May 31, 2023

Chery Laskowski
Branch Chief
Transportation Fuels Branch
California Air Resources Board
1001 I Street
Sacramento, CA 95812

Dear Dr. Laskowski,

Thank you for the opportunity to comment on the Draft Tier 1 Calculator for sugarcane ethanol, posted on CARB's website on April 24th, 2023. The Brazilian Sugarcane and Bioenergy Association (UNICA) represents the largest ethanol producers in Brazil. This past harvest, UNICA's members produced nearly 8BG of ethanol in Brazil. We pride ourselves in being a committed stakeholder to CARB's LCFS program and driving force in the progress of reducing carbon intensity of the state's fuel pool since the beginning of the program.

We would like to start our comments by recognizing CARB's technical staff's diligent work and willingness to engage with us in the process of updating the tier 1 calculator for sugarcane ethanol. Our member companies are continuing to review the updates and we share below an initial set of comments on the items we were able to identify.

CARB has a big task at hand, one that will shape transportation policy for years to come in the State, and in other jurisdictions in the United States and abroad. California's policy outcomes are indeed so important that we were disappointed that draft tier 1 calculators were released for comment without granting stakeholders access to the CA-GREET 4.0 model. Our member companies can not clearly and fully evaluate the updates to the tier 1 calculator without understanding the modeling behind it. By not granting this access, CARB leaves many questions unanswered, and does not provide transparency about the methodology and what it may mean in future discussions.

We believe CARB intents to have a transparent and efficient public comment engagement, and we appreciate the opportunity to engage with staff, but we urge CARB to release access to the complete model, so our companies can do a full analysis of what is being implemented, which undoubtedly will have a significant impact on this industry and their livelihoods after more than a decade of investment in this policy regime and market. We are eager to assess if the calculation methodologies reflect the reality of production in Brazil, and if Brazilian sugarcane ethanol is being credited for all its improvements in recent years and the potential it still offers for decarbonizing transports in California.

UNICA members were pleased to see that CARB staff agreed that maritime transportation should not be penalized with backhaul emissions penalties. We have worked hard with our members to pull together information and track records, that we shared[1] with CARB staff, to demonstrate that not only the size of the ships were different form CARB's assumptions, but also they were not returning empty to Brazil after delivering ethanol to Californian ports. We were also glad to see that CARB has updated the number of routes mills are able to choose to ship their fuel to California. By doing so, CARB will allow mills the opportunity to use the most logistically efficient route available for them, while also considering its GHG implications.

As glad as we were to see these positive updates, we were disappointed that a number of others did not make it to this new version of the calculator. The Brazilian ethanol sector firmly believes that CARB needs to implement them so the agency can more accurately score the carbon intensity of Brazilian

[1] Technical Report on Maritime Transportation for Brazilian ethanol shared via e-mail with CARB staff on April 19, 2023.

ethanol so our product can contribute with its fair share of credits to the LCFS program. We urge CARB to review the information shared below and implement the updates in the final version of the calculator, using the most current data available.

In doing this, CARB will be in line with the intent of its Board, who have emphasized the importance of utilizing the latest science to ensure accurate measurement and accounting of CI scores across new and existing fuels. We applaud this commitment by Board Members and would like to highlight how important these outcomes are as markets across the US and world look up to CARB for leadership and standard setting.

We remain committed to supporting CARB's efforts to update and refine modeling under the LCFS program, we appreciate staff's patience and answers to some of our questions, but there are still important questions unanswered. In order for us to provide complete feedback, we need access to complete information. We believe that only with complete information in hand, stakeholders can provide staff with much needed comments for draft tier 1 calculators.

We remain at your disposal to further dive into any technical detail or question you may have, and to contribute in the best way we can for the improvement and success of the LCFS. Please find our comments below based on the information currently available to us.

**Comments -**
In these comments, we would like to focus on a few items, summarized below, that we have already discussed with CARB in the past. The details and evidence about each topic is extensively presented in the Appendix.

1. **Electricity Exported Credits**
The report below provides additional details on sugarcane bioelectricity exported to the grid, focusing on showing evidence of the complementarity between sugarcane bioelectricity and hydroelectric generation during the dry season (April to November) in Brazil. We believe that CARB should consider calculating the electricity export credits taking into account the displacement of the margin of the national electricity grid, based on the contribution of sugarcane electricity in the total thermoelectric generation in the dry season. Sugarcane bioelectricity helps substitute part of energy dispatching from fossil thermoelectric mainly throughout this period and also contributes to the reduction of the risk of energy deficit during the critic period of low water reservoirs.We also disagree with CARB's approach that excludes energy exported in the off-season and doesn't consider the energy produced by cogeneration from third-party biomass. CARB's current approach can induce a "double standard", in which the rainy season is used to calculate the average of the national electricity grid, but it is ignored when CARB excludes export electricity credits generated in the off-season months. Both approaches significantly impact the CI value of ethanol mills in Brazil.

2. **Mechanized Harvest**
Mechanized harvesting in Brazil represents more than 95% of the total sugarcane harvested area in the Center-south region. However, Tier1 sugarcane ethanol calculator offers two default values for sugarcane mechanization for Brazil: 80% for São Paulo state and 65% for other states, including the Center-South region. Given (i) the weight of this input in the tier 1 calculator and given all the effort and investment from the industry to reduce emissions by adopting more modern techniques for harvesting, and (ii) the implications of CARB's policies not only to California but for the rest of the country and the world, we would ask that CARB staff reviews this information with care. These advances should be recognized by CARB's policy, and it is important that CARB assumptions regarding mechanized harvesting reflect sugarcane production patterns in Brazil more accurately, in addition to translating into better carbon intensity for Brazilian ethanol. We urge CARB to use the most updated scientific data to reflect mechanization levels and diesel consumption in Brazil.

3. **Straw Yield**

The CA-GREET 3.0 calculator considers a straw yield of 0.28 wet tonne straw per tonne cane, wet straw containing 15% moisture. However, evidence recovered from scientific literature extensively present the value of 0.14 tonne straw (dry) per tonne sugarcane. This value is widely accepted by the academic community, is being used in many studies, and even in the most recent versions of the Argonne GREET Model. We urge CARB consider revising the current value in the CA-GREET 3.0 calculator.

**4. Vinasse Transport and Distribution**

CA-GREET 3.0 considers CH4 and N2O emissions from open channel transportation of vinasse, However, such transportation strategy does not reflect either the industry practices or the regulatory conditions of vinasse logistics in Brazil. It would be more appropriate that CARB disregards CH4 and N2O emissions from open vinasse channels as a representative condition considered in CA-GREET

**5. N2O from applied N**

The emission factor for direct $N_20$ emissions from N inputs considered by CA-GREET 3.0 is 0.01 kg-N2O-N/kg N-fert applied to soils, according to the IPCC (2006), which were extracted from studies dominated by cases from Europe and North America. The general recommendation from IPCC is that, when available, regional data should be considered over global parameters. Therefore, we strongly recommend that CARB consider the value 0.006 kg-$N_2O$-N/kg N-fert, which better reflects the prevailing conditions in areas under sugarcane production in South-Central Brazil, instead of the IPCC values of 0.01 in CA-GREET.

## Appendix

## A.1 Electricity Export Credit

In the next sections, we present:

(i) a brief context about the sugarcane bioelectricity exported to the national grid and an overview about CARB's approach (Section A.1.1);

(ii) details about the importance of sugarcane products in the Brazilian energy matrix, focusing on showing evidence of the fundamental role of the surplus electricity from sugarcane mills in the Brazilian electricity mix, including monthly energy generation from thermoelectric plants from biomass and sugarcane bagasse (Section A.1.2);

(iii) evidence of the complementarity of energy generation from hydroelectric and thermoelectric plants from sugarcane bagasse in the dry season, that contributes to the reduction of fossil fuels such as natural gas and coal (Section A.1.3); and

(iv) Conclusions (Section A.1.4);

All information used here was generated and made publicly available by national institutions responsible for monitoring the Brazilian electricity sector.

### A.1.1. Electricity Export Credits: overview of CARB

Sugarcane mills in Brazil have a high potential for producing electricity from bagasse. Bioelectricity of sugarcane is not only used for the mill's own consumption, but also generates a surplus that is exported to the grid (for example, 60% of the electricity generation from bagasse in the mills was exported to the grid in 2021). In the last five years, thermoelectric plants based on sugarcane bagasse were responsible for 5.23% of the national thermoelectric generation, and contributed on average 75.3% of the generation of biomass thermoelectric plants [2,3].

Energy generation from sugarcane biomass is complementary to hydroelectric in the dry season, and it is fundamental to contribute to the reduction in the demand for fossil power generation. Besides, it is essential for ensuring energy security and equity in the Center-South, which is the region with the highest national energy consumption. In Brazil, mills have the option to store their own bagasse to produce electricity in the off-season months to be exported to the grid, avoiding other more polluting energy sources from being tapped.

However, CARB ignores the complementarity of hydro and biomass power generation and, consequently, the electricity export credits are calculated based on the displacement of the average of the national electricity grid. Since bioelectricity from sugarcane contributes to minimizing the need for fossil energy when injected into the national electricity grid, we argue that the correct assumption is to calculate electricity credits using electricity at the margin (natural gas or oil) in Brazil. This approach was correctly taken by CARB in the initial regulation and should be reinstated.

