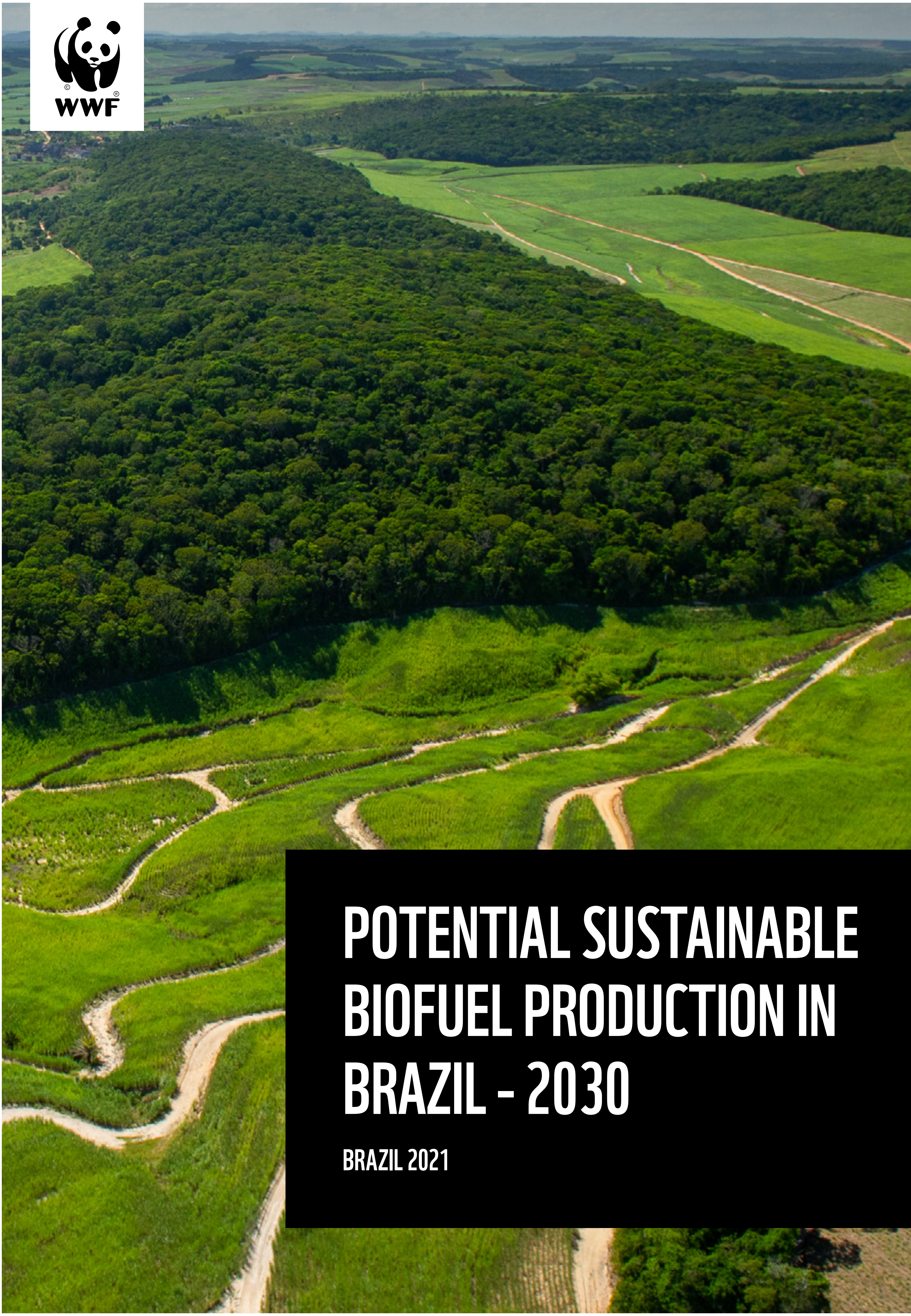

# POTENTIAL SUSTAINABLE BIOFUEL PRODUCTION IN BRAZIL - 2030

BRAZIL 2021

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## SUMMARY


COVER LETTER 5

Introduction 6

Biofuels used in transport in Brazil 6

Effects on transport matrix and carbon emissions 8

ADVERSE IMPACTS OF BIOFUELS 10

Competition with other crops 10

Deforestation 11

Solutions to control the impact of biofuels 11

PRODUCTION POTENTIAL - 2030 14

Ability to meet the demand of the transport sector 16

Reduction of carbon emissions and reflection on Brazilian contributions to the climate 18

Main assumptions and limitations of estimates 21

CONCLUSIONS 22

The supply potential is high, but it is not able to supply all the demand of the Brazilian transport sector 23

The use of biofuels reduces GHG emissions, but there are other alternatives such as modal diversification, electrification fleet and forest restorationl 23

PUBLIC POLICIES RECOMMENDATIONS 26

RenovaBio 26

Carbon pricing and other fossil fuel externalities 26

Control mechanisms 26

Technological development 26

Biofuels as niche solution 26

Residues 27

APPENDIX 28

REFERENCES 38


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# COVER LETTER

Combating climate change is the greatest challenge humanity has ever faced. Among the sectors that emit the most greenhouse gases (the so-called GHGs), transportation is where change is most complicated. Overall, transport accounts for about a quarter of all GHG emissions and is the sector where these numbers have grown most (UNEP, 2019).

Currently, fossil fuels are still the main viable option to ensure the autonomy that vehicles need. This dependence on oil in Brazil became even clearer in June 2018, during the truckers' strike against the rise in fuel prices.

Motivated by the oil crisis of the 1970s, Brazil adopted sugarcane ethanol as a substitute for gasoline with Proálcool. In 2019, almost fifty years after the start of Proálcool, ethanol consumption was 36 billion liters, corresponding to 49% of the total in equivalent gasoline for light vehicles (thanks to flex engines and the presence of 27% ethanol in the gasoline mixture). In the aviation and maritime transport sectors, which have their own international agreements to reduce emissions, the use of biofuels represents a unique possibility for a transition period in the fight against climate change. In addition to reducing greenhouse gas emissions, biodiesel has the possibility to stimulate the agricultural sector, including family farming.

Thus, if biofuels on the one hand represent an option to reduce dependence on fossil fuels, the adoption of this type of fuel cannot run the risk of generating more deforestation, appropriating land that could be destined for food production and forest restoration or even cause more impacts in the face of the challenge of climate change. If this happens, its advantages fall apart and instead of being part of the solution run the risk of worsening the problem.

In addition, it is essential that the expansion of biofuel production, if it occurs, is exclusively in degraded areas, eliminating the possibility of converting native areas, incorporating the effective implementation of the forest code and compliance with environmental legislation.

The objective of WWF-Brazil in conducting this study is to contribute to the debate on the potential Brazilian capacity to produce biofuels in a sustainable way and to delimit the safeguards that must be taken throughout the process. The result is that, as long as it is well guarded by social and environmental concerns, biofuels can be an interesting alternative not only for the Brazilian rural sector, but also to support the country towards a low carbon economy. If these measures are ignored, the damage can be as traumatic as that of fossil fuels.

As in other sectors, the balanced analysis of Brazilian potential is a fundamental step towards defining policies that make emissions reduction targets more ambitious and ensure nature conservation and human development.

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# INTRODUCTION

Biofuels are biomass-derived fuels that can partially or totally replace petroleum and natural gas-derived fuels in combustion engines or other types of power generation[1]. Although biofuels were initially proposed as an alternative to ensure energy security in the face of oil scarcity, today they are considered as an option to combat climate change.

Because they are mostly from currently wasted plant crops or organic waste, there is a considerable decrease in greenhouse gas (GHG) emissions compared to fossil fuels when considering fuel life cycles. This, combined with the experience gained with Proálcool[2] and the National Program for Biodiesel Production and Use – PNPB[3] and the large share of the fuel market (49% and 10% of the consumption of light and heavy vehicles, respectively), makes biofuels an important part of Brazilian policy for compliance with the Paris Agreement.

## BIOFUELS USED IN TRANSPORT IN BRAZIL

In Brazil, the most widely used and known biofuel is first generation ethanol from the fermentation of sugarcane juice. With the advent of flex-fuel engines, ethanol can replace gasoline by up to 100%, and is typically used in light vehicles. Other biofuels, however, have been gaining ground, such as second-generation ethanol, biodiesel and biomethane. Second-generation ethanol, also called cellulosic ethanol or lignocellulose, is obtained from the breaking of cellulose chains present in plant fibers. This biofuel would allow the use of a much wider range of raw materials, including plant waste. However, currently, its development has run into obstacles and its mass production is not expected in the next decade[4].

Biodiesel is produced from the transesterification of vegetable oils and animal fat, being added to diesel and can even replace it. Several vegetable oils can be used such as soybean oil, palm, babassu, macaúba and castor bean, among others. It is also possible to use animal fat, such as bovine tallow, processing residue in refrigerators and butchers. Even the cooking oil used in frying can be transformed into biodiesel, offering as an additional benefit to the fuel the treatment of these residues.

