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Brazil in a Well Below 2°C World

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Brazil in a Well Below 2°C World

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Index

Presentation

The Instituto Clima e Sociedade (iCS) is a philanthropic and re-granting organization that promotes prosperity, justice and low-carbon growth in Brazil. The Institute serves as a bridge between international and national funders and local partners. As an independent Brazilian organization, iCS belongs to an international network that catalyze world leading climate policy at international, national and city levels to reduce the emission of greenhouse gases (GHG). The Institute looks for measures that reduces GHG emissions, also generating improvements in the quality of life for the most vulnerable.

The Center for Energy and Environmental Economics (CENERGIA) is a research lab at the Federal University of Rio de Janeiro (UFRJ), which forms part of the University's Program on Energy Planning (PPE) at the Albert Luiz Coimbra Institute for Post-Graduation and Engineering Research (COPPE). CENERGIA's mission is to develop applied research and disseminate innovative knowledge about complex interactions of the energy sector with socioeconomic development and global and local environmental dimensions. Applying pioneer energy planning modeling tools, CENERGIA's work supports policy and policymakers in understanding of the synergies and conflicts associated with technological innovation for a transition to a low-carbon economy in Brazil, Latin America and the Caribbean, and the world.

Following its commitment to science and qualified debate on climate, iCS commissioned this assessment from CENERGIA, to identify the key social and economic aspects of a pathway towards a zero or near – zero emission scenario at the Brazilian energy sector.

Roberto Kishinami
Coordinator of the Energy Portfolio at iCS

August 2019

Introduction

The study “Brazil in a Well Below 2°C World” analyses different pathways towards a Brazilian low- or zero-emission power and transport sector, which will be crucial to achieve the Brazilian commitment within global climate protection.

CENERGIA ran a combination of relevant integrated assessment models (IAMs) in order to evaluate the required pathways for three different Brazilian scenarios and the related emission budgets. For each scenario, the study shows how the country’s energy and land use sectors would need to behave in order to meet the established GHG emission limits by 2050. Urban transportation and power generation were focused due their importance to reduce GHG emission at long-term.

As a result of the study, the evolution of the Brazilian energy and land use systems are estimated, including the electricity and urban mobility mix, providing important insights into the development of central-market segments. Electric vehicles, for example, appear as a key element to meet more stringent emission requirements, and to find new markets for ethanol fuel is presented as a challenge.

By allowing the analysis on how the sectors are organized in a low-carbon future, the study gives a perspective of the technological developments necessary to allow this future. Technologies, such as Carbon Capture and Storage (CCS) and second-generation biofuels, appear as important means of emission reduction although they have not yet reached commercial availability.

The study also provides valuable insights on whether the country’s current policies and the existing incentives are consistent with Brazil´s established emission reduction targets. This understanding is fundamental to provide a basis for a coherent and effective structuring of public policies.

Scenarios Evaluated for Brazil

- **National Current Policies (NCP):** The NCP scenario is based on current and indicated Brazilian climate, energy and land use policies and the expected resulting CO_2e emissions up to 2050.
- **Brazilian budget for 2°C (N2D)**: The N2D scenario explores the pathway towards achieving the Brazilian targets of the Paris Agreement, indicated by the NDC assumptions. It is based on an emissions budget of 24 $GtCO_2$ for the period between 2010 and 2050.[1]
- **Brazilian budget for 1.5°C (N1.5D):** The N1.5D scenario considers global and regional emissions budget to limit the average global temperature increase to 1.5°C. For Brazil, an emissions budget of 17 $GtCO_2$ for the period between 2010 and 2050 was considered.[2]