In addition, we would like CARB to reconsider the understanding that the electricity exported during off-season months (normally from November to March) should be annulled. Mills insert into the sugarcane ethanol Tier 1 calculator all the biomass externally acquired, either during season and off-season, when the biomass enters the mills (item 3.8). And the calculator automatically converts this biomass into electricity monthly (item 3.9). Although, as CARB already know, the biomass (either

[2] ANEEL - Agência Nacional de Energia Elétrica. Quantidade de usinas termelétricas por tipo. 2023a. https://dadosabertos.aneel.gov.br/dataset/usinas-termeletricas-por-tipo. Accessed on: 10 May

[3] EPE- Empresa de Pesquisa Energética. 2019. Termelétricas a biomassa nos leilões de energia no Brasil - Características técnicas dos empreendimentos e resultados dos últimos leilões. Expansão da geração. Available at: https://www.epe.gov.br/pt/imprensa/noticias/termeletricas-a-biomassa-nos-leiloes-de-energia-epe-publica-estudo-sobre-as-caracteristicas-tecnicas-dos-empreendimentos-e-resultados-dos-ultimos-leiloes

bagasse or any other) can be stored and they are not immediately used in cogeneration. Also, the electricity generated from this third-party biomass (item 3.9) is discounted from the surplus electricity exported to the grid (item 3.13) before calculating the credit for co-product (electricity surplus). Thus, the electricity generated from third-party biomass does not create any credit for the mill, which excludes the possibility of gearing.

Therefore, it should not matter what period the electricity is being exported, as the calculator prevents any chance of external biomass creating credits. This current approach penalizes the mills twice, first when the electricity from external biomass enters the mill, which is understandable, and second when CARB requires the off-season electricity exported to be excluded, which we see as the main problem.

We disagree with CARB's approach that excludes energy exported in the off-season, which, for example in 2022, corresponded to 920 GWh[4], equivalent to 6% of energy generated by fossil thermoelectric plants in the off-season in the same year[5]. Brazilian sugarcane ethanol must not be penalized by this practice.

This current CARB approach about these two points related to exported energy (the average mix for the grid and the electricity exported during off-season being neglected) can induce a "double standard", when the rainy season (November to March) is used to calculate the average of the national electricity grid, but it is ignored when CARB excludes export electricity credits generated in the off-season months. Both approaches significantly impact on the CI value of ethanol mills in Brazil.

### A.1.2. Importance of sugarcane products in the Brazilian energy matrix

Brazil stands out for the high share of renewable sources in its energy matrix (48%), compared to the rest of the world (Figure 1). Sugarcane biomass is essential to maintain the renewable level of the Brazilian energy matrix, contributing with about 37% of the internal energy supply from renewable sources, followed by hydraulics (25%)[6]. Sugarcane bioenergy currently contributes with 14.7% of primary energy production in Brazil, and 16.4% of internal energy supply in the national energy matrix, both equivalent to 49.4 Mtoe (base year 2021) (Figure 2).

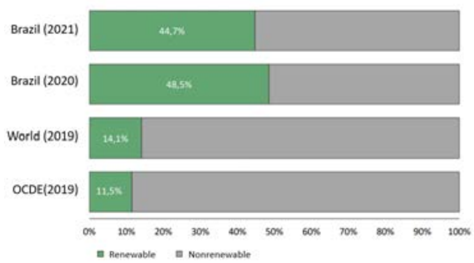



**Figure 1.** Participation of renewable and non-renewable sources in the Brazilian energy matrix and in different places. Source: EPE (2022) [7]. In 2020, the share of renewables in the energy matrix was marked by an increase in the supply of sugarcane and biodiesel associated with a reduction in the supply of non-renewables. In 2021, the reduction in the share of renewables occurred due to the drop in the supply of hydraulic energy, associated with water scarcity and the activation of thermoelectric plants.

---

[4] UNICA. Observatório da Cana -PAINEL DE GERAÇÃO DE BIOELETRICIDADE E DAS DEMAIS FONTES DA MATRIZ ELÉTRICA, 2023. https://observatoriodacana.com.br/listagem.php?idMn=134 (accessed May 10, 2023).

[5] ONS – Operador Nacional do Sistema Elétrico. Histórico da geração de energia. 2023. Available at: https://www.ons.org.br/Paginas/resultados-da-operacao/historico-da-operacao/geracao_energia.aspx

[6] EPE - Empresa de Pesquisa Energética. 'Balanço Energético Nacional. Ano base 2021', 2022. https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2022 (accessed Mar. 12, 2023).

[7] EPE - Empresa de Pesquisa Energética. 'Balanço Energético Nacional. Ano base 2021', 2022. https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2022 (accessed Mar. 12, 2023).

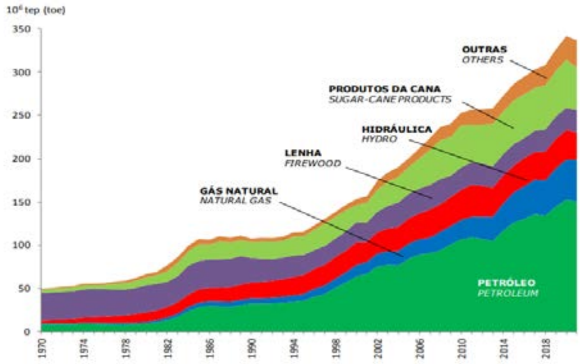
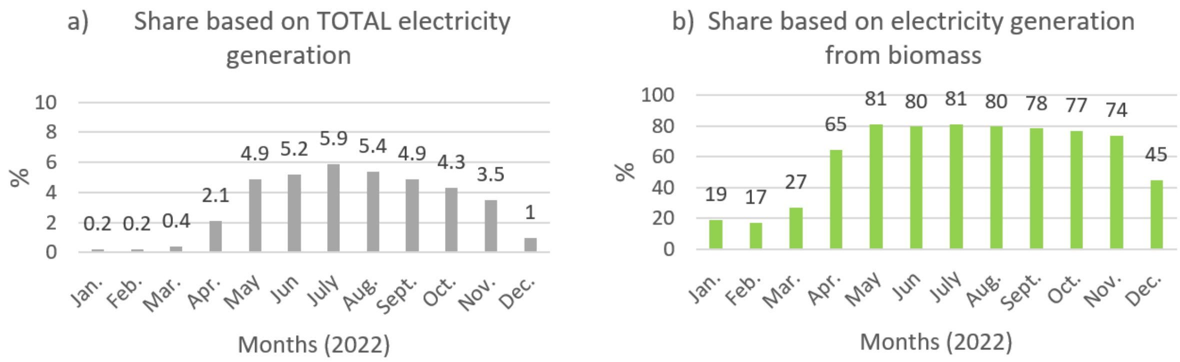



**Figure 2.** Primary energy production in Brazil from 1970 to 2021.
Fonte: EPE (2022).

Thermoelectric generation from biomass has strategic importance for the national electricity sector[8,9]. On average, the use of biomass was responsible for 8.5% of all electricity produced in Brazil in recent years (2017-2021), second only to hydroelectric and natural gas thermoelectric plants[10]. Among the biomasses used, the majority share of bioelectricity generation is from sugarcane, which in recent years has contributed on average to 75.3% of the generation of thermoelectric plants using biomass and was responsible for 5.23% of national electricity generation (2017-2021 average)[11.12]. Figure 3 presents the monthly share of bioelectricity from sugarcane based on the total electricity generation (including, non-renewable, solar, wind, and other sources), and the percentile representation of the sugarcane bagasse in the electricity generation from biomass, both in 2022.




---

[8] EPE- Empresa de Pesquisa Energética. 2019. Termelétricas a biomassa nos leilões de energia no Brasil - Características técnicas dos empreendimentos e resultados dos últimos leilões. Expansão da geração. Available at: https://www.epe.gov.br/pt/imprensa/noticias/termeletricas-a-biomassa-nos-leiloes-de-energia-epe-publica-estudo-sobre-as-caracteristicas-tecnicas-dos-empreendimentos-e-resultados-dos-ultimos-leiloes

[9] EPE - Empresa de Pesquisa Energética. 'Balanço Energético Nacional. Ano base 2021', 2022. https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2022 (accessed Mar. 12, 2023).

[10] EPE - Empresa de Pesquisa Energética. 'Balanço Energético Nacional. Ano base 2021', 2022. https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2022 (accessed Mar. 12, 2023).

[11] EPE- Empresa de Pesquisa Energética. 2019. Termelétricas a biomassa nos leilões de energia no Brasil - Características técnicas dos empreendimentos e resultados dos últimos leilões. Expansão da geração. Available at: https://www.epe.gov.br/pt/imprensa/noticias/termeletricas-a-biomassa-nos-leiloes-de-energia-epe-publica-estudo-sobre-as-caracteristicas-tecnicas-dos-empreendimentos-e-resultados-dos-ultimos-leiloes

[12] ANEEL - Agência Nacional de Energia Elétrica. Quantidade de usinas termelétricas por tipo. 2023a. https://dadosabertos.aneel.gov.br/dataset/usinas-termeletricas-por-tipo. Accessed on: 10 May

**Figure 3**. Percent share of bioelectricity from sugarcane in (a) total electricity generation (including, non-renewable, solar, wind, etc), and (b) electricity generation from biomass, in Brazil in 2022.
Source: UNICA (2023)[13], based on CCEE (*Câmara de Comercialização de Energia Elétrica*, in Portuguese)

The total sugarcane biomass electricity is increasing significantly during the last years. In the period 2008-2021, the accumulated generation of sugarcane bioelectricity for the grid was 219,708 GWh (Figure 4). Since 2013, the bioelectricity produced from sugarcane exported to the grid exceeds that destined for the mills' own consumption. In 2021, 20202 GWh of surplus bioelectricity were exported to the National Interconnected System (SIN, in Portuguese) [14].

