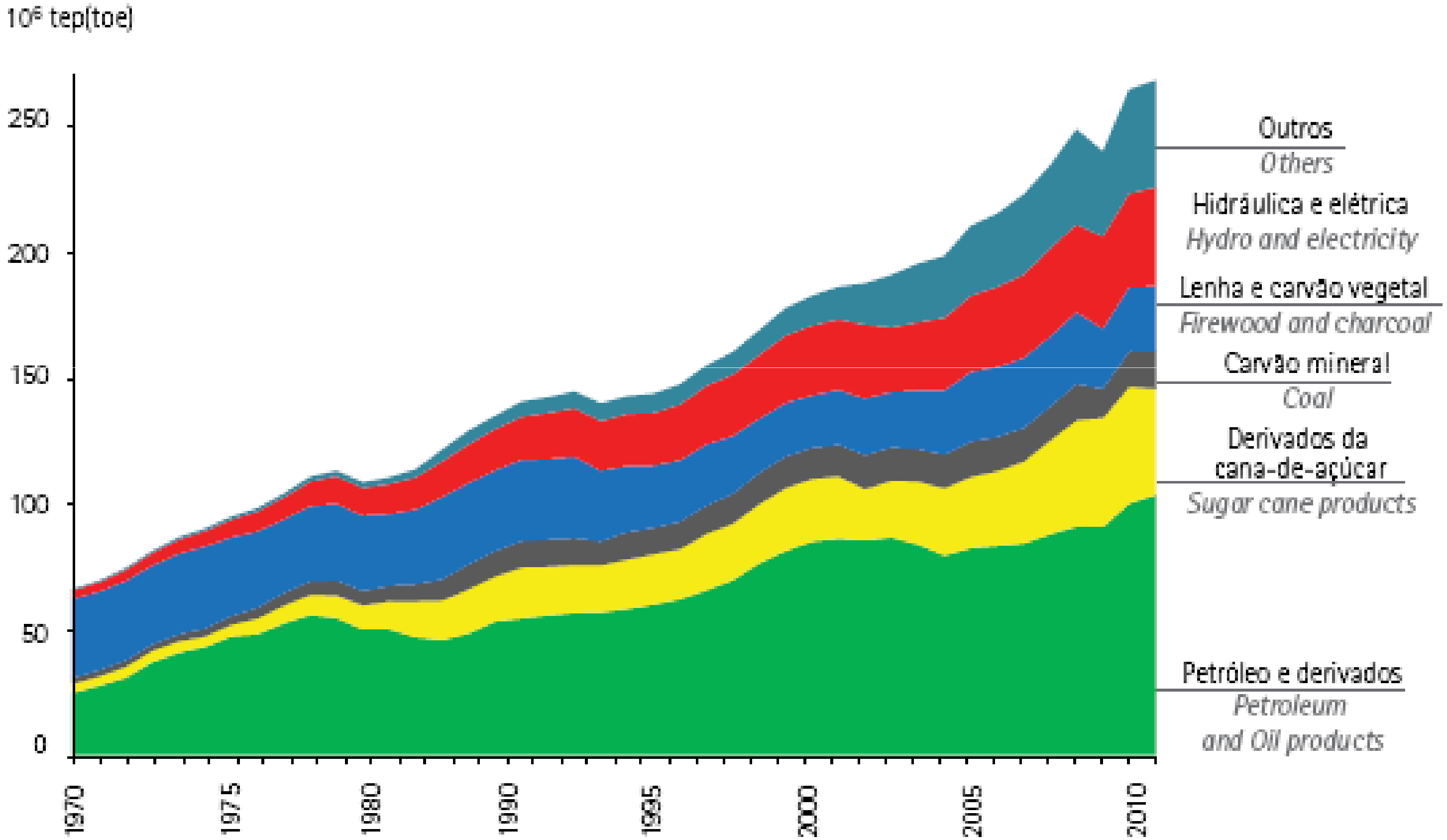
Presentation Outline

- Sugarcane in the Brazilian context
- Sugarcane energy and potential for improvements
- The use of residues
- Results

