Executive Summary

Brasil 2045

Future of Energy: OC vision for a just transition in Brazil

Brazil 2045: Building an Environmental Powerhouse
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OBSERVATÓRIO DO CLIMA
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SUMMARY

Brasil 2045

1

INTRODUCTION

Brazil can make a just energy transition, correcting social injustices and fighting against energy poverty, without letting go of its economic growth in the coming decades. In the study *Futuro da energia: visão do Observatório do Clima para uma transição justa no Brasil (Future of energy: Observatório do Clima vision for a just transition in Brazil)*, the organizations of the Observatório do Clima's (OC) Climate and Energy Working Group detail a proposal for Brazil to implement a transition in the coming years — starting now — with strong but technically grounded and feasible goals and commitments, without ignoring the increase in energy demand in different economic growth scenarios.

Adopting the assumptions and guidelines advocated by Observatório do Clima, "the **OC vision** scenario", considered an average GDP annual growth of 2.1%, the Brazilian energy sector will emit, in 2050, 102 million tons of CO_2e. This represents around 80% less than what the energy sector currently emits — 490 million tons of CO_2e, according to data from the Greenhouse Gas Emissions and Removals Estimation System (SEEG) for 2022.[1]

This study is part of Observatório do Clima's Brazil 2045 Strategy, which advocates that our country can become the first major economy in the world to sequester more greenhouse gasses (GHG) than it emits, becoming carbon negative by 2045. It also takes into account the goal of reducing net emissions by 92% by 2035 compared to 2005 levels, a number advocated by Observatório do Clima for the new Brazilian NDC proposal.[2] This would mean a commitment to reduce net GHG emissions from 2.44 billion tons of CO_2e, the 2005 quantity estimated by SEEG, to around 200 million tons of CO_2e.

Thus, although complete decarbonization of the energy sector is unlikely, it is possible that residual emissions could be offset by a strategy of preserving biomes and intensifying low-carbon agriculture. This would mean that the Brazilian economy as a whole would be able to capture more carbon from the atmosphere than it emits, with the country reaching carbon negative status by 2045.

Unlike most countries, Brazil is not starting from scratch. The share of renewable sources in the Brazilian energy matrix was 49.1% in 2023, according to the official National Energy Balance (BEN)

[1] View data from **Greenhouse Gas Emissions and Removals Estimation System (SEEG).** Available in: https://plataforma.seeg.eco.br/. Accessed on: September 17th, 2024.

[2] OBSERVATÓRIO DO CLIMA, 2024. **Technical Note – Basis for the proposal of a 2nd NDC for Brazil**. Available in: https://oc.eco.br/nota-tecnica-bases-para-proposta-de-2a-ndc-para-o-brasil/. Accessed on: September 21th 2024.

2024 report[3]. The share of these renewable sources in our electricity matrix was 89.2%. Considering only the National Interconnected System (SIN), the proportion in electricity generation reaches 93%.

These numbers, quite high when compared to most countries, including members of the Organization for Economic Cooperation and Development (OECD), are due to the strong supply of electricity from hydroelectric plants, the main source of the Brazilian electricity matrix, in addition to the "significant increase in wind and solar sources in the electricity generation, as well as biomass," according to BEN 2024.[4] Coal represents only 4.4% of our energy matrix,[5] a reality that is very different from other countries with emerging economies, such as China, Russia,or India.

The main source of GHG generation in Brazil is land use change, since deforestation accounts for 48.3% of our emissions, followed by agriculture and cattle raising, with 26.6% of emissions, according to SEEG data for 2022.[6] Next are the energy sector (17.8%), waste (3.9%), and industrial processes (3.4%).

In light of these numbers, it is worth recognizing the important and rapid advances made by the current government in controlling deforestation in the Amazon region. However, eliminating deforestation in all biomes and adopting low-carbon agriculture, although essential, are not enough for Brazil to meet the goals of the Paris Agreement. These are priorities that should not cause neglect of the Brazilian energy sector, especially when proposals to expand oil and fossil gas production in areas that are sensitive from a socio-environmental perspective receive enthusiastic support from important government authorities, as has been the case in the debate over the exploration of the mouth of the Amazon River basin, and other sedimentary basins on the Brazilian Equatorial Margin.

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[3] EPE, 2024. **National Energy Balance (BEN): Summary Report 2024 – Base Year 2023.** Available in: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-819/topico-715/BEN_S%C3%ADntese_2024_PT.pdf. Accessed on: September 17th, 2024.

[4] EPE, 2024. **National Energy Balance (BEN): Summary Report 2024 – Base Year 2023.** Available in: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-819/topico-715/BEN_S%C3%ADntese_2024_PT.pdf. Accessed on: September 17th, 2024.

[5] EPE, 2024. **National Energy Balance (BEN): Summary Report 2024 – Base Year 2023.** Available in: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-819/topico-715/BEN_S%C3%ADntese_2024_PT.pdf. Accessed on: September 17th, 2024.

[6] View data from the **Greenhouse Gas Emissions and Removals Estimation System (SEEG).** Available in: https://plataforma.seeg.eco.br/. Accessed on: September 17th, 2024.

The expansion of the use of fossil sources in the energy sector must not be part of the government's options, as it risks nullifying the advances made in reducing GHG emissions through the control of deforestation, the intensification of low-carbon agriculture, the expansion of renewable sources, and energy efficiency initiatives, among other measures..

Due to these risks, the study also considered a **tendential** scenario, with assumptions and guidelines that relate to what Observatório do Clima understands as trends in the energy sector for the coming years. For this purpose, the organizations analyzed the commitments — positive or negative — made by the government, focusing on federal government programs and legislation discussed in the National Congress, in addition to market trends and the strategic plans of companies such as Petrobras.

In the **tendential** scenario, even with the increase in renewable sources in the electrical matrix and the expansion of the use of biofuels and battery electric motors in transport, the Brazilian energy sector would by 2050 — considering an average GDP growth of 2.1% per year — emit 558 million tons of CO_2e. Therefore, instead of drastically reducing its emissions, as occurs in the **OC vision** scenario, the energy sector would followa slightly upward trajectory compared to 2022.