Biomethane is produced by the filtration of biogas until it reaches the characteristics defined by the legislation[5]. Biogas, in turn, comes from anaerobic bio digestion of organic matter by bacteria, resulting in methane, carbon dioxide and other gases. Biomethane replaces natural gas, which, because it is a gaseous fuel, is mostly used in industry, commerce and homes, but also has vehicular use.

Biokerosene, produced by several chemical routes, has a composition similar to aviation kerosene (QAV), and can replace it. There are factories capable of producing it in Brazil, although its high cost limits its use both in the country and abroad to experimental flights and other tests.

The summary of the main characteristics of these biofuels can be found in the following table.

1. (ANP, 2017)
2. (Brasil, 1975)
3. (MAPA, 2004)
4. (EPE, 2020)
5. Regulamento Técnico ANP no 1/2015

## TABLE 1

*Biofuels main characteristics*

| BIOFUEL | ETHANOL | BIODIESEL | BIOKEROSENE | BIOMETHANE |
|---|---|---|---|---|
| **Replaces** | Gas | Diesel | Aviation kerosene (QAV) | Vehicular Natural Gas or Diesel |
| **Main raw materials** | Sugarcane, Corn | Soy, beef fat, waste oils and fats (OGR), palmacana | Cane, macaúba | Organic waste (e.g. vinasse and pie, sewage, animal waste) |
| **Current production (in billions L)** | 347.7 (2019)*<br>Corn: 1.3 (2019)* | 5.9 (2019)* | Not significant* | Not significant* |
| **Current participation in the energy mix** | 7% (2019)* | 1.84% (2019)* | <0.1% | <0.1% |
| **Area for the production of biofuels (there is millions – % total agricultural area)** | 4.3 (5.7%) | Soy: 5.08 (6.75%)<br>Palma: Not Significant | Not significant | It does not depend on own cultivation |
| **Area occupied by crops (There is millions – % total agricultural area)** | 8.6 (11.4%) | Soy: 35.8 (47.5%) | 8.6 (11.4)% | It does not depend on own cultivation |
| **Carbon intensity $gCO_{2eq}$/MJ)*** | 21 to 26<br>(24% to 30% of gas) | Soy: 27 (31% of diesel)<br>OCR: 3.8 (4% of diesel) | 35 (40% of QAV) | 4 to 7 (5 to 8% of GNV) |
| **Disadvantages** | Stimulates sugarcane monoculture, with little space for small producers | Most of the production from soy, with little room for small producers | Competes with ethanol for raw materials; high production cost | Requires effective integration with the activities that generate waste |

** source:[6]; ^source:[7]*

6 (EPE - a, 2020)
7 (EPE - b, 2020)

## EFFECTS ON BRAZILIAN FUEL SUPPLY AND CARBON EMISSIONS

Brazil is the country with the largest participation of biofuels in transport in the world, a process initiated with the creation of Proálcool in the 1970s and recently intensified with the PNPB, which stimulated the production of ethanol and biodiesel. Even with the drop in production in recent years, ethanol accounts for 49% of consumption in light vehicles (gasoline sold to consumers also has 27% anhydrous ethanol in its composition)[8], while biodiesel accounts for 11% of diesel sold since October 2019. This participation, in addition making the Brazilian fuel supply for transportation partially renewable, contributes to its diversification, making it less sensitive to problems with the supply of oil and natural gas derivatives.

The use of biofuels contributes to the reduction of greenhouse gas emissions, because the biomass that gives rise to them absorbs the CO2 emitted in the burning of biofuel. The reduction in greenhouse gas emissions varies depending on the biofuel and fossil fuel it replaces. In general, one liter of fossil fuel emits just under 3 kg of $CO_{2eq}$, and the emission factor of diesel is the largest and that of natural gas, the smallest. Although a 100% reduction in emissions was expected since during burning the gases that were absorbed during plant growth are released. In fact, the methodology adopted by national emissions inventories assumes that, and includes indirect emissions (e.g., Biofuel transportation) in yearther chapter of the inventory. Although, both the IPCC methodology and the RenovaBio[9] assess that biofuels have emissions greater than zero. This is because they consider emissions beyond burning, which include the remainder of the life cycle of fossil and renewable fuels, such as emissions from the production inputs or transport of biofuel.

In any case, both methodologies show that the use of biofuels allows significant reductions in greenhouse gas emissions, especially when produced in a complementary way to other agricultural activities or from waste.

Storage silo for soybeans and other agricultural commodities

8. (EPE - a, 2020)
9. (Brasil, 2017) - RenovaBio is a national policy (Law No. 13,576 / 2017) that seeks to recognize the strategic role of all types of biofuels in the Brazilian energy matrix, both for energy security and for mitigating the reduction of greenhouse gas emissions (MME, 2017) http://www.mme.gov.br/web/guest/secretarias/petroleo-gas-natural-e-combustiveis-renovaveis/programas/renovabio/principal).


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# ADVERSE IMPACTS OF BIOFUELS

If, on the one hand, biofuels contribute to reducing emissions and increasing the generation of jobs in Brazil (in 2015, almost 800,000 jobs, or about 8% of the total jobs in renewable energy in the world was in Brazil[10]), its production can cause adverse impacts on the environment and society, making its use unsustainable. The main impacts are deforestation and competition with food production. These problems and possible solutions are discussed below.


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## COMPETITION WITH OTHER CROPS

Biofuels should not affect continuous food production and must not harm either the environment or society to be considered sustainable. Despite this, sugarcane and soybean, the main supplies currently used in biofuel production in Brazil, are typically produced in large-scale monoculture systems, which provide few ecosystem services and have part of their destination for food.

Some studies associate with the production of biofuels in European countries the decrease in food production or suppression of native vegetation in other areas[11], indicating that some regions stop producing food to produce biofuels. In Brazil, there is no evidence of significant competition between biofuel production and food in such way as to harm supply. In the case of sugarcane, the harvest is currently destined in similar quantities to ethanol production and sugar production. As much as this proportion is determined by the market prices of these two commodities, there is no record of a lack of sugar supply, and even the effect of this competition on the price is controversial[12]. In any case, it is necessary to consider this limitation when planning the growth of sustainable biofuel production in the long term.

## DEFORESTATION

The production of biofuels cannot also be considered sustainable if it causes, directly or indirectly, the conversion of natural ecosystems. From an environmental perspective, an area of native vegetation is more important than the production of biofuels due to the ecosystem services provided there. The production will not be sustainable if, even occurring in areas already converted, it causes deforestation by the displacement of the activity previously developed in the area (indirect land use change – iLUC). In Brazil, this phenomenon was observed with soybeans, responsible for the displacement of livestock to the borders of the Amazon, causing deforestation of this biome[13].

In 2016, the Brazilian government considered that the country still had agricultural land (144 million ha, twice the area currently destined for agriculture) in sufficient quantity not to affect food production and to avoid deforestation of the Amazon Forest, the Pantanal and the remaining fragments of the Atlantic Forest[14]. However, this estimate was based only on legal impediments to deforestation at the time and considered as a possible area of expansion part of natural habitats of the Cerrado and Caatinga.

The present study assumes that the production of biofuels from deforested areas is not sustainable, which is why it considers as reference the areas already converted or degraded by 2014[15], unlike the current policy, which considers degraded areas until 2018.

## SOLUTIONS TO CONTROL THE IMPACT OF BIOFUELS

There are solutions that allow the increase in biofuel production without the need to expand the cultivated area, avoiding food shortages and the impairment of Brazilian biomes. The increase in production yields is one of them. Great efforts have been made to increase both productivity in the agricultural phase (t/ha) and in the industrial phase, when biomass is transformed into biofuel (L/t). The increase in productivity may come from incremental improvements, related to the selection of varieties of crops more appropriate to processing (sugarcane with higher sugar content, for example) and improvement of production processes, especially in the production of biokerosene and biodiesel, cases in which production chains are more recent. In addition, increased productivity can also come from disruptive innovations, such as

**BIOFUELS SHOULD NOT AFFECT CONTINUOUS FOOD PRODUCTION AND MUST NOT HARM EITHER THE ENVIRONMENT OR SOCIETY TO BE CONSIDERED SUSTAINABLE**

**THE PRODUCTION WILL NOT BE SUSTAINABLE IF, EVEN OCCURRING IN AREAS ALREADY CONVERTED, IT CAUSES DEFORESTATION BY THE DISPLACEMENT OF THE ACTIVITY PREVIOUSLY DEVELOPED IN THE AREA**

10. (IRENA, 2018)
11. (HLPE, 2013) e (CCE, 2015)
12. (Renzaho et al 2017)
13. (Richards et al 2014)
14. (EPE, 2016)
15. (Strassburg et. al, 2014)

**THERE ARE SOLUTIONS THAT ALLOW THE INCREASE IN BIOFUEL PRODUCTION WITHOUT THE NEED TO EXPAND THE CULTIVATED AREA, AVOIDING FOOD SHORTAGES AND THE IMPAIRMENT OF BRAZILIAN BIOMES**

the development of a new biochemical route (as should be the case with cellulosic ethanol).