Brazilian TPES Evolution



Source: EPE, 2012 (National Energy Balance) – BEN 2012

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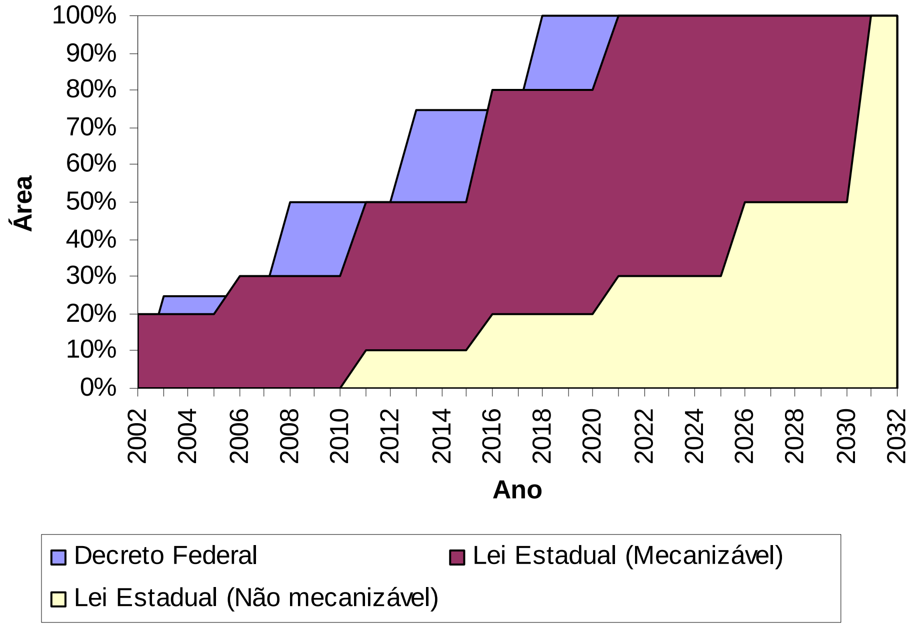
Brazilian Road Transport Fuel Pool (%)

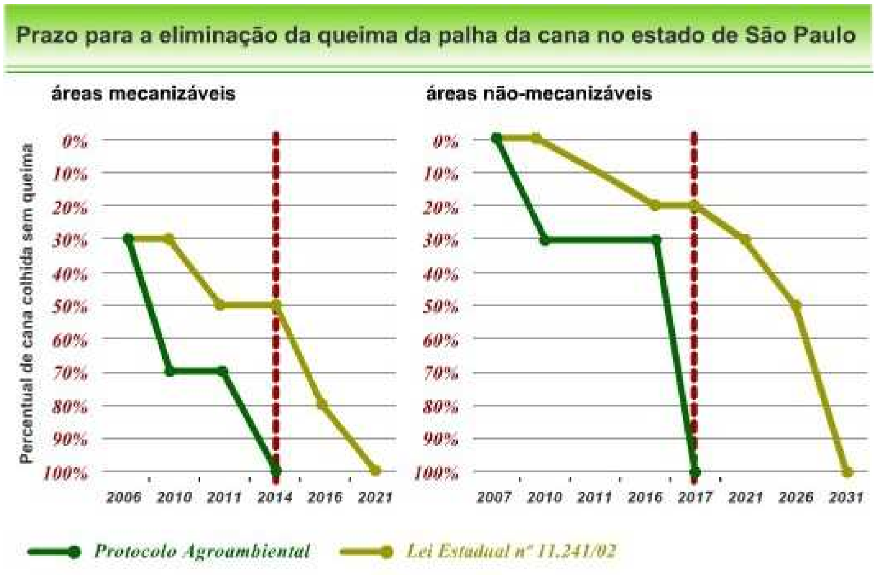
Fuel	2002	2009	2010	2011
NG	1.9	3.3	2.8	2.6
Diesel	56.4	50.9	51.0	50.9
Gasoline	28.0	25.4	27.4	30.7
Ethanol	13.7	20.5	18.8	15.8
Total	100.0	100.0	100.0	100.0

EPE/MRE, 2012

Sugarcane harvesting

Sugarcane trash burning phase out schedule





Nota: os pontos destacados nas linhas do gráfico mostramos anos específicos citados na Lei ou no Protocolo.
Elaborado pela Unica.

Sugarcane Green Harvesting Development[1]

State	2006	2007	2008	2009
Goiás	40%	54%	61%	64%
Mato Gross do Sul	27%	27%	43%	43%
Mato Grosso	55%	62%	69%	70%
Minas Gerais[2]	38%	46%	60%	60%
São Paulo[2]	40%	42%	49%	53%
Paraná	17%	33%	20%	24%

