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Systemic approach for bioenergy policies: A study case for Brazilian energy matrix and the sugarcane sector

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Abstract. Energy consumption is correlated with the Human Development Index (HDI) and it tends to be higher in developing countries. However, 84.3% of the energy comes from non-renewable sources regarding the average global energy matrix in 2019. Therefore, the challenge is to sustainably improve energy supply. To do so, countries may rely on public policies as a tool to ensure adequate predictability and competitiveness of renewable energy sources. Renovabio is a Brazilian national biofuel policy that aims to reduce the national greenhouse gases (GHG) emissions and to expand the use of biofuels. A constraint of this policy is that only biofuel producers and importers can benefit from it. Other energy sources, such as bioelectricity, are not directly approached. So, to show the opportunity if this policy included electricity, we analyzed its production for 10 years, in Brazil, to evaluate

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the growth rate of the share of non-renewables in its matrix. Then, Renovabio was explored to support the proposal of a systemic framework to support public policies aimed at a low-carbon economy. Finally, scenarios of bioelectricity production from Brazilian sugarcane mills were considered to estimate the contribution of this framework to the increase in renewability of the Brazilian electricity matrix and the consequent equivalence of carbon mitigated. The scenario with 50% of the sugarcane factories without cogeneration starting to cogenerate, with an additional 60% of sugarcane factories without biogas, starting to produce, presented the best results, with an additional electricity of 10.95 TWh supplied to the grid, increasing 1.7% the renewability level of the electricity matrix for 2021, 1.38% for 2035, and approximately 4,848 tons of mitigated CO2-eq per year.

Keywords: Energy policy; RENOVABIO; CBio; Biogas; Carbon credit.

1. Introduction

Countries have to develop themselves using energy as acknowledged by United Nations Sustainable Energy 4 All initiative [1] and supported by the Sustainable Development Goal 7 [2]. Besides, the consumption of energy is correlated with the Human Development Index (HDI) and it tends to be higher in developing countries. However, 84.3% of the energy comes from non-renewable sources regarding the average global energy matrix, in 2019 [3]. Therefore, human development has to respect environmental boundaries, and the challenge is to provide energy sustainably [4]. To do so, countries may rely on public policies as a tool to ensure adequate predictability and competitiveness of renewable energy [5].

Renovabio is a Brazilian national biofuel policy to reduce the national greenhouse gas emissions (GHG) and expand the use of biofuels. It, aims at providing contributions to the fulfillment of the commitments determined by Brazil under the Paris Agreement, promoting biofuel expansion in the energy matrix, with emphasis on the regularity of fuel supply, and ensuring predictability for the fuel market. The establishment of annual national decarbonization targets for the fuel sector is a way to encourage increased production and participation of biofuels in the country's transport energy matrix, a constraint of this public policy is that only biofuel producers and importers can benefit from it. Other energy sources, such as bioelectricity, are not directly contemplated by the policy, the origin of electricity generation, being renewable, could stimulate the energy matrix in a complete way.

The fact that the Renovabio program does not include the surplus electricity generated by biofuel producers in its energy-efficiency scores makes it difficult to expand beyond the transport matrix, which could even contribute to a program in the electricity sector, which could acquire proven renewable energy to also decarbonize the electricity matrix.

In this study, to show the opportunity if this policy included electricity, we analyzed 10 years of electricity production in Brazil to evaluate the growth rate of the share of non-renewables in its electricity mix. Then, Renovabio was explored to support the proposal of a systemic framework to support public policies aimed at a low-carbon economy, not just considering those already contemplated, as is the case of biofuels, but also adding up possibilities for bioelectricity, such as from increased cogeneration and additional from bioelectricity from biogas. To do so, we explored scenarios of bioelectricity production from Brazilian sugarcane mills to estimate the contribution of this framework to the increase in renewability of the Brazilian electricity matrix and the consequent CO_2 mitigated.

2. The context of the Brazilian electricity matrix and sugar-energy sector

Brazil has the cleanest electricity mix worldwide (84.8% renewable) [6] in comparison to 15.7% from the global average [3]. So, although this level has been already reached, the concern about it is a correlation between HDI and energy use, which is even more evident when developing countries are analyzed [7]. Brazil reached 17.135 GW of installed power, in 2011, a 5-GW increase compared to 2010. Out of this number, it is distributed in 37.1% corresponded to the increase in hydraulic plants, 52.4% in thermal plants, and 10.5% in wind engines [6]. It is worth mentioning that hydraulic power reached its peak in the same year (Figure 1).

