ICAT Brazil Project

CBC – Centro Brasil no Clima

Report 3

Indicators for Progress Monitoring in the Achievement of NDC Targets in Brazil

Centro Clima / COPPE / UFRJ

June / 2019

CENTRO CLIMA/COPPE/UFRJ

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Acknowledgments: Branca Americano, for the information kindly provided to the research team.

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Presentation

The Brazilian NDC has an economy-wide goal of 37% GHG emissions reduction in 2025 and an intended 43% reduction in 2030, compared with the absolute level in 2005 (base year). In its annex "for clarification purposes," it is specified that these goals translate into an aggregate limit of 1.3 Gt CO_2-eq in 2025 and 1.2 Gt CO_2-eq in 2030 (GWP-100, IPCC AR5). This annex also presents some quantified sectorial goals in energy, land use and forests, and agriculture as we have previously detailed in Report 2 of this study.

Brazil also made previous voluntary commitments in COP15 held in Copenhagen in 2009 and formalized through NAMAs presented to the UNFCCC establishing that the country would reduce GHG emissions between 36.1 and 38.9% against a baseline scenario for 2020. The Baseline emissions, as well as the means to achieve the NAMAs goals, were detailed by the 2009 Climate Change Law (12187/09) and related executive decree (7360/2010). Section 1 presents these values.[1]

The Brazilian government has been monitoring and reporting its GHG emissions through national inventories (the preparation of the fourth edition is underway) and biannual reports submitted to the UNFCCC. The country has also been issuing annual GHG emissions estimates and publishing its reports on the National Emissions Registration System (SIRENE), an online platform launched by the Ministry of Science, Technology, Innovation and Communications (MCTIC, the Brazilian acronym) in 2016.

"SIRENE's mission is to support decision-making in the scope of policies, plans, programs and projects in climate change, particularly in the adoption of mitigation actions. This platform optimizes not only the management processes of calculations results but also the disclosure of such information through graphics and tables generated by the management system, available on the Internet. Such initiative aims at contributing to the continuity of the work directed to the quantification of greenhouse gas emissions, as well as management of information related to GHG emissions in Brazil" (Brasil, 2017).

Still according to Brasil (2017), "the Brazilian Government categorizes SIRENE as an MRV (measuring, reporting and verification) system for emissions at an aggregated level, of the inventory sectors, including:

[1] The NAMAs values are estimated with the GWP of the second assessment report (SAR).

- ✓ Type of gas (carbon dioxide – CO_2; methane – CH_4; nitrous oxide – N_2O; hydrofluorocarbons – HFCs; perfluorocarbons – PFCs; sulfur hexafluoride – SF6; nitrogen oxides – NOx; carbon monoxide – CO and other non-methane volatile organic compounds – NMVOC);
- ✓ Emissions by sources and removals by sinks - for the Energy, Industrial Processes, Use of Solvents and Other Products, Agriculture, Land Use, Land-Use Change and Forestry, and Waste; and,
- ✓ The historical series of emissions published in the national inventory, as part of its National Communications, of the Biennial Update Reports, as well as of the Annual Emissions Estimates reports, whose elaboration complies with the established by the National Policy on Climate Change."

These measures provide technical subsidies to monitor the evolution of Brazilian emissions over time. However, they don't represent a systematic monitoring and reporting system of the mechanisms, effects, and impacts of sectorial mitigation plans, as required to allow a review of the mitigation efforts whenever needed.

Before that, in 2013, the Ministry of the Environment in cooperation with the ministries in charge of the climate change sectorial plans had already outlined a proposal to monitor and follow-up greenhouse gas emissions reductions associated with those sectorial plans. This proposal led to the Modular System for Monitoring Actions and GHG Emissions Reductions (SMMARE) with guidelines and methodological bases established in 2014. However, SMMARE still needs further improvements before being fully implemented as it was designed for monitoring sectorial plans, within the context of a national voluntary commitment based on a business as usual projection (NAMAs), not encompassing the NDCs targets (Brasil, 2017).

Current initiatives at the governmental level still lack a robust monitoring system able to track the pathways of multiple mitigation actions in the country. Therefore, this project aims at developing a methodology to calculate the effect of different sets of mitigation actions (grouped in mitigation scenarios) in terms of avoided GHG emissions to help measuring/monitoring, reporting and verification – MRV of the progress achieved in the implementation of quantified commitments of the Brazilian NDC. A draft decree expanding the regulation of the climate change national policy to embrace the follow-up of NDCs is also envisaged.

The indicators provided by this project can be considered an initial step toward the establishment of a robust and transparent MRV process capable of assessing the various actions that will lead to the desired accomplishment of the Brazilian NDC mitigation targets in a transparent and participatory process. It may also help the design of eventual carbon pricing mechanisms (carbon taxes and/or cap-and-trade systems) that would rely on a trustworthy MRV of the performance of the various kinds of mitigation actions.

Section 1 presents an evaluation of the achievement of NAMAs presented in COP15 to meet the voluntary Copenhagen pledges made by the Brazilian government in terms of GHG emissions reductions up to 2020. It is more detailed than the previous evaluation presented in Report 2, embracing both economy-wide and sectorial perspectives. Section 2 synthesizes the three Scenarios (A, B and C) developed for the assessment of avoided GHG emissions by mitigation policies and measures underway to meet NDC targets up to 2030, as described in greater detail in Report 2. Section 3 presents a summary of the achievement of NDC targets under the three different scenarios presented in Report 2. Section 4 presents sectorial indicators, and Section 5, finally, presents a preliminary proposal of a set of indicators to be used as part of an MRV system of the NDCs targets.

1. 2020 Targets: Evaluation of NAMAs

Brazilian government made a statement of its NAMAs to the UNFCCC COP15 in Copenhagen (2009) and eventually approved National Decree 7390 in 2010 presenting a mitigation commitment expressed as a percentage range of GHG emissions reduction in 2020 compared to a baseline scenario, from 36.1% to 38.9%. The background calculations of the two documents are only slightly different. However, in the case of the AFOLU sector only, figures of emissions from LULUCF are significantly different in absolute terms, leading to a substantial difference in the economy-wide emissions total. Table 1 compares the figures of the two documents.

Table 1. GHG Emissions ($MtCO_2$-eq) and Emission Reductions (%) in 2020: NAMAs and Decree 7390

	NAMAs		Decree 7390		Difference (%) (Decree-NAMAs) /NAMAS	
Total emissions in Baseline Scenario ($MtCO_2$-eq in 2020)	**2,704*** ***		**3,236***		**20%**	
Emissions reduction in 2020 (% compared to Baseline Scenario)	36.1%*	38.9%*	36.1%*	38.9%*	-	-
Total Emissions in Mitigation Scenario ($MtCO_2$-eq in 2020)	**1,728*** ***	**1,652*** ***	**2,068***	**1,977***	**20%**	**20%**
LULUCF ($MtCO_2$-eq in 2020)	*669**		*888**		*33%*	
Agriculture ($MtCO_2$-eq in 2020)	*133**	*166**	*134***	*163***	*1%*	*-2%*
Energy ($MtCO_2$-eq in 2020)	*166**	*207**	*234**	*234**	*41%*	*13%*
IPPU/waste ($MtCO_2$-eq in 2020)	*8**	*10**	*8**	*10**	*0%*	*0%*
Total emissions reduction target in 2020 ($MtCO_2$-eq)	976***	1052***	1,168*	1,259*	20%	20%

* Values as in the original document (either already expressed in CO_2e or according to our own calculations based only on the figures presented in the original document).
**Values of the ABC Plan, since Decree 7390 indicated targets of mitigation actions in other metrics only.
*** own calculations
Note: Global Warming Potential of the IPCC Second Assessment Report as used in the Brazilian NAMAs and in the Decree 7390 commitments.

Our assessment shows that if current policies and trends persist as assumed in Scenario A, GHG emissions would reach 1512 $MtCO_2$-eq in 2020. In this case, both NAMAs GHG emissions commitments (1652 - 1728 $MtCO_2$-eq) and Decree 7390 goals (1977 - 2068 $MtCO_2$-eq) would be met in 2020, from an economy-wide perspective. In our analysis, we have accounted for the carbon uptake in conservation units (CU) and indigenous land (IL), in accordance with the updated methodology of Brazilian GHG Emissions Inventory. However, if we disregard these carbon uptakes (calculated according to SEEG, 2018), as in the methodology at the time of the first Brazilian inventory (the document that methodologically supported the NAMAs), GHG emissions in Scenario A would be of 1823 $MtCO_2$-eq in 2020. Therefore, while Brazilian commitments as stated by Decree 7390 would be respected, the specific NAMAs targets would not be met. Table 2 summarizes these figures.