Source: INPE, 2012

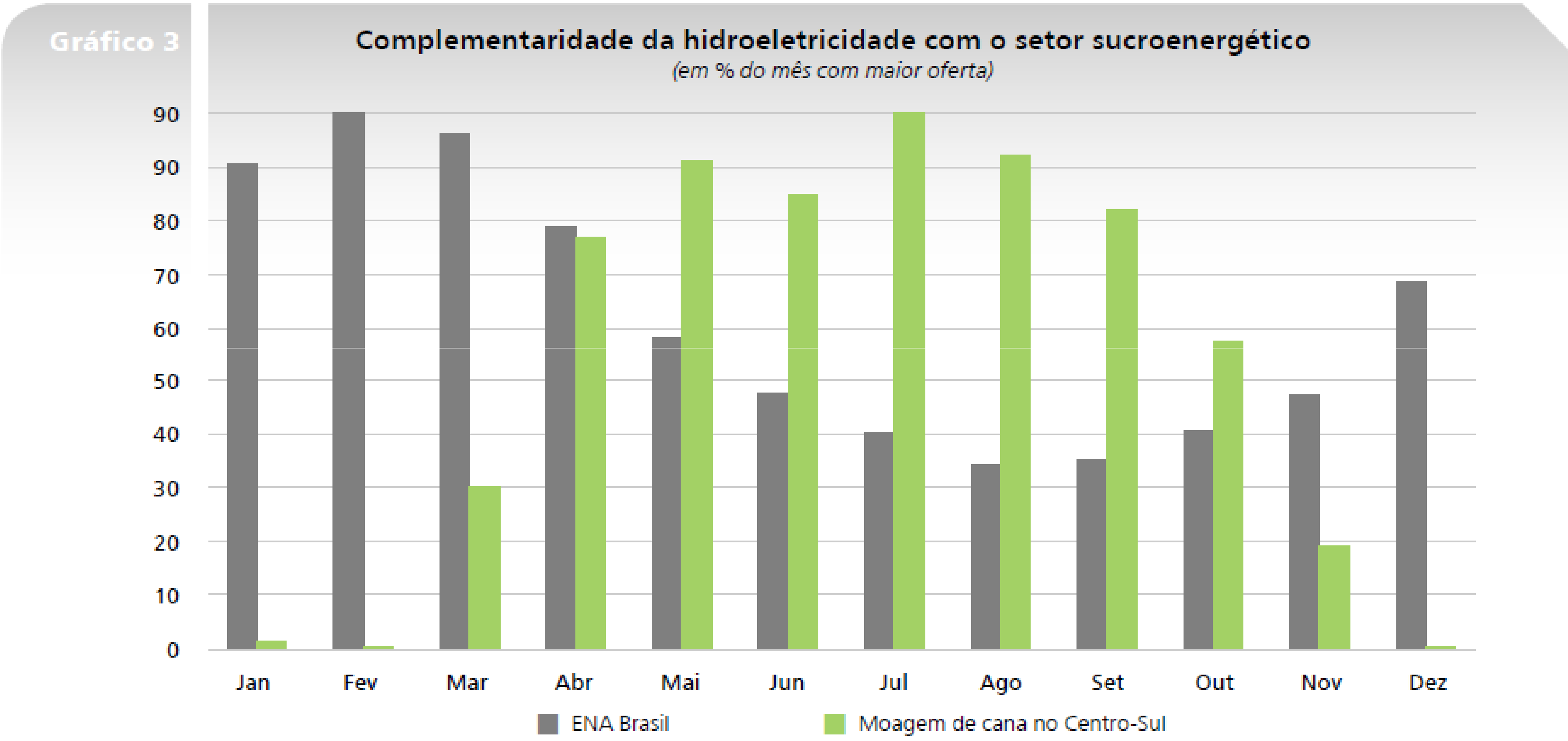
Notes:
1. % of sugarcane harvested unburned
2. Minas Gerais and São Paulo have environmental protocols to finish cane burning completely by 2017

Mill power generation profile

Mill type	No. of mills	(%)	Total milled cane (Mtc/y)	(%)	Avg mill size (Mtc/y)
Selling power	111	28	283.0	47	2.55
Non selling power	282	72	319.9	53	1.13
Total	393	100	602.9	100	1.53