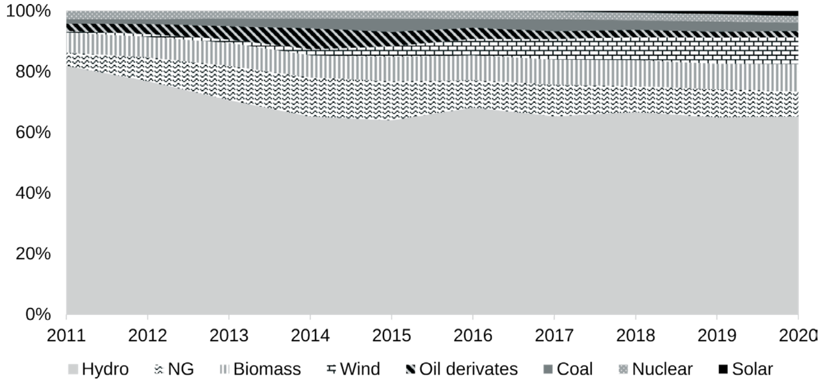

Figure 1. Composition of electricity matrix in Brazil, from 2011 to 2020 [6].

Brazil is the largest producer of sugar and the second-largest producer of ethanol in the world, which are the main products of the sugar-energy sector. The energetic products of the sugarcane industry accounted for 19.1% of the country's energy matrix in 2020, showing its importance to Brazilian energy production. However, there is room for improvement. In 2020, 58.5% of the sugarcane mills did not export bioelectricity to the grid and just 2 mills generated bioelectricity from biogas. Table 1 shows the main characteristics of this sector in 2020.

Table 1. Main characteristics of the sugarcane industry in 2020 [8]

Parameter	**Unit**	**Value**
Sugarcane harvested	Gg	654,527.80
Harvested area	ha	8,616,100
Sugarcane factories	#	422
Factories that produce biogas to generate bioelectricity	#	2
Factories that commercialize bioelectricity	#	247
Ethanol production	m^3	29,746,430
Sugar production	Gg	29,605.946
Power installed	GW	11.60
Bioelectricity commercialized	GWh	22,513.61
Bioelectricity commercialized from biogas	GWh	23.61

Figure 2 shows the processed sugarcane, ethanol, and bioelectricity production from season 1980/81 to 2020/21 [8]. Sugarcane processing evolved from 123.7 (1980/81) to 657.4 million tons (2020/21).

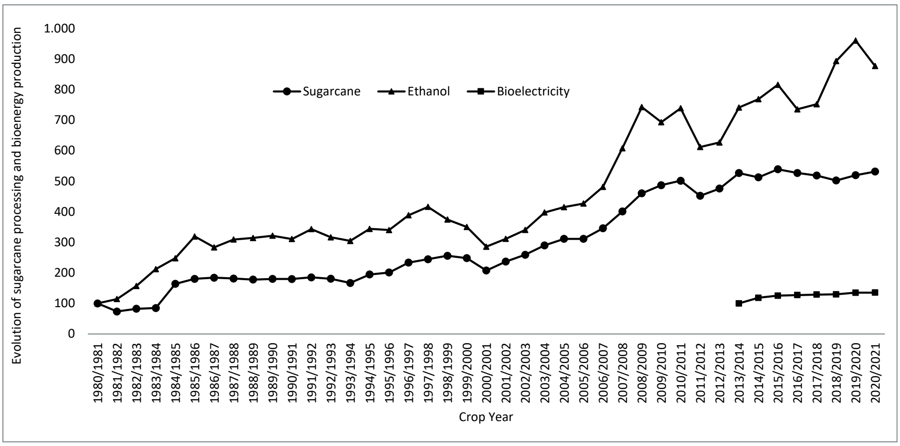

Figure 2. Sugarcane, ethanol, and bioelectricity productions from 1980 to 2020 [8].

Ethanol production from 3.7 to 32.5 billion liters in the same period. More recently, cogenerated electricity (2012/13) started to be accounted increasing sharply from 0.37 to 22.5 TWh (2020/21). The initial data was omitted to avoid miscomprehension on 100-basis, since it was a 61-fold increase. It can be observed that ethanol production reached a plateau from 2010 to 2016, with an 18% production increase approximately. So, to incentivize the expansion of biofuel to overcome this plateau, the Brazilian government created Renovabio, a program to both promote investments focused on the biofuel sector and assist the country to meet its decarbonization goals committed in the Paris Agreement in 2015 (COP 21) [9]. Regarding bioelectricity, in the sugar-energy sector, additional energy production gained relevance at the end of the first decade of the 21st century, surpassing the generation of 20,000 terawatts hour (TWh) and stabilizing, returning to show growth in 2019.