Table 2. NAMAs and the Decree 7390 Economy-wide GHG Emissions Targets in 2020, compared with Brazilian Emissions in Scenario A (the Current Trend Emissions) - ($MtCO_2$-eq and %)

	Emissions in 2020 ($MtCO_2$-eq*)
NAMAs Economy-wide Target	
36,1 – 38,9% emissions reduction compared to Baseline Scenario in 2020	1,652 – 1, 728
Decree 7390 Economy-wide Target	
36,1 – 38,9% emissions reduction compared to Baseline Scenario in 2020	1,977 – 2,068
Scenario A (current policies and trends)	
including carbon uptake in CU and IL	1,512
NOT including carbon uptake in CU and IL	1,823

* Global Warming Potential of the IPCC Second Assessment Report as used in the Brazilian NAMAs and in the Decree commitments.
Note: biomass content per biome of SEEG (2018) used in Scenario A.

From a sectorial perspective, as already mentioned, LULUCF target would be met only if we add up the amount of carbon uptake that takes place in conservation units and indigenous lands, otherwise emissions would be higher than the commitment. In the other sectors, emissions reductions are not spelled out in Decree 7390. In energy, that comprehends all the emissions from every single source including fugitive emissions, figures are provided for the Energy sector as a whole in the Baseline and Mitigation Scenarios but not for each mitigation action. For IPPU and Waste, values are added up and presented jointly, and no mitigation action is envisaged. Table 3 presents the sectorial disaggregation of Decree 7390 Commitment and sectorial emissions estimates.

Table 3. Decree 7390 Commitment and sectorial emissions estimates, 2005-2020 ($MtCO_2$-eq and %)

GHG Emissions/Mitigation Actions (Mt CO_2-eq)	**2005 Emissions** (Second National Inventory data)	**2020 Baseline Emissions** (Decree 7390)	**2020 Emissions in Mitigation Scenario - 36,1% reduction compared to Baseline** (Decree 7390)	**2020 Emissions in Mitigation Scenario - 38,9% reduction compared to Baseline** (Decree 7390)	**36,1% Abatement in 2020** (Decree 7390)	**38,9% Abatement in 2020** (Decree 7390)	**Scenario A: emissions in 2020** (carbon uptake in Cons. Units and Indigenous Lands **NOT** included)	**Scenario A: emissions in 2020** (carbon uptake in Cons. Units and Indigenous Lands included)	**Scenario A: change in emissions in 2020 compared to Decree goal** (carbon uptake in Cons. Units and Ind. Lands NOT included)	**Scenario A: change in emissions in 2020 compared to Decree goal** (carbon uptake in Cons. Units and Ind. Lands included)
	$MtCO_2$-eq						$MtCO_2$-eq		%	
	(A)	(B)	(C)	(D)	(E) = (B) - (C)	(F) = (B) - (D)	(G)	(H)	(I) = (G)/(C)	(J) =(H) /(D)
LULUCF	**1268**	**1404**	**516**		**888**		797***	486***	**54%**	***-6%***
Amazon		948	190		758		434	434	129%	*129%*
Cerrado		323	194		129		195		1%	
Other Biomes		133	133		0		239		80%	
Others			-		-		-72	-382	-	-
Agriculture/Husbandry	**487**	**730**	**596,1**	**567,1**	**133,9***	**162,9***	**419**		**Range: -29% to -26%**	
Restoration of grazing land					83*	104*				
Integrated crop-livestock system					18*	22*				
No-till farming					16*	20*				
Biological nitrogen fixation					10*	10*				
Others					6,9*	6,9*				

GHG Emissions/Mitigation Actions (Mt CO_2-eq)	**2005 Emissions** (Second National Inventory data)	**2020 Baseline Emissions** (Decree 7390)	**2020 Emissions in Mitigation Scenario - 36,1% reduction compared to Baseline** (Decree 7390)	**2020 Emissions in Mitigation Scenario - 38,9% reduction compared to Baseline** (Decree 7390)	**36,1% Abatement in 2020** (Decree 7390)	**38,9% Abatement in 2020** (Decree 7390)	**Scenario A: emissions in 2020** (carbon uptake in Cons. Units and Indigenous Lands **NOT** included)	**Scenario A: emissions in 2020** (carbon uptake in Cons. Units and Indigenous Lands included)	**Scenario A: change in emissions in 2020 compared to Decree goal** (carbon uptake in Cons. Units and Ind. Lands NOT included)	**Scenario A: change in emissions in 2020 compared to Decree goal** (carbon uptake in Cons. Units and Ind. Lands included)
Energy	**362**	**868**	**634**		**234**		**427**		**-33%**	
Energy efficiency										
Increase in the use of biofuels										
Increase in energy supply by hydroelectric power plants										
Alternative energy sources										
IPPU + Wastes	**86**	**234**	**234**				**180**		**-23%**	
Total (sum of sectorial values)	**2.203**	**3236**	**1981****	**1952****	**1256****	**1285****	**1823**	**1512**	**-8%**	**-6%**
Total emissions in Decree 7390		**3236**	**2068**	**1977**	**1168**	**1259**				

* values of ABC Plan
** values calculated based on Decree 7390 sectorial values
Notes: Global Warming Potential of the IPCC SAR as used in the Brazilian Decree 7390. Biomass content per biome of SEEG (2018) used in Scenario A.
Sources: 2005 values from the Second National Communication. Decree 7390 values from Brazil (2010). Scenario A values from our estimates.

The following sections analyze the Brazilian 2020 commitments from a sectorial perspective. We evaluate mitigation actions underway in AFOLU, Transport, Industry and Energy Supply, sectors with some specific parameters presented in Decree 7390.

1.1. AFOLU

The Brazilian NAMAs presented in 2009/2010 notably focused on the country's largest emission source, which used to be deforestation. The effort targeted reducing deforestation rates in the Amazon and the "Cerrado" (savannahs) biomes, among other actions in the AFOLU sector.

The voluntary commitment reinforced by the National Policy on Climate Change - PNMC (Law No. 12.287/2009 and Decree No. 7.390/2010) and its mitigation plans established the mitigation actions and targets for the AFOLU sector by 2020. It is worth mentioning that for LULUCF, figures in the NAMAs and in Decree 7390 are significantly different. The mitigation actions as presented in Decree 7390[2] are described below:

i) Reduction in 80% of the annual deforestation rate in the Amazon, compared to the historical average in the period 1996–2005; this figure is of 1.953 Mha/year, and together with the average biomass density of 132.3 t C/ha (484 t CO_2/ha as in the second national communication) was used to project the BAU emission level of 948 $MtCO_2$-eq/year in 2020; assuming a constant biomass density, this decrease in the Amazon deforestation rate would avoid emissions of 758 Mt CO_2/y in 2020 (La Rovere et. al, 2010).

ii) Reduction in 40% of the annual deforestation rate in the savannahs, compared to the historical average in the period 1999–2008; this figure is of 1.570 M ha/year, and together with the average biomass density of 56 t C/ha (206 t CO_2/ha as in the second national communication) was used to project the BAU emission level of 323 $MtCO_2$-eq /year in 2020; assuming a constant biomass density, this decrease in the Cerrado deforestation rate would avoid emissions of 129 $MtCO_2$-eq/year in 2020 (La Rovere et al., 2010).

iii) Restoration of grazing land. Range of estimated mitigation of 83-104 $MtCO_2$-eq in 2020. Decree 7390 and the ABC Plan estimate a restored area of 15 million ha.

[2] For low-carbon options in Agriculture, Decree 7390 presented targets related to emission drivers only. Targets expressed in GHG emission values were obtained from the ABC Plan.

iv) Increased use of crop-livestock integrated systems. Range of estimated mitigation of 18-22 $MtCO_2$-eq, in 2020. Decree 7390 of 2010 and the ABC Plan estimate the adoption of such systems in an additional area of 4 Mha by 2020.

v) Increased use of zero tillage planting techniques. Range of estimated mitigation of 16-20 $MtCO_2$-eq by 2020.

vi) Increased use of Biological Nitrogen Fixation cropping technique. Range of estimated mitigation of 16-20 $MtCO_2$-eq, in 2020. Decree 7390 of 2010 and the ABC Plan estimate an increase in the use of this technique of 5.5 Mha by 2020.

vii) Increased use of technologies to treat 4.4 million m3 of animal waste. Estimated mitigation of 6.9 $MtCO_2$-eq in 2020.

Table 4 summarizes the results of emissions and removals according to our analysis in Scenario A and the limit of emissions and removals expected for 2020 according to the Decree 7390 (2010) and the ABC Plan.

In Scenario A, the annual emissions from deforestation during the period 2018-2020 was assumed to be equal to the average annual deforested area in the period 2012–2016[3], for all biomes. This rationale was applied considering that in 2012 there was a reversal in the declining deforestation trend in the Brazilian Amazon and that deforestation has leveled out at high annual rates in the Cerrado biome. Therefore, the estimates are conservative.

To investigate if the current level of the emissions would lead to an achievement of the commitment in 2020, we recalculated the emissions from the deforestation area considering the deforested area provided for in Decree 7390 and the carbon stocks per hectare applied in this study (from SEEG, 2018).