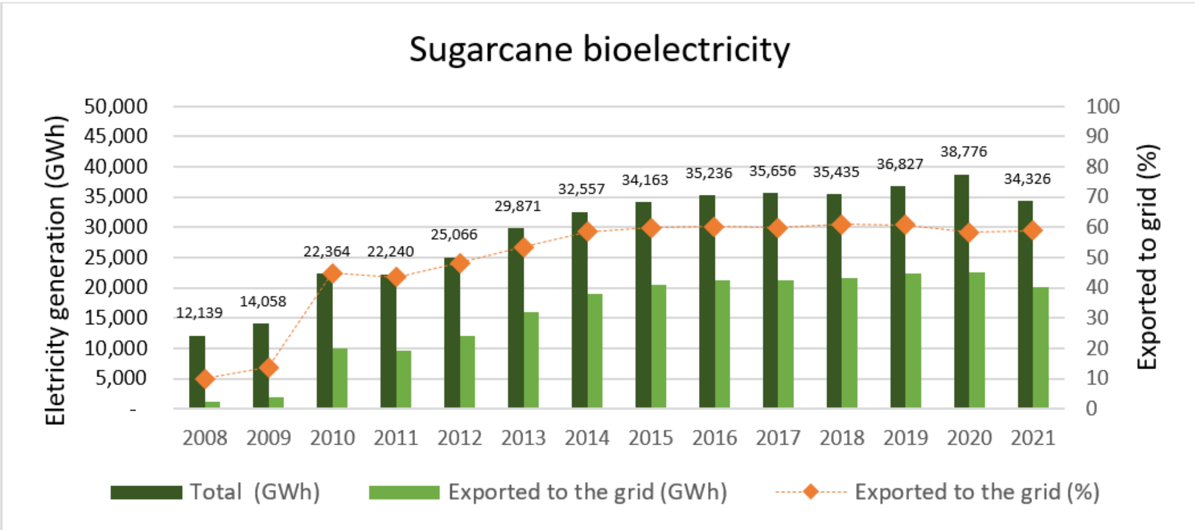



**Figure 4.** Electricity generation (GWh) from sugarcane bagasse since 2008. The reduction observed in 2021 is related to the hydrological crisis registered this year.
Source: Elaborated by Agroicone, based on UNICA (2023)[15], EPE (2017)[16], EPE (2022)[17]

### A.1.3. How the Brazilian Electrical System works

The Brazilian Electrical System (National Interconnected System - SIN) is 99% interlinked[18], so virtually all the production and transmission of electricity in Brazil happens in one main grid closely monitored by the National Electric System Operator (ONS), a federal agency responsible for coordinating and controlling operation of the electricity generation and transmission facilities in the SIN under the supervision and regulation of the National Electric Energy Agency (ANEEL). This unique system adopted by the country creates certainty as to what sources contribute to the marginal generation of power. Sugarcane biomass-based electricity in Brazil receives a fixed income to deliver a "package" of energy per year to the grid. Sugarcane biomass receives this fixed income for the energy it produces

[13] UNICA. Observatório da Cana -PAINEL DE GERAÇÃO DE BIOELETRICIDADE E DAS DEMAIS FONTES DA MATRIZ ELÉTRICA, 2023. https://observatoriodacana.com.br/listagem.php?idMn=134 (accessed May 10, 2023).

[14] UNICA. Observatório da Cana -PAINEL DE GERAÇÃO DE BIOELETRICIDADE E DAS DEMAIS FONTES DA MATRIZ ELÉTRICA, 2023. https://observatoriodacana.com.br/listagem.php?idMn=134 (accessed May 10, 2023).

[15] UNICA. Observatório da Cana -PAINEL DE GERAÇÃO DE BIOELETRICIDADE E DAS DEMAIS FONTES DA MATRIZ ELÉTRICA, 2023. https://observatoriodacana.com.br/listagem.php?idMn=134 (accessed May 10, 2023).

[16] EPE- Empresa de Pesquisa Energética. Balanço Energético Nacional. Ano base 2017', 2018. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-303/topico-419/BEN2018__Int.pdf

[17] EPE - Empresa de Pesquisa Energética. 'Balanço Energético Nacional. Ano base 2021', 2022. https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2022 (accessed Mar. 12, 2023).

[18] https://www.ons.org.br/paginas/sobre-o-sin/sistemas-isolados

and declares its Unit Variable Cost (UVC) equal to zero, since cogeneration of sugarcane biomass electricity occurs in order to meet the demand of the sugar and ethanol production in the mill. Wind and solar sources also have a UVC equal to zero. In this way, all the electrical energy these sources produce is made available to the national grid (since the government already paid a fixed income for it).

The process is different for thermo-gas sources. On top of the fixed income they receive to be on standby, their UVC is greater than zero, meaning if and when the ONS utilizes them, they receive payment for their fuel cost and the operation. In fact, since sugarcane biomass is classified with a unit variable cost equal to zero, the ONS adopts the so-called merit order, where thermal plants from lower to higher operating costs are dispatched in order to meet demand. The ones with lower UVC are the first to be called to meet domestic demand. Since biomass plants have unit variable cost equal to zero, when available (during the sugarcane harvest season), they are the first to be dispatched to the system, without the need for an order from the ONS. Differently from sources like coal, diesel, and natural gas, the generation of energy from sugarcane biomass sources is controlled and dictated by the industrial process itself instead of by order of the national operator.

The Figures 5 and 6 show that the share of hydropower in Brazil oscillated significantly with a decrease trend from 2012 to 2021, mainly due to droughts that have significantly impacted reservoirs and due to the reduction of the multi-annual regulating capacity of the hydroelectric reservoirs, since the most recent hydropower projects in Brazil are composed of “thread-of-water” mills[19], mills that are only able to hold water for a few hours or days. According to the Brazilian Ministry of Mines and Energy’s (MME) Ten-year Energy Expansion Plan (PDE 2031), the decreasing trend is predicted to continue [20], and Brazil has relied (and will rely) on thermo-gas sources to provide the marginal power it needs, and to guarantee the security of the electrical system in the country. Since sugarcane mills operate on a fixed revenue basis described above with zero Unit Variable Cost (UVC), we know bagasse-burning electricity cogeneration goes straight into the grid to substitute the marginal increase of energy. If we look at the marginal sources that have increased over the last few years, we see natural gas has the largest share in the system. Given the operational cost differential between biomass and thermo-gas sources, the seasonality of hydro and biomass energy generation and the fact that hydro mills have a decreased capacity of holding water, we know bagasse electricity cogeneration is displacing fossil fuel sources of power in Brazil, in the daily operating system.

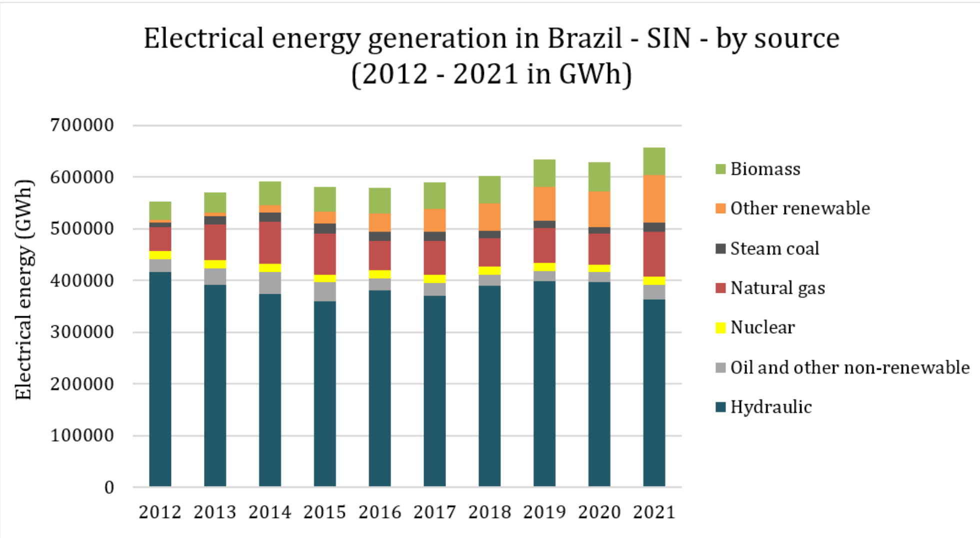



**Figure 5.** Electricity generation in Brazil by source (GWh). Source: EPE (2022).

[19] https://www.ana.gov.br/sar/sin

[20] EPE. Ten-Year Energy Expansion Plan/Introduction. 2022. Available at: https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/Paginas/PDE-2031---English-Version.aspx.

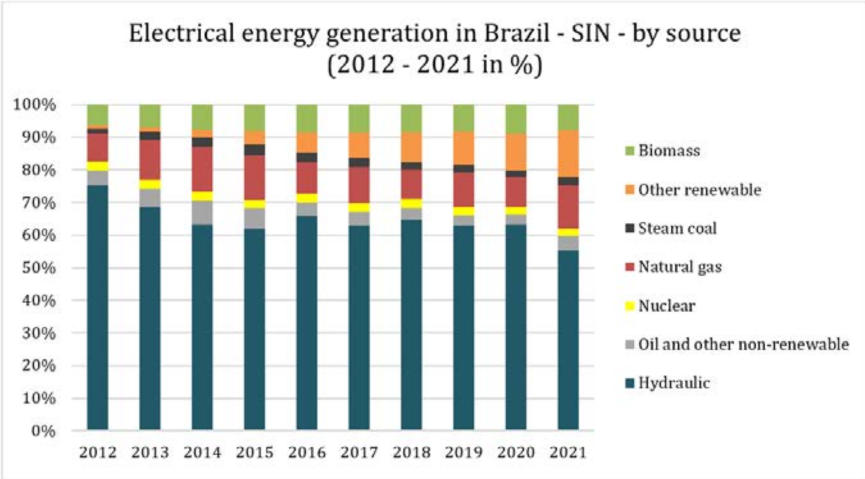
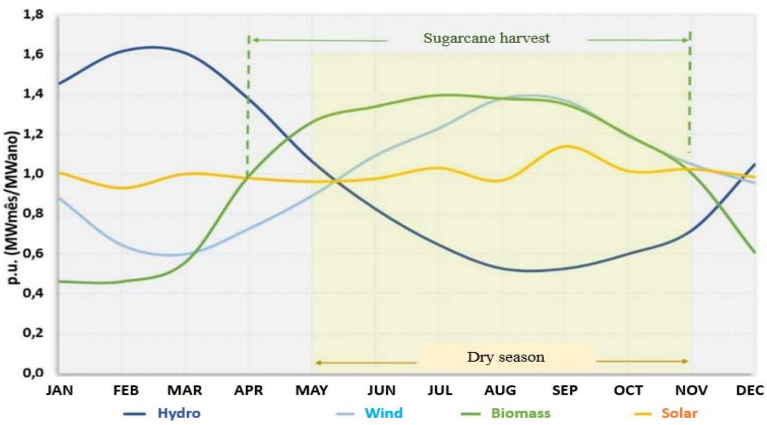



**Figure 6.** Electricity generation in Brazil by source (%). Source: EPE (2022).

### A.1.3. Complementarity between sugarcane bioelectricity and hydroelectricity

The energy generation profile from sugarcane biomass has higher available in the dry season of the SIN and is therefore complementary to the water supply (Figure 7), contributing to a reduction in the demand for fossil fuels. Its participation in the national electrical matrix is important because the generating plants are close to the largest electricity consumer centers, which tends to reduce the need to use the energy transmission system over long distances and electrical losses, reducing electricity costs to the consumers. Sugarcane mills are also able of operating between harvests, from December to March, with a biomass stock, making generation uninterrupted, unlike sources such as wind and photovoltaics, used in distributed generation, which are intermittent and non-dispatchable (EPE, 2019[21]; EPE, 2021[22], LNBR, 2021[23]).