Another option is the use of alternative raw materials. An example is macaúba, a native palm species that has a much higher yield than soybeans in oil production (4000 kg/ha compared to 500 kg/ha of soybean) that can be converted into biokerosene and biodiesel[16]. In many cases, such crops can be integrated into crop-livestock-forest (ILPF) systems, optimizing land use with benefits for land productivity and resilience[17]. If it is possible to produce these alternative raw materials in line with family farming and ILPF systems, they are excellent possibilities.

The increase in productivity can also occur in livestock, which currently accounts for 70% of the farmland occupied in the country. As livestock productivity increases, there will be free space for growing food and biofuels. The use of these areas, as well as the pasture areas currently degraded, can be considered sustainable, as it does not imply the conversion of natural areas and does not prevent food production. Analyses show that an increase in livestock productivity from the current 32-34% to the potential of 49-52% would release 36 million ha for agricultural expansion, an area sufficient to accommodate the expansion of food[18] and biofuel production.

Finally, the energy use of municipal and agricultural waste can be increased, including for the production of biofuels[19]. This type of raw material is particularly interesting from an environmental point of view because, in addition to contributing to the energy contribution, it also reduces the amount of waste and pollutants deposited in the environment. There is potential for a large increase in biomethane production from the controlled decomposition of agricultural waste and municipal landfills, and the first production plants have already been installed in Brazil[20]. It should be noted that, although biomethane is the main biofuel obtained through the reuse of waste, it is also possible to produce biodiesel and biokerosene from materials that are currently wasted.

Nelore cattle on green pasture.
São Paulo, Brazil

16. (Simone Palma Favaro - Embrapa Agroenergia, personal communication)
17. (Lobato, 2017)
18. (MAPA, 2019)
19. (FGV, 2017)
20. (CBiogás, 2015), (Electrical sector, 2016) and (CBiogás, 2017)

# PRODUCTION POTENTIAL – 2030

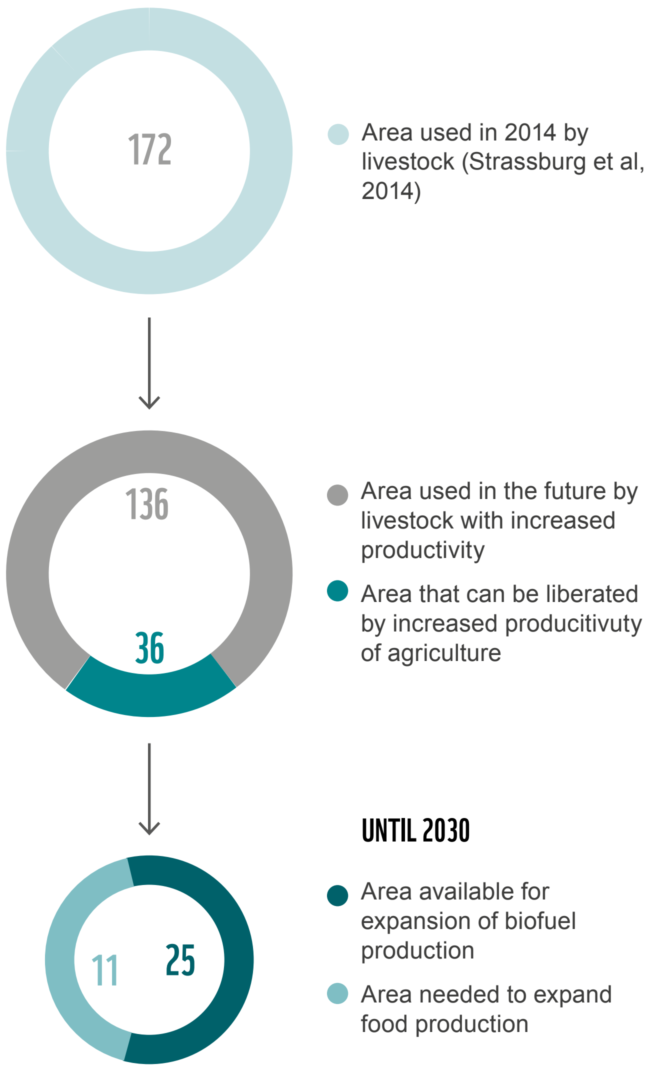
In view of the benefits and threats related to the production and consumption of biofuels, it is essential to evaluate what is the potential sustainable supply of biofuels that Brazil is able to guarantee. In other words, how far can the fuel matrix be made more renewable and reduce carbon emissions without causing further deforestation and harming food security?

With this in mind, the potential for biofuel production was calculated in 2030, the last year to achieve the goals proposed in the Brazilian first NDC[21] as defined in the Paris Agreement. For this, conservative projections of increase in yield in production, crop diversification and other biomass sources were considered (Annexes 1 and 2). The available area considered is that of the relocation of areas currently degraded or low productivity, typically composed of pastures. Based on calculations by Strassburg et al (2014), the increase in productivity of Brazilian livestock can release 36 million ha for other uses without the need for deforestation of native areas.

From this released area (36 million ha[22]), the amount needed to meet the demand for food was subtracted, calculated from the extrapolation to 2030 of official government projections made by MAPA[23], thus obtaining the area available for biofuel production in 2030. As the area demanded by the expansion of food production was estimated at 11 million ha, about 25 million ha would be available for the expansion of biofuels (Figure 1).

**FIGURE 1**

*Explanatory scheme for calculating the area available for biofuel production in 2030. The available area comes from the expectation of increased herd productivity between 2014 and 2030, freeing up the area for food and biofuels production.*



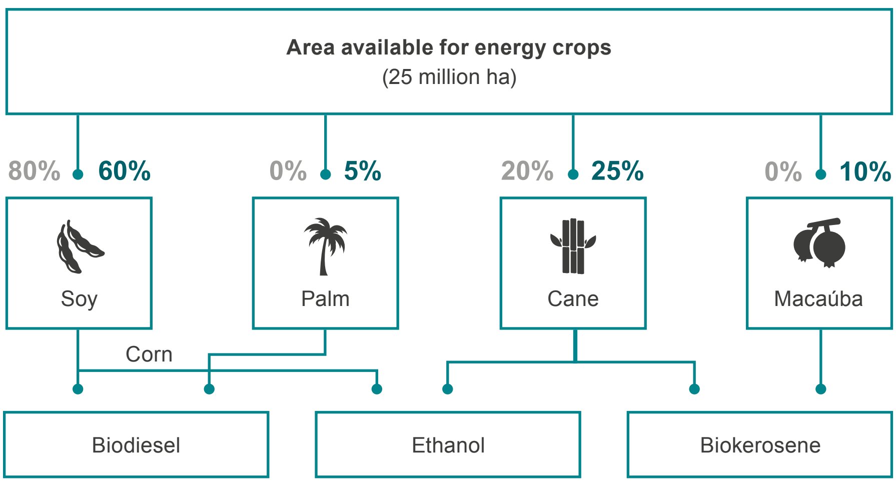

21. NDC stands for Nationally Determined Contribution. It corresponds to the set of commitments made by the countries in the Paris Agreement to contribute to climate change mitigation and adaptation to its effects.
22. (Strassburg et al, 2014)
23. (MAPA, 2019)

Based on the available area and current production, two scenarios of potential supply for 2030 were created composed of the production of ethanol, biodiesel, biokerosene and biomethane, which varied in the percentage of this area that would be destined for each crop (Figure 2; Table 2). The scenarios were created considering two opposite situations of biofuel production: (1) agribusiness, focusing on production in current commodities and monocultures and (2) alternative, increasing the importance of the participation of crops currently underexploited, but which offer higher yield in production (Figure 2; Table 2). Sugarcane, soybean, macaúba and palm crops were considered, as well as the expected productivities by MAPA[24], MME[25] and FGV26 for each of them (Annexes 1 and 2).


## HOW FAR CAN THE FUEL MATRIX BE MADE MORE RENEWABLE AND REDUCE CARBON EMISSIONS WITHOUT CAUSING FURTHER DEFORESTATION AND HARMING FOOD SECURITY?