According to our assumption (that in 2020 emissions would equal the annual average in the 2012-2016 period), in Scenario A emissions from deforestation in the Amazon biome would be of 434 $MtCO_2$-eq (Table 4), corresponding to an annual deforestation rate of 591 thousand ha in 2020 (Table 5). According to Decree 7390, its emission target would be 189 $MtCO_2$-eq in 2020. When we applied the updated carbon content of the biomass used in this study (199.9 t C/ha) to the area mentioned in Decree 7390, emissions from the deforested area in the Amazon biome in 2020 would be of 274 $MtCO_2$-eq. The results of Scenario A thus show that the reduction

[3] Deforestation in the Amazon reached 27 thousand km² in 2004 and fell to 4.5 thousand km² in 2012. It then rose again to almost 8 thousand km² in 2016, and then dropped again in 2017 to 6.7 thousand km².

target of 80% in the deforestation rate in the Amazon biome will not be achieved in 2020 if current trends persist. Emissions in scenario A would be 58% higher than the NAMA target of 274 $MtCO_2$-eq for 2020 (considering the updated carbon stocks of this study) whereas the annual deforestation rate of 591 thousand ha in 2020 would be 51% above the targeted 392 thousand ha/year.

In the case of the Cerrado biome, according to Scenario A, the commitment would be met. Emissions in 2020 would total 195 $MtCO_2$-eq (Table 4), corresponding to an annual deforestation rate of 838 thousand ha/year (annual average in the period 2012-2016) (Table 5). The target for the annual deforestation rate in 2020 was of 942 thousand ha/year. This deforested area would correspond to emissions of 194 $MtCO_2$-eq in 2020, according to Decree 7390 (Table 5). When we recalculate the emissions associated to the deforested area considering the updated carbon content of the biomass per hectare applied in this study (63.4 t C/ha) the emission would be of 219 $MtCO_2$-eq/year in 2020.

For the other biomes, our Scenario A results show higher values than those in Decree 7390 (Table 4). One of the possible reasons is related to the data about the deforestation of Atlantic Forest. The annual gross emissions from land use change in this biome published by the Brazilian government (Third National Inventory and annual estimates) for the period 2005/2010 and also adopted in other studies, such as SEEG, are controversial and do not correspond, for example, to the data on deforested area available for this biome available from the Atlantic Forest Foundation. Emissions reported by governmental publications are very high indicating the possibility of data problems. A strong and thorough review of the published values is recommendable.

Summing up, according to the Decree 7390, the 2020 target for emissions from land use change would be of 516 $MtCO_2$-eq in 2020, or 839 $MtCO_2$-eq recalculated according to the updated carbon stocks used in this study. Total emissions from annual deforestation (in all biomes) in 2020 would amount to 867 $MtCO_2$-eq (Table 4), higher than the target.

Concerning other mitigation actions like removals from commercial planted forests, use of integrated cropping-livestock-forest systems (ICLF systems) and restored pastureland, Scenario A results indicate that targets will not be met in 2020, considering both the driving forces and the amount of carbon removal, if current trends persist. On the other hand, targets for zero-tillage and Biological Nitrogen Fixation would be met (Table 4 and Table 5).

Table 4. Evolution of AFOLU emissions and removals and results of Mitigation Actions for 2010-2020 in Scenario A and Decree 7390 Targets ($MtCO_2$-eq)

Emission Drivers[1]	Results of Emissions and Removals according to Scenario A ($MtCO_2$-eq*/year)					Emissions and Removals according to Decree 7390/2010 and ABC Plan ($MtCO_2$-eq*/year)	
	2010	2015	2016	2017	2020	2020 Targets (same area and carbon stocks of the original documents)	2020 Targets (same area as in original documents but with updated carbon stocks used in this study)
Emissions from annual deforestation rates - LULUCF							
Emissions from annual deforestation rate in Amazon biome		455	579	486	434[2]	189[3]	274[5]
Emissions from annual deforestation rate in Cerrado biome		220	220	220	195[2]	194[3]	219[5]
Emissions from annual deforestation rate in other biomes		207	295	158	239[2]	133[3]	346[5]
Total Emissions		***882***	***1094***	***864***	***868***	***516[3]***	***839[5]***
Carbon Removals - LULUCF							
Removals from area under use of ICLF systems[6]		25	15	15	15	18-22[3;4]	
Removals from area of commercial planted forests		12	12	0	0	-	
Removals from area of restored pastureland		14	16	19	25	83-104[3;4]	
Avoided Emissions and Carbon Removals - Agriculture							
Removals from area under zero-tillage practices		6.1	7.9	9.8	16	16-20[3;4]	
Avoided emissions from the use of Biological Nitrogen Fixation		20	N.A	N.A	20	16-20[3;4]	
Avoided emissions from manure under management		15	NA	NA	15	6.9[7]	

* GWP SAR

[1]This table only contains the mitigation measures actions in Decree 7390 and ABC Plan; [2]Estimate for 2020 = annual average of the deforestation area in 2012-2016; [3]Values indicated in Decree 7390; [4] Values indicated in the NAMA document and ABC Plan; [5]Values recalculated considering the updated carbon stocks per hectare applied in this study; [6]ICLF = integrated cropping/livestock/forest systems, also considering ILF = integrated livestock/forest systems, and ICF = integrated cropping/forest systems; [7] ABC Plan because Decree 7390 targets were established in m^3 only.

Table 5. Evolution of AFOLU emission drivers and mitigation actions in 2010-2020: Scenario A results and Decree 7390 Targets (ha/year and m^3/year)

Emission drivers/Mitigation Actions	Scenario A results					Brazilian Targets for 2020	
LULUCF	2010	2015	2016	2017	2020	2020 Targets	Source
Annual Deforestation rate in Amazon biome (thousand ha/year) [1]	700	620	789	662	591	392	Decree 7390
Annual Deforestation rate in Cerrado biome (thousand ha/year) [1]	647	948	948	838	838	942	Decree 7390
Annual deforestation rate in other biomes (thousand ha/year) [1]	269	262	273	257	266	-	Decree 7390
Area under use of ICLF systems[2,3] (Mha/year)	0.9	2.0	2.1	2.2	2.6	4.9[4]	Decree 7390 and ABC Plan
Area of commercial planted forests[3] (Mha/year)	6.5	6.9	6.7	6.4	6.3	9.5[4]	Decree 7390 and ABC Plan
Area of restored pastureland[3] (Mha/year)	-	3.9	4.5	5.1	6.9	15	Decree 7390 and ABC Plan
Agriculture							
Area under zero-tillage practices[3] (Mha/year)	30.8	34.1	34.1	36.2	39.3	38.8[4]	Decree 7390 and ABC Plan
Area under Biological Nitrogen Fixation[3] (Mha/year)	23.3	32.2	32.3	32.4	32.7	28.8[4]	Decree 7390 and ABC Plan
Manure under management[3] (Mm3/year)	7.4	9.4	9.4	9.4	9.4	4.4	Decree 7390 and ABC Plan

[1]published data for 2010-2017 and scenario results for 2018-2020; [2]ICLF = integrated cropping/livestock/forest systems, also considering ILF = integrated livestock/forest systems and ICF = integrated cropping/forest systems; [3]other mitigation actions: published data until 2015 and projection for 2016-2030; [4]official documents refer to additions to the 2010 level (+4; +3; +8.8; +5.5).

1.2. Transportation

The Second Biennial Update Report of Brazil to the United Nations Framework Convention on Climate Change (Brazil, 2017) presents the development mechanisms to support the implementation of the NAMAs at sectorial scale, according to Decree 7390. In the energy sector, there are two actions related to transportation: (1) Increase the supply of anhydrous and hydrated ethanol, as well as biodiesel to replace fossil fuels; and (2) Reducing the use of fossil fuels and electricity through the increase of energy efficiency in different sectors of the economy. Table 6 presents the goals.

Table 6. Transportation NAMAs - Description

	NAMA	
	(1) Implementation of Energy Efficiency	**(2) Increased Use of Biofuels**
Sector	Energy	Energy
Period of evaluation	2010 to 2017	2010 to 2017
GHG emissions	CO_2-eq	CO_2-eq
Description	Reducing the use of fossil fuels and electricity through the increase of energy efficiency in different sectors of the economy	Increase the supply of anhydrous and hydrated ethanol, as well as biodiesel to replace fossil fuels
Main objective	Reducing the consumption of fossil fuels and electric power	Increase the amount of Biofuel in the National Energy Supply
Sectorial objective (Transport)	Reducing the consumption of fossil fuels	Supply of anhydrous and hydrated ethanol and biodiesel

Source: adapted from Brazil (2017).

Concerning the implementation of the Energy Efficiency NAMA, Brazilian Labeling Vehicle Program (PBEV) aims to provide information about energy efficiency and GHG and pollutant emissions, trying to stimulate consumers and producers to reduce the use of fossil fuels in the transportation sector. Most automakers and importers located within Brazil´s territory have joined, reaching 90% of the automobiles marketed (Brazil, 2017). Moreover, from 2010 to 2017, the fleet of hybrids and BEV light vehicles (automobiles, light commercial and motorcycles) presented a significant growth, from virtually nothing to 7 thousand vehicles. This number tends to increase by 642% until 2020, to reach 59,200 vehicles.