The assumptions and guidelines considered in the **tendential** and **OC vision** scenarios, which are essential for calculating emission levels from energy sector activities, were discussed and analyzed between November 2023 and August 2024, in meetings with the organizations of the Climate and Energy Working Group and members of Observatório do Clima's secretariat team. All definitions were made collectively.

The study presents the results of these discussions by addressing scenarios for the main energy sources in Brazil — oil, fossil gas[7], coal, biofuels, hydrogen, hydro, solar, wind, and nuclear. It also includes analyses of transport and industrial activities, as well as essential topics such as energy poverty, the socio-environmental impacts of renewables and energy efficiency.

In addition to the assumptions and guidelines of the scenarios described, the calculations also considered three possible growth projections for the Brazilian economy. These economic projections generated, in turn, three different total energy demands for Brazil, which should be met by an energy matrix envisioned in the tendential scenario — still with a significant presence of fossil fuels — and in the OC vision — which substantially reduces the use of fossil fuels, taking into account the necessary socio-environmental safeguards in the use of renewables.

[7] Observatório do Clima took the decision to no longer use the adjective "natural" for the fossil-based product.

The three economic projections adopted can be described as follows:

- average growth of 1.3% per year — a linear trend that considers the historical series of Brazilian GDP results between 1960 and 2023, according to data compiled and made available by the World Bank;[8]

- average growth of 2.8% per year until 2050 — a value defined by taking the average of the upper and lower GDP growth rates presented by EPE[9] in its Ten-Year Energy Expansion Plan (PDE) 2034; and

- average growth of 2.1% per year — adopting the simple average between the annual growth of the two previous projections.

Figure 1 shows Brazilian annual GDP growth between the years 1960 and 2023 and illustrates the results that would be obtained in a hypothetical future (2024 to 2050) in which GDP growth, from 2024 onwards, varies according to each of these three rates.

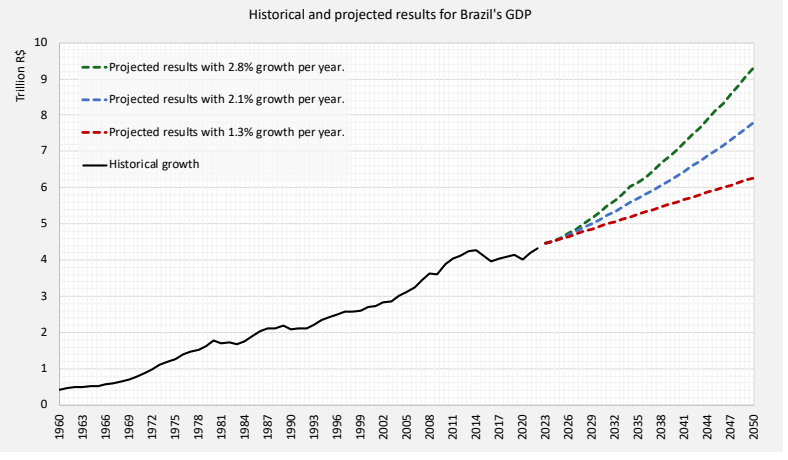

Figure 1 - ***Graph with three GDP growth projections (numbers in constant Real (R$) value, with 2010 as the base year)****. Source: Own elaboration.*

[8] World Bank, 2024. **Open Data - Brazil**. Available in: https://data.worldbank.org/country/brazil?_gl=1%2A15qu3y0%2A_gcl_au%2AMTY5Nzk4NTk0Mi4xNzI3MjkyNDg4. Accessed on: September 25th, 2024.

[9] Empresa de Pesquisa Energética - The official Brazilian energy planning authority.

In presenting the results, the study highlighted how each emitting activity in the energy sector — freight transportation; passenger transport; fuel production; steel industry; chemical, cement and food industries, among others; electricity generation; buildings; and agriculture and cattle raising (energy consumption only) — is expected to behave in terms of GHG emissions if the assumptions and guidelines of the **OC vision** scenario and an average GDP growth of 2.1% per year until 2050 are considered.

Next, the GHG emissions of each activity were analyzed in the **tendential scenario**, still considering an average growth of 2.1% per year until 2050. These results were, at the same time, compared with those obtained in the **OC vision scenario**, to clarify how each political choice could impact the level of emissions in the energy sector — and, consequently, on Brazil's ambition to become an environmental and climate powerhouse.

Finally, the study showed how emissions from the energy sector would change in scenarios of lower growth, of 1.3% per year, and higher growth, of 2.8% per year, which affect the country's energy demand.

On the path to a just energy transition, the study shows that choices must be made. Brazil has great potential to continue increasing the share of renewable energy sources, especially solar and wind, in addition to implementing an ambitious biofuels program combined with the electrification of engines and the development of new green hydrogen technologies. However, the implementation of these technologies still faces challenges, especially when we consider the negative socio-environmental impacts of wind and other renewable energy projects resulting from weak regulation, in addition to the need for adequate infrastructure and investment in more remote and vulnerable areas, especially in relation to distributed electric energy generation.

Thus, in order to ensure a just transition, the study also looked at the socio-environmental impacts — which are already occurring — of new renewable sources and the mining of strategic metals, indicating which safeguards and mitigation initiatives the government should adopt. In addition, it addressed topics such as reform of the electricity sector, provided guidelines on how to overcome energy poverty and correct injustices, and pointed out ways to improve energy efficiency in various sectors.

Brasil 2045

2

RESULTS

2.1. OC vision scenario

The OC vision scenario assumes an average GDP growth of 2.1% per year until 2050, and considers the population projection by the Brazilian Institute of Geography and Statistics (IBGE), which forecasts that the number of Brazilians should stabilize at around 220 million people. As a result, GDP per capita should increase significantly, as can be seen in Figure 2.

