Prospects and challenges concerning carbon dioxide removal from the atmosphere by biomass-based capture and storage in Brazil

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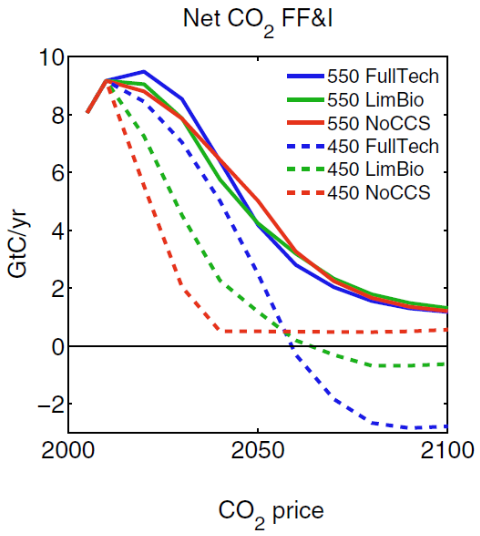
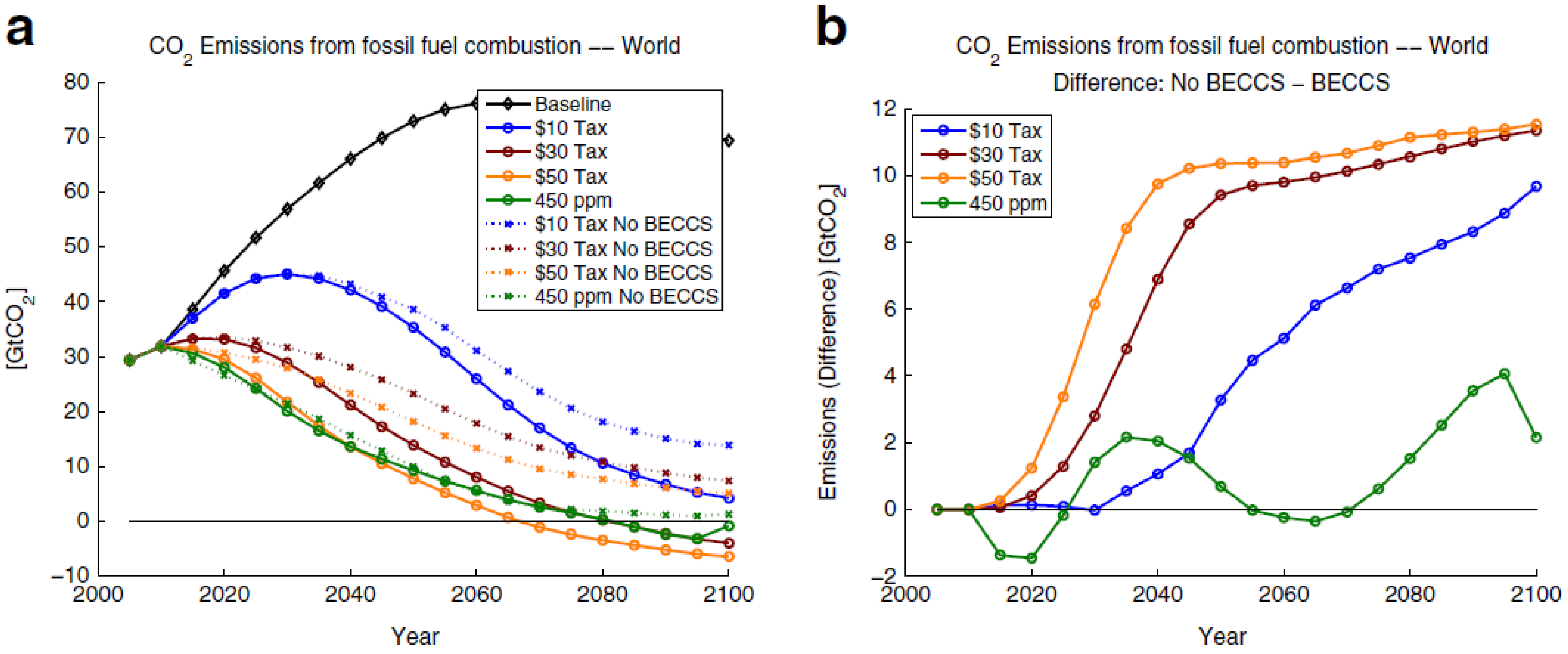
Overshoot 450 with BECCS (BioCCS)

With delays in reaching a global agreement on mitigation, 450 overshoot scenarios with BECCS have gained acceptance as a viable option.