3. The systemic approach of carbon emission avoided beyond ethanol

Brazil created its national biofuel policy in 2017 called RenovaBio, which has focused on reducing GHG emissions in the transport sector. Brazilian decarbonization has occurred in this sector since 84.8% of its electric matrix already comes from renewable sources [6]. Brazil has defined its decarbonization targets and has shared them with the fossil-fuel distributors since 2020. So, each one of the fuel distributors has had its annual targets based on its market share regarding its fossil fuel sales [10], accounted as mass of equivalent carbon dioxide. The accumulated goals in millions of CBios came out of 14.5 in 2020, and it may reach 90.5 million of CBios in 2030 [11].

To reach these targets, fuel distributors are obligated to buy an amount of CBio equivalent to their goals, which is the decarbonization instrument of Renovabio. Each CBio represents one ton of equivalent CO2 mitigated, it is similar to a carbon credit, and it is a financial title, i.e., it can be negotiated on the B3 (Brazil Stock Exchange and Over-the-Counter Market) [12]. The emission of CBio comes from biofuel sales associated with the Energy-Environmental Efficiency Score (EEES), which is the difference between the biofuel's carbon intensity (CI) and its equivalent fossil fuel, in gCO2-eq MJ-1 [9]. For example, biomethane has a score of 76.59, biodiesel 69.12 and anhydrous ethanol 59.95 gCO2-eq MJ-1[13]

For instance, when we divide 1 ton of CO2eq by the EEES median of hydrated ethanol (59.39 gCO2-eq MJ-1), we will have 16,837.85 MJ, which is the total energy from hydrated ethanol necessary to generate a CBio regarding a median value of EEES. Considering that a liter of hydrated ethanol has 21.34 MJ [14], it would be required to produce and sell almost 800 liters of ethanol to emit a CBio. Moreover, producers might invest in reducing production costs and developing new technologies to reduce the carbon footprint of their processes since the higher the EEES, the higher the CBio emissions [15]. It is worth mentioning that only biofuel producers or importers can emit CBios, which is baked by the biofuel sales invoice and valid when it is carried by a bank or a brokerage [16].

Taking into account the influence of bioelectricity in the EEES in the sugar-energy sector, Renovacalc indirectly includes it by allocating the carbon footprint of the agricultural, industrial, and transport processes between the coproducts. The problem is that bioelectricity is not considered in this case. One possible systemic approach is to consider bioelectricity directly. On one hand, energy producers from renewable sources might also emit and sell financial titles such as CBio. On the other hand, electricity distributors, as well as fuel distributors, would have to share the responsibility of national goals and buy these titles.

In this case, bioelectricity would have its EEES, which would be the difference between the carbon intensity of electricity from fossil-fueled thermal power plants and the bioelectricity plant. With that, bioelectricity plants could emit the decarbonization instrument and have financial benefits from it. The trade-off of this decision is that by allocating the biogas for burning in an Otto-cycle generator to produce electricity, instead of allocating it to the production of biomethane as fuel, at that moment the price perspectives will be considered. This approach might enable more investments in the renewable energy sector, increasing the bioelectricity offered to the grid, the CBio emission, and the renewability of the national electricity matrix. To begin illustrating that, one should consider the CG50 scenario where 50% of Brazilian sugarcane mills that did not produce bioelectricity, 88 sugarcane mills, started generating it, taking into account that they had the same production pattern as the average producers in 2020.

Besides, other energy routes could increase the bioelectricity supply by the sugarcane industry, such as the use of biogas from vinasse for electricity generation. Given that, other three scenarios are presented: CG50B20, CG50B40, and CG50B60, besides assumptions of CG50 they consider, respectively 20%, 40%, and 60% of mills starting producing bioelectricity from biogas out of 420 mills that do not produce biogas, in 2020. Table 2 presents these scenarios and the electricity surpluses.

Table 2. Electricity surplus scenarios.