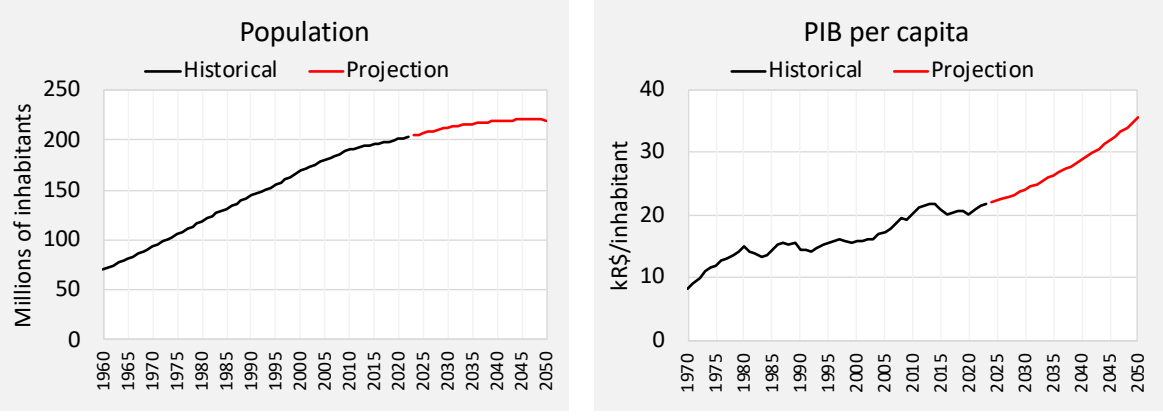

Figure 2 - ***Historical (1970-2022) and projected (2023-2050) population and GDP per capita.*** *Source: Own elaboration.*

These are indicators that put pressure on energy and consumer goods demand, which would mean an increase in activity rates across all GHG emitting activities.

The graph below (figure 3) shows that, to achieve the objectives of the **OC vision**, emissions from the energy sector by 2045 — the year in which Brazil, in the OC vision, should achieve carbon negative *status* — could be reduced to the same level as emissions in 1970, when the country had less than 100 million inhabitants, was more unequal and the demand for energy and consumer goods was lower.

The challenge is not just to keep the Brazilian economy going, overcoming the bottlenecks of a still developing country, while reducing emissions. It is, above all, to continue the process of democratization, social and **energy** inclusion, and meeting the population's demands for more consumer goods, more food and more energy — and preferably more affordable energy — **at the same time** as emissions are reduced to a level compatible with Brazil's carbon neutrality by 2045.

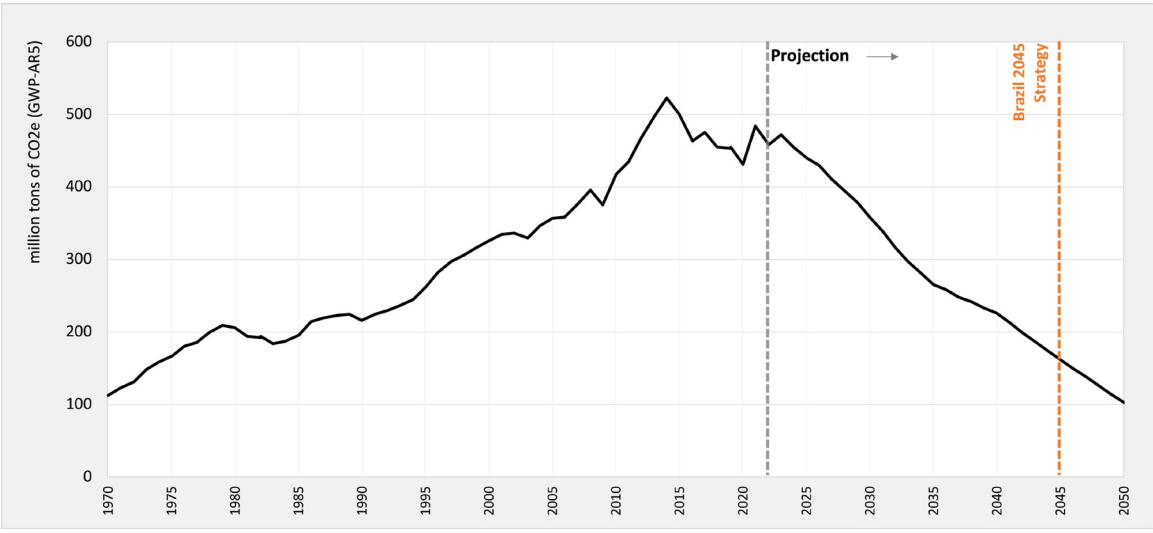

Figure 3 - ***Historical (1970-2022) and projected energy emissions (2023-2050) in millions of tons of CO_2e.*** *Source: Own elaboration.*

THE BRAZIL 2045 STRATEGY IN THE OC VISION SCENARIO

- Freight transport: 8% reduction in emissions by 2045 compared to 2005.
- Passenger transport: 68% reduction in emissions by 2045 compared to 2005.
- Chemical, cement and food industries, among others: 71% reduction in emissions by 2045 compared to 2005.
- Steel industry (energy consumption and industrial processes): 85% reduction in emissions by 2045 compared to 2005.
- Electricity generation: 80% reduction in emissions by 2045 compared to 2005.
- Buildings: 66% reduction in emissions by 2045 compared to 2005.
- Agriculture and cattle raising (energy consumption only): 27% reduction in emissions by 2045 compared to 2005.

In order to achieve this goal, the **OC vision** adopts the assumption that, with the exception of fossil fuel production, energy consumption in the activities that are currently emitting — transport, industry, agriculture and cattle raising, buildings and electricity generation — must continue to grow, in line with GDP growth, while **at the same** time decoupling from GHG emissions. If the actions indicated here are adopted, it is even possible that the Brazilian energy sector's peak emissions have already been reached, as shown in figure 3.

For this to actually happen, the solutions for the energy sector must include a reduction in the use of fossil fuels; electrification and greater use of biofuels in freight and passenger transport; a paradigm shift in Brazilian cities that results in an interruption in the growth of the use of individual transport; re-industrialization committed to replacing fossil fuels; and the effective implementation of energy efficiency programs.