Source: Klein et al 2014



Source: Kriegler et al 2013

Most Models show Brazil deploying significant BioCCS in mitigation scenarios

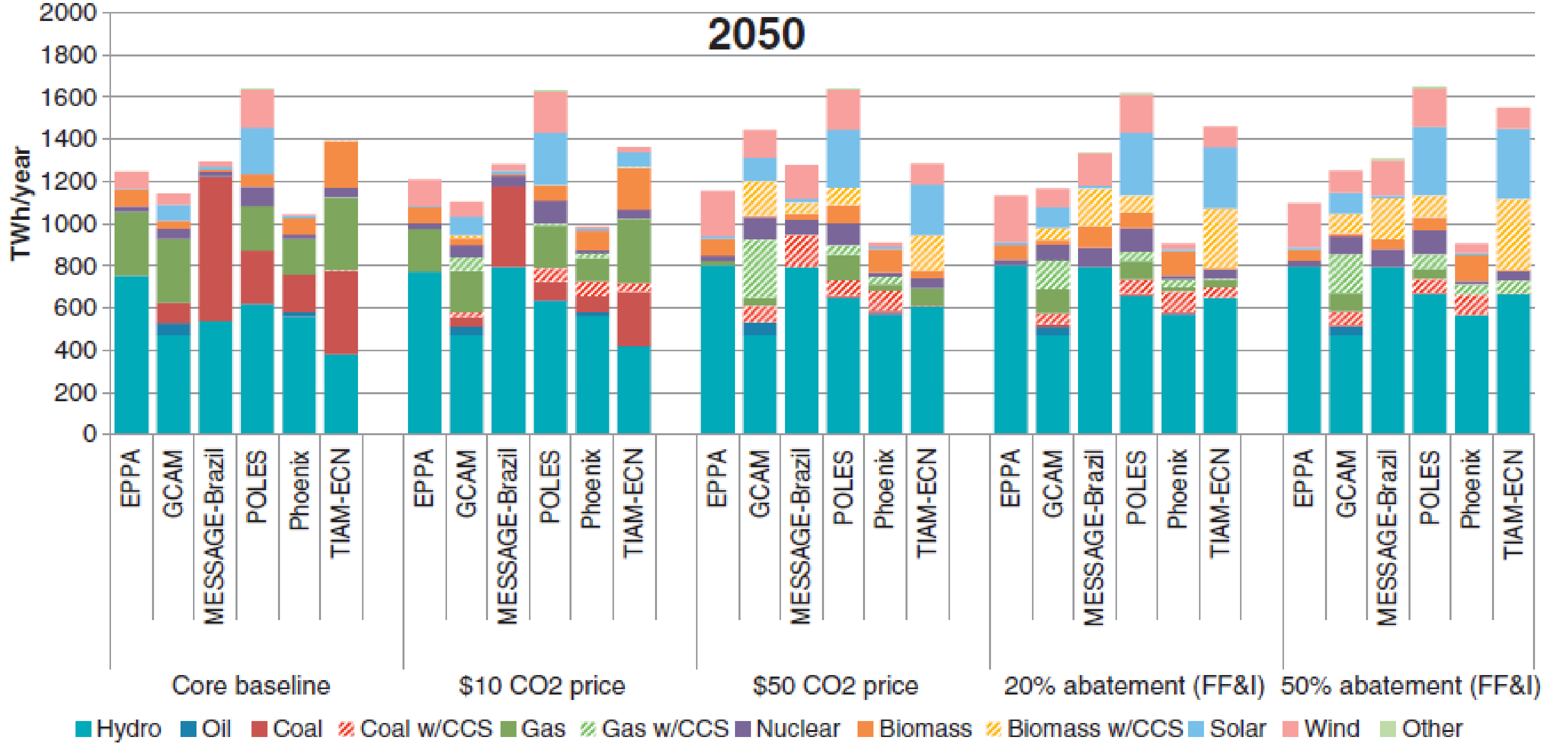
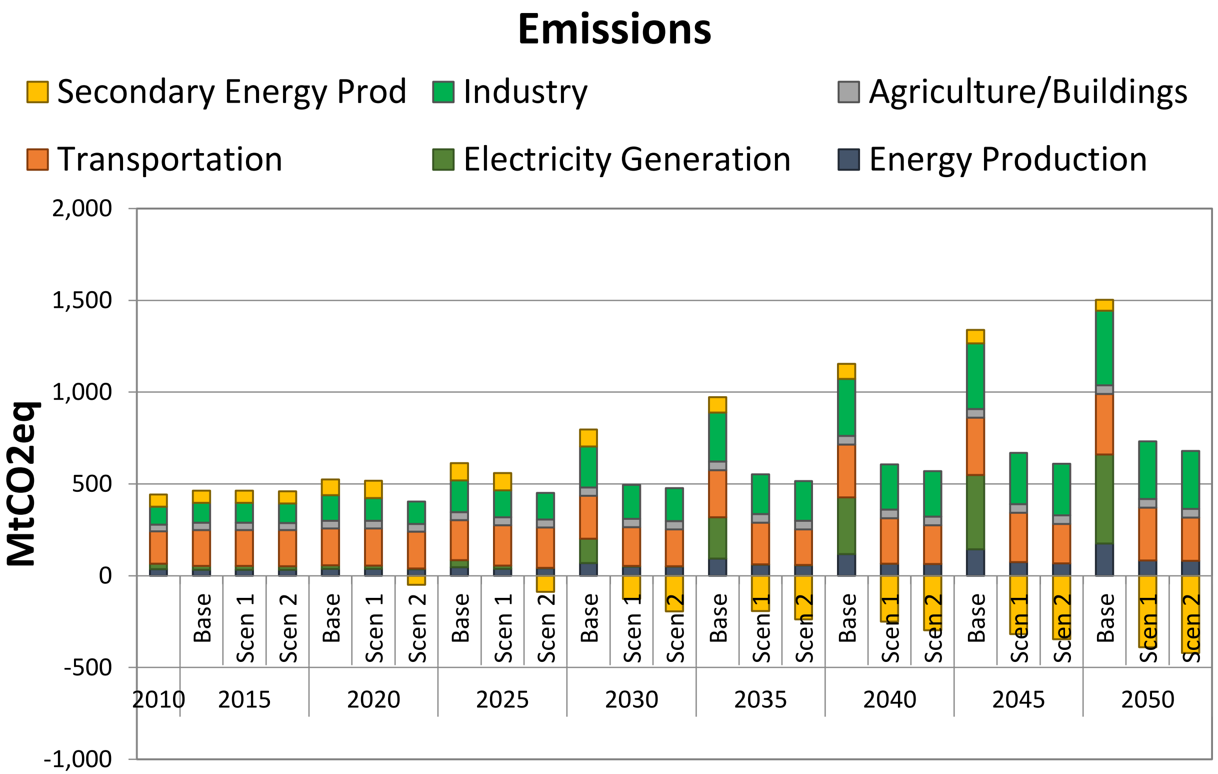


Fig. 4. Electricity mix in the baseline and in the climate policy scenarios for Brazil.