Scenario	**Definition**	**Electricity surplus (TWh/year)**
CG50	50% of non-bioelectricity producers in 2020 started exporting bioelectricity to the grid.	7.98
CG50B20	CG50 + 20% of mills generating bioelectricity from biogas.	8.97
CG50B40	CG50 + 40% of mills generating bioelectricity from biogas.	9.96
CG50B60	CG50 + 60% of mills generating bioelectricity from biogas.	10.95

To estimate the CBio emission from bioelectricity, we considered the values from the sugarcane industry in 2020 (section 3) to determine the EEES from bioelectricity through Renovacalc [17] in comparison to the carbon intensity of Brazilian natural gas thermal power plants (148.38 gCO_2 MJ^{-1}) [18]. When compared to the carbon intensity from biogas electricity generation, which has 25.0 gCO_2eq MJ^{-1} [19] generating an EEES of 123.4 gCO_2eq MJ^{-1} by renewable bioelectricity. Based on this avoided emission, for each megawatt hour (MWh) generated by biogas, there would be a reduction in the carbon footprint of 444.2 kilograms, with the possibility of obtaining the carbon credit for every 2.3 MWh or $2.3x10^{-6}$ TWh. After that, to demonstrate the feasibility we multiplied the EEES by electricity surpluses from the suggested scenarios (Table 2). Table 3 demonstrates the results.

Table 3. EEES, tons of mitigated CO_2-eq, and CBio emissions, per year for each scenario

Scenario	EEES (gCO_2-eq MJ^{-1})	Mitigated CO_2-eq and CBios emissions per year (Mg)
CG50	124.98	3,521.49
CG50B20	122.97	3,969.66
CG50B40	122.97	4,408.64
CG50B60	122.97	4,847.62

We analyzed the tendency of the Brazilian supply and consumption of electricity and the renewability of the electricity matrix regarding this tendency. To do so, we calculated the average annual growth of electricity supply and consumption between 2011 and 2020.

Then three schemas were built to estimate what would be the electricity trend from 2021 to 2030: the base scenario with the average annual growth for both supply (1.46%) and consumption (1.34%), the UP scenario 1.5-time higher than the average annual growth rate for both supply (2.19%) and consumption (2.01%), and the DOWN scenario 1.5-time lower for both supply (0.73%) and consumption (0.67%). The same logic was used to estimate what would be the renewability of the Brazilian electricity matrix from 2021 to 2030. So, we calculated the average annual rate of renewability from 2011 to 2020, taking into account the sum of the share of hydric, biomass, wind, nuclear, and solar sources. Then, three scenario variations were assumed: the "Base" scenario with the average annual rate of renewability (-0.48%), the "High" scenario 1.5-time higher than the average annual rate (-0.32%), and the "Low" scenario 1.5-time lower (-0.72%). Figure 3 shows the electricity supply, consumption, and renewability trends.

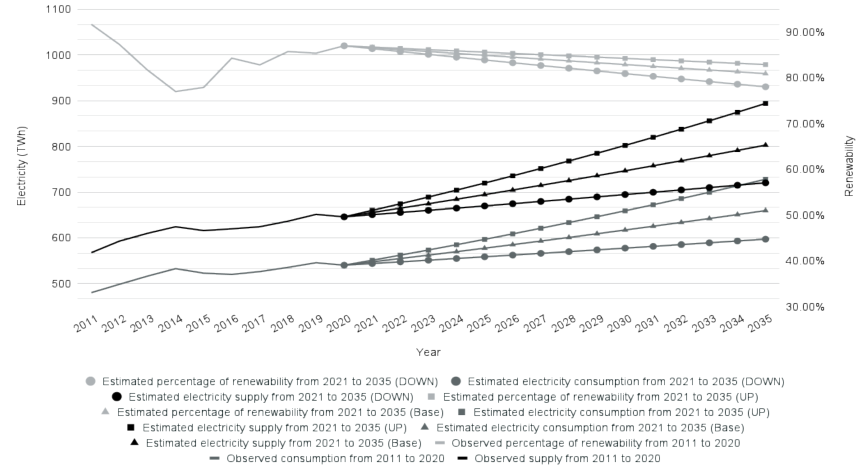

Figure 3. Brazilian electricity supply, consumption, and renewability estimated trends.

