ESTIMATION OF GREENHOUSE GAS ABATEMENT POTENTIAL FOR THE SUGAR-ENERGY SECTOR

ESTIMATIVA DO POTENCIAL DE ABATIMENTO DE GASES DE EFEITO ESTUFA PARA O SETOR SUCROENERGÉTICO

Juliana Picoli [1*], Marília Folegatti-Matsuura [2], Joaquim Seabra[3]

[1] MSc, Universidade Estadual de Campinas, Faculdade de Engenharia Mecânica, Departamento de Energia, Campinas, Brasil
[1] Dr, Empresa Brasileira de Pesquisa Agropecuária, Meio Ambiente, Jaguariúna, Brasil
[3] Dr, Universidade Estadual de Campinas, Faculdade de Engenharia Mecânica, Departamento de Energia, Campinas, Brasil
* email: julianafp@fem.unicamp.br

Abstract

In 2017, Brazil established the National Biofuel Policy (RenovaBio), a state program that aims to boost the production and use of biofuels in the country in more sustainable standards, through efficiency gains and reduction of greenhouse gases (GHG) emissions in productive processes. In this scenario, Brazil has a great potential for abatement of GHG emissions related to the use of sugarcane, both through cogeneration of electricity and through the production of ethanol. However, from the sectoral point of view, it is also necessary to recognize the existence of mitigation opportunities in the sugarcane industry itself, which would allow increasing, even more, the environmental appeal of its products. The objective of this article was to estimate the GHG abatement potential for the Brazilian sugarcane industry, through RenovaCalc, generating the carbon intensity index of the biofuel (in g CO_2eq MJ^{-1}). The analysis contemplates measures related to the agricultural, industrial and transportation segments. The abatement potential of each measure was determined by quantifying its effect on net mitigation capacity relative to a baseline scenario for the sugar-energy sector, taking into account the respective environmental performances throughout the life cycle. Cumulative improvements in all segments promoted reductions in carbon intensity, decreasing GHG emissions in about 11.6 gCO_2eq MJ^{-1} when compared to baseline scenarios. The results of this work could help policymakers and decision makers associated with the sugar-energy sector to identify the main opportunities for GHG emission mitigation.

Keywords: life cycle assessment; biofuels; mitigation; sustainability.

Purpose

The greenhouse gas (GHG) reduction targets set out in the Paris Agreement in 2015 put the replacement of fossil fuels at the center of the debate. Recently, in 2017, Brazil established the National Biofuel Policy (RenovaBio), a government program that will support the continued development and use of low-carbon biofuels (BRASIL, 2017a). It's expected that RenovaBio promotes innovation in the biofuel production chains in more sustainable patterns through efficiency gains and emissions reductions, contributing to the achievement of goals of decarbonization of the Brazilian economy (BRASIL, 2017b).

In this scenario, Brazil has a great potential for abatement of GHG emissions related to the use of sugarcane, both through bioelectricity and bioethanol production (CAVALETT et al, 2013). Nevertheless, from the sectoral point of view, it is also necessary to recognize the existence of mitigation opportunities in the sugarcane industry, which would allow to increase even more the environmental appeal of its products.

The purpose of this paper is to estimate the GHG abatement potential for the Brazilian sugar and ethanol sector, through RenovaCalc - a tool developed for RenovaBio Policy, which accounts for GHG emissions from the agricultural and industrial information provided by the producers, generating the Carbon Intensity (in g $CO_2eq\ MJ^{-1}$).

Methods

RenovaCalc provides a comprehensive, life-cycle based approach that allows comparing the carbon intensity of conventional and advanced technologies of biofuel production. This tool was applied to evaluate GHG abatement potention of the different mitigation technologies accessed in this study.

RenovaCalc

The RenovaCalc is a analytical tool that accounts for GHG emissions in the biofuel life cycle. The tool was developed by experts from the RenovaBio Life Cycle Assessment Working Group (GT- ACV). Table 1 summarized the methodological approach of the RenovaCalc tool.

Table 1. Methodological approach of the RenovaCalc tool.