Concerning the second NAMA (Increased Use of Biofuels), the production of fuel ethanol (anhydrous and hydrated) increased from approximately 23 billion liters in 2010 to 26 billion liters in 2017 (EPE, 2018). Moreover, gasoline-ethanol anhydrous blend increased from 25% in 2015 to 27% in 2017, a higher share compared to other countries such as the US (15%) and Paraguay (25%).

Biodiesel from vegetable oils, animal fats and other feedstocks are also stimulated by the mandatory blending of biodiesel into fossil diesel since 2008 (Law N° 11.097/2005), reaching the proportion of 10% (B10) in 2018. In this case, the national biodiesel supply reached 3.8 million m^3 in 2016, which represents a growth of 65% compared to 2010, when production was of 2.3 million m^3 only. During the period, the share of biofuels in the total fuels market decreased by 1.7%, from 19.7% in 2010 to 17.8% in 2017, mostly due to the lower production of hydrous ethanol. Until 2020 the participation tends to reach 18% of the transportation energy consumption mix.

The corresponding impacts of these NAMAs on GHG emissions for the 2010-2017 period, as well as projections up to 2020, are in Table 7.

Table 7. Transportation NAMAs – Evolution of annual avoided emissions, 2010-2020 (MtCO_2-eq)

Year	Implementation of Energy Efficiency	Increased Use of Biofuels
2010	-	0.7
2011	2.9	0.7
2012	3.5	0.6
2013	3.2	1.8
2014	3.0	4.4
2015	2.8	8.9
2016	2.6	6.2
2017	2.4	7.6
2018	2.6	10
2019	2.9	10
2020	3.1	13

GWP SAR

It is important to highlight that the NAMA on Energy Efficiency includes both the emissions avoided by improvements in energy efficiency of the engine technology and traction system; and emissions avoided by the growth of electric vehicles fleet (hybrids and BEV). While the first category means gradual efficiency gains (e.g. improvements on internal combustion engines), the second comes from the penetration of new technology: electric vehicles in the fleet, instead of conventional combustion engine vehicles.

1.3. Industry

For Industry, Decree 7390 established a single NAMA: an increase in the use of charcoal from planted forests in the steel industry and an improvement in the efficiency of the carbonization process. The main objective of this action is "to promote the sustainable production of charcoal used as an input in the production of iron and steel, aimed at reducing emissions of the sector" and the specific target is to reduce 8 to 10 $MtCO_2e$ in 2020 comparing to 2010, according to the Mitigation Plan (MRE and MCTIC, 2017).

The evolution of the iron and steel industry emissions up to now and the projection for 2020 indicates that although the energy intensity declines, the use of biomass as a share of fuel supply also declines, leading to an increase in the emissions intensity over time as in Table 8.

Table 8. Industry NAMAs – Evolution of the Iron and Steel Sector, 2005-2020 ($MtCO_2$-eq).

Indicator	2005	2010	2015	2020
Total emissions ($MtCO_2e$)	43	45	48	49
Emission intensity (t CO_2e/t)	1.37	1.38	1.44	1.45
Energy intensity (ktoe/10^6t)	535.1	499.1	502.2	498.2
Biomass share in energy supply (%)	28.4	20.5	17.9	15.1

GWP SAR

Therefore, NAMA's emissions reduction targets for 2020 (8-10 $MtCO_2$) in this sector wouldn't be achieved. Emissions have grown from 2010 to 2015 and the values estimated for 2020 are 49 $MtCO_2e$, or 4.0 $MtCO_2$ higher than in 2010.

Table 9 presents the evolution of emissions, energy intensity and other indicators of the industrial sector as a whole.

Table 9. Industry NAMAs – Evolution of the Industrial Sector, 2005-2020 (MtCO2-eq).

Indicator	2005	2010	2015	2020
Emissions ($MtCO_2$-eq)	**141**	**163**	**170**	**178**
Emissions Intensity (t CO_2-eq/10^6R$)	103.4	99.3	107.4	112.1
Energy Intensity (Ktoe/10^9R$)	53.6	52.2	53.7	56.2
Biomass share in energy supply (%)	38.9%	40.0%	38.9%	38.9%

GWP SAR

1.4. Energy Supply (fuel combustion)

Decree 7390 established as mitigation actions (NAMAs) in the energy sector: increase of hydropower supply, increase of renewable energy sources supply (namely wind power, small hydropower, bioelectricity, and biofuels) and increase of energy efficiency.

Hydropower installed capacity was 20% higher in 2016 compared to 2010 (EPE, 2017). Nevertheless, the yearly generation from those plants has decreased by 6% in the same period. It is not clear yet if the factors that led to this decrease in production are structural or not. If they are structural, that could harm the contribution of this source to mitigate GHG emissions.

In any case, hydropower expansion rate tends to slow down as new projects have one or more of the following problems: 1) environmental concerns, 2) higher costs than other options and 3) lack of large reservoir to allow for steady annual production. As a result, in the "Decennial Energy Plan 2026" reference scenario, there is only 1.3 GW of additional hydropower capacity (excluding small hydro plants) between 2023 and 2026.

Other renewables, on the other hand, are increasing at a fast pace their share in the system, especially wind power. There was less than 1 GW of wind power connected to the grid in 2010 and more than 10 GW in 2016. Wind farms are performing well on energy auctions, offering very competitive prices[4].

As for energy efficiency actions, according to the national conservation program (PROCEL), a total of 100.8 TWh was saved from 2010 to 2017.

Emissions from charcoal production can be reduced by more efficient kilns and by replacing the use of the native forest by planted forests. The enforcement of legislation against deforestation has shown some results. In 2005, 54.1% of charcoal was produced from native forests. This figure went down to 30.4% in 2010 and is still decreasing: 12.9% in 2015 and 8.0% in 2017 (IBGE, 2018).

Table 10 presents the amount of avoided emissions obtained by an expansion of renewables and biomass up to 2020 compared with a baseline of constant use of these sources since 2009 or 2010. We assumed that renewable power sources would be replacing natural gas-fired power generation. Ethanol and biodiesel would substitute for gasoline and diesel oil, respectively.

Table 10. Energy NAMAs – Mitigation in the Energy Sector, 2009-2020 ($MtCO_2$-eq).

$MtCO_2$-eq	Avoided emissions in 2020 compared to 2009 level	Avoided emissions in 2020 compared to 2010 level
Energy Source	**Scenario A**	
Hydropower	146.2	106.3
Other Renewables	320.2	288.3
Total Renewable Electricity	*466.3*	*394.5*
Ethanol	44.7	44.3
Biodiesel	7.4	5.6
Total biofuels	*52.1*	*49.9*
Total	**518.5**	**444.5**

GWP SAR

[4] In A-6 Auction, performed in August 31th 2018, the average wind energy price was 90.45 BRL/MWh, or 22.30 USD/MWh.

Table 11 presents the installed capacity of power plants illustrating the evolution (historical data up to 2016 and Scenario A results for 2020) of some of the mitigation actions in Decree 7390 that were modeled in this study: hydropower, renewables and bioelectricity.

Table 11. Renewable power generation supply (installed capacity in GW), 2005 - 2020

Indicator	Unit	Historical data					Scenario A
		2005	2010	2015	2016	2017	2020
Total renewable power generation capacity	GW	73.6	88.2	110.6	118.7	N.A.	143.1
Wind power installed capacity (average CF: 40%)	GW	0.0	0.9	7.6	10.1	N.A.	16.8
Sugar cane products power generation installed capacity (average CF: 42%)	GW	2.3	6.2	10.6	11.0	N.A.	12.8
Firewood power generation installed capacity (average CF: 35%)	GW	0.2	0.4	0.7	0.7	N.A.	0.8
Distributed photovoltaic installed capacity (average CF: 18%)	GW	0.0	0.0	0.0	0.0	N.A.	0.4
Utility scale photovoltaic installed capacity (average CF: 25%)	GW	0.0	0.0	0.0	0.0	N.A.	3.7
Hydropower installed capacity (average CF: 48%)	GW	71.1	80.7	91.7	96.9	N.A.	108.6

Note: CF = capacity factor; N.A = not available.

Table 12 presents the corresponding values for electricity generation, by source.