Computational models for scenario evaluation

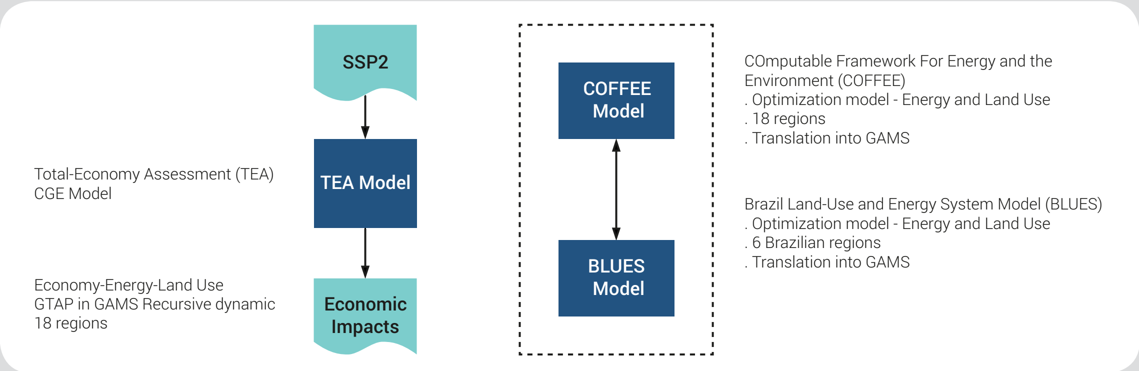
CENERGIA works on the development and maintenance of computational integrated assessment models (IAMs) to evaluate scenarios related to GHG emissions and energy and land use. Two central models where employed in this study, both developed by CENERGIA/PPE researchers on the MESSAGE platform[3]:

- The COmputable integrated Framework For Energy and the Environment – COFFEE is a global optimization model for energy and land use systems. The COFFEE model divides the world into 18 regions, being Brazil one of them.
- The Brazil Land-Use and Energy Systems model– BLUES is an optimization model for the Brazilian energy and land use systems.

In addition to the COFFEE AND BLUES models, the global economic model TEA, also developed by CENERGIA/PPE, was applied in order to calibrate the inputs for the COFFEE model:

- The Total-Economy integrated Assessment model – TEA is a global computable equilibrium model which simulates the evolution of the global economy until 2100. The model uses the same 18 regions as COFFEE.

Figure 1. Information exchange between models



Source: Own illustration

[1] Result of the COFFEE model optimization for a global emissions budget of 1,000 $GtCO_2$ from 2011 to 2100, which is related to a 66% probability of staying under 2°C according to IPCC's Scenario Database for AR5 (2014).
[2] Result of the COFFEE optimization for a global emissions budget of 400 $GtCO_2$ from 2011 to 2100, which is related to a 66% probability of staying under 1.5°C according to IPCC's Scenario Database for AR5 (2014).
[3] MESSAGE is an energy system platform developed by the International Institute for Applied System Analysis (IIASA), which is a reference scientific research institute located in Laxenburg, Austria.

Central assumptions on international and national emission budgets

The Brazilian emissions budget was estimated by using the COFFEE model, a global optimization model of the energy and land use systems. One of the results of this model is the estimation of the optimal allocation of GHG emission budgets for 18 regions of the world at minimum overall cost. Brazil is represented as a single region in this model.

It is important to notice that the budgets obtained by the model do not reflect the Brazilian commitments on emissions reductions, but **the achievement of the international climate change targets at minimum overall cost.**

The international target of limiting the average global temperature increase to 2°C until 2100 will most likely be achieved by limiting the worldwide GHG emissions to 1,000 $GtCO_2$ until 2100, while the 1.5°C target would limit the overall budget to 400 $GtCO_2$.

The ideal Brazilian share in these budgets were estimated 24 $GtCO_2$ for the N2D and 17 $GtCO_2$ for the N1.5D scenarios.

Brazil has ratified its Nationally Determined Contribution (NDC) in 2016. Although the Brazilian NDC represents an economy wide emissions reduction commitment, targets for single sub-sectors of the economy are indicated within the NDC. The full implementation of these targets is the baseline for the N2D scenario, while the NCP scenario only considers mitigation measures that were already converted into national policies or can reliably be expected to be converted into such. However, for the energy sector, the measures envisaged by the NDC are almost all achieved under the baseline scenario (NCP).

Table 1. Summary of measures at the Brazilian NDC – considered as assumptions on Scenarios N2D and N1.5D

LULUCF	Forestry	Strengthen Forest Code
		Zero illegal deforestation in Amazonia by 2030, with sequestrations compensating for emissions from legal suppression of vegetation
		Enhancing sustainable forest management practices
		Restoring and reforesting 12 million hectares of forests by 2030
ENERGY	Primary Energy	45% renewables by 2030
		Non-hydro renewables to 28-33% by 2030
	Electricity Generation	Non-hydro renewables at least 23% by 2030
	Efficiency	10% efficiency gains up to 2030
	Transportation	Promote efficiency measures
		Improve public transport infrastructure
	Biofuels	18% biofuels in primary energy mix by 2030
	Industry	Promote new standards of clean technology
AGRICULTURE		Strengthen Low-Carbon Agriculture Plan (ABC Plan)
		Restore 15 million hectares of degraded pastures by 2030
		Five million hectares of integrated cropland-livestock-forestry systems by 2030