[21] EPE- Empresa de Pesquisa Energética. 2019. Termelétricas a biomassa nos leilões de energia no Brasil - Características técnicas dos empreendimentos e resultados dos últimos leilões. Expansão da geração. Available at: https://www.epe.gov.br/pt/imprensa/noticias/termeletricas-a-biomassa-nos-leiloes-de-energia-epe-publica-estudo-sobre-as-caracteristicas-tecnicas-dos-empreendimentos-e-resultados-dos-ultimos-leiloes

[22] EPE. 'CENÁRIOS DE OFERTA DE ETANOL E DEMANDA DE CICLO OTTO 2022-2031', vol. 2021, Accessed: Mar. 12, 2023. Available at: http://www.epe.gov.br

[23] LNBR, 'O futuro da bioeletricidade da cana-de-açúcar', 2021. https://lnbr.cnpem.br/en/o-futuro-da-bioeletricidade-da-cana-de-acucar/ (accessed Mar. 12, 2023).

**Figure 7.** Annual complementarity between biomass and several energy sources. The diversity of energy production sources over the course of the same year makes it possible to mitigate the effect of the seasonality of the water supply. Source: ONS (2022)[24].

Figure 8 shows the spatial distribution of biomass thermoelectric plants, and wind and solar plants in Brazil. Sugarcane bagasse thermoelectric plants are predominantly located in the Center-South region, where is found the highest population concentration in the country. Other renewable energy generation systems such as wind and solar are more dispersed, or in the case of wind power, concentrated on the northeastern coast. This highlights the importance of electricity generation from bagasse, especially in the Center-South region.

a) b) c)


d)

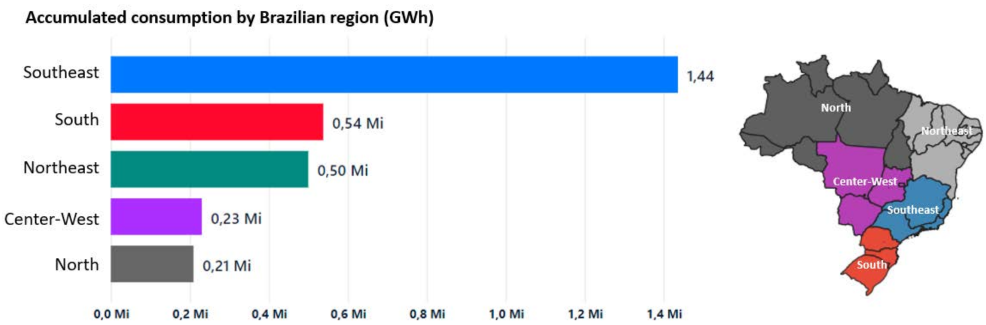



**Figure 8**. Distribution of (a) biomass thermoelectric plants, (b) solar and (c) wind plants in Brazil; (d) total energy consumption accumulated from 2017 to 2022, by region. Sources: EPE (2023a,2023b)[25, 26]

Figures 9 and 10 evidence the complementarity between biomass (total biomass (Fig.9) or sugarcane bagasse (Fig. 10)) and hydro energy generation, both in long-term trends and in year-by-year cycles. The hydro obeys precipitation cycles and diminishes generation in the dry season of the year (between May and November), when the reservoir levels of the hydroelectric plants are low. Consequently, in this period, the electricity system relies on less hydropower and more backup sources (such as natural gas or oil), which has much higher cost and emissions. Sugarcane harvesting has the opposite temporal behavior and occurs in highest levels during the dry season. For this reason, the use of sugarcane bagasse for energy generation minimizes the use of oil and natural gas power plants, and is essential to contribute to the renewable energy supply and to reduce power prices to consumers. Figure 9 clearly

---

[24] ONS – Operador Nacional do Sistema Elétrico. Plano da Operação Energética 2022/2026- PEN 2022. Relatório das condições de atendimento. 2022. Available at: https://www.ons.org.br/AcervoDigitalDocumentosEPublicacoes/NT-ONS%20DPL%200102-2022_PEN%202022%20-%20Condi%C3%A7%C3%B5es%20de%20Atendimento.pdf

[25] EPE. Webmap EPE. 2023a. [Online]. Available at: https://gisepeprd2.epe.gov.br/WebMapEPE/

[26] EPE. Painel de Monitoramento do Consumo de Energia Elétrica. 2023b. Available at: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/consumo-de-energia-eletrica

shows that in the absence of biomass, additional backup electricity would be used, which would necessarily be from fossil sources ("thermoelectric plants (non-biomass)"). It also shows that a clear and predictable cyclical behavior of higher hydropower in sugarcane off season and higher fossil power generation during the sugarcane harvesting.

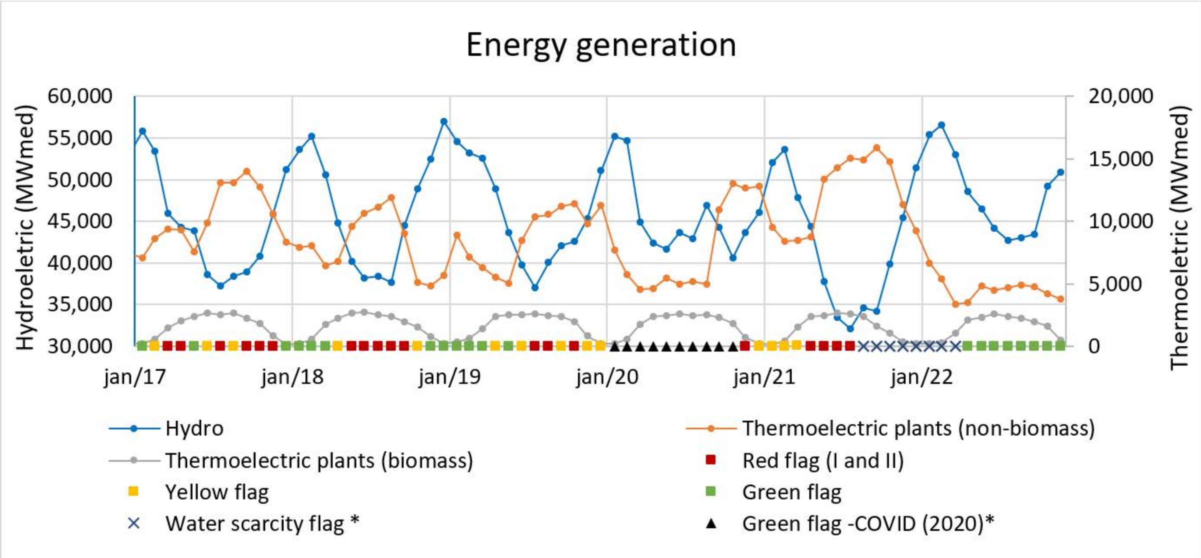



**Figure 9.** Monthly energy generation from hydroelectric and thermoelectric plants (using renewable sources "biomass", and unrenewable sources "non-biomass"), and the monthly tariff flags from 2017 to 2022. Source: Agroicone, based on ONS (2023)[27] and ANEEL (2023b)[28].

Figure 10 evidence that the sugarcane bioelectricity is sold monthly to the grid, mainly in the dry season, but not only[29]. In 2019, 91% of the total sugarcane bioelectricity to the grid was supplied in the dry season, between April and November, with bioelectricity saving the equivalent of 15% of the total energy stored in the reservoirs of the hydroelectric plants of the Southeast/Center-West submarket[30]. In 2022 the percentage exported to the grid was already higher. From the 18,397 GWh generated for the grid in 2022, around 17,477 GWh (95%) were offered between April and November, months that make up the dry and critical period for the electricity sector. During the rainy season, 920 GWh[31] was sold to the grid, which correspond to 6%[32] of the energy generated by fossil thermoelectric plants in the off-season in the same year.