Table 12. Electricity generation from Renewables (% and TWh), 2005 - 2020

Indicator	Unit	Historical data					Scenario A
		2005	2010	2015	2016	2017	2020
Share of renewables, other than hydropower, in the power supply	%	3.4%	6.5%	12.2%	14.6%	16.1%	19.9%
Total electricity generation	TWh	403.0	515.8	581.2	578.9	588.0	646.3
Share of renewables in total electricity generation	%	87.1%	84.7%	74.1%	80.4%	79.2%	87.3%
Wind generation	TWh	0.1	2.2	21.6	33.5	42.4	62.1
Sugarcane produtcts power plant generation	TWh	7.7	22.4	34.2	35.2	35.7	49.4
Firewood powerplant generation	TWh	0.6	1.7	2.2	2.0	2.0	2.4

Indicator	Unit	Historical data					Scenario A
		2005	2010	2015	2016	2017	2020
Distributed photovoltaic generation	TWh	0.0	0.0	0.0	0.1	0.2	0.7
Utility scale photovoltaic generation	TWh	0.0	0.0	0.0	0.0	0.7	8.1
Hydropower generation	TWh	337.5	403.3	359.7	380.9	370.9	436.1

Another indicator of the decarbonization of power generation is the carbon content of the electricity supplied from the grid. Historical data show an increase from 2005 to 2015 but according to Scenario A results they would be lower in 2020 than in 2005, as presented in Table 13.

Table 13. Grid emission factors (kg CO_2 /MWh), 2005 - 2020

	2005	2010	2015	2020
	kg CO_2/MWh			
Grid emission factor	71.1	78.7	130.0	70.1

Source: MCTIC from 2005 to 2015. Authors for 2020.

2. Assessment of avoided emissions and the achievement of NDC targets up to 2030 under Three Scenarios

The methodology of this study starts with the estimate of a baseline scenario (Scenario A) to represent the current emissions trends up to 2030, considering the country`s commitments to the UNFCCC. It includes the effect of mitigation policies underway to meet them, according to their performance as assessed by the expertise of different stakeholders gathered under the umbrella of FBMC. The additional mitigation actions required to meet the NDC targets are grouped in two other different scenarios (Scenarios B and C) and the quantification of the avoided emissions is calculated for each action. They make it possible to achieve the economy-wide targets for 2025 and 2030, representing different combinations of sectorial mitigation actions allowing for achieving the NDC goals.

The three scenarios are described below:

Scenario A (Current Policies and Trends Scenario) is based upon current GHG emission trends including all the policies and measures put in place to cope with the Brazilian NAMAs and NDC commitments. This scenario represents the emissions pathway of the country if the mitigation actions currently underway keep the current performance, according to expert judgment.

Scenario B (AFOLU Mitigation Scenario) reaches the mitigation targets for 2025 and 2030 as in the NDC commitment thanks to the inclusion of additional mitigation actions proposed by FBMC with more emphasis on the AFOLU sector.

Scenario C (Balanced Mitigation Scenario) also reaches the mitigation targets for 2025 and 2030 as in the NDC commitment thanks to the inclusion of a more balanced set of additional mitigation actions proposed by the FBMC, with a substantial reduction of emissions from other sectors than AFOLU.

All three GHG emissions scenarios are based on the same economic scenario for Brazil up to 2030. The qualitative storyline for the evolution of the Brazilian economy is the same described in recent governmental plans: the National Energy Plan – PNE 2050 (EPE, 2015), and in the Ten Year Energy Plan 2026 (PDE 2026). Some quantitative assumptions about demographic growth, oil prices, global GDP growth rates, among other parameters, were updated. (for details see our previous Report 2 of this study). Table 14 summarizes the key assumptions about GDP growth rates assumed up to 2030.

Table 14. GDP Growth Rate (real growth in constant prices, % per year) – Historic data and projection, 1950-2030.

Period	GDP growth per year
1950 – 1993	5,7%
1994 – 2014	3,2%
2015	-3,8%
2016	-3,6%
2017	1,0%
2018-2020*	2,5%
2021-2030*	3,2%

Source: based on IPEADATA (2018) and BACEN (2018).
* Projection

The following subsections summarize the assumptions and results of GHG emissions up to 2030 in the three scenarios. A more detailed description including the motivation of the assumptions and the analysis of results is found in Report 2 of this study.

2.1. AFOLU Emissions: Scenarios A, B and C - Synthesis

The estimates of the AFOLU sector consider the sectorial mitigation actions defined in the governmental commitments (NAMA and NDC) and policies for the Agriculture Sector (Low-Carbon Agriculture - ABC Plan) (Brazil, 2010). The mitigation actions are described below:

Land use change and Forestry

i. Reduction of annual deforestation rate
ii. Increased protected areas (increased accounting of carbon sinks)
iii. Restoration of native forests
iv. Carbon sinks in the natural regrowth of deforested areas
v. Planting commercial forests
vi. Use of integrated cropland-livestock-forestry systems (ICF+ILF+lCLF)
vii. Restoration of pastureland

Agriculture

i. Increased zero-tillage practices
ii. Increased area under Biological Nitrogen Fixation (replacement of chemical fertilizers)
iii. Increased manure management (from cattle, swine and other animals)

Emissions and removals estimated in the AFOLU sector in Scenario A are related to the assumption that the current pace of mitigation actions implementation (recorded during the 2005-2016 period) will continue until 2030. In Scenarios B and C the estimates take into account the penetration levels proposed by the FBMC, with the mitigation ambition in AFOLU higher in Scenario B than in Scenario C. The projections for all scenarios take into account the sectorial mitigation actions defined in the governmental commitments (NAMA and NDC), however the pace of implementation (scope and effectiveness of actions) is different.

Table 15 summarizes the emissions and removals in the AFOLU sector in scenarios A, B and C. Scenario B assumes a stronger mitigation effort in the AFOLU sector. Net AFOLU emissions would be of 344 $MtCO_2$-eq in 2030 in this Scenario. The total net emissions of the AFOLU sector in Scenario B are 62% lower than in Scenario A and 37% than in Scenario C. This huge mitigation mostly results from the reduction of the annual deforestation rates in the Amazon biome and the increase of protected areas as shown in Table 16.

Table 15. Emissions and removals from AFOLU in Scenarios A, B and C, 2005-2030 ($MtCO_2$-eq)

AFOLU Emissions and Removals ($MtCO_2$—eq*)						
Land Use Change and Forestry	**2005[1]**	**2010[1]**	**2015**	**2020**	**2025**	**2030**
Gross Emissions						
Scen A	2171	668	913	925	927	928
Scen B				760	655	626
Scen C				759	677	673
Removals						
Scen A	249	313	500	518	538	553
Scen B				567	622	735
ScenC				510	540	582
Total Net Emissions						
Scen A	1922	355	413	407	389	375
Scen B				193	33	-109
Scen C				249	137	91
Agriculture	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Total Emissions						
Scen A	459	473	522	491	498	519
Scen B				486	468	429
Scen C				492	478	442
Total Emissions AFOLU	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Scen A	2.381	828	935	899	887	894
Scen B				679	500	320
Scen C				741	614	533

* GWP AR5
[1]Data published by the III National Inventory (GWP-AR5) (BRASIL, 2016).

The evolution of emission drivers related to mitigation actions in Scenarios A, B and C (recorded values for 2005-2015 and estimates for 2016- 2030) is presented in Table 16.

Table 16. AFOLU Emission Drivers in Scenarios A, B and C, 2005-2030 (Mha and Mm^3)

Emission drivers	2005	2010	2015	2016	2017	2020	2025	2030
Increase of protected areas (Mha)								
Scen A		191	247	258	269	269	269	269
Scen B		191	247	258	269	269	287	305
Scen C		191	247	258	269	269	278	287
Restoration of native forests (Mha)								
Scen A				0.1	0.1	0.5	0.9	1.4
Scen B				0.20	0.50	1.3	3.4	9,0
Scen C				0.09	0.10	0.40	1.10	3.0
Area of commercial planted forests (Mha)								
Scen A	5.3	6.5	6.9	6.7	6.4	6.3	6.7	7.4
Scen B	5.3	6.5	6.8	7.2	7.2	7.7	8.6	9.5
Scen C	5.3	6.5	6.8	6.6	6.3	6.2	6.5	6.9
Area under ICLF systems (Mha)								
Scen A	0.3	0.9	2.0	2.1	2.2	2.6	3.2	3.8
Scen B	0.30	0.9	1.95	2.1	2.3	2.9	3.9	4.9
Scen C	0.30	0.90	1.95	2.1	2.3	2.8	3.6	4.4
Area under zero-tillage practices (Mha)								
Scen A	25.5	30.8	34.1	34.1	36.2	39.3	42.9	45.1
Scen B	25.5	30.8	34.1	34.1	36.1	39.2	45.2	47.9
Scen C	25.5	30.8	34.1	34.1	36.1	39.3	45.1	47.8
Area under Biological Nitrogen Fixation (Mha)								
Scen A		23.3	32.2	32.3	32.4	32.7	36.3	38.4
Scen B		23.3	32.2	32.3	32.4	32.7	39.2	42.4
Scen C		23.3	32.2	32.3	32.4	32.7	38.6	41.3
Area of Restored pastureland (Mha)								
ScenA			3.9	4.5	5.1	6.9	9.9	12.0
Scen B			3.9	4.9	6,0	9.3	14.6	20,0
Scen C			3.9	4.7	5.5	7.8	11.7	15.6
Manure under management (Mm^3)								
Scen A		7.4	9.4	9.4	9.4	9.4	9.4	9.4
Scen B		7.4	9.4	9.8	10.3	11.8	12.8	13.5
Scen C		7.4	9.4	9.4	9.4	9.4	9.4	9.4

2.2. Transportation Emissions: Scenarios A, B and C – Synthesis

GHG emissions estimates for the transportation sector take into account the sectorial mitigation actions defined in the governmental commitments (NAMA and NDC) and other policies and applicable measures related to this sector.