Source: BRASIL (2015)

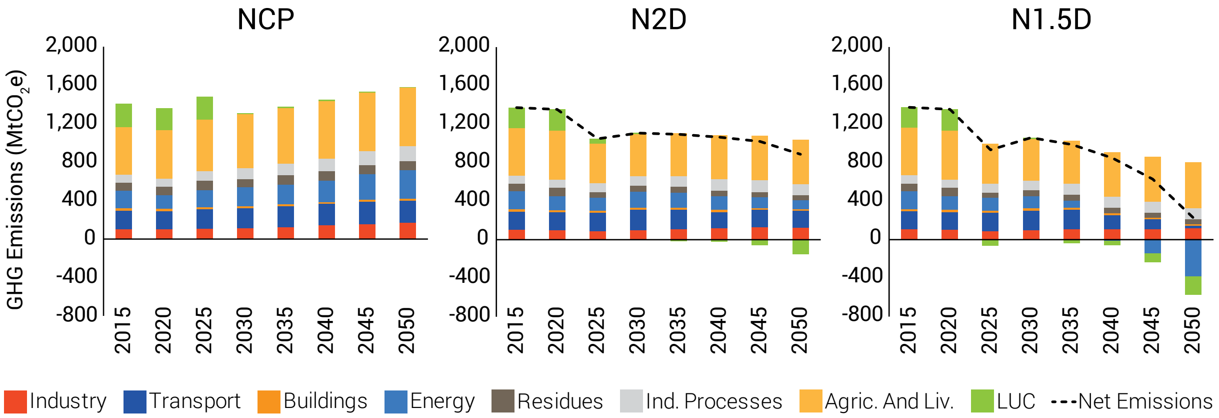
Scenarios Comparison

The results of the models show the development of CO_2eq emissions for different economy sectors.

GHG Emissions from AFOLU, Energy Use and Industry Processes

The following figures show the behavior of the Brazilian GHG emissions from AFOLU, Energy Use and Industry up to 2050 for the three analyzed scenarios.

Figure 2. Behavior of the Brazilian GHG Emissions from AFOLU, Energy Use and Industry Processes between 2015 - 2050



Source: Own illustration

In the NCP scenario, all energy-related gases will continue to grow until 2050 reaching overall annual GHG emissions of 1.6 $GtCO_2$eq in 2050, which is about 42% above the 2015 baseline emissions. In this scenario, in the absence of additional restrictions, economic advantages lead to an increased use of fossil fuels instead of clean energy alternatives.

In the N2D scenario, the total GHG emissions from AFOLU, Energy and Industry will be 44% below the 2015 level by 2050, totaling 0.9 $GtCO_2$eq. A sharp decrease after 2030 is mostly caused by negative emissions from the land use sector, related to the improvement and recuperation of pastures. Energy related GHG emissions reach around 0.5 $GtCO_2$eq in 2050, with a relatively steady reduction rate of about 1% a year from 2030 to 2050.

The N1.5D scenario would require an emissions reduction of 85% until 2050, with a total of 0.25 $GtCO_2$eq in 2050. In this scenario, the decrease of GHG emissions after 2030 is even steeper, mainly due to an intensified use of BioCCS[4] in addition to the efforts of the negative emissions in the land use sector, which will achieve around 0.4 $GtCO_2$ of negative emissions in 2050.

Even with net negative emissions from the energy system in 2050 (-0.21 $GtCO_2$) due to the production of biofuels combined with CCS, over 0.32 $GtCO_2$ are captured and there are still positive emissions of about 0.11 $GtCO_2$ related to energy use. Results show that, even in a highly stringent scenario on GHG emissions, there might be positive emissions (e.g. from fossil fuels or industrial processes), since they are overmatched with negative carbon mitigation options.

[4] Biomass conversion combined with Carbon Capture and Storage technology

Impact of the availability of CCS

Carbon Capture and Storage (CCS) is one of the main mitigation options considered in this study. However, it is important to remember that large-scale CCS is not yet a commercially available technology and that it is still a long way to reduce both investment cost and energy penalty[5]. Additionally, there are uncertainties related to the regulatory framework and the macroeconomic conditions.

A global scenario for a below 2°C world was optimized with and without considering CCS, in order to check whether the target could be achieved without the availability of CCS. In the absence of CCS, early action (starting just right now) would be required in order to reduce GHG emissions sharply right after 2020. Without CCS, constantly low GHG emissions until the end of the century are required to stay within the overall budget.