Source: Lucena et al 2015

MESSAGE-Brazil emissions under a 1 $GtCO_2eq$ total emissions cap in 2030-2050

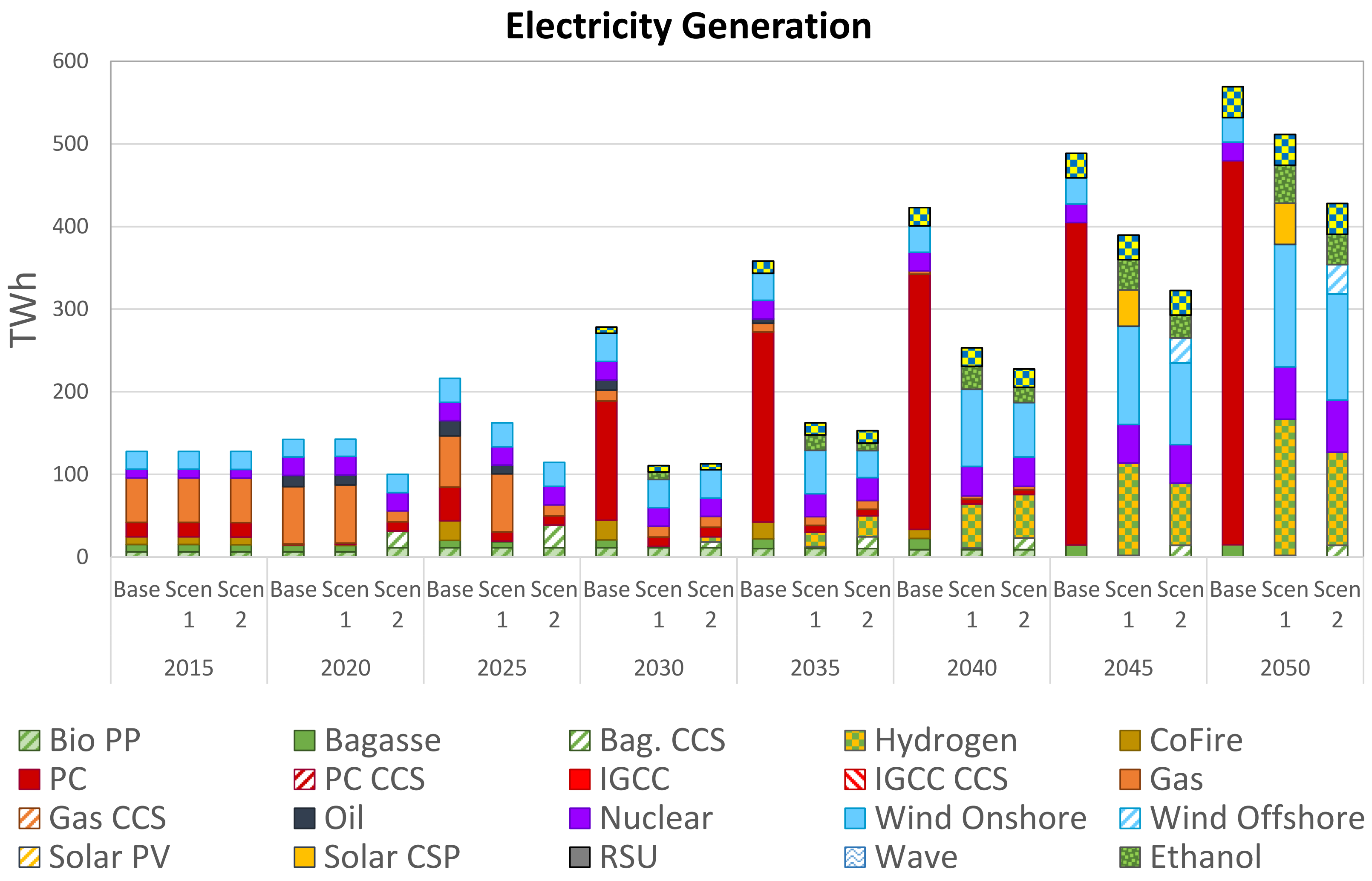


Base: 796 $MtCO_2eq$
Scen 1: 394 $MtCO_2eq$
Scen 2: 311 $MtCO_2eq$

- Significant BioCCS starting in 2020
- Mostly from pure CO_2 stream of fermentation phase of ethanol production
- Some BioCCS in H_2 production from biomass through gasification/FT

- Under stringent mitigation scenarios, MSG deploys ethanol w/ CCS in order to obtain negative emissions, producing a surplus of ethanol (assumed exported in this regional partial equilibrium model)

Non-hydro electricity generation under 1 $GtCO_2eq$ cap 2030-2050



- Hydropower generation steady at around 800 TWh in 2030-2050
- Wind and solar play important role