Considering the projection of average GDP growth of 2.1% per year in the **OC vision** scenario, all emitting activities, with the exception of freight transport, converge to a level below 20 million tons of CO_2e by 2050, as shown in the graph below (figure 4).

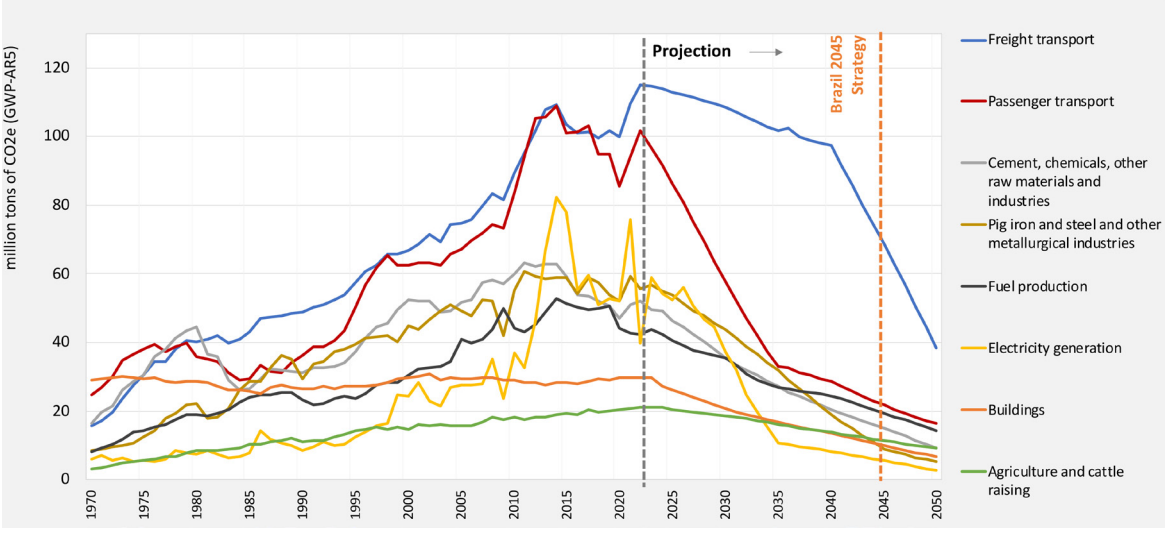

Figure 4 - ***Historical (1970-2022) and projected energy emissions (2023-2050) in millions of tons of CO_2e according to sectors and general activities****. Source: Own elaboration.*

Freight transport

It is the energy sector's main emitting activity, as it is mostly road-based, and the **OC vision** scenario assumes that this pattern will continue for years to come, even if there is greater investment in railroads and waterways. As a result, this activity should account for around 38% of the energy sector's total emissions by 2050.

Freight transport also poses the biggest challenges: the OC vision scenario assumes that the reduction in emissions will be relatively slow until 2040, but that it should accelerate from then on.

- **2022 emissions:** 115 million tons of CO_2e (SEEG).
- **2050 emissions:** 38 million tons of CO_2e.

The main guidelines for achieving this goal are:

- great importance of biofuels, especially in heavy and semi-heavy trucks, which have more limits to electrification;
- slower reduction of emissions in the first stage, until 2040, with a greater focus on biodiesel and an increase in its participation in heavy and semi-heavy trucks — since March 2024, it represents 14% in the conventional diesel blend and its share should increase by 1 p.p. from 2025, until it reaches 20% in March 2030, and may reach 25% later, if the National Energy Policy Council (CNPE) decides, as established by Law 14,993/2024 (Combustível do Futuro / Fuel for the Future);
- from 2040 onwards, the reduction in emissions should accelerate with greater introduction of green diesel;
- regarding light and semi-light trucks, investments in technology to gradually electrify the fleet and the viability of hydrogen engines, obtained from the electrolysis of water, will pave the way for diversifying engine options with low or zero carbon dioxide emissions.

It should be noted that efforts to reduce emissions from road transport could be nullified if the production of biofuels, which is fundamental to making the sector's energy transition viable, rep-

resents an element of environmental pressure, resulting in more deforestation, excessive use of water and impacts on the soil due to extensive monoculture. Socio-environmental safeguards, with control of areas and resources to produce these new fuels, as well as the definition of exclusion zones — such as the Amazon rainforest — are equally important. The priority must be to recover already degraded areas for planting the crops that make biofuels viable.

Passenger transport

The **OC vision** scenario assumes that the set of possibilities for reducing emissions from passenger transport is promising, with investment in the provision of public transport by bus, subway, tram and in infrastructure for the use of bicycles instead of individual cars. In addition, this scenario projects a complete replacement of gasoline with ethanol in flex-fuel vehicles by 2035, given the country's potential to produce biofuel and accompanied by the gradual electrification of the fleet.

Even so, this activity is expected to remain the energy sector's second main source of emissions by 2050 (16% of the total).

- **2022 emissions:** 102 million tons of CO_2e (SEEG).
- **2050 emissions:** 16 million tons of CO_2e.

The main guidelines for achieving this goal are:

- complete replacement of gasoline with ethanol in flex-fuel vehicles by 2035;
- car sales by 2050: 20% flex fuel, 10% flex hybrid, 20% flex plug-in hybrid, 35% battery electric, 15% hydrogen;
- the use of gasoline should be residual, restricted to the fleet that depends exclusively on this fuel;
- battery electric motors will be the majority, both in the different categories of buses and motorcycles;
- petroleum diesel oil will be replaced by green diesel in combustion engines, which will be of great importance in the many bus categories;

- a shift in the paradigm of cities, which should be more compact and have shorter journeys, with investment in the provision of public transport by bus, subway, tram and in infrastructure for the use of bicycles to the detriment of individual cars; [10]

- public transport is expected to grow at a faster rate than cars and motorcycles, both in terms of passenger-kilometers and sales;

- the domestic airline industry is expected to follow the international one towards carbon neutrality by 2050, with the increased use of SAF — which should reach a 23% share in the consumption of this mode of transport by that year.