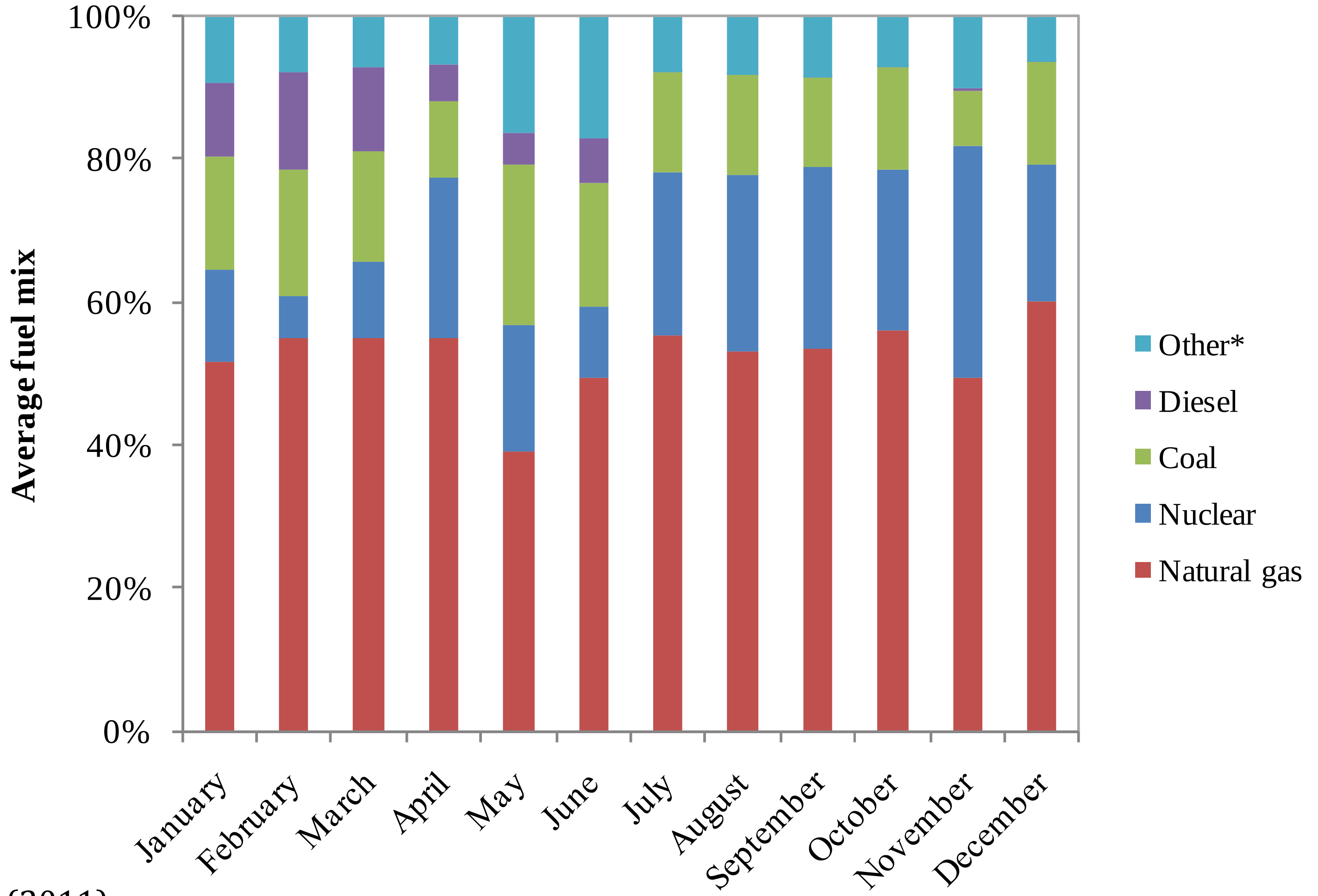
Source: CONAB, 2010

Complementarity with hydroelectricity



Castro et al. (2009)

Brazilian SIN Operating Margin in 2008



Seabra et al. (2011)

Sugarcane Primary Energy and Products (per tc)

Component/Product	Quantity	Energy (MJ, HHV)
Sugars (kg)	150	2,400
Stalk fibers (kg)	135	2,400
Leaf fibers (kg)	140	2,500
Total components	425	7,300
Ethanol (L)	82	1,920
Electricity (kWh)	60	216
Surplus bagasse (kg, db)	13.5	240
Total products	-	2,376
Recovery efficiency (%)		32.5

Source: Authors' calculations

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Alternatives for GHG emissions mitigation

Reference case	Green cane harvesting and residues left on the soil; no/small surplus power generation
Alternative 1	Surplus power generation with steam cycle (CEST) using bagasse and 40% of the straw
Alternative 2	Surplus power generation with BIG/CC technology using bagasse and 40% of the straw
Alternative 3	2G ethanol production by biochemical process (hydrolysis) using bagasse and 40% of the straw
Alternative 4	2G ethanol production by thermochemical process using bagasse and 40% of the straw
Alternative 5	Biochar production and incorporation in the soil using surplus bagasse and 40% of the straw;
Alternative 6	Sell surplus bagasse and 40% of the straw to displace FO.