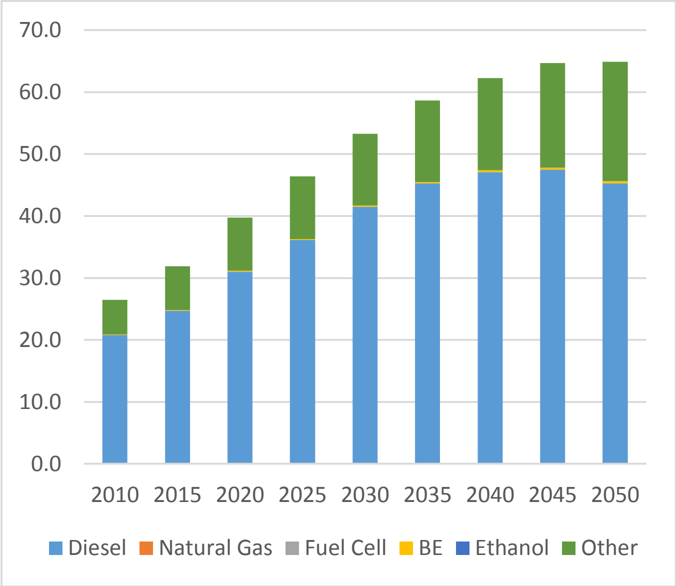
- H_2 from biomass accounts for 165 TWh in Scen 1 and 112 TWh in Scen 2 in 2050
- 100% H_2 produced w/ CCS

- Ethanol stationary generation accounts for 46 TWh in Scen 1 and 37 TWh in Scen 2 in 2050
- >97% EtOH produced w/ CCS

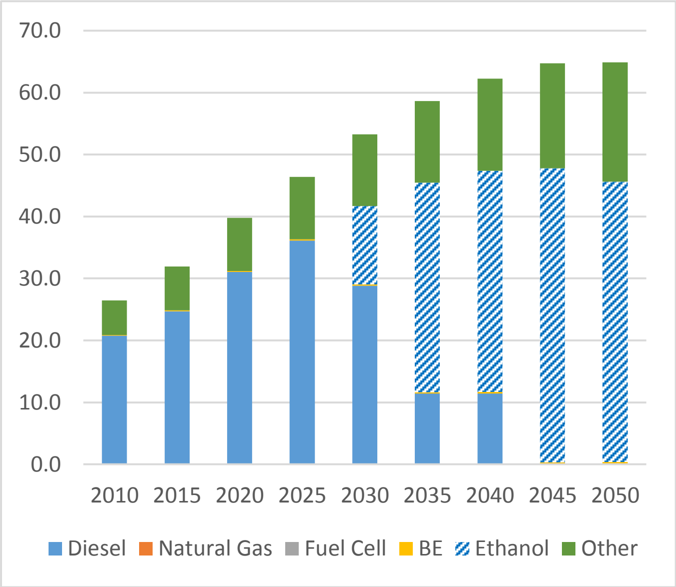
Ethanol use under 1 GtCO$_2$eq cap 2030-2050

- Flex LDV in private transport(in both scenarios, same as in BL)

- <u>Public Transport</u>:
- Scenario 1: not too different from Baseline (>70% Diesel)
- Scenario 2: Ethanol buses (added option)
    - starts at 23% in 2030 and rises to over 70% post 2045 (completely displaces diesel).



Scenario 1



Scenario 2

>94% of Ethanol produced w/ CCS

EJ of Ethanol produced						
	Scenario 1			Scenario 2		
	Total	CCS	%CCS	Total	CCS	%CCS
2008	0.6	0.0	0	0.6	0.0	0
2010	0.7	0.0	0	0.7	0.0	0
2015	0.6	0.0	0	0.6	0.0	0
2020	0.5	0.0	0	2.2	2.1	94.2
2025	0.6	0.1	10.1	3.0	2.9	95.2
2030	3.9	3.8	96.4	4.0	3.9	97.5
2035	5.3	5.1	97.2	5.2	5.2	98.6
2040	5.3	5.1	96.8	5.2	5.2	98.5
2045	5.3	5.1	96.5	5.4	5.3	98.5
2050	6.6	6.4	97.2	6.8	6.7	98.8

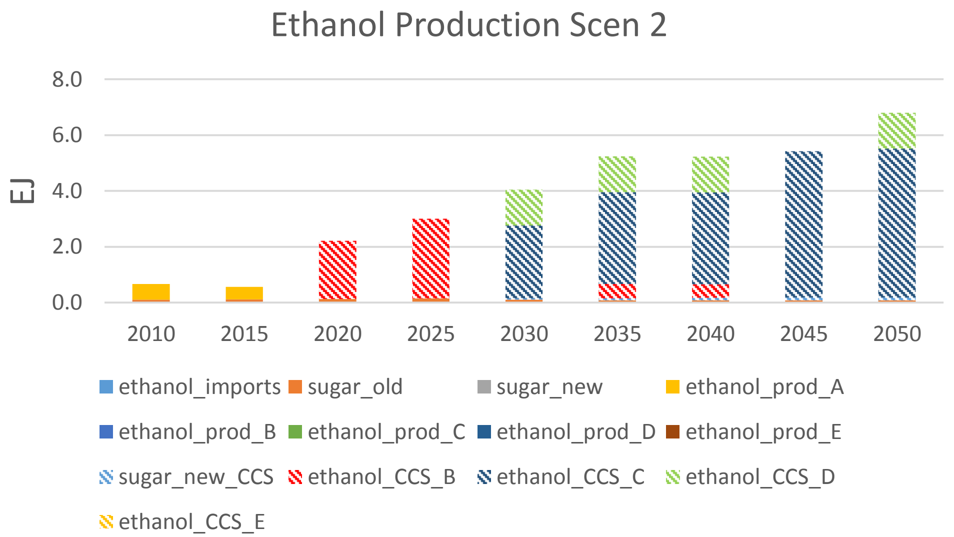
Scenario 1:

- Until 2025 0.5 EJ of EtOH produced w/o CCS
- New sugar mills deployed w/o CCS in EtOH production

- After 2030 >96% produced w/ CCS virtually all of it in 2nd generation plants that also make 1st gen EtOH
- 2nd gen route is gasification+FT BTL from bagasse and straw

Scenario 2:

- After 2020 >94% produced w/ CCS virtually all of it in 2nd generation capable plants that also make 1st gen EtOH:
- 19-32% in 2030-2050 in gasification+FT w/ CCS
- 63-78% in bagasse hydrolysis plants
- Both w/ CCS in fermentation phase of 1st gen process
- New sugar mills deployed w/ CCS for their EtOH production from 2030



CO_2 capture potential in Scenario 2

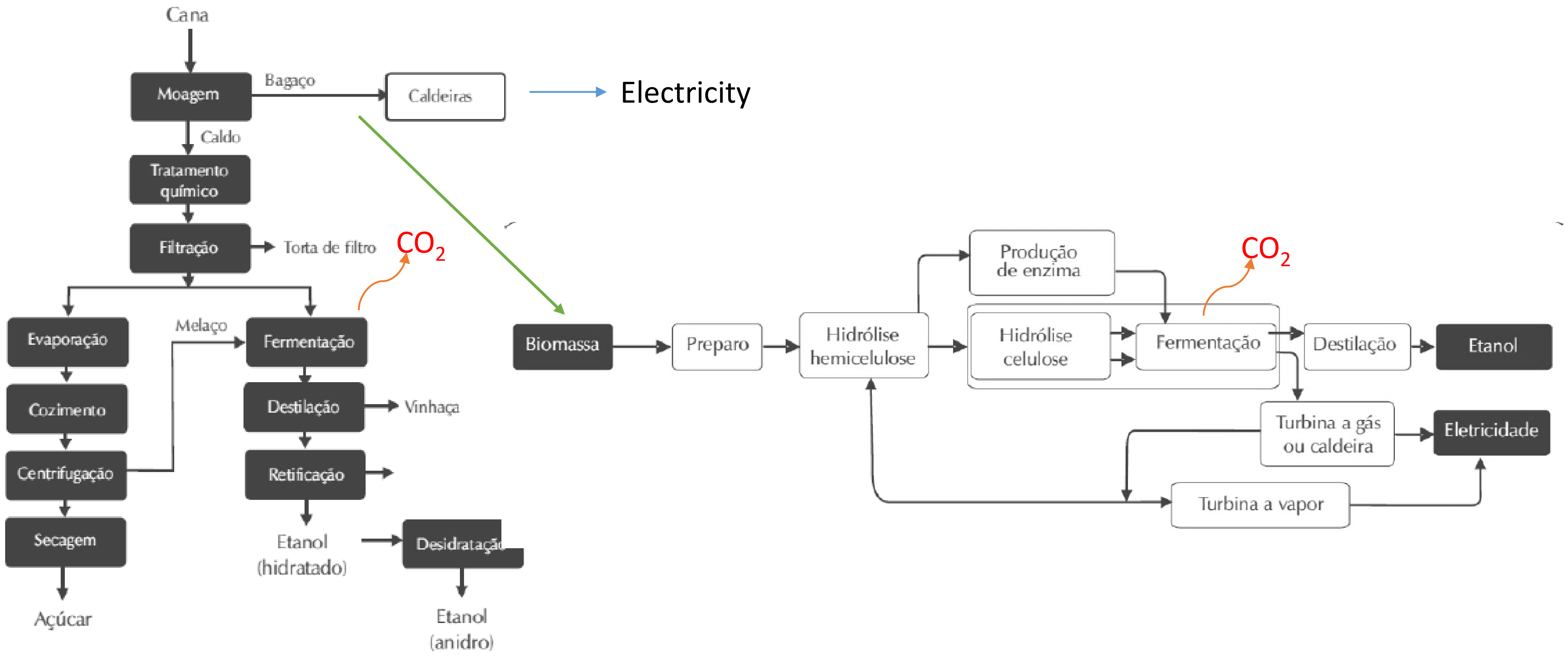
- 0.956 t CO_2/ton of EtOH produced (Merschmann 2014)
- Over 230 Mt CO_2 potentially captured in 2050 (annually)

Scenario 2

	t EtOH produced	t CO2 Captured*
2020	78,550,529	75,095,227
2025	106,701,721	102,008,096
2030	143,464,891	137,154,118
2035	185,939,890	177,760,716
2040	185,415,711	177,259,594
2045	192,444,873	183,979,556
2050	241,198,802	230,588,884