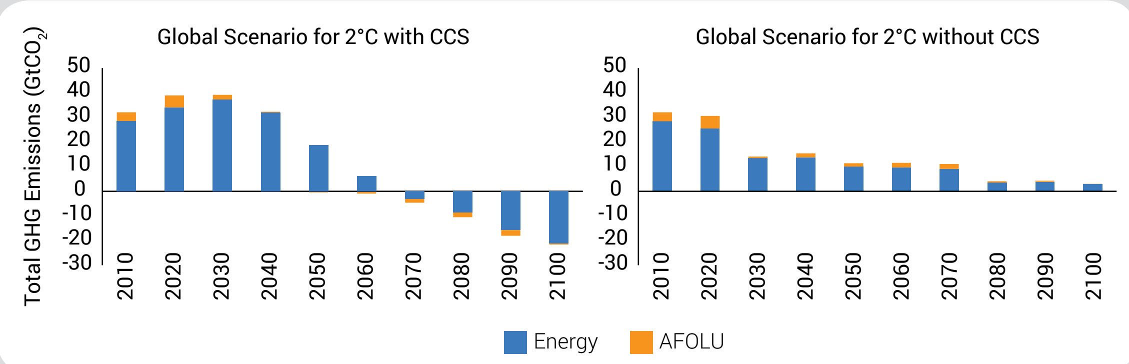
The availability of CCS offers more time for the reduction of GHG emissions: net negative emissions by around 2070 would compensate for higher GHG emissions up to 2030.

This could mean that, in delaying action to mitigate climate change (just as it can be observed in the real world up to now), the world would be constantly dependent on CCS technology in order to maintain a low-carbon stabilization pathway.

The unavailability of CCS presents a challenge for the reduction of energy-related GHG emissions. In this case, emissions from the energy sector need to be reduced even more, by a stronger use of renewables for electricity generation, as well as a higher penetration of electric vehicles.

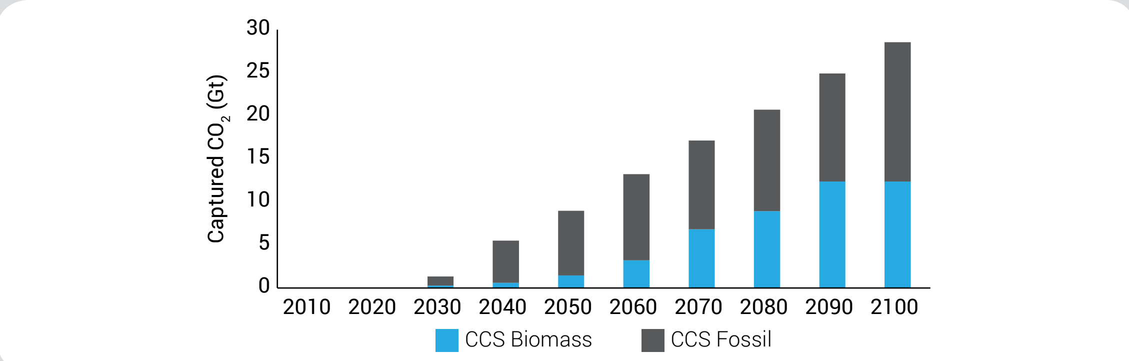
The results of the Global scenarios show the importance of CCS as a mitigation option.

Figure 3. Global GHG emissions in the 2°C scenario showing CCS as a mitigation option



Source: Own illustration

Figure 4. Global CCS Breakdown in the 2°C scenario



Source: Own illustration

[5] Energy penalty is the fraction of fuel that must be dedicated to CCS for a fixed quantity of work output. That penalty can manifest itself as either an additional amount of fuel required to maintain a power plant's output or a loss of output for a constant fuel input.

Emissions from electricity

The Brazilian electricity generation will increase until 2050 in each of the three scenarios. The strongest increase can be expected for the 1.5°C scenario, since the increase of electric vehicles in the fleet leads to a higher electricity demand. The stricter the emissions target, the faster the penetration of electric vehicles and the smaller the emissions from the electricity sector by a stronger participation of renewables in electricity generation.