Mitigation actions assumed are described in table 17. Actions were ordered starting with those already underway and according to the difficulty and timing of implementation. This order was followed in the calculation of avoided emissions by each mitigation action.

Table 17. Mitigation Actions in Transportation: Assumptions of Scenarios A, B and C

	Mitigation actions	Scenario B	Scenario C
1	Shifting freight transport patterns and its infrastructure	Increased share of rail and water transportation, considering only investments in progress	Same elements of Scenario B, but setting more ambitious targets
2	Increased biofuels supply	Biodiesel and ethanol	Same as Scenario B, adding biomethane and biokerosene
3	Expansion of electric vehicles fleet (BEV and hybrids)	Automobile, light commercial, motorcycles, urban buses	Same as Scenario B, adding light and medium trucks
4	Adoption of sustainable programs for freight transportation	PLVB, Despoluir and CONPET programs	Same elements of Scenario B, but setting more ambitious targets
5	Adoption of sustainable programs for passenger transportation and incentives to active transportation	EEMU and Active Transport	Same elements of Scenario B, but setting more ambitious targets
6	Energy efficiency gains in the transportation sector	Energy efficiency gains in new vehicles and in air, water, and rail transportation. Focus on engine technology and traction system.	Same elements of Scenario B, but setting more ambitious targets
7	Incentive for collective transportation systems	Demand captured from private transport to public transportation, bus fleet qualification, bus renewal schemes, integrating policies (fares), expansion of exclusive bus lanes, and optimization of public transportation	The same elements of Scenario B, but setting more ambitious targets

Resulting emissions pathways are shown below for the transportation sector as a whole (in Table 18) and disaggregated by freight and passenger transportation, and by transport mode and the main vehicle categories (in Table 19).

Table 18. Emissions from Transportation in Scenarios A, B and C, 2005-2030 ($MtCO_2$-eq)

Year	Historical	Scenario A	Scenario B	Scenario C
	$MtCO_2$—eq*			
2005	144			
2010	178			
2015	203			
2016	204			
2017	207			
2020		208	204	200
2025		224	211	193
2030		247	217	175

* GWP AR5

Table 19. Disaggregated emissions from Transportation in Scenarios A, B and C, 2005-2030 ($MtCO_2$-eq).

Year	2005	2010	2015	2020	2025	2030
	$MtCO_2$-eq*					
Scenario A	**144**	**178**	**203**	**208**	**224**	**247**
Freight	**78**	**94**	**97**	**102**	**112**	**120**
Road	70	85	90	93	101	113
Rail	2.8	3.3	2.8	3.2	3.5	3.7
Air	1.5	1.1	1.5	1.6	2.1	2.5
Water	3.4	4.3	2.9	4.0	4.9	1.0
Passenger	**66**	**84**	**107**	**105**	**112**	**126**
Road – light vehicles	44	55	72	73	77	82
Road - buses	18	20	25	24	24	26
Air	4.8	8.8	9.6	8.9	10	13
Water	0.2	0.2	0.2	0.2	0.2	5.3
Scenario B	**144**	**178**	**203**	**204**	**211**	**217**
Freight	**78**	**94**	**97**	**101**	**104**	**112**
Road	70	85	90	92	94	102
Rail	2.8	3.3	2.8	3.2	3.3	3.5
Air	1.5	1.1	1.5	1.5	1.5	1.6
Water	3.4	4.3	2.9	4.0	4.9	5.9
Passenger	**66**	**84**	**107**	**103**	**107**	**105**
Road – light vehicles	44	55	72	70	70	63
Road - buses	18	20	25	24	26	29
Air	4.8	8.8	9.6	9.0	11	13
Water	0.2	0.2	0.2	0.2	0.2	0.2
Scenario C	**144**	**178**	**203**	**200**	**193**	**175**
Freight	**78**	**94**	**97**	**99**	**98**	**97**
Road	70	85	90	91	88	85
Rail	2.8	3.3	2.8	3.1	3.2	3.6
Air	1.5	1.1	1.5	1.5	1.5	1.5
Water	3.4	4.3	2.9	4.0	5.3	6.9
Passenger	**66**	**84**	**107**	**101**	**95**	**78**
Road – light vehicles	44	55	72	68	59	37
Road - buses	18	20	25	24	25	29
Air	4.8	8.8	9.6	9.0	11	12
Water	0.2	0.2	0.2	0.2	0.2	0.3

* GWP AR5

2.3. Industry Emissions: Scenarios A, B and C – Synthesis

GHG emissions estimates for the industry sector take into account the sectorial mitigation actions defined in the governmental commitments (NAMA and NDC) and other policies and applicable measures related to this sector. They encompass emissions from fossil fuels combustion and industrial processes and product use (IPPU).

The major source of greenhouse gases emissions in the industrial sector is the consumption of fossil fuels; therefore, the main mitigation actions focus on energy efficiency: (i) optimization of combustion; (ii) heat recovery systems; and (iii) steam recovery systems. Another way to reduce the consumption of fossil fuels is to replace them by renewable sources, *e.g.* coal by charcoal in the iron and steel industry, or the use of natural gas to replace other fossil fuels with higher carbon content. Table 20 shows the assumed reduction in energy intensity, in percentage, between 2015 and 2030 in each scenario.

Table 20. Energy intensity reduction assumptions by mitigation action in the Industrial Sector, 2015 - 2030 in Scenarios A, B and C (toe/t of product)

Industrial branch	Mitigation measure	Energy intensity reduction (toe/t product) in 2015-2030		
		Scenario A	Scenario B	Scenario C
Cement	Optimization of combustion	1.0%	4.0%	6.0%
	Heat recovery systems	2.8%	6.0%	9.0%
Iron and steel	Optimization of combustion	2.8%	10.0%	14.0%
Iron alloy	Heat recovery systems	3.0%	10.0%	14.0%
Non-ferrous metals	Optimization of combustion and Heat recovery systems	-	5.0%	9.0%
Pulp and paper	Optimization of combustion and Steam recovery systems	-	5.0%	8.0%
Mining and pelleting	Optimization of combustion	2.0%	8.0%	14.0%
Chemical	Optimization of combustion	1.5%	5.0%	7.0%
	Heat recovery systems	1.5%	5.0%	8.0%
Food and beverage	Optimization of combustion	1.0%	3.0%	5.0%
	Steam recovery systems	1.5%	4.5%	7.0%
Textile	Optimization of combustion	0.5%	4.0%	5.0%
	Heat recovery systems	0.5%	4.0%	5.0%
Ceramic	Optimization of combustion	0.5%	3.0%	4.0%

Industrial branch	Mitigation measure	Energy intensity reduction (toe/t product) in 2015-2030		
		Scenario A	Scenario B	Scenario C
	Heat recovery systems	1.0%	5.0%	7.0%
Other industry	Optimization of combustion	1.0%	3.0%	5.0%
	Heat recovery systems	1.0%	4.0%	7.0%

Source: own analysis based on Henriques, Dantas and Schaeffer (2010).

Table 21 shows the percentage of fossil fuel replaced up to 2030 by natural gas or renewable biomass.

Table 21. Replacement of fossil fuels in the Industrial Sector up to 2030, in Scenarios B and C (%)

Industrial branch	Replacement of oil fuels or coal by natural gas		Replacement of fossil fuels by renewable biomass	
	Scenario B	Scenario C	Scenario B	Scenario C
Cement	0.0%	1.5%	-	-
Iron and Steel	-		5.0%	7.0%
Iron alloys	-		1.1%	2.0%
Non-ferrous and other metals	5.0%	7.0%	-	-
Pulp and paper	2.0%	4.0%	0.5%	2%
Textile	1.0%	2.0%	-	-
Ceramic	1.0%	2.0%	0.0%	3.0%

Source: own analysis based on Henriques (2010)

For emissions from industrial processes and product use, we assumed specific mitigation actions in each industrial branch with substantial emissions of this kind. For example, in the cement production process, the mitigation action adopted was the use of additives to reduce the clinker/cement ratio (in 7% in Scenario B and 11% in C). Regarding product use, in the consumption of fluorinated greenhouse gases in air-conditioning devices and refrigeration equipment, the mitigation action assumed was the replacement or leakage control of gases and the end-of-life recollection.

Resulting emissions pathways for the industry sector in the three scenarios are shown below in Table 22, split by source: fossil fuel combustion and IPPU. In sequence, Table 23 presents the emissions in Scenarios A, B and C, by industrial branch.