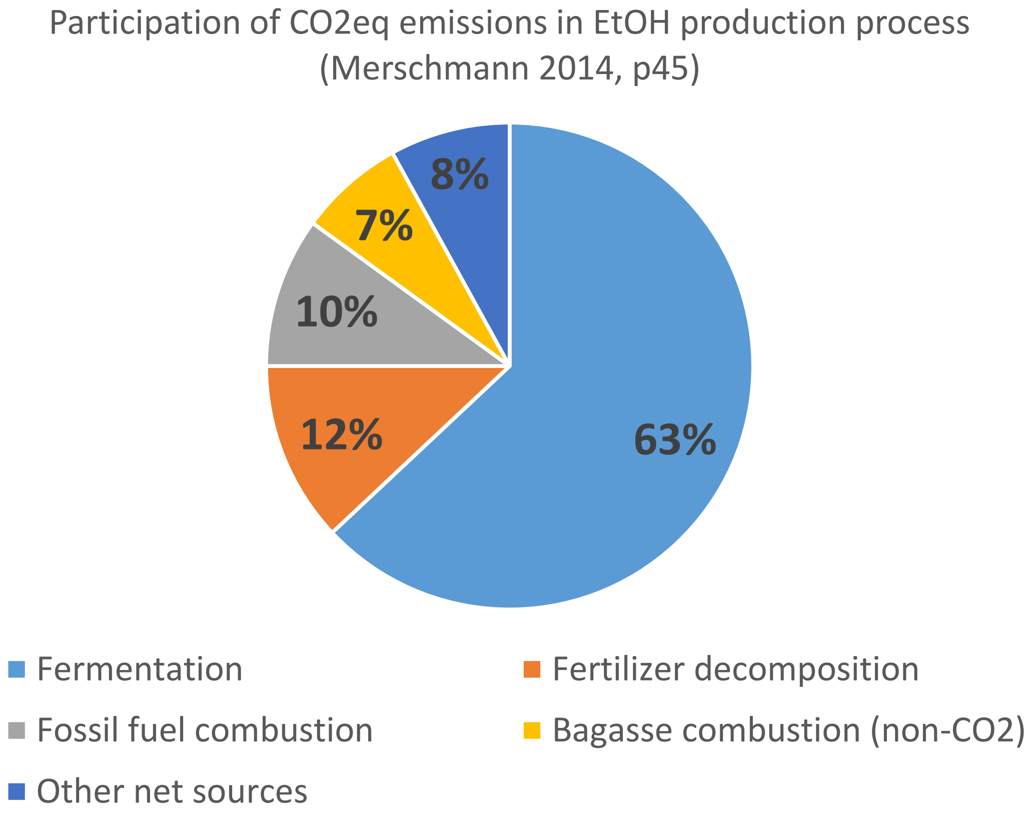
*All routes

Ethanol production routes



Flowcharts from Portugal-Pereira et al (2015)

1st Generation Ethanol production emissions



- Exhaust from fermentation normally 85% CO_2
- Easy to bring to 95% (ideal fermentation)
- 95% considered pure CO2 for stocking purposes,
- Needs only to be dehydrated to avoid carbonic acid formation (causes pipe corrosion)
- Capture and compression costs US$6-12/t$CO_2$

Source: Merschmann 2014, costs in 2004 US$

Novel uses for surplus ethanol

Implemented in model:

- Ethanol bus
- Ethanol-fueled stationary power generation:
  - Otto cycle engines (0.3 efficiency assumed)

To be implemented:

- Ethanol light duty trucks (urban delivery, e.g.)
- Ethanol-fueled stationary power generation (Koberle et al 2015)
  - Dual-fuel diesel cycle engines running on E85
  - Modified aeroderivative turbine
    - 43 MW GE model tested in Brazilian PP for 1000 hours
    - 18,000 L/h consumption of ethanol to run at full capacity => logistics challenge

Stationary power generation from EtOH

- Ethanol aeroderivative turbines running on 100% EtOH
- Dual-fuel reciprocating engines running on 85% EtOH (more possible)
- Renewable, possibility of BioCCS leading to negative emissions
- Can be used to firm intermittent RE
  - Flexible and dispatchable
  - Quick ramp times of < 10 mins
- High fuel consumption => should be located near distilleries to reduce logistics challenge