---

[27] ONS – Operador Nacional do Sistema Elétrico. Histórico da geração de energia. 2023. Available at: https://www.ons.org.br/Paginas/resultados-da-operacao/historico-da-operacao/geracao_energia.aspx

[28] ANEEL - Agência Nacional de Energia Elétrica. Bandeira Tarifária - Acionamento. 2023b. Available athttps://dadosabertos.aneel.gov.br/dataset/bandeiras-tarifarias/resource/0591b8f6-fe54-437b-b72b-1aa2efd46e42https://dadosabertos.aneel.gov.br/dataset/bandeiras-tarifarias/resource/0591b8f6-fe54-437b-b72b-1aa2efd46e42 (accessed on: 10 May)

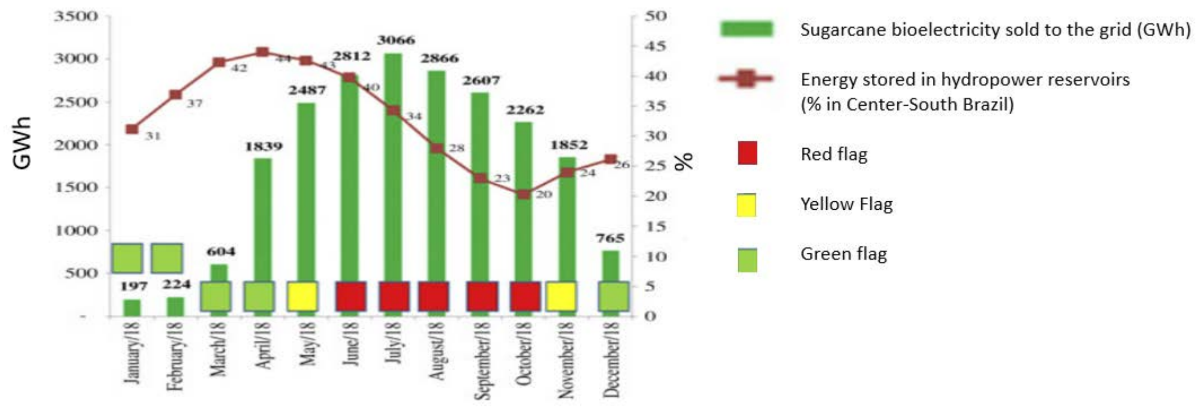
[29] UNICA, "A bioeletricidade da cana," 2019, [Online]. Available: https://www.unica.com.br/wp-content/uploads/2019/07/UNICA-Bioeletricidade-julho2019-1.pdf.

[30] SUCRE. Sugarcane electricity in the Brazilian electrical grid. 2020. Available at: https://lnbr.cnpem.br/wp-content/uploads/2020/07/Sugarcane-Bioelectricity.pdf

[31] UNICA. Observatório da Cana -PAINEL DE GERAÇÃO DE BIOELETRICIDADE E DAS DEMAIS FONTES DA MATRIZ ELÉTRICA, 2023. https://observatoriodacana.com.br/listagem.php?idMn=134 (accessed May 10, 2023).

[32] ONS – Operador Nacional do Sistema Elétrico. Histórico da geração de energia. 2023. Available at: https://www.ons.org.br/Paginas/resultados-da-operacao/historico-da-operacao/geracao_energia.aspx

**a) Production of sugarcane bioelectricity, hydroelectric reservoirs, and flags**




**b) Monthly sugarcane bioelectricity sold to the grid (GWh), from 2020 to 2022**

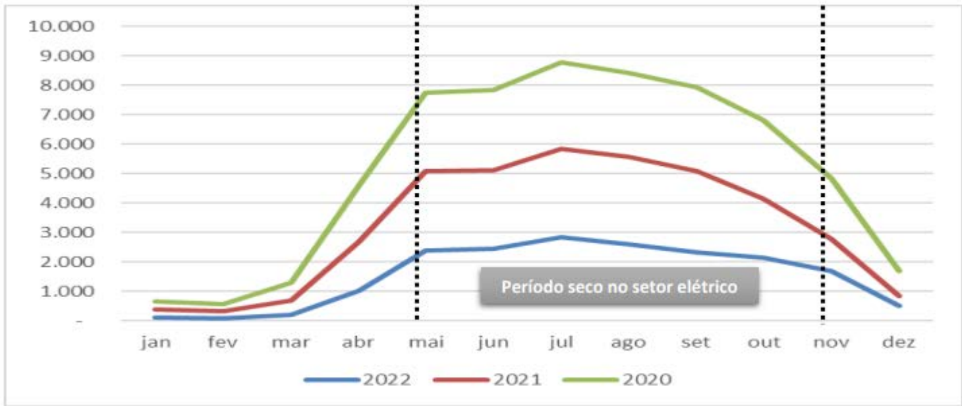



**Figure 10.** (a) Production of sugarcane bioelectricity sold to the grid, and percentage of energy stored in hydropower reservoirs in Center-South Brazil during 2018 and the monthly tariff flags; (b) Monthly sugarcane bioelectricity sold to the grid, from 2020 to 2022. Source: UNICA (2019, 2023)[33].

Since 2015, the Brazilian Electricity Regulatory Agency (ANEEL, in Portuguese) implemented a tariff system flags that signals generation conditions and costs to power consumers. “Red flags” are attributed to the periods that depend on high-cost electricity sources and “green flags” to low-cost. The flags attributed in each month since 2017 are presented in Figure 9. Some exceptions can be observed during 2020 when a special flag (green) was attributed to minimizing economic impact on consumers during the pandemic period, and from September/2021 to April/2022 due to a strong water scarcity period.

The “reg flag” and “yellow flags” are concentrated in the dry season due to the use of thermoelectric plants from non-biomass fuels. In this period, thermoelectrics from biomass can contribute to more than 30% of the total electricity generation from thermoelectrics (from fossil and biomass), as presented in Figure 11. This highlights the importance of biomass thermoelectric power to ensure national energy security and equity. The installed power of thermoelectric plants that use sugarcane bagasse corresponds to more than 25% of the installed power of all thermoelectric plants (fossil and biomass)

[33] UNICA. Observatório da Cana -PAINEL DE GERAÇÃO DE BIOELETRICIDADE E DAS DEMAIS FONTES DA MATRIZ ELÉTRICA, 2023. https://observatoriodacana.com.br/listagem.php?idMn=134 (accessed May 10, 2023).
UNICA, “A bioeletricidade da cana,” 2019, [Online]. Available: https://www.unica.com.br/wp-content/uploads/2019/07/UNICA-Bioeletricidade-julho2019-1.pdf.

[34,35]. In years of water scarcity such as 2021, in which it was even necessary to implement a special flag in the period from September/2021 to April/2022 (Figure 9), the bioelectricity of sugarcane produced even from December to April contributes to mitigating the use of fossil sources in the electricity sector.

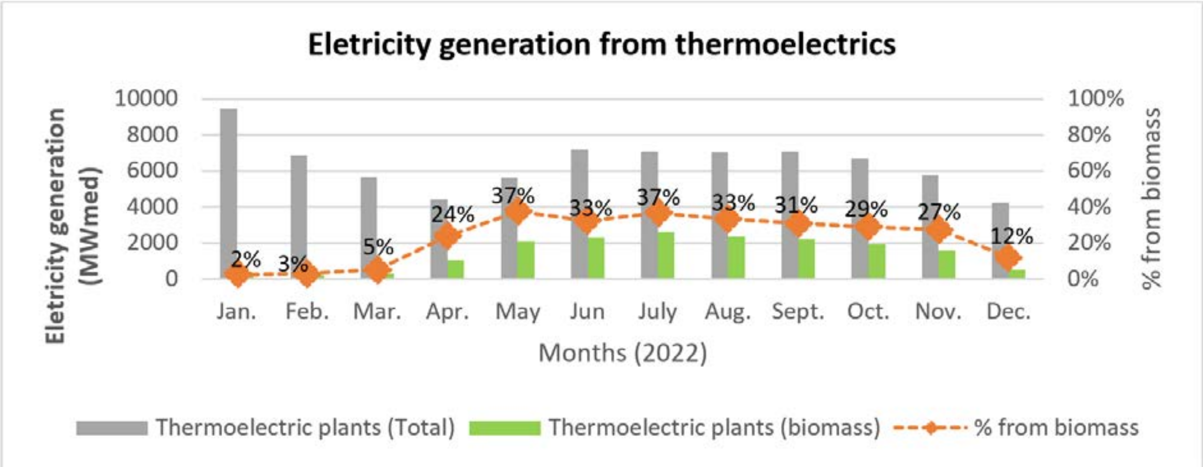



**Figure 11**. Electricity generation (MWmed) from thermoelectric plants, from all sources (total), and only from biomass. Percentage share of biomass in total thermoelectric generation in each month. Base year 2022. Source: Agroicone, based on ONS (2023)[36].

### A.1.4. Conclusion

This document presents evidence of the complementarity between sugarcane bioelectricity and hydroelectric generation boosting the reliability of the electrical system and reducing the risks of power shortage and price increases during the dry season. During the dry season, the thermoelectrics from biomass contribute to more than 30% of the total electricity generation from total thermoelectrics (fossil and biomass). Sugarcane bagasse is responsible for 80% of biomass thermoelectric power during the dry season.

We believe that the CARB should consider calculating the electricity export credits taking in account the displacement of the margin of the national electricity grid, based on the contribution of sugarcane electricity in the total thermoelectric generation in the dry season, allowing to reallocate energy dispatching mainly throughout this period and resulting in a reduction of the risk of the deficit without aggravating water reservoir conditions (and requiring fossil electricity). We reinforced that the credits using electricity at the margin (natural gas or oil) had already been taken by CARB in the initial regulation and should be reinstated.

It was also presented monthly energy generation data from thermoelectric plants from sugarcane bagasse, showing that sugarcane electricity from biomass stock is also generated and exported in the off-season months, from December to March. This seems to have been implemented to avoid gearing from external biomass. However, electricity from external biomass is already discounted when it is informed as an external source in Tier1 calculator. Excluding it again during the offseason months is therefore a double penalty.

---

[34] ANEEL - Agência Nacional de Energia Elétrica. Quantidade de usinas termelétricas por tipo. 2023a. https://dadosabertos.aneel.gov.br/dataset/usinas-termeletricas-por-tipo. Accessed on: 10 May

[35] ONS – Operador Nacional do Sistema Elétrico. Histórico da geração de energia. 2023. Available at: https://www.ons.org.br/Paginas/resultados-da-operacao/historico-da-operacao/geracao_energia.aspx

[36] ONS – Operador Nacional do Sistema Elétrico. Histórico da geração de energia. 2023. Available at: https://www.ons.org.br/Paginas/resultados-da-operacao/historico-da-operacao/geracao_energia.aspx

## A.2 Mechanized Harvest

Currently, the Tier1 sugarcane ethanol calculator offers two default values for sugarcane mechanization for Brazil: 80% for São Paulo state and 65% for other states, including the Center-South region.