### FIGURE 2

*Explanatory projection scheme. Each crop and its respective biofuels that would be planted in the area released by increased herd productivity, subtracted from the area needed for food production. The two scenarios vary in the percentages of the degraded area that would be destined for each crop.*





### TABLE 2

*Percentage of the area destined to each crop in each projection scenario, as well as the total area cultivated as a result of this percentage.*

| SCENARIOS | Percentage of available crop area | | | | Crop area dedicated to biofuels (millions ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | * | * | | |
| | 20.0 | 80.0 | 0.0 | 0.0 | 16.2 | 35.4 | 0.0 | 0.0 |
| | 25.0 | 60.0 | 10.0 | 5.0 | 17.4 | 30.4 | 2.5 | 1.2 |
| Current value (18/19) | – | – | – | – | 4.3 | 7.2 | ? | ? |

24. (MAPA, 2019)
25. (MME, 2020)
26. (FGV, 2017)

**LEGENDA**

- Soy
- Palm
- Cane
- Macaúba

Production potentials were also estimated from other biomass sources that do not depend on the expansion of the agricultural area, such as bovine tallow and cooking oil for biodiesel production, and municipal solid waste, sewage and agricultural waste for biomethane production. Finally, the potential of biomethane production was calculated from vinasse, a by-product of ethanol. The analyses also considered the increase in productivity from the use of the rotation of corn and soybean crops, enabling the production of ethanol from corn, a practice that has grown considerably in recent years (Figure 2). However, due to technological challenges in the implementation of second generation ethanol and the low expectation that it will be viable in 2030, this biofuel was not considered.

## ABILITY TO MEET THE DEMAND OF THE TRANSPORT SECTOR

It is observed that the potential for biofuel production is lower in the scenario where current commodities are prioritized, since the fuel productivity of these crops by area is lower than that of other crops (table 3). It is also observed a high potential of biodiesel and biogas production from waste, which in environmental terms are the most advantageous (table 3 and table 4).

### TABLE 3

*Result of the production projections of liquid biofuels for each scenario and the comparison with the current production. The productions that are independent of the projected cultivation area (cooking oil biodiesel and bovine tallow biodiesel) are the same between scenarios.*

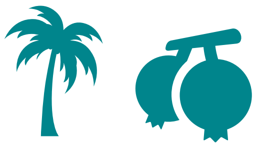
| SCENARIOS | Total production (billions L) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ethanol | Ethanol | Bio diesel | Bio diesel | Bio kerosene | Bio kerosene | Bio diesel | Bio diesel |
|  | 58.1 | 15.5 | 16 | 0 | 8.9 | 0 | 35.2 | 1.43 |
|  | 65.3 | 14.1 | 13 | 7.2 | 10 | 10 | | |
| Current value (18/19) | 34.81 | 0.06 | 4 | 0.12 | Not significant | Not significant | 0.09 | 0.66 |

### TABLE 4

*Result of biomethane production projections. Since most of the productions are independent of the projected cultivation area, with the exception of vinasse, no distinction was made between the scenarios for biogas.*

| SOURCE | | Production (millions $m^3$/day) | Demand met |
|---|---|---|---|
| Urban | RSU | 5.7 | 78% |
| | Sewer | 1.2 | 17% |
| Rural | Vinasse* | 7.4 | 101% |
| | Poultry | 9.4 | 129% |
| | Porcine | 4.1 | 56% |
| | Bovine | 5.2 | 72% |
| **Total** | | **32.7** | **447%** |

The analysis of the potential for sustainable supply of biofuels shows that it would be possible to ensure food supply and meet the demands defined in the legislation for the addition of ethanol, biodiesel and biokerosene[27] in fossil fuels in 2030 (Table 5).



**THE SCENERY WITH PALM AND MACAÚBA IS THE BEST MEETS DEMAND AND MORE OFFERS BENEFITS TO ENVIRONMENT**

### TABLE 5

*Percentage of legal demand, i.e. % of the mandatory mixture in fossil fuels, which would be met considering the production potential in each scenario.*

| SCENARIOS | ETHANOL | BIODIESEL | BIOKEROSENE |
|---|---|---|---|
|  | 176% | 473% | 9000% |
|  | 189% | 511% | 19000% |

However, it is not possible to meet the total Brazilian demand for liquid fuels in 2030. Ethanol production in the various scenarios would supply a maximum of 78% of demand (107 billion liters), while biodiesel production would meet, in the best case scenario, 58% of demand (103 billion liters; table 6). Only the total demand for kerosene (13 billion liters) could be reached, but only in the alternative scenario, which favors high yield crops (table 6).

* Considers the vinasse available in the scenario with higher sugarcane production. The comparison is with the total demand for natural gas in the transportation sector.

27. Based on the PDE estimates, 2029 and percentages of ethanol addition in gasoline and biodiesel in diesel and the estimates resulting from the application of RenovaBio, the demand for ethanol in 44 billion liters, diesel demand at 11.7 billion and biokerosene are estimated at 0.1 billion liters.

**TABLE 6**

*Percentage of total demand, i.e. total replacement of fossil fuels by biofuels, which would be met considering the production potential in each scenario.*

| SCENARIOS | ETHANOL | BIODIESEL | BIOKEROSENE |
|---|---|---|---|
|  | 72% | 54% | 72% |
|  | 78% | 58% | 158% |

For CNG, it is possible to supply the projected demand if biomethane production sources are diversified. Demand is projected at 7.3 million m³/day for transport by 2030[28]. The projections made in this study indicate a production potential of 32.7 million m³/day (Table 4), a value almost five times higher than the demand. This estimate considers that only part of biogas production (which gives rise to biomethane) will be destined for transport. Even so, the large supply of biomethane would replace part of diesel consumption, especially in rural properties. According to FGV[29], biomethane could supply up to 44% of diesel consumption in the transport sector.

Among the scenarios evaluated, the one that presented the highest capacity to meet the demand of all liquid fuels was the alternative scenario, which privileges palm and macaúba crops. This scenario also contributes to the higher production of biomethane because it maintains the highest production of ethanol and, therefore, biomethane from vinasse. Although the agribusiness scenario has the advantages of (1) having complementarity in the production of biodiesel and bran, since soybean processing produces bran and oil, the latter biodiesel's input, (2) take advantage of the productive chair and distribution that already exists for these commodities, and (3) depend less on technological advances to be achieved in the next decade , the alternative scenario represents greater benefits for the environment because it makes room for the cultivation of native plants and can be cultivated together with other crops in agroforestry systems (SAF) or integrated cropland-livestock-forestry systems (ICLFS), without prejudice to their production.

It should be considered that the rate of expansion of Brazilian agricultural activity necessary to occupy 25 million hectares by 2030 is much higher than the historical average in Brazil. Considering that it would be stimulated mainly by the expansion of biofuels, only very aggressive incentives could make the production of biofuels reach their full potential. It would even be necessary to ensure that such incentives did not stimulate deforestation, legal and illegal.

## REDUCTION OF CARBON EMISSIONS AND REFLECTION ON BRAZILIAN CONTRIBUTIONS TO THE CLIMATE

The reduction of carbon emissions provided by the adoption of biofuels is one of the main arguments for this alternative. In fact, emissions from the transport sector are significant: 200 million tonnes of $CO_{2eq}$ $CO_{2eq}$ in 2018, which corresponds to 10% of national emissions[30]. Thus, the contributions of the replacement of fossil fuels

28. (EPE, 2016)
29. (FGV, 2017)
30. (OC, 2020)
31. There are doubts as to whether Brazil will maintain this calculation. The reason for this is that the value of emissions in 2005 was revised to 2.8 billion tons of CO2 in the 3rd Brazilian emissions inventory, published the year after the Paris Agreement (MCTIC, 2016)
32. (Searchinger et al, 2017)
33. (Righelato & Spracklen, 2007)

by biofuels that can be produced in a sustainable way in two ways were calculated: according to the IPCC methodology and with that of RenovaBio, which considers the complete life cycle of biofuels. These contributions were compared with the Brazilian emissions target for 2030 (tables 7 and 8, respectively).

### TABLE 7

*Potential for reduction of $CO_{2eq}$ emissions in 2030 according to the methodology established by the IPCC.*

| SCENARIOS | ETHANOL (1t ton $CO_2$/ year) | BIODIESEL (1t ton $CO_2$/ year) | BIOKEROSENE (1t ton $CO_2$/year) | BIOMETYEAR (1t ton $CO_2$/year) | Total (1t ton $CO_2$/ year) | Contributions to NDC reduction - 2030 |
|---|---|---|---|---|---|---|
|  | 145.4 | 150 | 25.61 | 29.8 | 350 | 39% |
|  | 156.8 | 162.2 | 56.4 | 30.58 | 406 | 45% |

### TABLE 8

*Potential for reduction of $CO_{2eq}$ emissions in 2030 according to the methodology established by RenovaBio*

| SCENARIOS | ETHANOL (1t ton $CO_2$/ year) | BIODIESEL (1t ton $CO_2$/year) | BIOKEROSENE (1t ton $CO_2$/year) | BIOMETYEAR (1t ton $CO_2$/ year) | Total (1t ton $CO_2$/year) | Contributions to NDC reduction - 2030 |
|---|---|---|---|---|---|---|
|  | 96.7 | 103.6 | 15.5 | 26.4 | 242 | 27% |
|  | 108.6 | 112 | 34.16 | 27.1 | 281 | 31% |

The first Brazilian NDC stipulate a reduction in emissions by 43% below 2005 levels in 2030. Emissions in 2005 considered for the setting of targets were 2.1 billion tons of $CO_{2eq}$[31]. This reduction is quite significant, reaching almost 1/4 of the decrease with which Brazil committed itself in the Paris Agreement. In this sense, the use of biofuels brings a great benefit to the reduction of Brazilian emissions while making the energy matrix more renewable and less dependent on fossil fuels. Even when the complete life cycle is considered, contributions to CSD are still significant, although with a smaller reduction difference between scenarios.