Nevertheless, none of the scenarios proved capable of reaching zero emissions in the electricity sector until 2050. In 1.5D scenario, where emissions reach near zero values, the sources of GHG emissions are coal power plants with CCS. The power sector in this scenario still emits about 0.1 kgCO_2/kWh in 2050, even with a significant reduction in emissions through capture.[6]

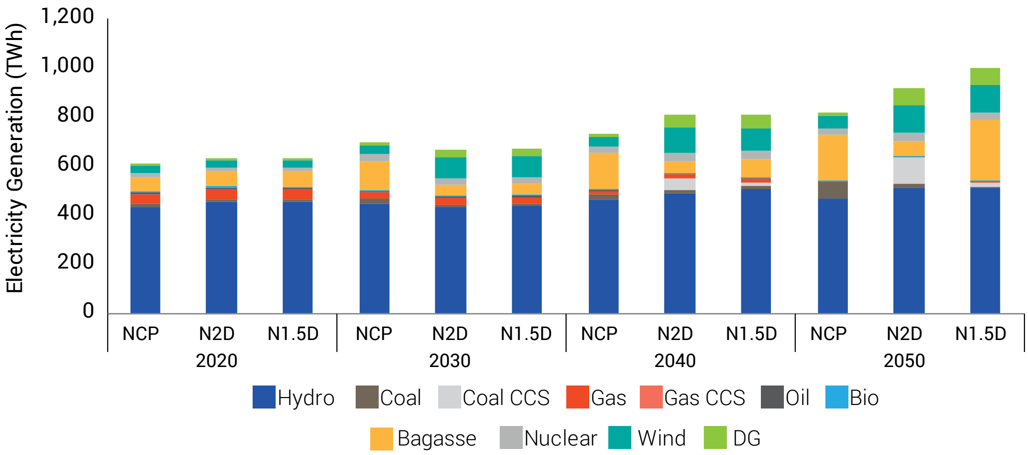
Hydropower generation will be the dominating energy source in all of the three scenarios. It increases after 2035 in both N2D and N1.5D scenarios, due to the repowering of existing plants and the introduction of hydrokinetic plants.

Bagasse-based power generation will develop differently in each of the 3 scenarios. It increases constantly in the NCP scenario, while it would keep unchanged from 2030 to 2050 in the N2D scenario due to a smaller ethanol production for fuel in this case. For the N1.5D scenario, the expansion is delayed, but it reaches higher values by 2050 due to the large ethanol demand for the production of advanced kerosene.

Solar energy will have a relatively low share in the NCP scenario (almost 3%) but will reach marginally higher levels in the N2D and N1.5D world, reaching up to 7% by 2050. In this assessment, most solar energy is expected to happen in distributed generation, although some will also come from centralized solar PV power plants. Fossil fuels will remain in the power mix in all scenarios. In the NCP scenario, near 8% of the generation mix in 2050 is based on fossil fuels, from which coal represents more than 90%. Fossil generation share reaches 14% in the N2D scenario, being 85% of that associated with CCS technologies. Finally, in the well below 2°C (N1.5D) scenario, the share of fossil fuels is about 3%, being coal power plants with CCS the most relevant fossil source.

The power mix and related emissions are shown in Figures 5 and 6 for all of the three scenarios.

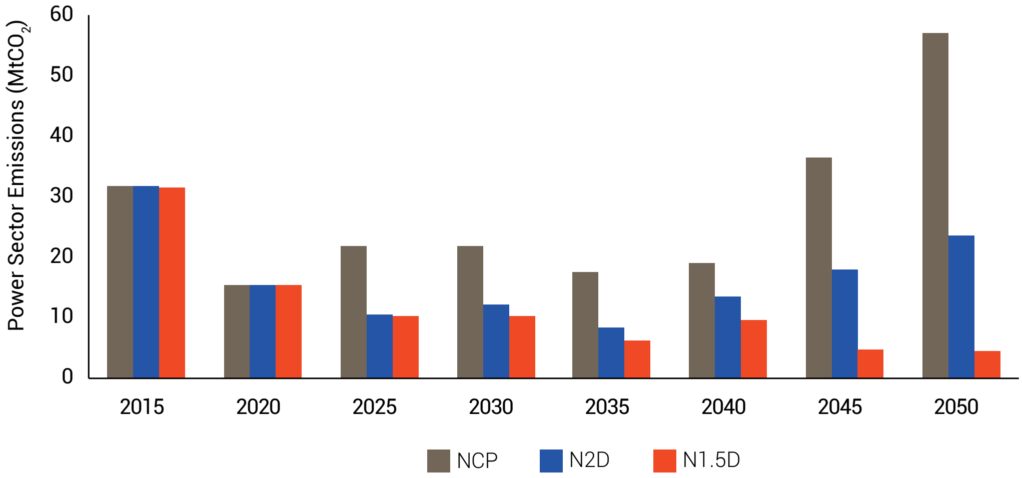
Figure 5. Brazilian electricity generation in all BLUES scenarios



Source: Own illustration

[6] These emissions do not included those derived from industrial combined heat and power plants (CHP) (steel industries and oil refineries, e.g.).