Fuel production

The drop in emissions from fuel production is directly related to the reduction in demand from other activities and, as a result, to the simple reduction in production — which, according to the assumptions adopted in the **OC vision** scenario, should be restricted to what is necessary to meet a decreasing domestic demand as the energy transition progresses. Even so, this activity is expected to be the energy sector's third largest emitter — 14% of the total.

- **2022 emissions:** 42 million tons of CO_2e (SEEG), the sum of what was emitted by the production of oil, fossil gas, coal and biofuels.

- **2050 emissions:** 14 million tons of CO_2e.

In addition to the reduction in emissions related to lower demand from the main emitting activities, attention must be given to the main guidelines for fuel production:

- Petrobras should substantially change its investment portfolio and start investing in renewable energy and biofuels;

- determination of exclusion zones in sensitive areas with a refusal of new oil projects in environmentally sensitive areas, such as the Equatorial Margin and the Pelotas basin;

[10] ITDP, 2024. **Compact Cities Electrified: Brazil.** Disponível em: https://itdp.org/publication/compact-cities-electrified--brazil-roadmap/. Acesso em: 23 set. 2024.

- decommissioning oil fields that have already exhausted their expected useful life, without outsourcing decommissioning to smaller companies with little structure;

- development and implementation of a timeframe to end oil auctions in Brazil, assuming the prospect of supplying the decreasing domestic demand for oil with existing wells;

- fossil gas should not be regarded as a transition fuel in both the electricity sector and industry, and its production should be limited to supplying needs in cases where there is no technological substitution possible, such as in the fertilizer sector or the chemical industry, as well as ensuring the supply of electricity in the event of water stress;

- low-carbon hydrogen should be made from renewables only, with a maximum carbon intensity of 2 $kgCO_2/kgH_2$, with priority use in transport activities and national industry;

- coal should be eliminated from electricity production from 2027 and be restricted to industrial use, with a gradual phase-out by 2044.

Metallurgical industry

The steel industry will have to replace the use of coal to produce pig iron and steel with electrification, hydrogen and charcoal. This scenario assumes that this process will take place in parallel with the country's reindustrialization plan and the increased competitiveness of Brazilian products on the international market. As a result, this activity is expected to account for 5% of total emissions from the energy sector — in this case, not only emissions from final energy consumption are taken into account, but also those resulting from the use of fuels as reducers; the latter portion is accounted for as Industrial Processes and Use of Products.

- **2022 emissions:** 56 million tons of CO_2e (SEEG), considering final energy consumption and emissions from Industrial Processes and Product Use.

- **2050 emissions:** 5.4 million tons of CO_2e

The main guidelines for achieving this goal are:

- replacing coal for the production of pig iron and steel with electricity, hydrogen and charcoal by 2044;

- retiring the steel production route that uses fossil fuels as reductants in blast furnaces, replacing it with technological options that already exist on the market — blast furnaces dedicated to the use of charcoal as a reductant fuel, direct reduction using gas and/or hydrogen, new smelting reduction processes, and recycling using an electric arc furnace;

- expanding the use of biomethane in the sector, replacing fossil gas.

Chemical, cement and food industries, among others

As with the steel sector, the increase in industrial activity, in the midst of Brazil's reindustrialization process, should occur in parallel with the increased use of electricity and biomass to replace fossil fuels, as well as increased productivity and energy efficiency.

- **2022 emissions:** 52 million tons of CO_2e (SEEG)

- **2050 emissions:** 9.3 million tons of CO_2e

The main guidelines for achieving these goals are:

- increasing the share of low-emission energy sources (electricity, biomass, and hydrogen) replacing fossil fuels, especially by 2035, combined with a rise in both productivity and energy efficiency;

- zero consumption of petroleum products and coal by 2030, and fossil gas by 2035 in the food and beverage, cement, and pulp and paper industries;

- gradual reduction in fossil gas consumption and replacement with biomethane;

- use of green hydrogen in the chemical industry by 2035, applying the RTC group's benchmark;

- in cement production, biomass should be responsible for supplying almost 50% of all the energy demand that cement plants will have by 2050;

- in the chemical industry, electricity, which should account for almost half of the energy matrix for this activity by 2050.

Electricity generation

The increase in demand for electricity, in view of the growing population and the electrification of various economic sectors, will occur at the same time as wind and solar sources grow, keeping the electricity matrix essentially renewable. This scenario assumes that hydroelectric plants will continue to be relevant in electricity generation, but that new large plants (over 300 MW) will be forbidden. Only medium and small plants (SHPs) should be allowed under socio-environmental safeguards and some restrictions, such as the prohibition of new plants in the Amazon region, in indigenous lands, and environmentally protected areas, among others.

Meanwhile, coal, diesel, and fuel oil thermoelectric plants will have to be shut down, while fossil gas plants will be restricted and activated only when necessary — for example, to ensure energy supply in times of water stress.

Emissions from electricity generation vary depending on whether these thermal plants are used. However, it is projected that they could fall at a faster rate already in this decade up to 2035, after which the fall will be less marked until 2050, when emissions should represent 3% of the total emitted by the energy sector.

- **2022 emissions:** 40 million tons of CO_2e (SEEG)
- **2050 emissions:** 2.7 million tons of CO_2e

The main guidelines for achieving these goals are:

- installed capacity should reach 194 GW for wind energy (onshore and offshore) and 224 GW for solar energy (adding 91 GW of centralized generation and 133 GW of distributed generation), based on the analyses and projections of the National Energy Plan 2050, the Ten-Year Energy Expansion Plan (PDE) 2034 and Absolar, among other organizations;
- a modest increase in hydroelectric plants, of 9.5 GW (9% more) in total installed capacity over 28 years, from 109.7 GW operating in 2022 to 119.2 GW in 2050;
- coal-fired thermoelectric plants should be shut down by 2027 (the use of coal should be restricted to industry until 2050);

- nuclear and fuel oil-fired power stations should be shut down immediately;
- fossil gas power plants will be restricted and activated only when necessary — for example, to ensure energy supply in times of water stress;
- sugarcane bagasse should be responsible for supplying more than 50 TWh of electricity by 2035 (almost double what was achieved in 2022), stabilizing at this level of generation until 2050.