However, the mechanized harvesting in Brazil has significantly expanded in the last decade and now represents more than 95% of the total sugarcane harvested area in the Center-south region[37]. This information is supported both by official governmental data and by RenovaBio primary data collected and audited in 2018 and 2019.

The IV National Inventory of Emissions and Measurements of Greenhouse Gases, published in 2021[38], was developed in accordance with the methodological guidelines of the IPCC 2006 for reporting GHG emissions and removals for the five sectors: Energy, Industrial Products and Process Uses (IPPU), Agriculture and Livestock, Land Use, Land Use Change and Forestry (LULUCF), and Waste. The Reference Report of the Agricultural Sector – Sub-sector Agricultural Waste Burning presents on Appendix A-table 1.4 the percentage of manual harvesting at the national, regional, and state level. This report shows that, in 2017, in the Southeast and Center-west regions, which represent more than 80% of the sugarcane harvested area in the country, the manual cutting was lower than 5% of the area.

According to CONAB (Brazilian National Supply Company), during the 2022/23 in the Center-South region of Brazil, 2.73% of the sugarcane was manually harvested. This rate has been below 10% since 2015/16. The Center-South region supplies more than 85% of all the sugarcane produced in Brazil.

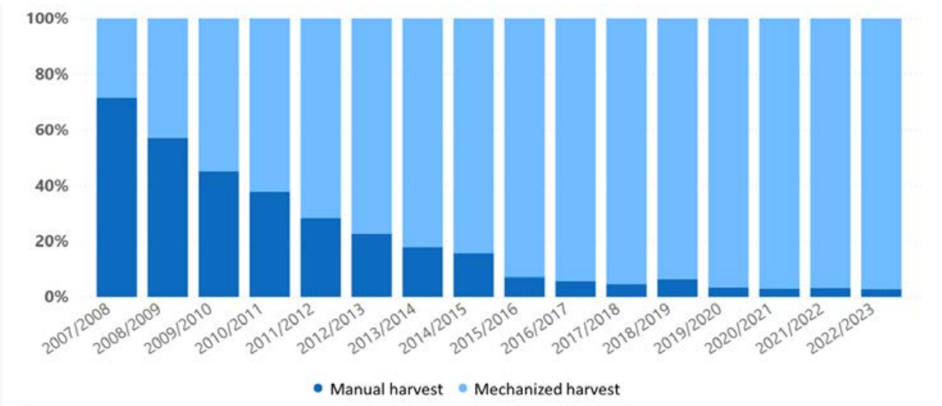



**Figure 12**. Ratio of manual and mechanized harvest in the Center-South region of Brazil.
Source: CONAB (Observatório da Cana)[39]

Corroborating with this data, UNICA have a database from the RenovaBio Program with audited information from 2018 and 2019 of 97 associated mills that shows that only 5% of the sugarcane that entered the mill was from a burned area. The data reported in RenovaBio is calculated based on the percentage of sugarcane with ashes that enters the mill, which is a totally reliable methodology once it reports not only the sugarcane burned for harvest but also the portion that was accidentally or illegally burned.

As requested by CARB, an analysis using remote sensing data was made using the Mapbiomas-Fire[40] and UNICA's sugarcane area vectors, the data were processed in the Qgis software. For each sugarcane polygon, the percentage of intersection with the polygon of burned area from Mapbiomas-Fire

[37] CONAB. https://observatoriodacana.com.br/listagem.php?idMn=4

[38] Ministério da Ciência, Tecnologia e Inovação. SIRENE. https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/publicacoes/relatorios-de-referencia-setorial

[39] CONAB. https://observatoriodacana.com.br/listagem.php?idMn=4

[40] MapBiomas. MapBiomas Project - Mapbiomas-Fire Collection 1. 2022. Available at: https://mapbiomas.org/en/colecoes-mapbiomas-1?cama_set_language=en

was estimated. After the geospatial statistics calculations, the results were added to the attribute table of the vector file and the statistics by state were calculated. Therefore, the total areas of sugarcane for 2020 was 10,280,528.7 hectares, which 82,847.1 hectares were burned, totaling 0.8% of sugarcane area.

The Mapbiomas-Fire product was elaborated from mosaics of Landsat Satellite images, with 30 meters of spatial resolution, covering the years from 1985 to 2020, providing monthly and annual data of the burned areas in Brazil. The burned area estimation was carried out using artificial intelligence from machine learning algorithms in the Google Earth Engine platform. The algorithm was trained with samples of burned and non-burned areas, in addition with the burned area product of MODIS sensors (MCD64A1) and hot spots data from INPE. It is important to mention that this product was not created for this purpose, thus it probably underestimates the burning areas on sugarcane cultures.

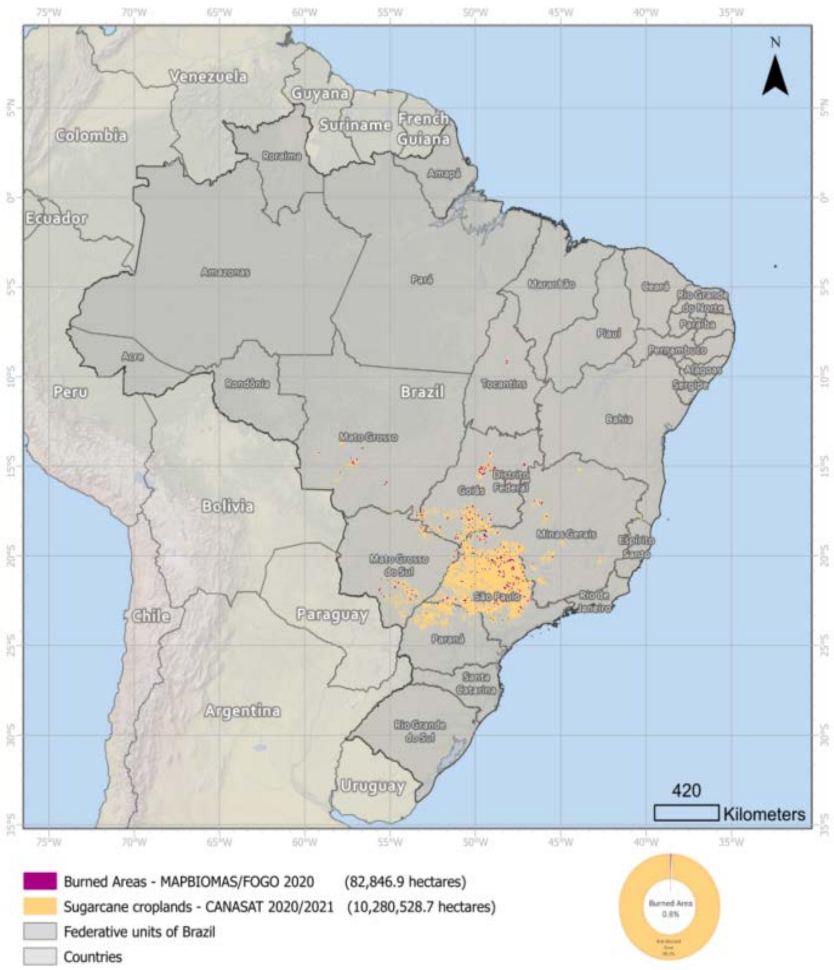



**Figure 13**. Intersection from the sugarcane area with the burned areas polygons from the MapBiomas-Fire for the center-south region of Brazil. Sources: Mapbiomas-Fire[41],Canasat

Mechanization has dramatically reduced emissions in sugarcane cultivation, and mills should be recognized for this progress. We again urge CARB to offer an option for self-declared mechanization percentage in the Tier 1 CI calculator. If for some reason this is not feasible, we respectfully ask staff to adjust the default mechanization values for Center-South Brazil to a value no lower than 95%. By doing so, CARB will be scoring input more closely to actual practice and will most likely avoid Tier 2 application requests from Brazilian mills, saving time and financial resources for both the Agency and the mills.

[41] MapBiomas. MapBiomas Project - Mapbiomas-Fire Collection 1. 2022. Available at: https://mapbiomas.org/en/colecoes-mapbiomas-1?cama_set_language=en

Regarding the **energy consumption** for sugarcane agricultural purposes, according to Renovabio's audited data from 2018 and 2019 collected from 97 mills, more than 90% refers to diesel. This data also shows that, on average, the mills consume between 97,000 to 118,500 BTU/tonne of sugarcane of diesel, which is a very similar number if compared to the value set on the CA-GREET 3.0 of 95,000 BTU/tonne of sugarcane.

These consumption values are possible due to a series of improvements applied by the sector both to the machinery and to the practices. Some examples are:

- With mechanized harvesting, there was an increase in harvest yield, where a harvester has a greater harvesting capacity than a cane loader (equipment for loading manually cut cane), thus the energy efficiency of the harvester is better.
- The mills have been making technical improvements in the equipment, changing the fleet for trucks, tractors, and machinery with greater energy efficiency. Also, they are implementing a two-row harvester, which optimizes the harvest and reduces diesel consumption.
- The technology embedded in the current equipment (on-board computer, field cruiser, among others), allows the mill to make adjustments according to the productivity of the sugarcane field, also contributing to the reduction of consumption.
- The management and monitoring tools for indicators, such as fuel consumption, are currently much better than those used in the past, allowing us to monitor the operations online, being able to see if there are excessive rotations, or anything out of the standards parameterized for the harvest of a certain area just in time, making decisions and correcting the operation, thus reducing consumption.
- The mills invested in training the operators and drivers aiming at saving fuel, in example, a harvester that was operated with an average of 2.400 rpm, today it harvests with an average of 1.900 rpm, reducing the diesel consumption in this operation. This was also done with the sugarcane transport operations where diesel fuel was reduced by up to 25%.

It is worth mentioning that, differently from the LCFS methodology, the RenovaBio data comprise the diesel consumed for sugarcane transported from the field to the mill. Thus, to adjust the value for what would be the input for the LCFS calculator and reach the value mentioned above it was necessary to make a balance on CA-GREET, discounting what should be the consumption for sugarcane T&D considering the average distance of sugarcane transportation.