With the electricity supply and renewability trends, we could estimate the potential of the CG50, CG50B20, CG50B40, and CG50B60 scenarios for increasing the renewability of the Brazilian electrical matrix. To explain that, we evaluated the electricity supply coming from fossil sources through the base scenario (Figure 3). After, we replaced part of this electricity with the generated from those scenarios described above. Finally, a new share estimation of non-renewable sources was determined, from 2021 to 2030 (Figure 4).

In short, the CG50B60 scenario presented the best results, with a 10.95 TWh increasing in electricity offered to the grid, 1.7% increasing in the renewability of the electricity matrix for 2021, 1.38% for 2035, approximately 4,848 emitted CBios that represents 4,848 tons of mitigated CO_2-eq per year.

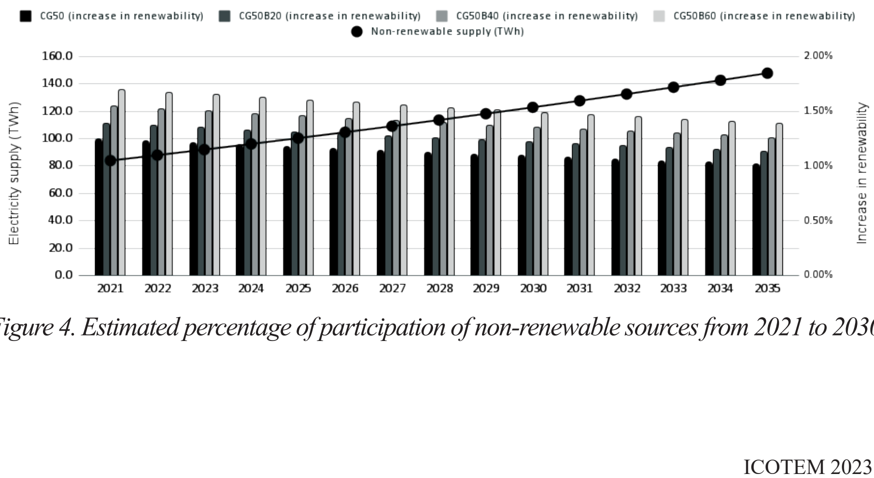

Figure 4. Estimated percentage of participation of non-renewable sources from 2021 to 2030.

4. Conclusions

Energy consumption is highly correlated with human development, especially in developing countries. But the challenge is to access energy sustainably. Therefore, the Renovabio program might be a suitable structure for building a systemic framework to support public policies aimed at a low-carbon economy, especially to increase the use of renewable energy vectors. Moreover, CG50, CG50B20, CG50B40, and CG50B60 scenarios in the Renovabio context demonstrated that this approach might increase the electricity offered to the grid, CBio emissions, CO_2 mitigation, and the renewability of the electricity matrix, helping the country meets its NDC targets. These scenarios would mitigate yearly from 3.5 to 4.8 thousand tons of CO_2-eq, besides increasing renewability of electricity matrix around 2%.

The study demonstrates the real demand for reviewing the decarbonization plan of the national energy matrix, recognizing the practices that generate additionality to processes of generating electricity from biomass. This bioelectricity must be recognized as a source of carbon credits, which can encourage its production and which has, as a consequence, an incentive to prevent it from becoming dirtier. This study provides insights about how a framework may help public policies to consider a systemic approach energy-wise. Further studies could investigate the economic effects of this systemic framework on the CBio emission surplus and the increase of mandatory participation, such as the inclusion of electricity distributors. Additionally, further studies could estimate the increase in electricity generation by other energy routes, such as changing low-pressure boilers to high-pressure boilers and using sugarcane straw as fuel for energy production.

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References

1. UN – United Nations, (2011) Sustainable Energy for All: Energy powers opportunity. It transforms lives, economies, & our planet. Available: https://www.un.org/millenniumgoals/pdf/SEFA.pdf (accessed Oct. 21, 2022)
2. UN - United Nations, (2020) Goal 7 | Department of Economic and Social Affairs. https://sdgs.un.org/goals/goal7 (accessed Sep. 12, 2022).
3. Ritchie H, and Roser M, (2020) “Energy mix,” Our World in Data. Available: https://ourworldindata.org/energy-mix (accessed Sep. 29, 2022).