Nevertheless, the adoption of biofuels may not be the best alternative for reducing GHG emissions in the medium and long term, since the land occupied by crops for their production can absorb more carbon if they are reforested to restore the biome, even partially[32]. It would even be possible to associate forest restoration with solar energy, ensuring energy supply and environmental protection[33]. However, this strategy is not yet feasible in the short term because it is a disruptive solution, without legal bases and still expensive. Because there are already legal incentives and ongoing research, biofuels are a transition option in the coming years to meet NDC targets. However, it is important to reinforce its transitory nature and that, concomitantly with the use of biofuels, it is essential to create legal and fiscal mechanisms that enable the reduction of GHG emissions considering the maintenance of local biodiversity, such as the practices described above. This practice will not only allow the development of cleaner energy, but will also allow the use of energy generation in a scenario of negative emissions, capturing atmospheric carbon dioxide.

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## MAIN ASSUMPTIONS AND LIMITATIONS OF ESTIMATES

This analysis was based on data from the 2029 Decenal Energy Plan[34], Agribusiness[35] and FGV[36] Projections. The estimates, based on a top-down approach, indicate the total potential for sustainable supply of biofuels, not representing biased scenarios. Utilization factors were estimated for some raw materials, including 70% of the cooking oil used for biodiesel production, 80% of the biogas produced by vinasse destined for biomethane production and the use of sewage only in cities with more than 100,000 inhabitants (Appendix 3).

No costs and cultivation logistics were considered in the areas in question, nor were it determined which degraded areas would be occupied. No possible social impacts of increased biofuel production have been computed, even though this has been considered in the selection of crops for the elaboration of scenarios. Finally, complementary environmental impacts were not considered, such as water use and river pollution caused by the excessive use of pesticides. A study considering edaphoclimatic conditions (related to climate and soil) of the available areas, as well as socioeconomic aspects of each region would be of great contribution to the effectiveness of sustainable biofuel production.

Two emission reduction calculations were performed: one in line with the procedures recommended by the IPCC for carrying out national inventories, which considers zero emissions in the burning of biofuels and the other according to renovabio's methodology, which considers the life cycle and assumes that biofuels also emit GHGs through the materials used in production or transport, for example. For fossil fuels, the $CO_2$ emission factors presented in the national inventories were considered[37]. In none of the calculations were considered the carbon emissions or capture stemming from direct land use change[38] (dLUC) possibly caused by biofuels. Finally, the reductions provided by the proper processing of urban and agricultural waste, part of which emit methane, a powerful GHG, during its natural decomposition are not included. This would further increase the contribution of this type of biofuel to the reduction of GHG emissions.

34. (MME, 2020)
35. (MAPA, 2019)
36. (FGV, 2017)
37. (ANAC, 2014) e (MMA, 2014)
38. The migration of pastures to energy crops can increase or decrease the carbon present in the soil. In general, degraded pastures have low carbon content, which tends to increase when receiving perennial or semi-perennial crops. Measurements carried out in Brazil indicate that even when considering pastures in better conditions and emissions from soil preparation for sugarcane ethanol production, carbon emissions from this process are offset between two and three years (Mello et al, 2014 and Galdos et al, 2010).

# CONCLUSIONS

## IT IS POSSIBLE TO PRODUCE BIOFUELS WITHOUT COMPROMISING THE SUPPLY OF FOOD AND THE PRESERVATION OF NATURAL HABITATS IF APPROPRIATE CONTROL MECHANISMS AND PUBLIC POLICIES ARE ADOPTED

Brazil has more than 170 million hectares of pasture, which have an average productivity of 33%[39]. Increasing this productivity to 50% would make 36 million hectares available for crops in general, an area more than enough to accommodate the expansion of food and biofuel production for several decades. Although the increase in the supply of biofuels can be obtained by optimizing the use of existing pastures, it is necessary to ensure that this growth does not stimulate the occupation of inadequate or even irregular areas, threatening the conservation of natural ecosystems. To this end, it is essential to apply and improve existing mechanisms for land use control, such as the Rural Environmental Registry (CAR) and agroecological zoning. Moreover, alternatives to monoculture-based production need to be explored on a larger scale. The use of native species such as macaúba and crop-livestock-forest integration can offer economically attractive levels of productivity and diversification.


Although there are sufficient-scale agricultural areas to accommodate biofuel production without compromising food supply, competition for land use can lead to price increases and even shortages of some crops. An example is the case of sugar and ethanol, where the price increase of one tends to decrease the supply of the other, and vice versa. On the other hand, there are cases in which there is a certain complementarity, such as in the production of soybean meal, which has as a by-product soybean oil, used in biodiesel production. Public policies for the biofuels sector should consider these dynamics so as not to compromise food supply.

39. (Strassburg, 2014)

## THE SUPPLY POTENTIAL IS HIGH, BUT IT IS NOT ABLE TO SUPPLY ALL THE DEMAND OF THE BRAZILIAN TRANSPORT SECTOR

The potential for sustainable supply of biofuels is able to meet the targets currently planned for the expansion of biofuels in the Brazilian energy matrix, but it is not enough to meet all the demand for fossil fuels planned for 2030. In the analyzed scenarios, even prioritizing the production of ethanol and biodiesel, it would not be possible to meet the total demand of the Brazilian fleet of road vehicles.

On the other hand, it is possible to meet the demand for VVO and CNG through the production of biokerosene and biomethane. This can even be better used: biomethane can be the fuel in the fleet of light and heavy vehicles used in the agricultural sector, eliminating the need to create an extensive distribution network. Biomethane can also be used in other activities, replacing natural gas in both rural and urban regions.

Given the difficulty of the adoption of electric propulsion systems in aviation, a public policy for increasing renewables in the transport sector could prioritize the production of biofuels for civil aviation, while stimulating the electrification of the fleet of road vehicles – for which the adoption of hybrid or purely electric systems is increasingly feasible.

## THE USE OF BIOFUELS REDUCES GHG EMISSIONS, BUT THERE ARE OTHER ALTERNATIVES SUCH AS MODAL DIVERSIFICATION, FLEET ELECTRIFICATION AND FOREST RESTORATION

Replacing fossil fuels with biofuels reduces GHG emissions even when considering the indirect emissions involved in their production and distribution. In addition, the adoption of renewable fuels is a necessary step towards long-term energy sustainability. Still, the use of biofuels is not a definitive solution or the only alternative to these needs.

In addition to other alternative fuels, it is possible to reduce consumption through the diversification of transportation modals, expanding the use of railways and waterways, increasing vehicle energy efficiency and expanding public transport in cities, among other actions.

With regard to the balance of emissions, analyses indicate that the forest restoration of areas that would otherwise be destined to biofuels provides much more intense and fast carbon capture, an important factor when considering the need to reduce emissions in the shortest possible time to limit global warming to a maximum of 20ºC, seeking 1.50ºC.

From an energy perspective, technological developments in electric vehicles offer an increasingly attractive option for reducing emissions from the transport sector as electricity generation from solar, wind and other alternative renewable sources becomes increasingly cheaper. In addition, it is possible to produce alternative fuels from various sources, including renewable ones.

**IT IS ESSENTIAL TO APPLY AND IMPROVE EXISTING MECHANISMS FOR LAND USE CONTROL, SUCH AS THE RURAL ENVIRONMENTAL REGISTRY (CAR) AND AGROECOLOGICAL ZONING**

Palm trees near Cachoeira Grande in Serra do Cipó, Minas Gerais, Brazil


© Vitor Marigo / WWF-Brasil

# PUBLIC POLICIES RECOMMENDATIONS

Even considering the full potential, biofuels produced on degraded land by 2014 and released by increased herd productivity – the only option for biofuels to be sustainable – are not enough to end fossil fuel consumption in transportation. In view of this, its use should be considered transitory and should be applied in conjunction with other alternatives. Therefore, the following public policies and actions are recommended:

## RENOVABIO

RenovaBio was a milestone for the biofuels sector in Brazil. However, this policy is focused on reducing emissions in combustion engines, disregarding other socio-environmental aspects, such as the valorization of family farming and biodiversity conservation. These criteria could be incorporated to assess the sustainability of the biofuel produced. Moreover, the fact that RenovaBio focuses on biofuels for combustion engines makes it impossible to include other low-carbon alternatives, such as hydrogen ($H_2$) and electric vehicles. Finally, it does not provide for the possibility of negatively issued fuels if associated with restoration/SAF/ILPF. This would make it possible, for example, to stimulate the restoration of degraded areas combined with the production of energy with solar panels, a practice already indicated as more efficient climatically and ecologically[40].