Buildings

For buildings, the **OC Vision** scenario considers as assumptions the adoption of clear commitments towards ending energy poverty, correcting the social injustices that hinder access to cheap and renewable energy for the entire population, as well as increasing electrification and solar energy for heating. Observatório do Clima believes that the precarious use of firewood must be eliminated.

- **2022 emissions:** 30 million tons of CO_2e (SEEG)
- **2050 emissions:** 6.6 million tons of CO_2e

The main guidelines for achieving these goals are:

- elimination of the use of LPG by 2045 and the gradual replacement of piped fossil gas with biomethane in homes;
- the use of solar heating in homes has been growing in recent years and could account for 20% of residential energy consumption by 2035;
- an increase in energy efficiency, expressed in the ratio of energy consumption to GDP, achieving an improvement of 30% in homes and 10% in the commercial and public sectors;
- elimination of the precarious use of firewood, with the goal of zero use in urban areas by 2030, and replacement with other energy sources.

Agriculture and cattle raising (energy consumption only)

Regarding energy consumption in agriculture and cattle raising, the **OC vision** scenario expects an increase in the use of electricity, but above all an intensification in the use of biofuels. Reducing emissions must also involve greater energy efficiency in the sector.

- **2022 emissions:** 21 million tons of CO_2e (SEEG)
- **2050 emissions:** 9 million tons of CO_2e

The main guidelines for achieving these goals are:

- increasing use of electricity, accompanied by a reduction in the share of firewood and petroleum diesel;
- an increase in the percentage of biodiesel, as stated in Law 14,993/2024 (Combustível do Futuro / Fuel for the Future), according to which, by 2030, the share of biofuel should represent 20% of the total volume in the diesel mix;
- energy efficiency, expressed in terms of energy consumption over the amount of GDP from agriculture and cattle raising, could double by 2050.

2.2. Tendential scenario

The **tendential** scenario describes the trajectory of Brazil's emissions if the country maintains its current characteristics and trends, without intensifying efforts and incentives for a consistent reduction in GHG emissions. Figure 5 shows that emissions will be five times higher than in the **OC vision** scenario, which is far below an ambitious target for Brazil to become carbon negative by 2045 or at least neutralize its emissions by 2050.

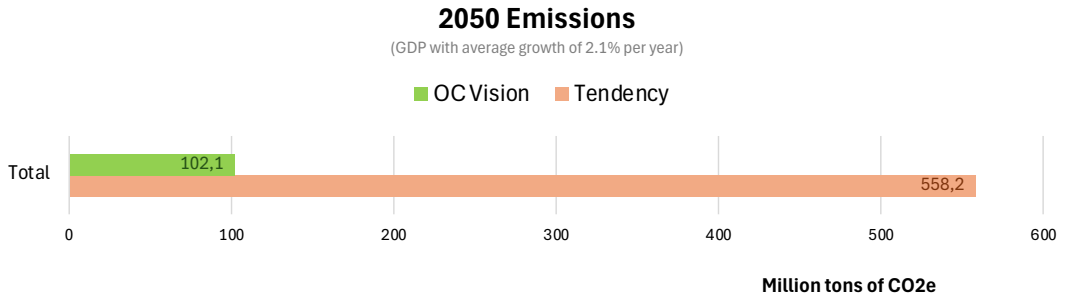

Figure 5 - ***Total emissions in the OC vision scenario and the tendency scenario.*** *Source: Own elaboration.*

In general terms, this scenario considers the continued exploration and use of fossil fuels, without disruptive initiatives to promote a transition to cleaner and more sustainable energy sources. Although Brazil stands out for its renewable electricity matrix, mainly due to the predominance of hydroelectric plants, the need to increase generation to meet the country's growing demand will result in an intensification of the use of non-renewable sources if there is no change in current policies.

In addition, other activities in the energy and industrial process sectors are already structured and rely heavily on fossil fuels. Without a robust change in the current paradigms, the trajectory of emissions in Brazil will continue to be far from the necessary reduction in emissions.

In the electricity sector, an increase in fossil gas power generation is expected in the coming years as a result of the Eletrobras privatization law, which establishes the contracting of 8 GW of gas-fired thermoelectric plants in the National Interconnected System (SIN) by 2044. This incentive for fossil generation will result in a prioritization of non-renewable energy sources. In addition, the system is still planning the completion of the Angra III Nuclear Power Plant, which involves environmental risks and high production costs.

In the planning of the Brazilian electricity system, it is also planned to continue installing new hydroelectric plants, expanding the installed potential. However, this growth could generate significant socio-environmental impacts for minority groups, such as indigenous communities and quilombolas, especially if there is no adequate and integrated social planning.

In the industrial sub-sector, there is resistance to changes in existing processes and limited planning to modify the current scenario. The prospects for significant changes are limited, with

the main focus on increasing the use of fossil gas. The government's moves indicate that this fuel is part of the national strategy for the energy transition in the coming decades.

For the freight and passenger transport sub-sectors, an increase in the adoption of electric and hybrid vehicles is expected. However, considering current incentives and growth, this increase still falls short of the ambitious emissions reduction targets needed to achieve a zero-emissions future.

THE BRAZIL 2045 STRATEGY IN THE TENDENTIAL SCENARIO

- Freight transport: for 2045, the **OC vision** scenario has emissions 48% lower than the **tendential scenario**
- Passenger transport: for 2045, the **OC vision** scenario has emissions 49% lower than the **tendential scenario**
- Cement, chemical and food industries, among others: for 2045, the **OC vision** scenario has emissions 80% lower than the **tendential scenario**
- Steel industry: by 2045, the **OC vision** scenario has emissions 90% lower than the t**endential scenario;**
- Electricity generation: for 2045, the **OC vision** scenario has emissions 90% lower than the **tendential scenario**;
- Buildings: for 2045, the **OC vision** scenario has emissions 71% lower than the **tendential scenario;**
- Agriculture and cattle raising (energy consumption only): for 2045, the **OC vision** scenario has emissions 61% lower than the **tendential scenario**.