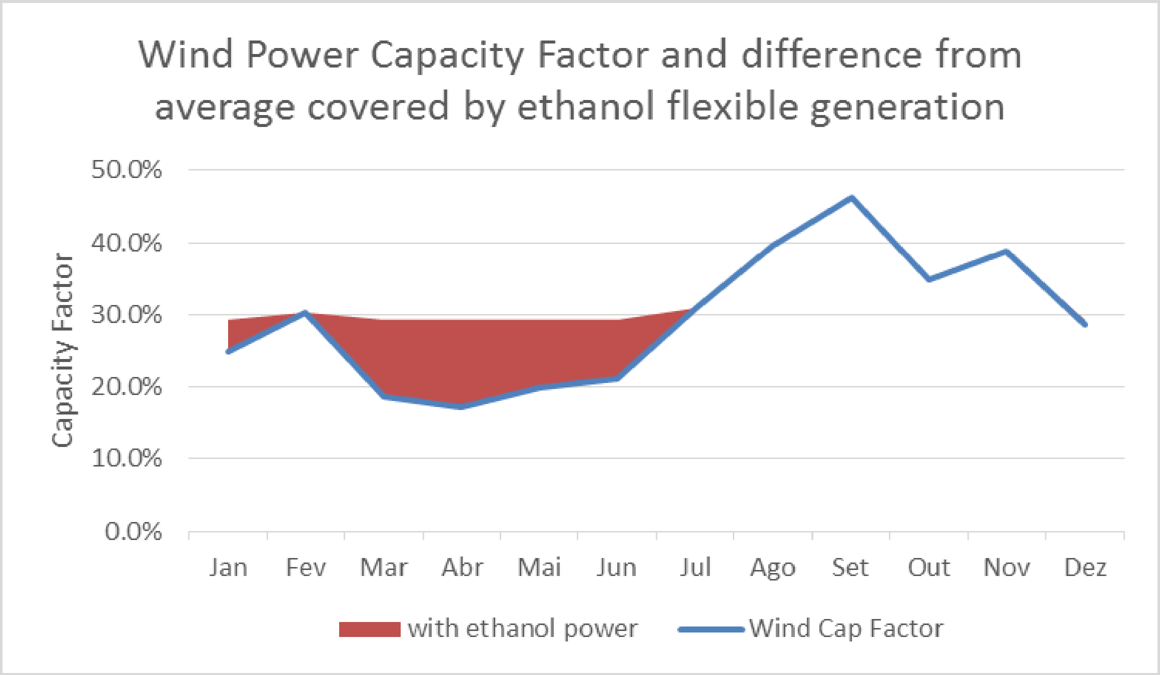
Source: Koberle et al 2015

Case study: firming wind power in the Northeast

Location of ethanol distilleries in Brazil

Distilleries in RN operating
with 7% occupancy ratio (ANP 2015)

Wind installed capacity in Rio Grande do Norte state: 2092 MW

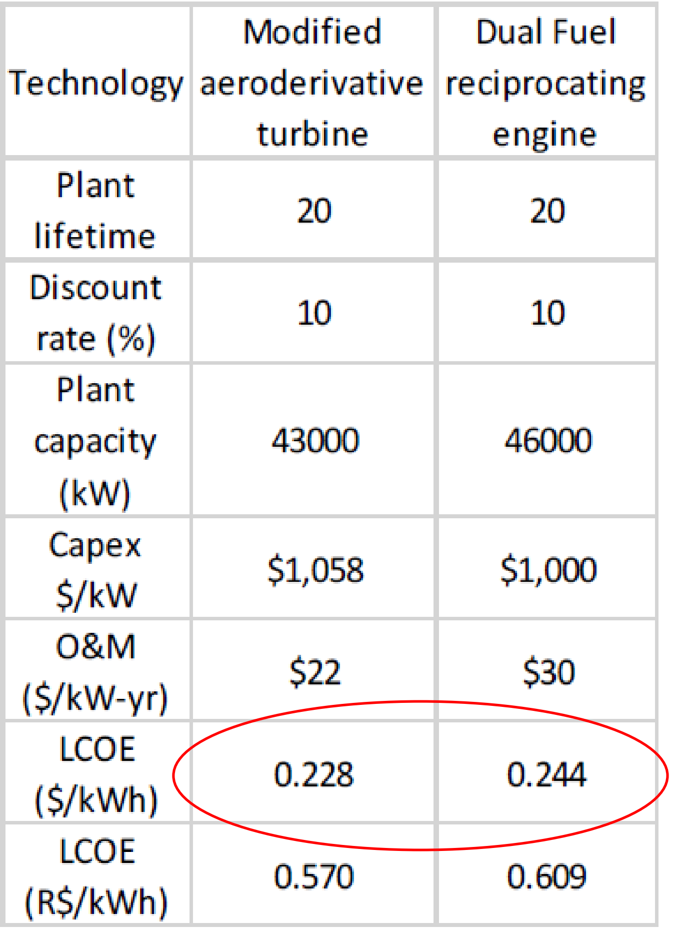


Annual operation: 329 hours => 3.75% CF (peaking plant)
Growing wind capacity => higher CF for EtOH plant (?)

Source: Koberle et al 2015

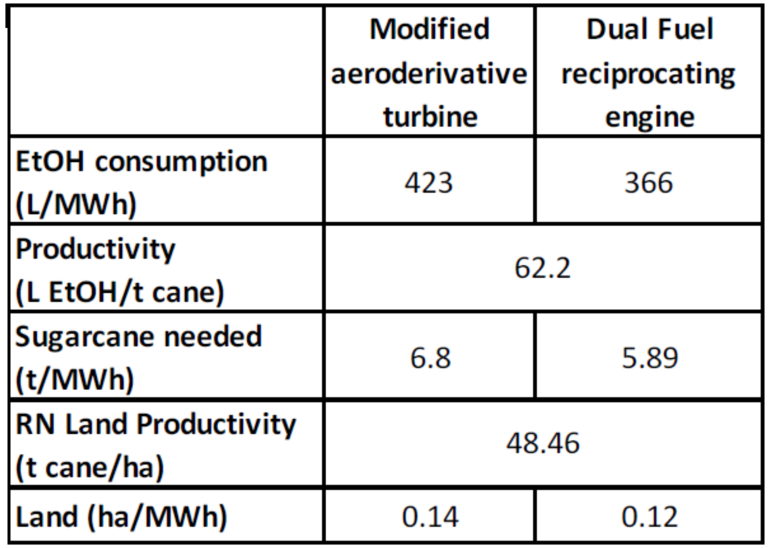
Stationary power generation from EtOH - Economics

Economics of EtOH flexible power generation



Technology	Modified aeroderivative turbine	Dual Fuel reciprocating engine
Plant lifetime	20	20
Discount rate (%)	10	10
Plant capacity (kW)	43000	46000
Capex $/kW	$1,058	$1,000
O&M ($/kW-yr)	$22	$30
LCOE ($/kWh)	0.228	0.244
LCOE (R$/kWh)	0.570	0.609

EtOH consumption, sugarcane needed, and land demand



	Modified aeroderivative turbine	**Dual Fuel reciprocating engine**
EtOH consumption (L/MWh)	423	366
Productivity (L EtOH/t cane)	62.2	
Sugarcane needed (t/MWh)	6.8	5.89
RN Land Productivity (t cane/ha)	48.46	
Land (ha/MWh)	0.14	0.12