Figure 6. Brazilian electricity generation emissions in all BLUES scenarios



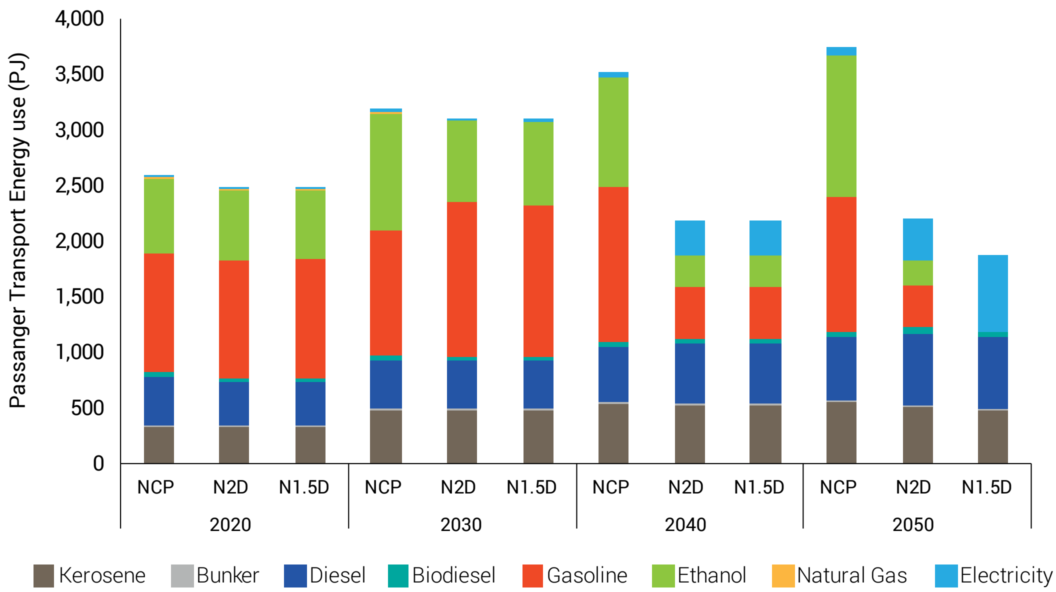
Source: Own illustration
Note: Industrial and refinery CHP excluded

Emissions from the transportation sector

The electrification of the passenger transportation, particularly in urban centers, plays a key role to reach the ambitious emission reduction targets. Figure 7 presents the energy mix for transport in all of the three scenarios, showing the significant increase of electricity consumption in mobility for both N2D and N1.5D scenarios after 2030. It also shows that the overall energy consumption in the transportation sector reduces significantly with the introduction of electric vehicles, showing that this option for mobility is more efficient in the use of energy than the current vehicles with internal combustion engines.

Hybrid plug-in vehicles will be used as a transition technology between flex-fuel and battery run electric vehicles.