We hope that CARB will review this information with the consideration it deserves and update its calculator to recognize the progress the Brazilian ethanol sector has achieve and continue to invest in to ensure our product is produced sustainably and can be used by markets around the world to achieve their GHG emissions reductions goals. It is important that CARB assumptions, regarding mechanized harvesting, more accurately reflect sugarcane production patterns in Brazil, in addition to translating into better carbon intensity for Brazilian ethanol.

### A.3 Straw Yield

The CA-GREET 3.0 calculator (sheet: Fuel_Prod_TS cell: CI269) considers a straw yield of 0.28 wet tonne straw per tonne cane, wet straw containing 15% moisture. Unfortunately, our specialists were unable to identify the source of this combination of values, which leads to a dry straw yield of 0.238 dry tonne straw per tonne of cane (fresh). The evidence recovered from scientific literature (presented below) clarifies that lower values should be considered.

The ratio of straw (tops and leaves) to sugarcane stalks have been measured and is estimated at **0.14 $\textbf{tonne}_{\textbf{straw}}$ (dry) per $\textbf{tonne}_{\textbf{sugarcane}}$**[42]. It is important to clarify that this value is the total straw available before any adjustment (such as leaves carried from the field due to mechanical harvesting). This value is widely accepted by the academic community[43,44], and is being used in many studies, as mentioned, and even in the most recent versions of the Argonne GREET Model. To calculate the amount of straw subject to decomposition, it's necessary to subtract the percentage of straw that is removed by mechanization, and the percentage of straw that is burned when manual harvesting occurs. However, all these considerations must be made upon the amount of straw initially available on the field, which is the value presented by literature and mentioned above: 0.14 $\text{tonne}_{\text{straw}}$ (dry) per $\text{tonne}_{\text{sugarcane}}$.

Waldhein et al., 2001 reached this result from the Project BRA/96/G31 which the Brazilian Ministry of Science and Technology coordinated. Below there's a piece of the document where it shows the ratio obtained by the study (Figure 14).

***TRASH AVAILABILITY FIELD TESTS***

The first activities of this part of the project were directed at the assessment of cane biomass quantity and quality in the cane field prior to, and after, harvesting. The influence of cane variety, age, cut, soil and climate was also investigated.

During the 1997/98 harvesting season, field tests were performed on routes C and D with the combined harvester Austoft A7700, with the trash extractor on and off. During the 1998/99 harvesting season, field tests were made with the machines involved in routes A and B.

The potential of sugar cane residues is approximately 14% of the mass of stalks. This means that for each tonne of sugar cane stalks, there is 140 kg of dry residues. This potential is only slightly lower than the bagasse yield itself and therefore the biomass potential can, theoretically, be almost doubled by using green harvesting.

**Figure 14.** Print of text regarding the measurement of residues.
Source: Waldhein et al., 2001

Also, there's an Evaluation Report[45] made by Eric D. Larson from Princeton University stating regarding the aforementioned project, among other things, that "*The most important result from this set of activities was the accurate measurement of the amount of trash produced (trash produced per unit of sugarcane stalk) for common commercial varieties of sugarcane grown in Southeast Brazil. The careful measurements made in this work help to clarify the actual potential supply of sugarcane trash in SE Brazil. Prior to this work being completed, authors in the literature reported a wide range of trash production rates, so there was considerable uncertainty about the actual availability of trash in any specific case.*"

---

[42] L. Waldhein, M. Moris, and M. R. L. V. Leal, Biomass power generation: sugar cane bagasse and trash. A. V. Bridgwater, 2001. https://doi.org/10.1002/9780470694954.ch41

[43] M. R. L. V. Leal, M. V. Galdos, F. V. Scarpare, J. E. A. Seabra, A. Walter, and C. O. F. Oliveira, 'Sugarcane straw availability, quality, recovery and energy use: A literature review', Biomass and Bioenergy, 53 (2013), 11–19.

[44] L. M. S. Menandro, H. Cantarella, H. C. J. Franco, O. T. Kölln, M. T. B. Pimenta, G. M. Sanches, S. C. Rabelo, J. L. N. Carvalho. Comprehensive assessment of sugarcane straw: implications for biomass and bioenergy production. Biofuels, Bioproducts and Biorefining, (2017), 488-504, 11(3).

[45] E. D. Larson. Final Evaluation Report for UNDP/GEF Project BRA/96/G31, "Biomass Power Generation: Sugar Cane Bagasse & Trash". Princeton Environmental Institute, Princeton University. 2003. Available at: <https://www.eartheval.org/sites/ceval/files/evaluations/117%20Biomass%20Power%20Generation%20Sugar%20Cane%20Bagasse%20and%20Trash.pdf>

More recently, the Project BRA/10/G31 – Sugarcane Renewable Electricity (SUCRE)[46], implemented by CNPEM - National Center for Research in Energy and Materials – and managed in coalition with the United Nations Development Programme and LNBR - Brazilian Biorenewables National Laboratory, presented detailed information on studies carried out on the use of sugarcane straw for sustainable electricity generation. In its final report, on page 95, the value of 0.12 tonnes of (dry) straw per ton of sugarcane is referenced, which corroborates that the suggested value of 0.14 tonnes of straw per tonne of sugarcane is accurate and even conservative (Figure 15).

### 3.4.2 RESULTS

#### I. GOOD PRACTICES FOR STRAW REMOVAL: KNOWLEDGE BACKGROUND FOR STRATEGIC DECISIONS

An important part of carrying out strategic sugarcane straw removal is the knowledge related to straw characteristics, the potential sugarcane yield, and the impacts of straw removal on the soil-plant-atmosphere system. These aspects allow the definition of principles for strategic removal and also assist in the managers' final decision making.

The study performed in the SUCRE Project showed that straw composition has different potentials for nutrient recycling and for second-generation ethanol and bioelectricity production, depending on whether it is characterized by green tops or dry leaves (*Figure 66*). In addition, this study showed a productive potential of 120 kg of straw (dry basis) for each megagram of stalks produced (wet basis). Thus, a ratio of 12% can be used to estimate straw yield in sugarcane fields of Center-South Brazil (Menandro et al., 2017). This is an important piece of information that is included in the step-by-step process of the removal strategies.

**Figure 15.** Print of text regarding the measurement of residues.
Source: SUCRE, 2020

46 SUCRE, 2020. < https://lnbr.cnpem.br/wp-content/uploads/2020/07/SUCRE-Project-Final-Report.pdf>

## A.4 Vinasse Transport and Distribution

CA-GREET 3.0 considers $CH_4$ and $N_2O$ emissions from open channel transportation of vinasse, with an impact of approximately 0.24 gCO2e/MJ ethanol. Even though vinasse unlined tanks and open channels feature conditions that may lead to methane emissions ($N_2O$ emissions are very low), such transportation strategy does not reflect either the industry practices or the regulatory conditions of vinasse logistics in Brazil.

Regulations in the state of São Paulo, for example, established back in 2005 schedules for the impermeabilization of vinasse tanks and channels[47]. Other States from Brazil's center-south region also have regulations addressing vinasse transport and use as agricultural fertilizer. For example, in Paraná (PR), since 2010, there has been a regulation regarding the impermeabilization of storage ponds and master or primary canals for vinasse transportation[48]. In Minas Gerais (MG), the regulation referring to vinasse storage and use is dated from 2011[49]. In Mato Grosso do Sul (MS), there is a regulation since 2015 that establishes criteria and procedures for the storage, distribution, and application to agricultural soil of vinasse in natura and residual water generated from sugarcane processing[50]. These States represent almost 75% of the sugarcane planted areas in the country and nearly 80% of the sugarcane milled[51]. Furthermore, Brazilian mills have also adopted systems based on closed tanks and pipes, which further reduce methane emissions during vinasse transportation[52]. Also, the more technologically advanced mills from UNICA reported that a significant part of their vinasse is transported and applied by a method called "localized" (*aplicação localizada*, in Portuguese), which means that the vinasse is transported on tanks by trucks from the mill to the field.  The localized application at the base of the plant, without dispersion, extends the area benefited, optimizes the application rates, and reduces the application by the other method. Regarding the diesel consumption for this method, according to RenovaBio's database, it has a very low impact on the total agricultural energy consumption (BTU/tonne sugarcane). Therefore, it would be more appropriate that CARB disregards $CH_4$ and $N_2O$ emissions from open vinasse channels as a representative condition considered in CA-GREET

[47] CETESB, São Paulo. Portaria CTSA – 01, from November 28th of  2005. São Paulo, 2005, published on DOE SP on november 29th of 2005. < https://cetesb.sp.gov.br/camaras-ambientais/wp-content/uploads/sites/21/2013/12/P4_231.pdf>

[48] IAP, Paraná. Portaria IAP nº 239 from november 30th of 2010. Paraná, 2010, published on DOE PR on December 6th of 2010. <https://www.legisweb.com.br/legislacao/?id=144482>

[49] COPAM, Minas Gerais. Deliberação Normativa COPAM nº 16, from march 30th of 2011. Minas Gerais, 2011, published on DOE MG in April 12, 2011. <https://www.legisweb.com.br/legislacao/?id=142793>

[50] SEMADE, Mato Grosso do Sul. Resolução n.19, from september 2nd of 2015. Mato Grosso do Sul, 2015, published on DOE MS in september 4th of 2015. <https://www.legisweb.com.br/legislacao/?id=303034>

[51] CONAB. COMPANHIA NACIONAL DE ABASTECIMENTO. Boletim Cana 4 Levantamento 21-22, abril 2022 – safra 2021/2022. Brasília: Companhia Nacional de Abastecimento. 2022.

[52] Oliveira, et al.,2017. Methane emissions from sugarcane vinasse storage and transportation systems: Comparison between open channels and tanks. Atmospheric Environment. Volume 159, June 2017, Pages 135-146.