## CARBON PRICING AND OTHER FOSSIL FUEL EXTERNALITIES

RenovaBio should be associated with a policy of pricing carbon and other externalities caused by fossil fuels, which would allow the socio-environmental impacts they cause to society to be incorporated into fossil fuels. Such a policy would stimulate the development and adoption of low carbon fuels, contributing to the mitigation of Brazilian emissions and other socio-environmental benefits. In the short term, Cide (Contribution of Intervention in the Economic Domain) could be adjusted to make up this policy.

## CONTROL MECHANISMS

There must be, contrary to what is observed, an increase in the mechanisms of control of land use. Among them we can mention the establishment, improvement and creation of agroecological zoning specific for crops or for the production of biofuels; investments in the detection of iLUC and increased surveillance against deforestation.

## TECHNOLOGICAL DEVELOPMENT

The scenarios evaluated here consider the increase in productivity of several crops and the intensification of some crops currently focused on family farming. For this to be feasible, public policies are essential to increase investments in research and development in order to increase productivity of more promising crops associated with the creation of laws to protect production chains with family agriculture and SAF/ILPF models. These productive models, in addition to ensuring the socioeconomic aspect of sustainability, also ensure an increase in ecosystem services provided by the production[41] and maintenance of biodiversity[42].

## BIOFUELS AS NICHE SOLUTION

In the medium and long term, biofuels should be thought of as a solution for specific situations. For example, an island whose electricity generation is from diesel generators would benefit more from a fleet of ethanol-powered vehicles than a fleet of electric vehicles because, in addition to energy loss during the diesel burning process, ethanol emits less

GHG. This same island could benefit from replacing diesel with biodiesel. However, on the continent, where there are already commercially viable alternatives for electric vehicles and electricity is mostly obtained from renewable sources, it is necessary to plan to increase the fleet of electric vehicles, which would present low GHG emissions[43].

Another niche that biofuels must occupy for a longer time is aviation and maritime transport, in which electrification is not yet economically viable. In this way it is possible that biokerosene is needed longer than other biofuels. Taking this into account, incentives for research and development should be greater for this biofuel. In the scenarios it was considered that biokerosene can be produced from sugarcane and macaúba. For sugarcane the production chain is already established and in many cases near airports, which is why sugarcane production can help the production of biokerosene.

The macaúba, with higher yield than sugarcane, would be a good alternative for airports in the Midwest, where its natural distribution occurs. Public policies aimed at this crop should include protection of family farming and increased plant productivity in its natural habitat, encouraging SAF/ILPF production models.

## RESIDUES

Another recommended direction for public policies, mainly observed in biogas-related projections, is the increase of incentives for the reuse of agricultural and urban waste for the production of biofuels.

Analyses indicate that cooking oil could be used to produce biokerosene, which is why incentives to this alternative would allow the use of the oil collected in large centers, usually near airports. This would reduce oil pollution while facilitating the logistics of biokerosene production and distribution, reducing emissions in its full life cycle. On the other hand, biomethane can replace the use of diesel in the field by replacing part of the currently diesel-powered fleet. This substitution not only guarantees the reuse of waste but also reduces emissions of transport from diesel to the field.

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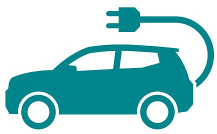

**THE PRODUCTION OF HYBRID VEHICLES IS A WAY TO TAKE ADVANTAGE OF THE BENEFITS PROVIDED BY BIOFUELS AND ELECTRIFICATION**

40. (Righelato & Spracklen, 2007)
41. (Lobato, 2016)
42. (Harvey & Villalobos, 2017)
43. (Fujii & Marin, 2017)

# APPENDIX I – DATA OBTAINED

| LAND | | |
|---|---|---|
| **DATA** | **VALUE** | **REFERENCE** |
| **Area released by the increase livestock productivity (million ha)** | 36 | Strassburg, B. B.N.; Latawiec, A. E.; Barioni, L. G.; Nobre, C. A.; da Silva, V. P.; Valentim, J.F.; Vianna, M.; Assad, E. D. When enough should be enough: Improving the use of current agricultural lands could meet production demands and spare natural habitats in Brazil. Global Environmental Change 28: 84–97, 2014. |
| **Total planted area in Brazil in 2019 (million ha)** | 75.4 | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Area destined for grains production (million ha) in 2019** | 62.8 | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Area destined for sugar cane production (million ha) in 2019** | 8.6 | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Minimum rate of cane growth until 2029** | -0.06% a.a. | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Maximum rate of cane growth until 2029** | 3.3% a.a | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Area destined for soy production (million ha) in 2019** | 35.8 | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Minimum rate of soy growth until 2029** | -0.03%a.a. | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Maximum rate of soy growth until 2029** | 4.6% a.a. | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |
| **Percentage of sugarcane area destined for ethanol** | 60.0% | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. |

| ETHANOL | | |
|---|---|---|
| **DATA** | **VALUE** | **REFERENCE** |
| **Ethanol legal demand – 2029** | 44000 | MME. Plano Decenal de Expansão de Energia 2029. Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília, 2019. |
| **Total Demand Ethanol – 2029** | 107000 | Previous Report. |
| **Emission factor for NDC hydrated ethanol** | 0 | Conversation with specialist Ricardo Fujii (WWF). |
| **Productivity of corn ethanol (L/ha)** | 3500 | ESTADÃO. Saiba as diferenças entre o etanol de milho e de cana de açúcar (2019). Disponível em: https://jornaldocarro.estadao.com.br/carros/diferencas-etanol-de-milho-e-decana-de-acucar/. Acessado em maio de 2020/ Justification: Considering the little data we have on the production of corn ethanol in Brazil and that the data found for productivity was the maximum value (compared to 8000 of sugarcane ethanol, for example - above that adopted by the PDE), it was not considered increase in productivity in the period. |
| **Sugarcane productivity 2029 (ton/ha)** | 83.4 | MME. Plano Decenal de Expansão de Energia 2029. Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília, 2019. |
| **Rate of increase in sugarcane productivity** | 1.2% a.a. | MME. Plano Decenal de Expansão de Energia 2029. Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília, 2019. |
| **Sugarcane: total recoverable sugar/ton** | 140* | MME. Plano Decenal de Expansão de Energia 2029. Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília, 2019. |
| **Hydrated ethane Yield (l'ART)** | 0.606* | MME. Plano Decenal de Expansão de Energia 2029. Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília, 2019. |
| | *multiplied by the growth rate of the period – very small – gives the same value. | |

| BIOGAS | | |
|---|---|---|
| **DATA** | **VALUE** | **REFERENCE** |
| **Yield of vinasse biogas (NL/L ethanol)** | 114 | ANA (2009). Manual de conservação e reúso de água na agroindústria sucroenergética. Agência Nacional de Águas; Federação das Indústrias do Estado de São Paulo; União da Indústria da Cana-de-Açúcar; Centro de Tecnologia Canavieira. – Brasília : ANA, 2009; 288p |
| **Sewage production/inhabitant *day (NL $CH_4$/inhab*day)** | 10.2 | Fujii, R. (2015). Estudo sobre viabilidade econômica e possíveis incentivos econômicos para alternativas tecnológicas para micro geração e geração descentralizada de energia (que contemple os aspectos eficiência, sociais, econômicos e ambientais). |
| **Production of MSW/inhabitant/ day (Kg)** | 0.948 | Fujii, R. (2015). Estudo sobre viabilidade econômica e possíveis incentivos econômicos para alternativas tecnológicas para micro geração e geração descentralizada de energia (que contemple os aspectos eficiência, sociais, econômicos e ambientais). |
| **Organic fraction of solid urban waste in the MSW** | 50.0% | Fujii, R. (2015). Estudo sobre viabilidade econômica e possíveis incentivos econômicos para alternativas tecnológicas para micro geração e geração descentralizada de energia (que contemple os aspectos eficiência, sociais, econômicos e ambientais). |
| **CH4/MSW ($Nm^3$/kg)** | 0.1 | Fujii, R. (2015). Estudo sobre viabilidade econômica e possíveis incentivos econômicos para alternativas tecnológicas para micro geração e geração descentralizada de energia (que contemple os aspectos eficiência, sociais, econômicos e ambientais). |
| **Number of pig heads in 2019** | 43679600 | Conab. Indicadores da Agropecuária. Companhia Nacional de Abastecimento. Brasília, 2019. Disponível em: www. conab.gov.br |
| **$CH_4$ production/swine head ($m^3CH_4$/head*day** | 0.144 | FOLHA DE LONDRINA. Em São Miguel do Iguaçu, uma granja do futuro. Disponível em: <https://www. folhadelondrina.com.br/folha-rural/em-sao-miguel-do-iguacu-uma-granja-do-futuro-961447.html> Acesso em: maio de 2020. |
| **Number of chick heads in 2019** | 6498200000 | Conab. Indicadores da Agropecuária. Companhia Nacional de Abastecimento. Brasília, 2019. Disponível em: www. conab.gov.br |
| **Waste production by chicken (kg/day *animal)** | 0.09 | BSG Equipamentos para Biogás. Saiba como fazer o cálculo da produção de Biogás. Disponível em: https://www. bgsequipamentos.com.br/calculo-da-producao-de-biogas/. Acessado em: maio de 2020 |
| **Methane yield/chiken waste ($m^3CH_4$/ton)** | 32 | Cabral, C. B. G. et al. Tecnologias de digestão anaeróbia com relevância para o Brasil: substratos, digestores e uso de biogás / Probiogás. Ministério das Cidades e GIZ. Brasília, 2015. |
| **Number of milked cow heads in 2019** | 16400000 | IBGE. 2019, Pesquisa Pecuária Municipal, https://sidra.ibge. gov.br/Table/94. Acessado em: maio de 2020. |
| **Biogas yield per milked cow ($m^3$/day*animal)** | 0.98 | COLDEBELLA, A. Viabilidade do uso de biogás da bovinocultura e suinocultura para geração de energia elétrica e irrigação em propriedades rurais. 2006. 74f. Dissertação (Mestrado em Engenharia Agrícola) – Universidade Estadual do Oeste do Paraná, Cascavel, 2006. |
| **Average percentage of Biomethane in the waste from milked cows** | 65% | COLDEBELLA, A. Viabilidade do uso de biogás da bovinocultura e suinocultura para geração de energia elétrica e irrigação em propriedades rurais. 2006. 74f. Dissertação (Mestrado em Engenharia Agrícola) – Universidade Estadual do Oeste do Paraná, Cascavel, 2006. |
| **Emission factor for NDC – Biomethane** | 0 | Conversation with specialist Ricardo Fujii (WWF). |