Figure 7. Final energy use in passenger transport in all BLUES scenarios

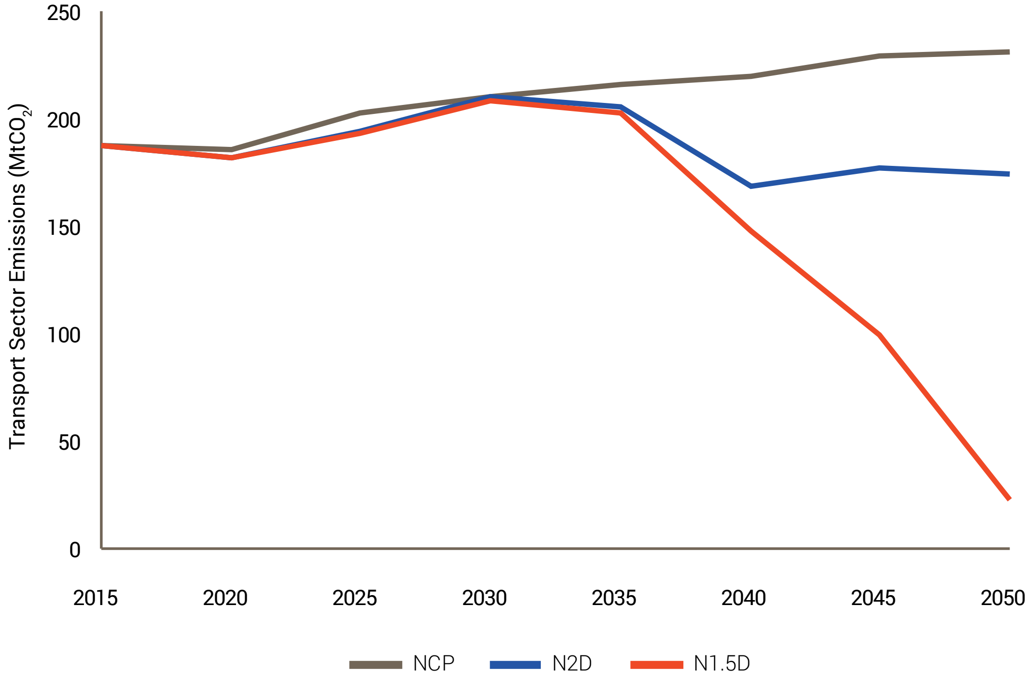


Source: Own illustration

The emissions from the transportation sector are significantly reduced in the N2D and N1.5D scenarios, due to the penetration of electric-driven vehicles and the large production of green diesel and ethanol-derived kerosene. Both scenarios present a peak of transport emissions by 2030, while in the NCP scenario GHG emissions steadily increase to about 0.24 $GtCO_2$ in 2050.

Transport emissions in the N1.5D scenario reach near zero values in 2050 due to the substitution of both diesel and kerosene by biomass-based fuels produced in combination with CCS, as well as the complete removal of gasoline consumption from passenger transportation. Emission sources in this scenario are limited to a small amount of fossil diesel fuel, still available in the national pool and, most importantly, due to the use of high density fuels, such as bunker and diesel for waterway and marine transportation.

Figure 8. Brazilian transport sector emissions in all BLUES scenarios



Source: Own illustration

New markets for ethanol

The electrification of passenger transportation poses a challenge: Where does all the ethanol fuel that is no longer used in transportation go? It is necessary to find new markets for ethanol, which has an important role in the Brazilian agro industry sector. The scenarios indicate that ethanol will be used after 2030 for the production of bio-jet fuels (kerosene from alcohol oligomerization) and biochemical platforms, as well as to blend with diesel and bunker (up to 20%).