Figure 6 illustrates the projected values for each sector, considering the **OC vision** and the **tendential scenario**. As can be seen, there is a considerable difference in terms of emissions in all the sectors evaluated. It is worth noting, however, that the difference is even greater in freight transport — 143.5 million tons of CO_2e versus 38.3 million tons of CO_2e — one of the most difficult sectors to decarbonize even taking into account the most optimistic forecasts. Emissions from industry and electricity generation will also remain at very high levels compared to the decarbonization possibilities described above in the **OC vision** scenario.

Giving up on this path, as the graph comparing the two scenarios shows, means ignoring the need for a just energy transition that Brazil — and other countries — will have to make if they want to meet the Paris Agreement targets and guarantee the viability of life on Earth.

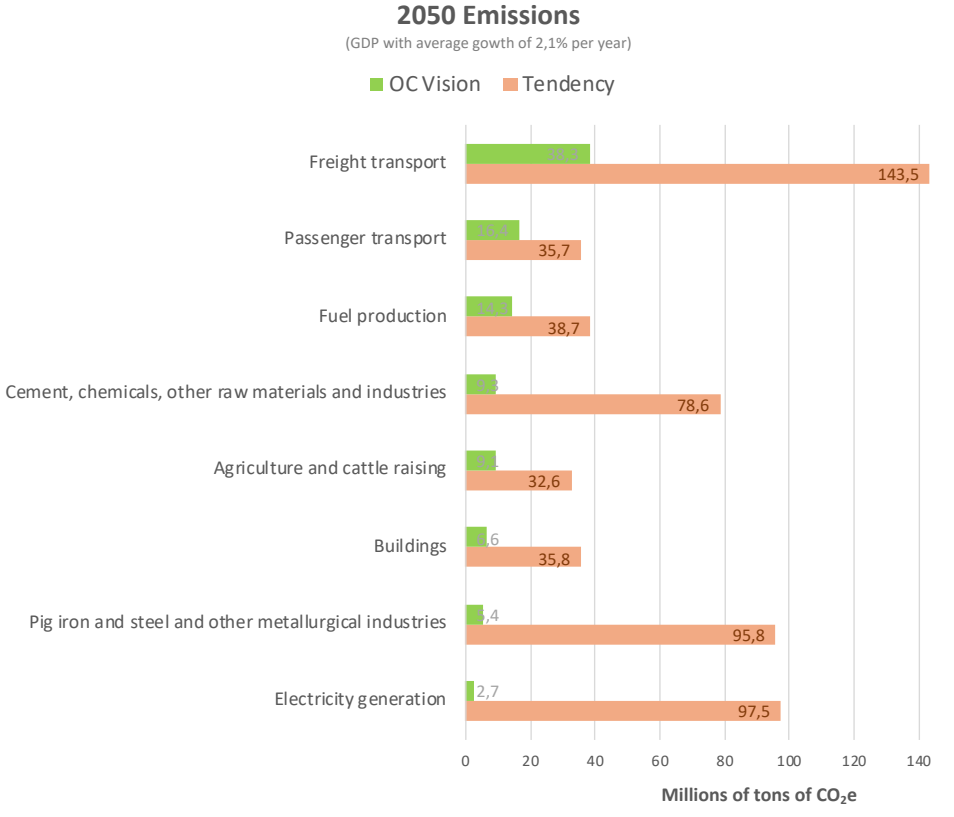

Figure 6 - ***Total emissions by sub-sector, for the OC vision and tendency scenarios in 2050.*** *Source: Own elaboration.*

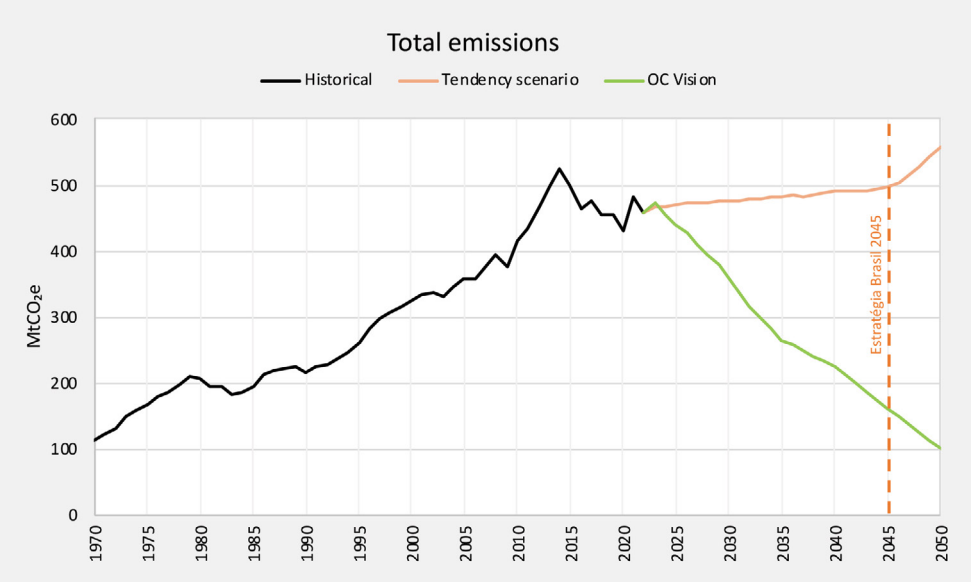

Figure 7 - ***Historical estimates (2000 to 2022) and projections (2023 to 2050) of total emissions, in millions of tons of CO_2e, in the Tendency Scenario and OC vision.*** *Source: Own elaboration.*

2.3 Changes in energy demand as a function of GDP

In order to see how emissions might vary depending on different energy demand trajectories linked to economic growth, we compared the **tendential** and **OC vision** scenarios, with emissions projected from a reference GDP growth rate (2.1% per year on average until 2050), with four different scenarios derived from two other economic growth trajectories: one with lower growth (1.3% per year) and another with higher GDP growth (2.8% per year), as explained above.