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Sugarcane ethanol

	Fossil energy use (kJ/MJ)	GHG emissions (g CO_2eq/MJ)
Sugarcane farming	88	6.8
Trash burning		3.8
Field emissions		6.7
Agr. inputs production	40	3.8
Sugarcane transportation	19	1.4
Sugarcane processing	4	2.6
Ethanol T&D	22	1.8
Tailpipe emissions		0.8
Credits		
Electricity	-60	-3.7
Bagasse	-33	-2.7
Total	**80**	**21.3**

Source: Seabra et al. (2011)

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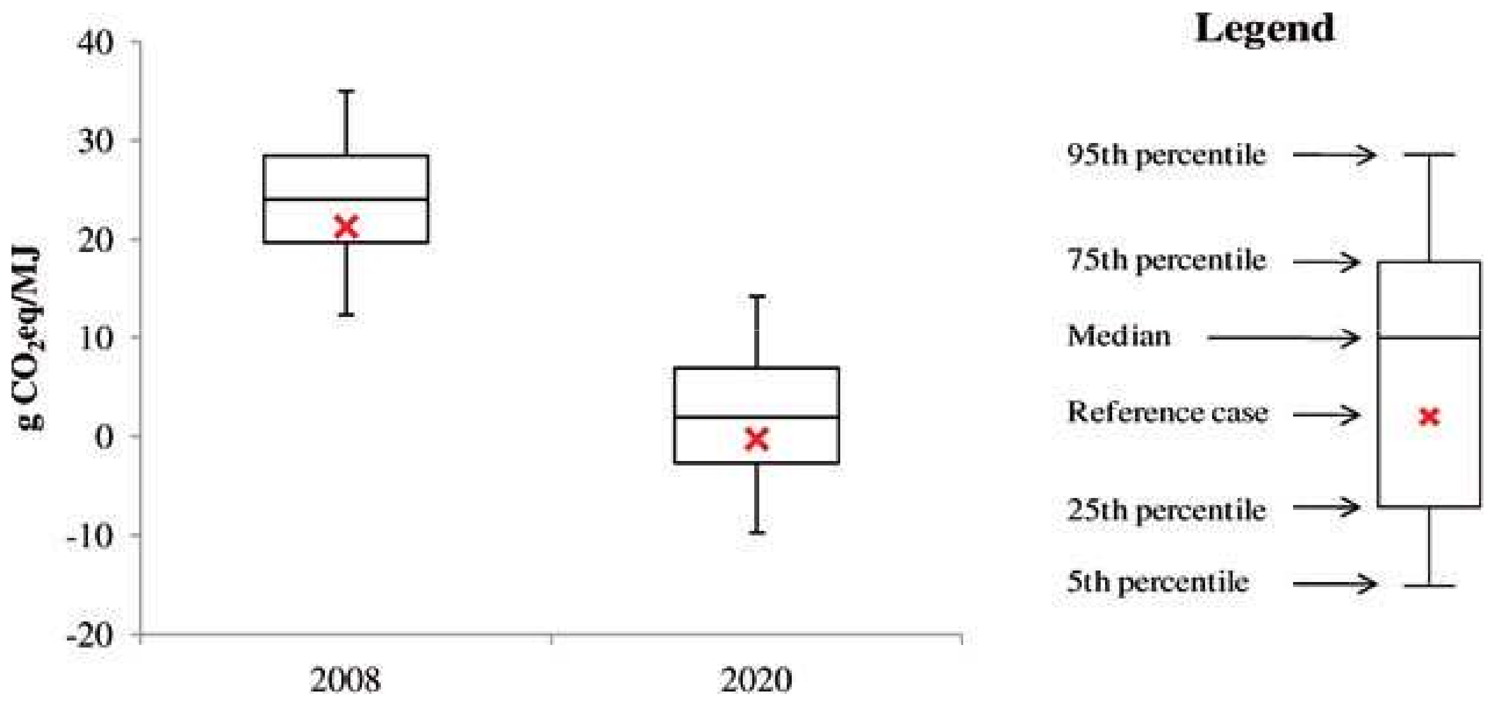
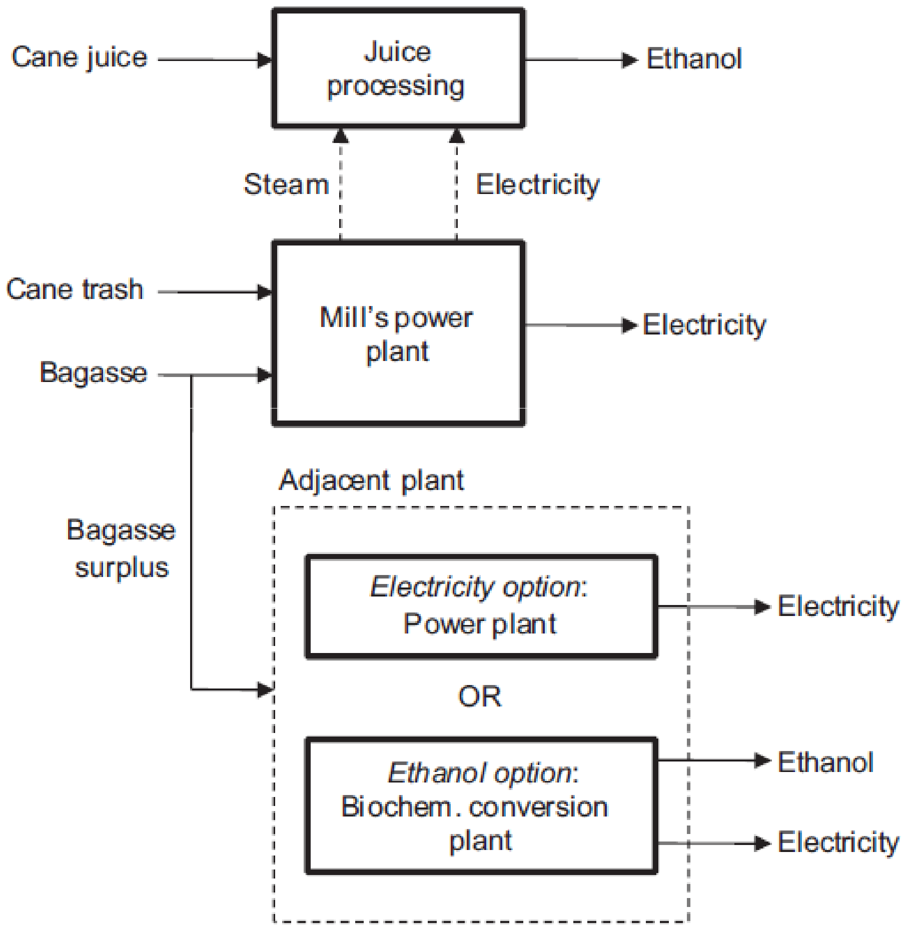
Uncertainty assessment