4. Jackson T, (2011) Prosperity without Growth: Economics for a Finite Planet. London: Routledge. doi: 10.4324/9781849774338.
5. Polzin F, Migendt M, Täube F A, and Von Flotow P, (2015) Public policy influence on renewable energy investments—A panel data study across OECD countries, Energy Policy, vol. 80, pp. 98–111, doi: 10.1016/j.enpol.2015.01.026.
6. EPE - Empresa de Pesquisa Energética (Brasil), "Brazilian Energy Balance 1970-2021," Rio de Janeiro: EPE, 2021. Available: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-145/topico-515/Cap%C3%ADtulo%201%20(An%C3%A1lise%20Energ%C3%A9tica%20e%20Dados%20Agregados)%201970-2021.xls (accessed Apr. 05, 2023)
7. Steinberger J K, (2016) Energising Human Development. Available: http://hdr.undp.org/en/content/energising-human-development (accessed Nov. 27, 2022).
8. UNICA - União da Agroindustria Canavieira do Estado de São Paulo (2022), Observatório da Cana, Observatório da Cana. https://observatoriodacana.com.br/ (accessed Dec. 19, 2022).
9. Salina F H, de Almeida I A, and Bittencourt F R, (2020) RenovaBio Opportunities and Biofuels Outlook in Brazil, in Renewable Energy and Sustainable Buildings: Selected Papers from the World Renewable Energy Congress WREC 2018, Sayigh A, Ed. Cham: Springer International Publishing, pp. 391–399. doi: 10.1007/978-3-030-18488-9_30.
10. ANP - Agência Nacional do Petróleo, Gás Natural e Biocombustíveis, (2021) Metas individuais compulsórias definitivas de redução de emissões de gases causadores do efeito estufa para 2021. Available: https://www.gov.br/anp/pt-br/assuntos/renovabio/metas-individuais-compulsorias-definitivas-de-reducao-de-emissoes-de-gases-causadores-do-efeito-estufa-para-2021 (accessed Mar. 17, 2023).
11. CNPE - Conselho Nacional De Política Energética, (2019) Resolução No 15, De 24 De Junho De 2019.
12. Grassi M. C B, and Pereira G A G, (2019) Energy-cane and RenovaBio: Brazilian vectors to boost the development of Biofuels, Ind. Crops Prod., vol. 129, pp. 201–205, doi: 10.1016/j.indcrop.2018.12.006.
13. MME – Ministério de Minas e Energia (2017) 1a Reunião do Comitê RenovaBio." Ministério de Minas e Energia. Available: http://antigo.mme.gov.br/web/guest/conselhos-e-comites/crbio (accessed Sep. 29, 2022)
14. ANP - Agência Nacional do Petróleo, Gás Natural e Biocombustíveis, (2021).

Orientações Gerais: Procedimentos para Certificação da Produção ou Importação Eficiente de Biocombustíveis, 02/SBQ v. 4. Available: https://www.gov.br/anp/pt-br/assuntos/renovabio/ocr/informe-tecnico-02-sbq.pdf/view (accessed Jan. 17, 2023)

15. Cardoso M, and de Costa H K, (2020) RenovaBio, uma análise sobre o programa e sua influência no desenvolvimento do mercado do biometano," Rev. Bras. Energ., vol. 26, no. 3, doi: 10.47168/rbe.v26i3.573.

16. Morandin M A B, (2020) The science behind Brazilian Biofuels Policy – RenovaBio," Jul. 13. Available: https://www.embrapa.br/busca-de-noticias/-/noticia/54067756/article-the-science-behind-brazilian-biofuels-policy--renovabio (accessed Feb. 12, 2023).

17. Matsuura M I S F, Scachetti M T, Chagas M F, Seabra J, Moreira M M R, Bonomi A, Bayma G, Picoli J F, Morandi M A B, Ramos N P, Cavalett O, Novaes R M L, (2018) RenovaCalcMD: Método e ferramenta para a contabilidade da Intensidade de Carbono de Biocombustíveis no Programa RenovaBio," Technical Note.

18. de Miranda M M, (2012) Fator de emissão de gases de efeito estufa da geração de energia elétrica no Brasil: implicações da aplicação da Avaliação do Ciclo de Vida, Universidade de São Paulo. doi: 10.11606/D.18.2012.tde-22012013-112737.

19. Luca V, Cagnoli P, Bonoli A, (2018) Estimation of environmental impacts of biomass power plants system at regional scale: The case study of Emilia Romagna (ITA): Methodology, data and results. In Life Cycle Assessment of Energy Systems and Sustainable Energy Technologies: The Italian Experience; Basosi, R., Cellura, M., Longo, S., Parisi, M.L., Eds.; Springer: Cham, Switzerland, pp. 194–209.