Topic	Description
Approach	"Well-to-wheel" attributional LCA
Functional unit	MJ of fuel
Allocation procedures	Coproducts - Energy based allocation Residues - Burden-free. Only emissions occurring after the generation of the waste are considered.
Data source	ecoinvent v. 3.1 database
Characterization factors	GWP100: CO2 = 1; CH4 fossil = 30; CH4 biogenic = 28; N2O = 265

Source: Folegatti-Matsuura et al. (2018).

Scenarios description

In the present study, the assessed scenarios considered mitigation measures related to three segments: agriculture, industry and transport. Table 2 summarizes the set of scenarios evaluated in this study representing technological evolution of ethanol production over baseline scenario.

Table 2. Summary of technical parameters for the evaluated scenarios.

Agricultural improvements									
Parameter	Unit	Baseline	Nitrogen source	No-tillage system	Precision Agriculture	Biodiesel in tractors	Biomethane in trucks	Industrial improvements	Distribution improvements
Sugarcane yield	$t\ ha^{-1}$	76.00	76.00	81.43	82.24	82.24	82.24	82.24	82.24
Straw recovery	$t\ ha^{-1}$	---	---	---	---	---	---	3.47	3.47
Lime	$kg\ t^{-1}$	5.26	5.26	5.26	4.52	4.52	4.52	4.52	4.52
Urea	$kg\ N\ t^{-1}$	1.33	---	---	---	---	---	---	---
Ammonium sulfate	$kg\ N\ t^{-1}$	---	1.33	1.10	0.74	0.74	0.74	0.74	0.74
Diesel B10	$L\ t^{-1}$	2.91	2.91	2.60	2.60	0.94	---	---	---

Agricultural improvements									
Parameter	Unit	Baseline	Nitrogen source	No-tillage system	Precision Agriculture	Biodiesel in tractors	Biomethane in trucks	Industrial improvements	Distribution improvements
Biodiesel	$L\ t^{-1}$	---	---	---	---	1.79	1.79	1.89	1.89
Biomethane	$L\ t^{-1}$	---	---	---	---	---	0.97	1.25	1.25
Anhydrous ethanol	$L\ t^{-1}$	85.00	85.00	85.00	85.00	85.00	85.00	85.40	85.40
Surplus electricity	$kWh\ t^{-1}$	12.00	12.00	12.00	12.00	12.00	12.00	185.80	185.80
Distribution	modal	road	road	road	road	road	road	road	pipeline

An traditional first generation plant producing anhydrous ethanol (autonomous distillery), as described by Dias et al. (2016), was considered in the baseline scenario. This plant produces ethanol from sugarcane juice and operates with low-efficiency boilers, so steam and electricity are just enough to attend the plant's operational demand.

Mitigation technologies were added cumulatively over the baseline scenario. Agricultural improvements include: replacement of the nitrogen source, use of the no-tillage system with soybean, implementation of precision agriculture (variable-rate lime and fertilizers application), and replacement of diesel B10. Industrial improvement include straw recovery, reduced steam consumption, efficient high-pressure boilers and molecular sieves for ethanol dehydration process, allowing large surplus electricity. Improvements in the transport phase considered the change in the distribution modalities from road to pipeline.

Abatement potential

The GHG abatement potential of each measure was determined by its effect on the net mitigation capacity over a baseline scenario, taking into account the respective carbon intensity.

Results and discussion

The key technical results for the evaluated scenarios are shown in Figure 1.