Seabra et al. (2011)

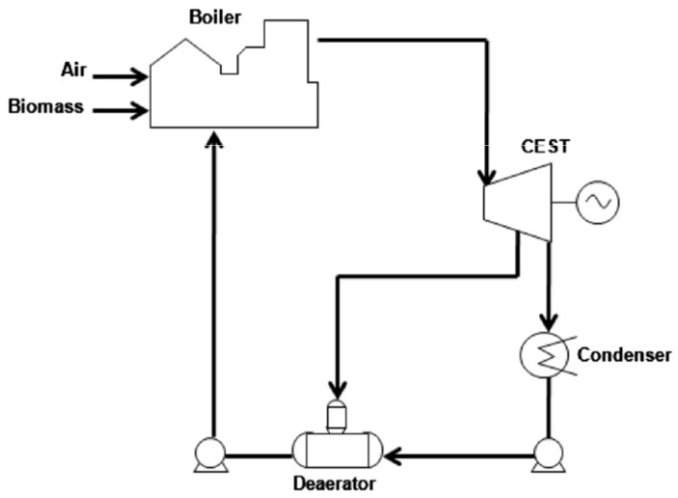
Future sugarcane biorefineries



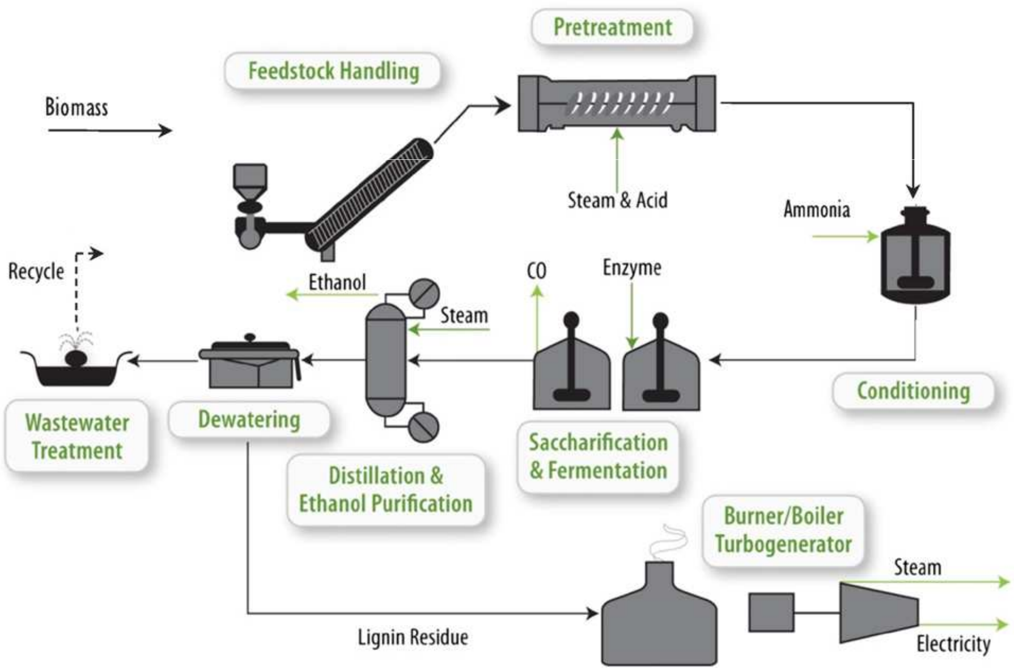
Seabra and Macedo (2011)