Considering reference GDP growth, the **tendential** scenario projects a 22% increase in emissions between 2022 and 2050. Considering lower energy demand (lower GDP growth), there is a timid 6% reduction in emissions. In other words, economic growth at the historical rate would keep emissions relatively stable until 2040, which has already been the case since 2015 — but still short of meeting the Paris Agreement targets.

With greater energy demand represented by higher GDP growth, the increase in emissions is 67% between 2022 and 2050.

The **OC vision** scenario, considering reference GDP growth, projects a 78% reduction in emissions between 2022 and 2050. Considering lower energy demand (lower GDP growth), the reduction reaches 83%. With higher energy demand, the reduction is 42%, with a resumption of emissions growth in the mid-2040s.

The variations in emissions considering the different GDP trajectories are mainly explained by the electricity generation activity, as can be seen in Figure 8.

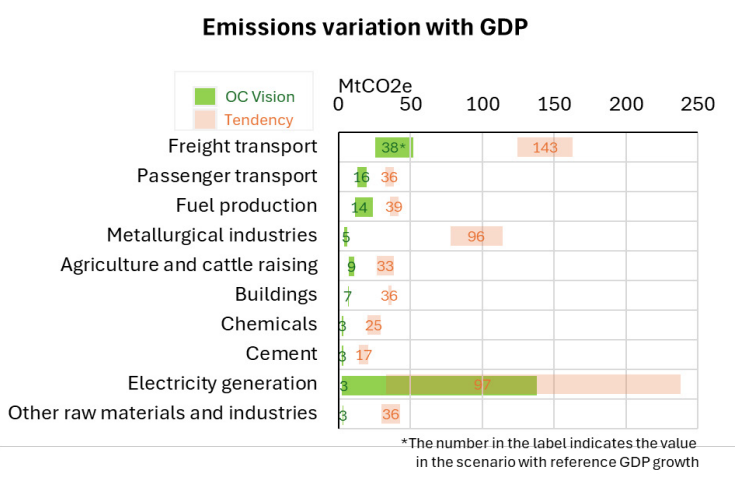

Figure 8 - ***Variation in annual emissions from each activity in 2050 as a function of GDP growth.*** *Source: Own elaboration.*

It is worth pointing out that, in the **OC vision** scenario, the gap between the results that take into account the reference GDP trajectory and the upper trajectory is mainly due to the definitions of installed capacity for electricity generation. If they remain limited to the values of the reference target scenario, fossil thermoelectric plants will have to be fired up to meet the greater demand for electricity.

This shows that, in order to maintain the same rate of decarbonization in the event of greater energy demand, a more significant expansion of renewable energies in the electricity sector must be pursued. It is worth noting that not all decarbonization potentials were fully considered in the **OC vision** scenario — such as biogas — which opens up space to maximize decarbonization in the event of greater growth in energy demand.

In the **tendential** scenario, the behavior of the variations in each activity is similar, but with a greater amplitude in the absolute variations in emissions. Electricity generation and freight transport continue to be the activities with the greatest amplitude, but metallurgy also stands out.

The variation of the results in the **tendential** and **OC vision** scenarios according to the different average GDP growth rates shows that economic development is a highly influential factor in the behavior of GHG emissions, which can be attenuated or even eliminated depending on the political choices that accompany it.

The growth of the Brazilian economy, with a corresponding increase in GDP, does not necessarily translate into higher emissions. This is a perspective that needs to be left behind, as it does not internalize the climate crisis. Economic development can — and should — be guided by decarbonization and climate justice.

Brasil 2045

3

CONCLUSIONS

The study *Futuro da energia: visão do Observatório do Clima para uma transição justa no Brasil (Future of energy: Observatório do Clima vision for a just transition in Brazil)* claims that it is possible to build a path that goes beyond current trends, which are dissonant with concerns about the prospect of effectively tackling the climate crisis. The energy sector only accounts for 17.8% of the country's gross greenhouse gas emissions, according to 2022 data, but it must assume decarbonization as a prerequisite for contributing to a carbon-negative Brazil by 2045. The energy transition is a structuring element of climate policy because it brings about changes with definitive marks. It's different in this respect from controlling deforestation, which can quickly go backwards with government changes.

The proposals were developed based on the real world. If the Brazilian government really wants to lead by example and become a world climate leader, an environmental powerhouse, the contents of the study presented here will provide important, detailed and technically robust support.

In addition to the guidelines summarized above, it is worth highlighting other measures that the **OC vision** scenario considers essential in its guidelines for a just energy transition in Brazil:

- the construction of a model for the development of the electricity sector that guarantees greater integration of renewables and optimizes its operation, allowing consumers the option of using non-dispatchable sources — such as distributed generation — together with new storage technologies, as well as guaranteeing equity and justice in access to energy;

- the elimination of government subsidies for fossil fuels, directing these resources to support a just energy transition;

- investments in biofuels must be accompanied by proper environmental control and all the necessary socio-environmental safeguards;

- the establishment of targets for reducing energy poverty and effective government action to tackle this problem;

- the guarantee of effective policies that reduce the impacts and promote a more harmonious relationship, with social control, of renewable energy projects, with the adoption of actions that actually translate into an improvement in the quality of life in the communities surrounding the projects;

- intensification of energy efficiency and demand management programs in the sector;
- the absolute prioritization of public transport over individual motorized transport in urban areas, accompanied by urban planning that reduces the distances between home and work and encourages active mobility whenever possible;
- the promotion of the public transport industry accompanied by the electrification of bus fleets, with federal support for sub-national governments for initiatives along these lines;
- ensuring that the country's necessary reindustrialization process is guided by the need to reduce greenhouse gas emissions;
- the reformulation of the National Solid Waste Plan (Planares), which should focus more on targets for non-generation of waste, reuse and recycling, and renounce the generation of energy through incineration.

OBSERVATÓRIO DO **CLIMA**

Brasil 2045