*LCOE not including fuel costs
*For CF = 3.75%

Source: Koberle et al 2015

Considerations for higher CF:
- A single 43 MW plant operating with 30% CF demands 50 ML EtOH
  - Brings occupancy ratio of distilleries up to 22%
  - LCOE could come down

Potential mitigation from BioCCS: 48 MtCO_2eq

Possible uses for captured CO2 in Brazil

- EOR
- Food & Beverages industry
- Methanol production
- Urea production

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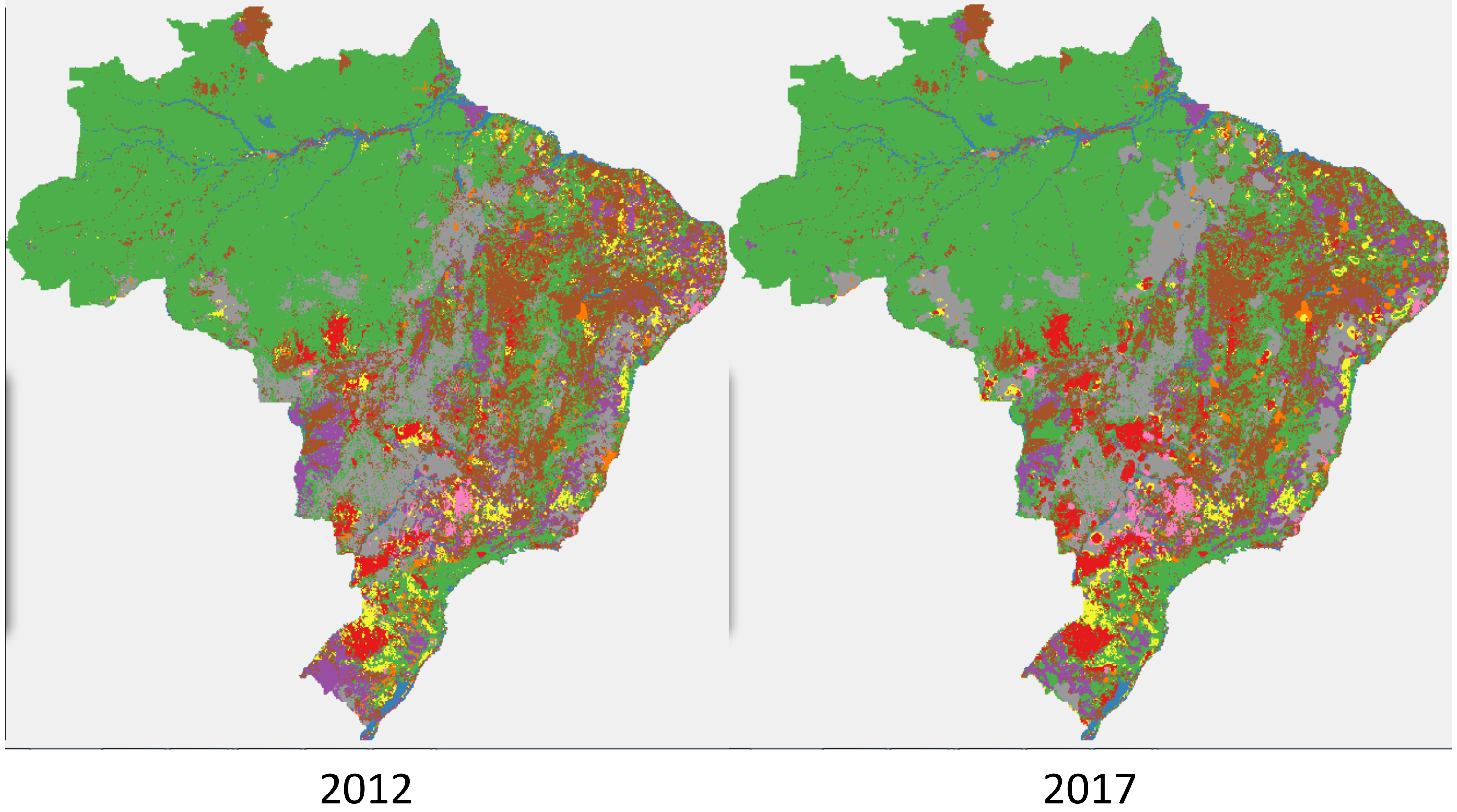
ANÁLISE DO POTENCIAL TÉCNICO E DE MERCADO DE USO INDUSTRIAL
DE CO_2 DE DESTILARIAS DE ETANOL DO CENTRO-SUL DO BRASIL

Paulo Roberto de Campos Merschmann

Tese de Doutorado apresentada ao Programa de Pós-Graduação em Planejamento Energético, COPPE, da Universidade Federal

Upcoming work: Land Use impacts – PLUC model

- PLUC = PCRaster Land Use Model (Verstegen et al 2015)
- Soy just implemented as separate land use class (Koberle et al, forthcoming)
    - Agricultural projections being generated
    - Baseline vs High Biofuels scenarios examined



Latin America Energy Model

- Expand Brazil model to include Latin America
- Countries included:
    - Argentina
    - Brazil
    - Bolivia
    - CAC
    - Chile
    - Colombia
    - Ecuador
    - Guianas
    - Mexico
    - Paraguay
    - Peru
    - Uruguay
    - Venezuela

Thank you

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