| BIOKEROSENE | | |
|---|---|---|
| **DATA** | **VALUE** | **REFERENCE** |
| **Legal Demand Biokerosene 2029** | 103 | MME. Plano Decenal de Expansão de Energia 2029. Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília, 2019. |
| **Total Biokerosene Demand 2029** | 12350 | Previous Report. |
| **Emission factor for NDC – Biokerosene** | 0 | Conversation with specialist Ricardo Fujii (WWF). |
| **Productivity of macauba's biokerosene (L/ha)** | 3833.33 | Biodieselbr. Macaúba é alternativa promissora para o Biodiesel (2016). Disponível em: https://www.biodieselbr.com/noticias/materia-prima/macauba/macauba-alternativa-promissora-para-o-biodiesel-150716. Acessado em: maio de 2020 |
| **Productivity of biokerosene sugarcane (L/ha)** | 4365 | Conversation with specialist João Paulo Rossi (Artemys) in 2016. |

| BIODIESEL | | | |
|---|---|---|---|
| **DATA** | **VALUE** | **REFERENCE** | |
| **Legal Demand Biodiesel 2029** | 11700 | MME. Plano Decenal de Expansão de Energia 2029. Ministério de Minas e Energia. Empresa de Pesquisa Energética. Brasília, 2019. | General Biodiesel |
| **Total Biodiesel Demand 2029** | 97850 | Previous Report. | |
| **Cattle herd in 2018 (millions)** | 31.9 | IBGE. 2019, Pesquisa Pecuária Municipal, https://sidra.ibge.gov.br/Table/3939. Acessado em: maio de 2020 | Cattle Lard |
| **Bovine production growth rate** | 1,7% a.a. | MAPA. Projeções do Agronegócio: Brasil 2018/19 a 2028/29. Ministério de Agricultura, Pecuária e Abastecimento. Brasília, 2019. | |
| **Biodiesel yield (Kg/head)** | 34 | Trigueirinho, F., Minelli, J.C., Tokarski, D.. Biodiesel: Oportunidades e Desafios no Longo Prazo. Aprobio (2016). | |
| **Biodiesel yield by cooking oil (L biodiesel/ton oil)** | 854.28 | Francechini, B.T. (2014). UTILIZAÇÃO DE ÓLEO DE FRITURA DESCARTADO PARA a PRODUÇÃO dE BIODIESEL. Universidade Federal do Rio grande do Sul. | Cooking Oil |
| **Amount of frying oil used in Brazil per month (million L)** | 5500 | O Estado de Minas. Óleo de Cozinha é transformado em Biodiesel. Disponível em:https://www.em.com.br/app/noticia/tecnologia/2016/02/29/interna_tecnologia,738403/oleo-de-cozinha-e-transformado-em-biodiesel.shtml. Acessado em maio de 2020. | |
| **Frying Oil density (kg/L)** | 0.891 | O Estado de Minas. Óleo de Cozinha é transformado em Biodiesel. Disponível em:https://www.em.com.br/app/noticia/tecnologia/2016/02/29/interna_tecnologia,738403/oleo-de-cozinha-e-transformado-em-biodiesel.shtml. Acessado em maio de 2020. | |
| **Productivity Soy biodiesel (L/ha) in 2019** | 590 | FGV. Biocombustíveis. FGV Energia Year 4, no 8. Rio de Janeiro, 2017. | Soy |

# APPENDIX II – PERFORMED CALCULATIONS

| LAND | | |
|---|---|---|
| **DATA** | **VALUE** | **CALCULATION** |
| **Average projected cultivation area of sugarcane in 2030 (million ha)** | 10.63 | Average of the minimum and maximum areas estimated for 2030 from the maximum and minimum growth rates for cultivation |
| **Average projected cultivation area soybean in 2030 (million ha)** | 46.57 | Average of the minimum and maximum areas estimated for 2030 from the maximum and minimum growth rates for cultivation |
| **Projected average expansion of cultivated area in 2030 (million ha) in Brazil to supply food and biofuels** | 13.2 | Minimum projection of the planted area of grains and sugarcane for 2030, subtracting the planted area until 2019 (i.e. expansion of the cultivated area in the period).<br>The same was done for maximum projection. The projected average is the calculation of the average expansion of these two scenarios |
| **Projected expansion average agricultural discounting area for biofuels (million ha)** | 11 | The area that the business as usual scenarios consider to be destined for biofuels ethanol and biodiesel (i.e. 60% of the sugarcane area and 20% of the soybean area) is subtracted from the average of the expansion projection. |
| **Percentage of cultivated area for sugar cane in 2019** | 11.4% | Area destined for sugarcane production (million ha) in 2019/ Total area planted in Brazil in 2019 (million ha) |
| **Percentage of cultivated area for soy in 2019** | 47.5% | Area for soy production (million ha) in 2019 / Total planted area in Brazil in 2019 (million ha) |

| ETHANOL | | |
|---|---|---|
| DATA | VALUE | CALCULATION |
| **Productivity of sugarcane ethanol (l/ha)** | 7160.5 | Sugarcane productivity (tc/ha) * ART/tc * yield (l/ART). Note: The increase in hydrated ethanol productivity was based on PDE2029 projections, which consider increased sugarcane productivity and ethanol yield |
| **Ethanol Legal Demand** | 41800 | Value quoted in PDE 2029, expanded according to the compound interest formula until 2030. Growth rate of 2.5% a.a. assumed for the PDE2029 period. Discounted 5% of the pandemic effect |
| **Ethanol Total Demand 2029** | 101650 | Previous Report – 5% due the pandemic |
| **Emission factor considering cycle – hydrated ethanol** | 0.444 | Renovabio value*energy density of biofuel |
| **Sugarcane productivity 2030 (tc/ha)** | 84.4 | Sugarcane productivity 2029*Increase rate in sugarcane productivity |

| BIOGAS | | |
|---|---|---|
| DATA | VALUE | CALCULATION |
| **Increase in the number of pig heads by 2030** | 2.4% a.a. | Based on the report data at Conab 2019, the average growth rate from 2015 to 2019 was made |
| **Increase in the number of chick heads by 2030** | 0.07% | Based on the report data at Conab 2019, the average growth rate from 2015 to 2019 was made |
| **$m^3$ of $CH_4$ produced by poultry per day** | 9429713 | [(heads_avines2030*waste_per_head) /1000] * $m^3CH_4$/ton *utilization |
| **$m^3$ of $CH_4$ produced by pigs per day** | 4082354 | pighead2020*production $CH_4$/head*utilization |
| **$m^3$ of $CH_4$ produced by cows per day** | 5523400 | milked_cows2018*biogas/milked_cows_day *%biomethane*utilization |
| **Emission factor considering cycle – biomethane** | 0.282 | Renovabio value*energy density of biofuel |

| BIOKEROSENE | | |
|---|---|---|
| **DATA** | **VALUE** | **CALCULATION** |
| **Legal Demand Biokerosene** | 97.85 | Value quoted in PDE 2029 “1% of total demand (103 thousand m³ in 29)”. Discounted 5% of the pandemic effect |
| **Total Demand Biokerosene 2029** | 11732.5 | Previous Report – 5% of the pandemic |
| **Emission factor considering cycle – Biokerosene** | 1.14 | Renovabio value*energy density of biofuel |