Adjacent plants

Conventional
steam power plant



Based on projected
NREL's enzymatic saccharification
co-fermentation process design



Seabra and Macedo (2011)

Future sugarcane biorefineries

Parameter	Units	2008	2020 Electricity	2020 Ethanol
Bagasse use		Low pressure cogeneration	Advanced cogeneration	Biochemical conversion
Electricity surplus	kWh/tc	10.7	130	50
Trash recovery	% total	0	40%	40%
Bagasse surplus	% total	3.3%	0	0
Ethanol yield	L/tc	81	91	124

Seabra and Macedo (2011)

Future sugarcane biorefineries

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GHG emissions balance for the sugarcane biorefinery (kg CO_2eq/t cane)

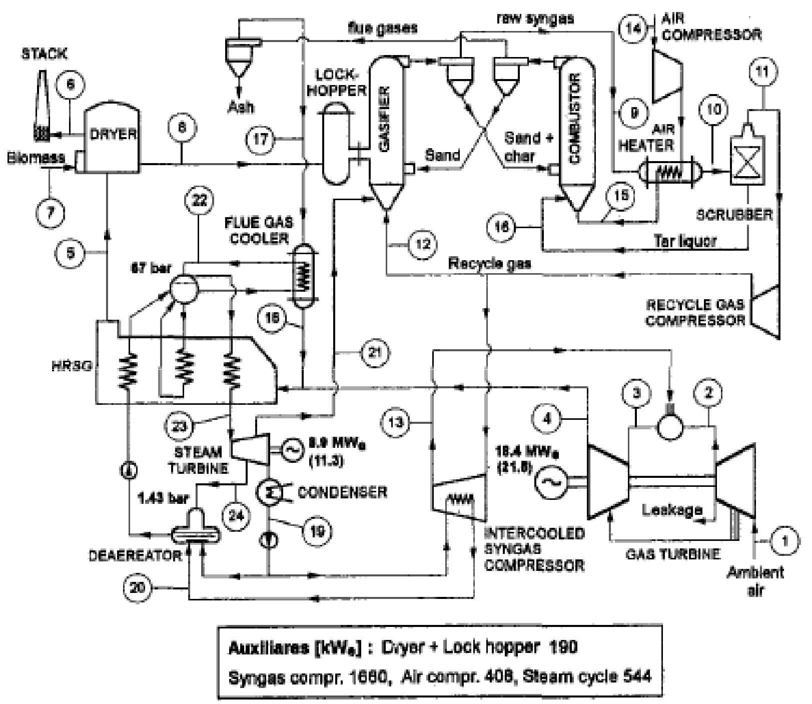
Parameter	2008	2020 Electricity option	2020 Ethanol option
Total emissions	47.8	40.0	42.3
Avoided emissions	-196.4	-281.8	-310.2
Gasoline displacement	-185.4	-205.1	-280.5
Marginal elect. displacement	-6.3	-76.6	-29.7
Fuel oil displacement	-4.7	0.0	0.0
Net avoided emissions	-148.6	-241.8	-267.9

Conclusions are naturally sensitive to the assumed yields and displaced products (e.g., NG, coal, etc.)