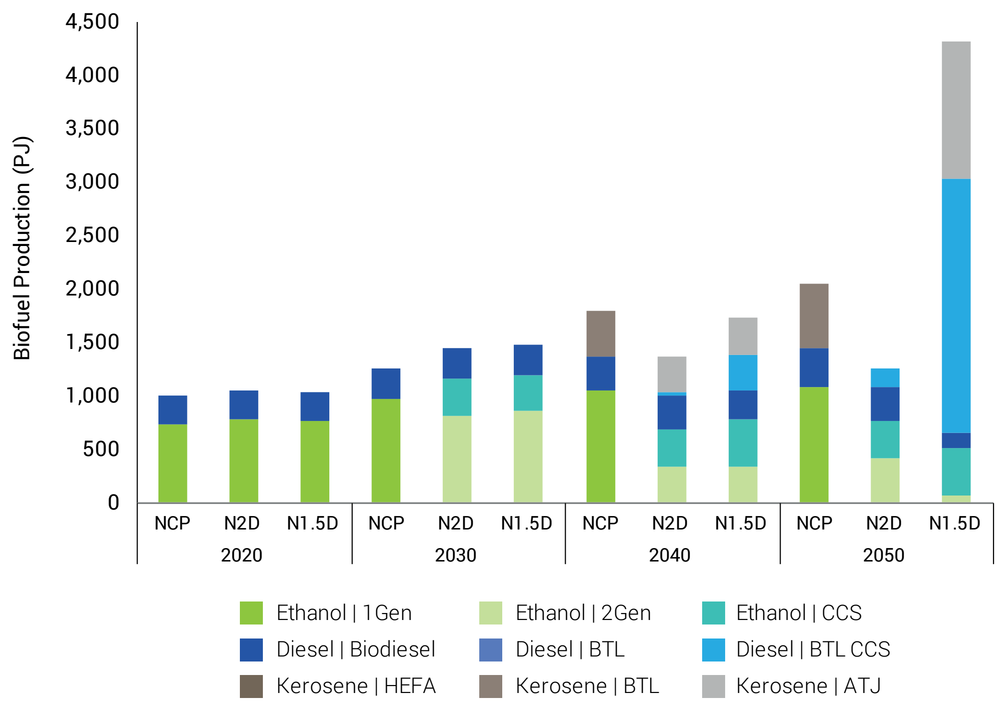
Liquid biofuels production

The existence of emission reduction targets in the N2D and N1.5D scenarios leads to a big change in the profile of liquid biofuels produced in Brazil. In the scenario NCP, representing the Brazilian evolution without an additional emission reduction target, the biofuel production keeps focused on first generation ethanol and biodiesel and, after 2040, synthetic kerosene from biomass (BTL) – which by then will become commercially feasible.

On the other hand, first-generation ethanol loses importance as final energy after 2030 in the N2D and N1.5D scenarios. It is firstly substituted by ethanol production in combination with CCS and later by second-generation ethanol, before also reducing in volume. In this assessment the best use of ethanol is, instead of its original use as fuel, to use it as input for bio-kerosene production in the ATJ (Alcohol-to-Jet) route[7].

The N1.5D scenario presents an overall production of ethanol slightly larger than that of the N2D scenario until 2040. Then, the production of green diesel from biomass-to-liquids with CCS (BTL CCS) gains force, emerging as an important technology to reach net negative emissions. Finally, in 2050, the diesel BTL CCS and kerosene from ATJ are largely expanded, which also allows for the export of liquid fuels. Brazil exports gasoline and eliminates diesel imports in 2050 in this scenario.

Figure 9. Biofuels' energy use in all BLUES scenarios



Source: Own illustration

[7] The ethanol used for ATJ is excluded from the figure to avoid double counting.

Main Conclusions

- Brazil, just as many other countries, is not on track for a well below 2°C world. Projections indicate that current policies will result in global cumulative emissions of 5,500 $GtCO_2$ between 2011 and 2100, leading the world to a temperature increase higher than the safe limits. The cumulative emissions in Brazil will be around 34 $GtCO_2$ between 2010 and 2050, if stricter targets are not established.
- Joint efforts into the commercial availability of CCS will be crucial to the achievement of international climate change targets. In the absence of early actions, reducing emissions drastically from 2020 on, Brazil (just as many other countries) will depend on CCS in order to be able to achieve ambitious reduction targets. A global emissions budget for the 2°C target can be achieved in a cost-efficient manner with or without the commercial availability of CCS, but without CCS it calls for early actions or for drastic lifestyle changes.
- Ambitious climate change targets will require a massive increase of renewable electricity generation in Brazil. Achieving the 1.5°C target will depend on supplying the Brazilian transport sector with renewable electricity. Renewable energy (hydropower, wind, solar and biomass) will continue to be the main elements of the Brazilian power mix, representing 89% of the total supply in 2030 and ranging from 82% to 94% in 2050.
- The stricter the target for emission reduction, the faster will be the penetration of electric vehicles in the Brazilian transportation sector. The replacement of ethanol- and gasoline-powered vehicles by electric vehicles increases in all three scenarios, with the electric fleet representing almost 10%, 68% and 100% of the total light-duty vehicles fleet in 2050 (NCP, N2D and N1.5D scenarios, respectively). The increase in electric vehicles will lead to a significantly higher electricity demand, but to a smaller overall energy consumption from the transportation sector, since the efficiency of electric vehicles is higher than that of internal combustion engines.
- A restriction on GHG emissions calls for advanced biofuels use in Brazil. First-generation ethanol will be entirely produced with carbon capture in carbon-restricted scenarios, with significant production from second-generation technologies. Green diesel production from biomass-to-liquids with CCS (BTL CCS) gains traction after 2040 in a well below 2°C world, eliminating diesel imports by 2050.
- Brazil offers new markets for its ethanol production in the adopted scenarios. Results indicate that electric vehicles will have significant share in domestic passenger and cargo transport in the future. The domestic use of first-generation ethanol loses importance as final energy in Otto engines, and it can be then used as input for jet fuel production. In a 2°C or well below 2°C world, bio-kerosene production through the ATJ (Alcohol-to-Jet) route appears as an important new market for ethanol.

About Instituto Clima e Sociedade

The Instituto Clima e Sociedade (iCS) is a philanthropic and re-granting organization that promotes prosperity, justice and low-carbon development in Brazil.

The Institute serves as a bridge between international and national funders and local partners. iCS belongs to a wide network of philanthropic organizations dedicated to building the solutions to the climate crisis.

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