| BIODIESEL | | | |
|---|---|---|---|
| | **DATA** | **VALUE** | **CALCULATION** |
| **General Biodiesel** | Legal Demand Biodiesel | 11115 | Value quoted in PDE 2029, expanded from according to the compound interest formula until 2030. Growth rate of 3.1% a.a. assumed for the period from 2023 to 2029 in PDE 2029. Discounted 5% of the pandemic effect |
| | Total Biodiesel Demand 2029 | 92957.5 | Previous Report – 5% of the pandemic |
| **Biodiesel from used cooking oil** | Biodiesel from used cooking oil (million l) | 35165.75 | [(oil_kitchen_Brazil_ month*12months)*density*10^ 6]*biodiesel yield*percentage used |
| **Soy Biodiesel** | Productivity of soy biodiesel in 2030 (L/ha) | 590 | From several sources we find that the productivity of soy biodiesel only dropped from 2006 to 2016. Therefore, we consider the highest value (FGV) among recent data, but we do not assume increased productivity until 2030 |
| | Emission factor considering cycle – Soy biodiesel | 0.95 | Renovabio value * energy density of biofuel |
| | Emission factor for NDC – Soy biodiesel | 0 | |
| **Cattle Biodiesel** | Tallow Biodiesel (million L) | 1429 | heads2018 * (production_growth_rate_bovine ^ years_ until_2030)] * yield_biodiesel_head |
| | Biodiesel yield (L/head) | 36.61 | Biodiesel yield in Kg / head * oil density |
| | Emission factor considering cycle – Bovine biodiesel | 0.135 | Renovabio value * energy density of biofuel |
| | Emission factor for NDC – Bovine biodiesel | 0 | |

# APPENDIX III – PREMISES

| GENERAL BIOFUEL | | |
|---|---|---|
| **PREMISE** | **VALUE** | **JUSTIFICATION** |
| **Effect of the Covid-19 pandemic on the total and legal demand for biofuels** | -5% | No study consulted to obtain the data has yet considered the effect of Covid-19. The objective of the study is to expose the potential, that is, what could be obtained. Therefore, we did not include an effect on the potential. On the other hand, there is likely to be an effect on fuel demand due to the effect on the economy. Therefore, we include a small decrease in demand |

| LAND | | |
|---|---|---|
| **PREMISE** | **VALUE** | **JUSTIFICATION** |
| **Percentage of cultivated areas for destined biofuels** | Same current percentages | To calculate the expansion of the area of business as usual, which indicates the expansion of the cultivated area in Brazil, it was considered that soy and sugarcane would have shares in equal % to that they have in the planted area in Brazil today |

| ETHANOL | | |
|---|---|---|
| **PREMISE** | **VALUE** | **JUSTIFICATION** |
| **Percentage of soybean area alternating with corn** | 80.0% | Conversation with specialist in the area João Carlos Rocha Abdo – AgroAbdo |
| **Percentage of corn alternating with soy that is destined for ethanol production** | 10.0% | Currently, this% is less than 5% (conversation with a specialist), however this sector is expanding, with large investments in the area. As the technology involved in the adoption of this new crop is not so complex, we expect high growth |

| BIOGAS | | |
|---|---|---|
| **PREMISE** | **VALUE** | **JUSTIFICATION** |
| **Percentage of Vinasse going to energy production** | 80.0% | Considering that we intend to expose a potential, that alternative sources will receive great incentive by RENOVABIO, and that this source represents an economy for the industry, we chose to include a high% of utilization. |
| **Percentage of vinasse destined for the production of energy that is destined for biomethane** | 80.0% | Considering that we intend to expose a potential, that alternative sources will receive great incentive by RENOVABIO, and that this source represents an economy for the industry, we chose to include a high% of utilization. |
| **Use of livestock for the production of biogas from waste** | 50.0% | It is considered that it is not feasible to use the entire national herd to collect waste for biomethane. Considering the exercise of estimating the potential, we indicate a 50% utilization of the generated waste (% still very optimistic). |
| **Number of inhabitants with collection of MSW** | > 100 thousand ha | We believe that it would be feasible to adopt the uptake and reuse of waste in cities with more than 100 thousand / ha. In 2019, the sum of the inhabitants of cities with more than 100 thousand inhabitants is 120,699,507. Considering that even in 2030 it will not be all the inhabitants of these cities that will contribute to the capture, we've maintained the number of inhabitants of 2019 for the estimates. |
| **Average percentage of Biomethane in Biogas** | 60.0% | In general, the percentage of biomethane in biogas varies, but always around 60%. Therefore, when the specific value was not found, we adopted this percentage. |

| BIODIESEL | | |
|---|---|---|
| **PREMISE** | **VALUE** | **JUSTIFICATION** |
| **Percentage of cooking oil that will be collected for biodiesel production** | 70.0% | Considering that we intend to expose a potential and that alternative sources will receive great incentive by RENOVABIO, we chose to include a high% of utilization. |
| **Percentage of herds that would be used for biodiesel production** | 50.0% | As there is a difficulty in transporting the raw material to the biodiesel plants, we maintained a percentage not so high with the previous ones. |


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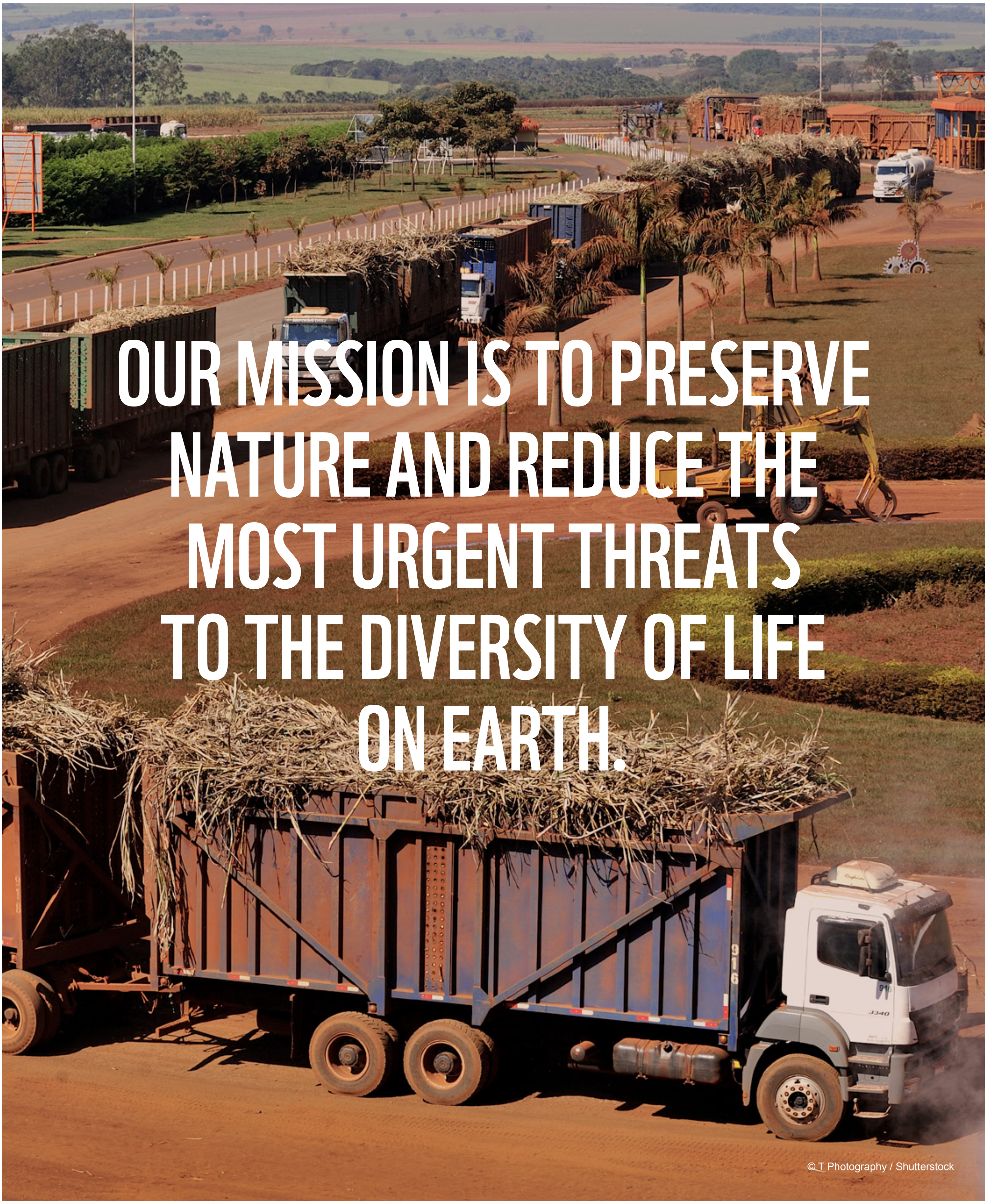


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