Seabra and Macedo (2011)

BIG/CC Configuration

P_{net} [MW_e] = 24.5 (29.5) $\eta_{net, HHV}$ [%] = 33.3 (34.4) $\eta_{net, LHV}$ [%] = 41.1 (42.5)

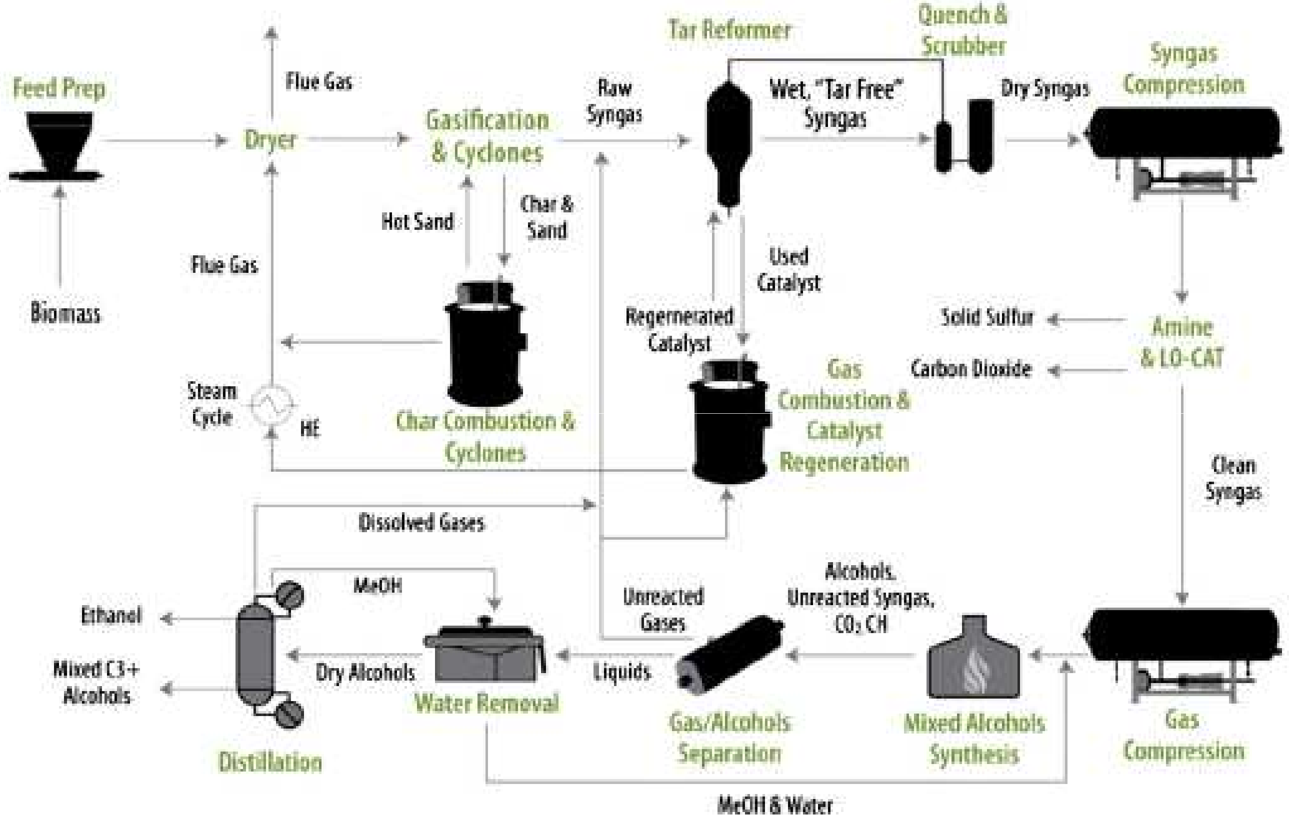


point #	T °C	P bar	ṁ kg/s
1	15	1.013	68.0
2	457	19.4	58.5
3	1147	18.8	61.6
4	466	1.07	70.6
5	195	1.04	79.0
6	94	1.013	82.1
7	15	1.013	7.35
8	70	1.013	4.32
9	874	1.30	4.50
10	329	1.27	4.50
11	17	1.21	3.72
12	38	1.50	0.61
13	150	27.1	3.11
14	15	1.013	7.97
15	615	1.50	7.97
16	17	1.50	0.05
17	1027	1.30	8.48
18	500	1.27	8.48
19	35	0.056	9.25
20	120	4.50	1.60
21	151	3.0	0.05
22	283	67.0	3.40
23	440	60.3	9.91
24	110	1.43	0.62

Fig. 3 Schematic, with temperature, pressure, and flow predictions for a BIG/GT combined cycle based on near-atmospheric pressure, indirectly heated gasification, and the LM2500 gas turbine with TIT = 1100°C, the same TIT as Figs. 1 and 2. Values shown in parentheses are for TIT = 1232°C, the rated capability of the LM2500 with natural gas. The higher TIT can be achieved with syngas from an indirectly heated gasifier, because the gas has a much higher heating value than that from directly heated gasifiers.

Source: Corsoni et al., 1996

Thermochemical Route for Ethanol



Source: Seabra et al., 2010

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Thank you

jseabra@fem.unicamp.br

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