Table 22. Emissions from energy consumption and IPPU from the Industry Sector in Scenarios A, B and C, 2005-2030 ($MtCO_2$-eq)

Emission Source	Emissions ($MtCO_2$-eq*)											
	2005	2010	2015	2020			2025			2030		
				A	B	C	A	B	C	A	B	C
Energy	62	72	73	74	72	70	80	76	72	86	81	74
IPPU	79	91	98	105	99	96	120	108	99	136	116	104
Total	**141**	**163**	**170**	**178**	171	166	199	184	171	222	197	178

* GWP AR5

Table 23. Emissions from energy consumption and IPPU from the Industry Sector, by Branch, in Scenarios A, B and C, 2005-2030 ($MtCO_2$-eq) .

Industrial Branch	2005	2010	2015	Emissions ($MtCO_2$-eq*)								
				2020			2025			2030		
				Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Mineral Industry	31	45	48	45	44	44	51	49	48	57	54	51
Iron and steel	42	45	48	49	48	46	54	51	47	59	54	47
Iron alloy	1,5	1,3	1,0	1,3	1,3	1,3	1,7	1,6	1,4	2,1	2,0	1,7
Mining and pelleting	6,7	7,3	7,7	8,4	8,3	8,0	9,8	9,5	8,9	11	11	9,9
Non-ferrous and other metals	11	14	14	20	19	19	23	23	22	28	27	25
Chemical	24	17	17	18	17	17	18	17	16	18	17	15
Food and beverage	5,0	5,5	5,6	5,4	5,2	5,2	5,6	5,3	5,2	5,8	5,4	5,3
Textile	1,2	1,0	0,67	0,66	0,64	0,63	0,68	0,65	0,63	0,70	0,65	0,62
Pulp and paper	4,2	4,2	4,1	4,3	4,2	3,9	4,8	4,6	4,1	5,3	5,1	4,5
Ceramic	4,0	5,2	5,0	4,9	4,8	4,4	5,2	5,0	4,3	5,5	5,2	4,4
HFCs and SF6	3,1	7,6	10	14	9,5	8,0	17	8,7	6,0	20	8,1	4,5
Non-energy products	0,68	0,64	0,64	0,64	0,64	0,57	0,64	0,56	0,50	0,64	0,51	0,43
Other industries	6,3	8,3	8,2	7,9	7,8	7,6	8,1	7,9	7,6	8,4	8,0	7,5
Total	141	163	170	178	171	165	199	183	171	221	197	178

* GWP AR5

2.4. Energy Supply: Scenarios A, B and C – Synthesis

GHG emissions estimates for the energy supply sector take into account the sectorial mitigation actions defined in the governmental commitments (NAMA and NDC) and other policies and applicable measures related to this sector. They encompass emissions from fuel combustion and fugitive emissions.

Oil and gas production in Brazil are substantially increasing thanks to the huge discoveries offshore in the “pre-salt” layer. Assumptions in this study follow the EPE’s study “Decennial Energy Plan 2026” up to 2026 and keep increasing at the same growth rate until 2030. Oil production is projected to reach over 6 million barrels/day, and natural gas production over 220 million m^3/day in 2030, more than doubling current levels. However, roughly two thirds (with slight variations across the three scenarios according to domestic oil consumption) of the oil production would be exported. Anyway, this huge increase in the production induces an important growth of fugitive emissions in oil & gas production platforms.

GHG Emissions from fuel combustion are derived from runs of MATRIZ model that simulates the evolution of Brazilian energy supply. It starts from an energy demand calculation based upon the assumptions for the evolution of Transportation, Industry and other sectors. Then, MATRIZ tries to optimize the fuel mix to supply the demand over time, taking into consideration the interplay of energy potentials and costs of the different sources with technological and other constraints. MATRIZ results for Scenario A present a small expansion only of power generation plants fired by natural gas and coal. In Scenario B, all the assumptions are the same as in Scenario A, but with different results (lower increase in energy supply) due to a reduced level of energy demand (thanks to energy efficiency assumptions in Transportation and Industry, as presented before). In Scenario C, there would be no expansion of fossil fuel power generation capacity beyond the plants that won energy auctions until 2017. Efforts would be made to foster a higher penetration of renewable sources, as photovoltaic, wind power, sugarcane bagasse and firewood fired power generation plants.

MATRIZ results of domestic energy supply and power generation installed capacity per source for the three scenarios are shown in Tables 24 and 25.

Table 24. Domestic Energy Supply between 2005 and 2030 in Scenarios A, B and C (10^3 toe)

Ktoe	2005	2010	2015	2020			2025			2030		
				Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Non-renewable	**121,819**	**148,644**	**175,903**	**163,537**	**165,429**	**159,799**	**181,532**	**179,547**	**165,2**	**205,654**	**196,772**	**171,383**
Petroleum and oil products	84,553	101,714	111,626	107,767	110,577	105,047	116,756	116,073	102,685	128,713	122,343	99,197
Natural gas	20,526	27,536	40,971	33,942	33,511	33,85	42,034	41,944	41,837	48,786	48,812	48,564
Coal and coke	12,991	14,462	17,625	17,47	17,106	16,671	18,561	17,384	16,544	20,68	18,754	16,779
Other non-renewable	3,749	4,932	5,681	4,358	4,236	4,231	4,181	4,146	4,134	7,475	6,862	6,842
Renewable	**96,117**	**120,152**	**123,672**	**134,894**	**131,597**	**137,345**	**149,342**	**147,139**	**156,572**	**160,779**	**161,092**	**173,899**
Hydraulic and electricity	32,379	37,663	33,897	40,176	39,934	39,665	42,115	41,731	41,379	44,157	42,956	42,534
Firewood and charcoal	28,468	25,998	24,9	20,828	20,878	20,997	21,392	21,258	21,406	22,54	22,882	22,05
Sugar cane products	30,15	47,102	50,648	51,705	52,529	54,671	59,639	60,491	64,24	64,08	68,360	74,889
Other renewable	5,12	9,389	14,227	22,186	18,256	22,013	26,196	23,659	29,547	30,002	26,894	34,426
Total	**217,936**	**268,796**	**299,574**	**298,431**	**297,026**	**297,144**	**330,874**	**326,686**	**321,772**	**366,433**	**357,864**	**345,282**

Table 25. Power generation installed capacity between 2005 and 2030 in Scenarios A, B and C (GW)

Installed capacity (GW)	2005	2010	2015	2020			2025			2030		
				Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Non-renewable	18,4	23,8	28,3	24,4	24,4	24,4	23,6	23,6	23,6	26,8	26,9	24,8
Natural gas	9,6	11,3	12,4	14,2	14,2	14,2	16,3	16,3	16,3	18,3	18,4	16,3
Coal	1,4	1,9	3,4	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,5	3,5
Nuclear	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	3,4	3,4	3,4
Others non-renewables	5,4	8,6	10,5	4,7	4,7	4,7	1,8	1,8	1,8	1,6	1,6	1,6
Renewable	74,4	89,5	112,6	144,4	144,4	144,4	157,4	157,2	158,2	170,5	167	174,9
Hydro	71,1	80,7	91,7	108,6	108,6	108,6	111	111	111	115,1	112,3	114
Biomass	3,3	7,9	13,3	14,9	14,9	14,9	18	17,8	18,4	19,4	18,7	22,6
Wind	0,0	0,9	7,6	16,8	16,8	16,8	20,8	20,8	20,8	23,8	23,8	24,8
Solar	0,0	0,0	0,0	4,1	4,1	4,1	7,6	7,6	8,0	12,2	12,2	13,5
Total	**92,9**	**113,3**	**140,9**	**168,7**	**168,7**	**168,7**	**181**	**180,8**	**181,8**	**197,3**	**193,9**	**199,6**

Resulting emissions from fuel combustion in the three scenarios are shown in Table 26, split by power generation, energy sector consumption and charcoal kilns.

Table 26. Emissions from Energy Supply (fuel combustion) in Scenarios A, B and C, 2005-2030 ($MtCO_2$-eq)

$MtCO_2$-eq*	2005	2010	2015	2020	2025	2030
Scenario A	49	61	99	69	78	89
Electricity generation	27	37	68	41	47	55
Energy sector consumption	22	24	30	28	30	34
Charcoal kilns	1.0	0.7	0.6	0.5	0.5	0.5
Scenario B	**49**	**61**	**99**	**69**	**76**	**88**
Electricity generation	27	37	68	41	45	55
Energy sector consumption	22	24	30	28	30	32
Charcoal kilns	1.0	0.7	0.6	0.5	0.5	0.6
Scenario C	**49**	**61**	**99**	**68**	**74**	**82**
Electricity generation	27	37	68	40	44	50
Energy sector consumption	22	24	30	27	29	31
Charcoal kilns	1.0	0.7	0.6	0.5	0.5	0.6

Regarding fugitive emissions in the Oil & Gas sector, Scenario A projects the mitigation efforts pursuing current trends. In the E&P (exploration and production) segment, platforms venting or flaring of the associated natural gas (3.4% in 2017) would be limited to 3.2% in 2020 and 3% from 2025 on. In Refining and Transportation of oil and gas fuels, no regulations constraining GHG emissions apply, as in the case of E&P. In Scenario B, assumptions are the same as in Scenario A. In Scenario C, the mitigation effort would increase in the E&P segment to reach 2% of venting or flaring of the associated natural gas in 2030 (current benchmark in the United Kingdom). In Refining and Transportation, we assume that refineries would apply management improvements and leakage monitoring and reductions. These actions would save, every 5 years, the same amount of fugitive emissions from leakage, venting and flaring saved in 2016 as reported in the Petrobras CDP inventory of 2017.