**A.5 $N_2O$ from applied N - consider the value 0.006 kg-N2O-N/kg N-fert**

Currently, the emission factor (EF) for direct $N_20$ emissions from N inputs considered by CA-GREET 3.0 is 0.01 kg-N2O-N/kg N-fert applied to soils, according to the IPCC recommendation (2006). Recent independent studies have found that the emission factors for regional-specific conditions (Tier 2) on the direct GHG emissions for sugarcane in Brazil are usually 40% below the IPCC Tier 1. Technical information indicates that the value 0.006 (i.e, 0.6%) is more appropriate for sugarcane in Brazil.

Carvalho et al. (2021)[53] developed an extensive work based on 14 publications that represent actual sugarcane N fertilization practices in South-Central Brazil. It is based on data from field studies from 17 experimental sites (laboratory experiments were excluded) and has background emissions of the $N_2O$ EF accounted for (more than 86 reported values of $N_2O$ EFs). The information includes $N_2O$ EFs obtained from sugarcane cultivated under green mechanized harvesting which represents more than 95% of the sugarcane area in the South-Central region of Brazil.

Carvalho et al. (2021) found the average $N_2O$–N EF of 0.006, considering all N fertilizer sources, for the sugarcane ratoon, which receives most of the N application of the sugarcane areas, and represents 80% of the sugarcane cycle and 89% of the total amount of N fertilizer consumed considering the entire sugarcane mill. The EF value recommended is 40% below the IPCC Tier 1 default value, due to the good drainage properties of the deep Oxisols, where sugarcane is commonly cultivated in Brazil.

Therefore, the review of *in situ* $N_2O$–N EF measurements from sugarcane in Brazil are below the default value proposed by the IPCC[54] and far below those observed in many sugarcane areas in other regions of the world[55]. The values estimated by IPCC (2019) were extracted from studies dominated by cases from Europe (34%), North America (28 %) and Asia (19%), while Central-South America formed around 6−7% of the dataset. Also, the general recommendation from IPCC is that, when available, regional data should be considered over global parameters. **Therefore, we strongly recommend that CARB consider the value 0.006 kg-$N_2O$-N/kg N-fert, which better reflects the prevailing**

53 Carvalho, J. L. N.; Oliveira, B. G.; Cantarella, H.; Chagas, M. F.; Gonzaga, L. C.; Lourenço, K. S.; Bordonal, R. O.; Bonomi, A. Implications of regional N2O–N emission factors on sugarcane ethanol emissions and granted decarbonization certificates. *Renewable and Sustainable Energy Reviews*, 149 (2021), 111423. https://doi.org/10.1016/j.rser.2021.111423

54 Gonzaga LC, Carvalho JLN, Oliveira BG de, Soares JR, Cantarella H. Crop residue removal and nitrification inhibitor application as strategies to mitigate N2O emissions in sugarcane fields. Biomass Bioenergy 2018;119:206–16. https://doi. org/ 10.1016/j.biombioe.2018.09.015.
Gonzaga LC, Zotelli L, do C, de Castro SGQ, de Oliveira BG, Bordonal R de O, Cantarella H, et al. Implications of sugarcane straw removal for soil greenhouse gas emissions in São Paulo state, Brazil. Bioenergy Res 2019;12:843–57. https://doi. org/ 10.1007/s12155-019-10006-9.
Lourenço KS, Rossetto R, Vitti AC, Montezano ZF, Soares JR, de Melo Sousa R, et al. Strategies to mitigate the nitrous oxide emissions from nitrogen fertilizer applied with organic fertilizers in sugarcane. Sci Total Environ 2019;650:1476–86. https:// doi.org/10.1016/j.scitotenv.2018.09.037.
Siqueira Neto M, Galdos MV, Feigl BJ, Cerri CEP, Cerri CC. Direct N2O emission factors for synthetic N-fertilizer and organic residues applied on sugarcane for bioethanol production in Central-Southern Brazil. GCB Bioenergy 2016;8:269–80. https:// doi.org/10.1111/gcbb.12251.
Paredes DS, Alves BJR, Dos Santos MA, Bolonhezi D, Sant'Anna SAC, Urquiaga S, et al. Nitrous oxide and methane fluxes following ammonium sulfate and vinasse application on sugar cane soil. Environ Sci Technol 2015;49:11209–17. https:// doi.org/ 10.1021/acs.est.5b01504.
Soares JR, Cantarella H, Vargas VP, Carmo JB, Martins AA, Sousa RM, et al. Enhanced-efficiency fertilizers in nitrous oxide emissions from urea applied to sugarcane. J Environ Qual 2015;44:423–30. https://doi.org/10.2134/ jeq2014.02.0096.

55 Allen DE, Kingston G, Rennenberg H, Dalal RC, Schmidt S. Effect of nitrogen fertilizer management and waterlogging on nitrous oxide emission from subtropical sugarcane soils. Agric Ecosyst Environ 2010;136:209–17. https://doi. org/10.1016/ j.agee.2009.11.002.
Denmead OT, Macdonald BCT, Bryant G, Naylor T, Wilson S, Griffith DWT, et al. Emissions of methane and nitrous oxide from Australian sugarcane soils. Agric For Meteorol 2010;150:748–56. https://doi.org/10.1016/j.agrformet.2009.06.018.
Jin VL, Baker JM, Johnson JM-F, Karlen DL, Lehman RM, Osborne SL, et al. Soil greenhouse gas emissions in response to corn stover removal and tillage management across the US corn belt. Bioenergy Res 2014;7:517–27. https://doi. org/10.1007/ s12155-014-9421-0.

**conditions in areas under sugarcane production in South-Central Brazil, instead of the IPCC values of 0.01 in CA-GREET.**

Excerpts of the published paper (Carvalho et al., 2021), that presented the $N_2O$–N EF value and the arguments commented on our proposal, are shown below:

Renewable and Sustainable Energy Reviews 149 (2021) 111423

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Implications of regional $N_2O$–N emission factors on sugarcane ethanol emissions and granted decarbonization certificates

João Luís Nunes Carvalho [a,*,1], Bruna Gonçalves Oliveira [b,1], Heitor Cantarella [b], Matheus Ferreira Chagas [a], Leandro Carolino Gonzaga [a,c], Késia Silva Lourenço [b], Ricardo Oliveira Bordonal [a], Antonio Bonomi [a]

[a] Brazilian Biorenewables National Laboratory (LNBR), Brazilian Center for Research in Energy and Materials (CNPEM), Rua Giuseppe Máximo Scolfaro 10000, Polo II de Alta Tecnologia, Campinas, SP, 13083-100, Brazil
[b] Agronomic Institute of Campinas (IAC), Soils and Environmental Resources Center, Barão de Itapura, 1481, Campinas, SP, 13001-970, Brazil
[c] Interdisciplinary PhD. Program in Bioenergy, University of Campinas (UNICAMP), Rua Monteiro Lobato, 80, Cidade Universitária, 13083-862, Campinas, SP, Brazil

Our findings indicated that the $N_2O$–N EFs obtained in sugarcane in Brazil are mostly below the default value proposed by the IPCC [10–15] and far below those observed in many sugarcane areas in other regions of the world [46–48]. These low $N_2O$–N EF values have been usually attributed to the good drainage properties of the deep Oxisols [49], where sugarcane is commonly cultivated in Brazil.

The average $N_2O$–N EF from N fertilizer in sugarcane ratoon was 0.60% (ranging from 0.07 to 2.03), which is 40% lower than the IPCC value. Large variations in the $N_2O$ EFs for N fertilizers (Table S6) could be associated with specific conditions, such as time of fertilization (dry or wet seasons), clay content, soil physical conditions, methods of fertilizer application, and amount of straw covering the soil surface [11,

The IPCC guidelines establish the default EF based on global data, most of which from regions of temperate climates [59], which do not represent the prevailing edaphoclimatic conditions of Brazil. Little information about soil $N_2O$ emissions in sugarcane fields was available in Brazil. However, recent research that generated many independent field results provide a robust database to make the first estimation of total GHG emissions from sugarcane ethanol using regional-specific data.

**2. Methodological approach**

*2.1. Data used to calculate $N_2O$ emissions*

We performed a literature review of studies reporting measurements of $N_2O$ emissions in areas under sugarcane production in Brazil, focusing on N fertilization and the addition of organic residues such as vinasse and filter cake. The keywords "sugarcane", "Brazil", "green cane", "$N_2O$ emissions", "$N_2O$ emission factor", "nitrogen fertilizer", "vinasse", "filter cake", "sugarcane by-products", "nitrification inhibitor", and their associations were used as search terms in the ISI Web of Science database and in the Google Scholar (in April 2020), yielding 29 papers (Table S1). However, only 14 publications met the criteria required (Table S1) for our review. The conditions for inclusion of publications were to represent actual sugarcane N fertilization practices in South-Central Brazil, contain data from field studies (laboratory experiments were excluded), and have background emissions of the $N_2O$ EF accounted for. We did not include studies from other countries because crop management and edaphoclimatic conditions are usually different. In addition, the literature on $N_2O$ emissions in sugarcane fields is relatively scarce globally.

Our analysis included information on $N_2O$ EFs obtained from sugarcane cultivated under green mechanized harvesting (excluding areas under burned harvesting), which represents more than 95% of the sugarcane area in the South-Central region of Brazil [32]. The $N_2O$ EFs

While we appreciate the opportunity to submit these comments, we believe that there is still much technical information to be reviewed, for which the depth and quality of our feedback depends, and many questions to be answered. We encourage CARB to recognize that time and resources are needed in order to thoroughly update and capture the improvements of Brazilian ethanol production and its contribution to California's progress under the LCFS program. We stand ready to collaborate with staff and share whatever is necessary to improve the understanding of ethanol production dynamics in Brazil. We are committed to returning further feedback in a timely fashion once we have more information about the methodology chosen for CA-GREET 4.0.

We look forward to continuing to dialogue and collaborate with you in order to get the updates done right for Brazilian biofuels that contribute for lowering emissions in California transport sector.

Respectfully submitted,

Evandro Gussi

President and CEO

Leticia Phillips

Representative - North America