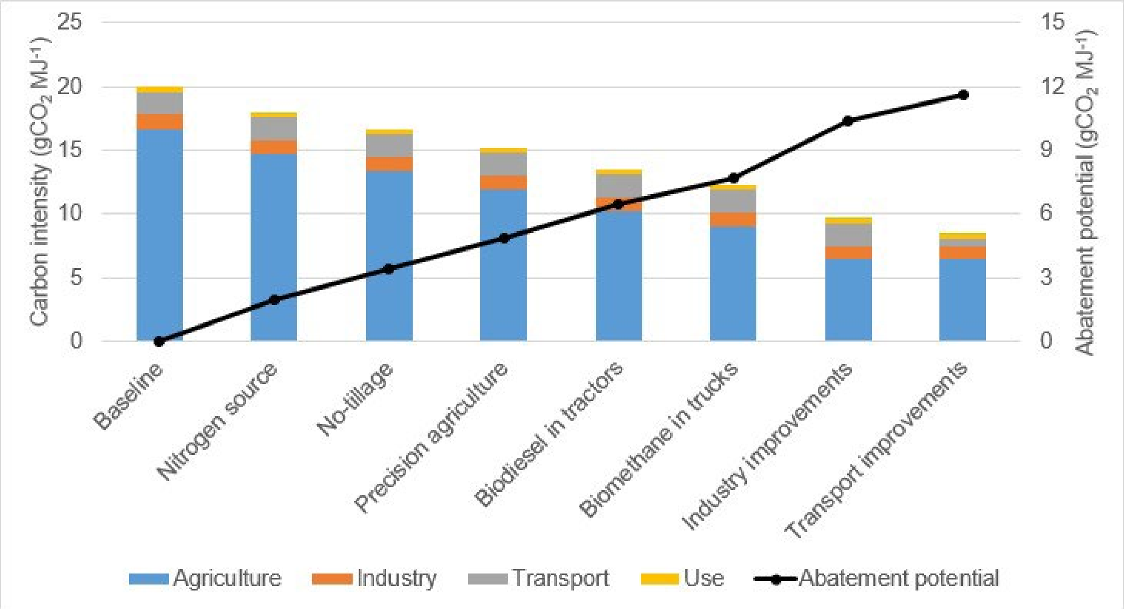

Figure 1. Mitigation mesures and their respective GHG abatment potential for evaluated scenarios.

“Agriculture” represents the emissions generated for the cultivation of sugarcane, including emissions from production and use of agricultural inputs. “Industry” represents the emissions generated during the ethanol production process and includes the emissions generated in the fermentation, distillation and cogeneration stages. Finally, “Transport” and “Use” are related to the environmental impact of the distribution of ethanol to the point of sale and the use of the fuel in the vehicles, respectively. As indicated in Figure 4, the agricultural phase accounted for more than 70% of the carbon intensity.

It is important to notice that cumulative measures allow the reduction of 58% of the carbon intensity when compared to baseline scenario, achieving an abatement potential of 11.6gCO$_2$eq MJ^{-1} (Table 3). If only agricultural improvements are considered, the reduction reaches 38%.

Table 3. Abatment potential and carbon intensity of the evaluated scenarios.

Scenarios	Carbon intensity (gCO$_2$eq MJ^{-1})	Abatement potential (gCO$_2$eq MJ^{-1})
Baseline	20.1	---
Nitrogen source	18.1	2.0
No-tillage	16.7	3.4
Precision agriculture	15.2	4.9
Biodiesel in tractors	13.6	6.5
Biomethane in trucks	12.4	7.7
Industrial improvements	9.7	10.4
Transport improvements	8.5	11.6

The most important factors for reducing GHG emissions of sugarcane production are the replacement of urea to ammonium sulfate, increased yield of sugarcane and increasing level of agricultural technology use, such as precision agriculture and biofuels in tractors and trucks. The reduction of GHG emissions in the mill is mainly due to the production of electricity, changing the allocation of environmental loads among the products.

Its important to highlight that the results of this work could help policymakers and decision makers associated with the sugar-energy sector to identify the main opportunities for GHG emission mitigation.

Conclusions

Mitigation technologies in agricultural, industry and transport segments were assessed in this study. Cumulative improvements in all segments promoted reductions in carbon intensity, decreasing GHG emissions in about 11.6 gCO$_2$eq MJ^{-1} when compared to baseline scenarios.

Improvements in agriculture phase presented the highest GHG abatement potential, followed by the improvements of the mill.

Despite the promising environmental performance, these technologies have to prove to be economically sustainable to be applied. Therefore economic analysis will help to better understand the sustainability of these scenarios.