The resulting fugitive emissions in the three scenarios are presented in Table 27, split by oil and gas E&P, refining and transportation, and the coal industry.

Table 27. Emissions from Energy Supply (fugitive) in Scenarios A, B and C, 2005-2030 ($MtCO_2$-eq)

Segment	2005	2010	2015	2016	Scenario A			Scenario B			Scenario C		
					2020	2025	2030	2020	2025	2030	2020	2025	2030
$MtCO_2$-eq* Oil and Natural Gas Systems													
E&P	10	10	11	12	13	20	25	13	20	25	13	20	23
Refining	6.8	7.4	8.3	7.7	9.7	10	11	9.7	10	11	9.1	9.0	9.6
Transport	0.29	0.31	0.35	0.32	0.40	0.58	0.73	0.40	0.58	0.73	0.40	0.58	0.73
Total	17	18	20	20	23	31	37	23	31	37	22	29	34

Segment	2005	2010	2015	2016	Scenario A			Scenario B			Scenario C		
					2020	2025	2030	2020	2025	2030	2020	2025	2030
Mining, processing, storage and transportation of coal													
Total	2.9	3.0	3.4	2.8	4.6	4.6	5.0	4.6	4.1	4.7	4.6	4.2	4.0
Total Fugitive Emissions													
Total	20	20	23	22	28	35	42	28	35	42	27	33	38

* GWP AR5

Table 28 presents the emissions from the Energy Supply sector consolidated.

Table 28. Emissions from the Energy Supply Sector ($MtCO_2$-eq)

Emission Sources				Scenario A			Scenario B			Scenario C		
(MtCO2-eq)	2005	2010	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030
Fuel Combustion	49	61	99	69	78	89	69	75	88	68	74	82
Fugitive emissions	20	20	23	28	35	42	28	35	42	27	33	38
Total	69	81	122	97	113	131	96	110	129	95	107	119

2.5. Waste Emissions: Scenarios A, B and C – Synthesis

The Waste sector encompasses the disposal of solid waste and the collection and treatment of wastewater. The sanitation infrastructure is still quite underdeveloped in Brazil. Governmental plans have set ambitious goals for closing this gap. However, implementation of the plans is lagging behind the targets. Stakeholders gathered in this study have used expert judgment to project the building-up of solid waste and wastewater treatment facilities in Brazil. The key assumptions concerning waste generation, final disposal and treatment processes are shown in Tables 29 and 30.

Table 29. Evolution of solid waste disposal and treatment infrastructure in Brazil in Scenarios A, B and C up to 2030 (Mt)

million t of waste (Mt)		2005	2010	2015	2020			2025			2030		
					Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Solid waste generation - municipal (MSW) and industrial (ISW)		63.3	71.2	79.8	85	85.0	85.0	92.3	92.3	92.3	99.7	99.7	99.7
MSW and ISW collected for disposal sites		52.9	63.4	72.5	77.1	76.8	76.8	83.4	82.0	82.0	89.6	86.9	86.9
Disposal Sites	Unmanaged Shallow	14.1	11.5	12.5	11.4	11.2	11.2	11.5	11.0	11.0	11.6	10.8	10.8
	Unmanaged deep	14.4	15.4	17.5	14.8	16.2	16.2	14.3	14.5	14.5	13.9	10.9	10.9
	Managed (landfills)	24.4	36.5	42.6	50.8	49.4	49.4	57.6	56.5	56.5	64.1	65.2	65.2
	methane flaring in the capitals	-	-	-	-	-	-	-	30%	-	-	-	-
	methane flaring in the capitals and cities in metropolitan regions	-	-	-	-	-	-	-	-	30%	-	-	-
	methane flaring in cities with more than 500 thousand people	-	-	-	-	-	-	-	-	55%	-	-	40%
	methane power plants in the capitals	-	-	-	-	-	-	-	50%	-	-	80%	-
	methane power plants in the capitals and cities in metropolitan regions	-	-	-	-	-	-	-	-	50%	-	-	80%
	methane power plants in cities with more than 500 thousand people	-	-	-	-	-	-	-	-	25%	-	-	40%
	with CH4 replacing natural gas in vehicular fleet	-	-	-	-	-	-	-	-	*17%*	-	-	*14%*
Not collected (uncategorized)		6.4	3.3	1.7	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.1
Aerobic composting		0.6	0.4	0.3	0.3	0.2	0.2	0.2	1.0	1.0	0.2	1.9	1.9
Paper Recycling		3.4	4.1	5.3	6.3	6.5	6.5	7.5	8.0	8.0	8.7	9.7	9.7

Note: ISW (II-A) = industrial solid waste, category II-A (organic matter)

Table 30. Evolution of wastewater collection and treatment infrastructure in Brazil in Scenarios A, B and C up to 2030 (Mt BOD)

Million t of Biodegradable Oxigen Demand (BOD)		2005	2010	2015	2020			2025			2030		
					Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Urban wastewater generation		**3.02**	**3.14**	**3.33**	**3.55**	**3.55**	**3.55**	**3.64**	**3.64**	**3.64**	**3.74**	**3.74**	**3.74**
Sewage treatment plant		**0.52**	**0.94**	**1.33**	**1.55**	**1.55**	**1.55**	**1.64**	**1.64**	**1.64**	**1.74**	**1.94**	**1.94**
Treatment	Emission-free processes	0.1	0.1	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0,04
Treatment	Activated sludge	0.2	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0,7
Treatment	Facultative lagoons	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0,1
Treatment	Other treatments. unspecified	0.02	0.04	0.08	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0,1
Treatment	Anaerobic Treatments	0.1	0.3	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	1.0	1,0
Treatment	*Biogas flaring in anaerobic urban plants (55% efficiency rate)*	*N.A.*	*N.A.*	*N.A.*	*60%*	*60%*	*60%*	*60%*	*65%*	*70%*	*60%*	*70%*	*80%*
Septic tank		**0.3**	**0.3**	**0.4**	**0.50**	**0.50**	**0.50**	**0.60**	**0.50**	**0.50**	**0.10**	**0.50**	**0.50**
Rudimentary tank		**0.5**	**0.4**	**0.4**	**0.30**	**0.30**	**0.30**	**0.20**	**0.20**	**0.20**	**0.70**	**0.10**	**0.10**
Launch in water bodies		**1.7**	**1.5**	**1.2**	**1.20**	**1.20**	**1.20**	**1.20**	**1.30**	**1.30**	**1.20**	**1.20**	**1.20**
% of total Industrial wastewater in anaerobic plants with biogas used for electricity generation		-	-	-	**40%**	**42%**	**44%**	**42%**	**44%**	**45%**	**43%**	**45%**	**47%**

Note: BOD stands for biodegradable organic matter

The mitigation actions adopted in the waste sector are presented below, in order of decreasing importance, by sub-sector:

1- Solid Waste:

- Decreased disposal in unmanaged deep landfills
- Decreased disposal in unmanaged shallow landfills
- Increased disposal in managed landfills without methane destruction
- Increased disposal in managed landfills with methane destruction

- Increased disposal in managed landfills with methane recovery for electricity generation
- Increased disposal in managed landfills with methane recovery for vehicular use
- Increased paper, cardboard and cellulose recycling
- Increased aerobic composting

2- Wastewater

- Decreased urban domestic wastewater treatment in septic and rudimentary tanks
- Increased of treatment in urban anaerobic plants with the destruction of methane in flares
- Other treatments (activated sludge, lagoons, launch in nature and unspecified)
- Rural domestic wastewater treatment

In Scenario B, investment in sanitation was assumed to be higher than in Scenario A, increasing the sector compliance to the PNRS (National Policy of Solid Waste) and the PNSB (National Policy of Basic Sanitation). In this scenario, not only there would be a reduction in the levels of inadequate waste disposal, but also in GHG emissions. Furthermore, from 2021 on, there would be an increase in methane recovery for flaring in anaerobic wastewater treatment plants, and also an increase in destruction and electricity generation in landfills.

In scenario C, simulations also consider a higher penetration of the mitigation actions suggested by FBMC than in Scenario B. The collection and treatment levels of both solid waste – including aerobic composting and recycling - and wastewater were maintained but with greater mitigation efforts.

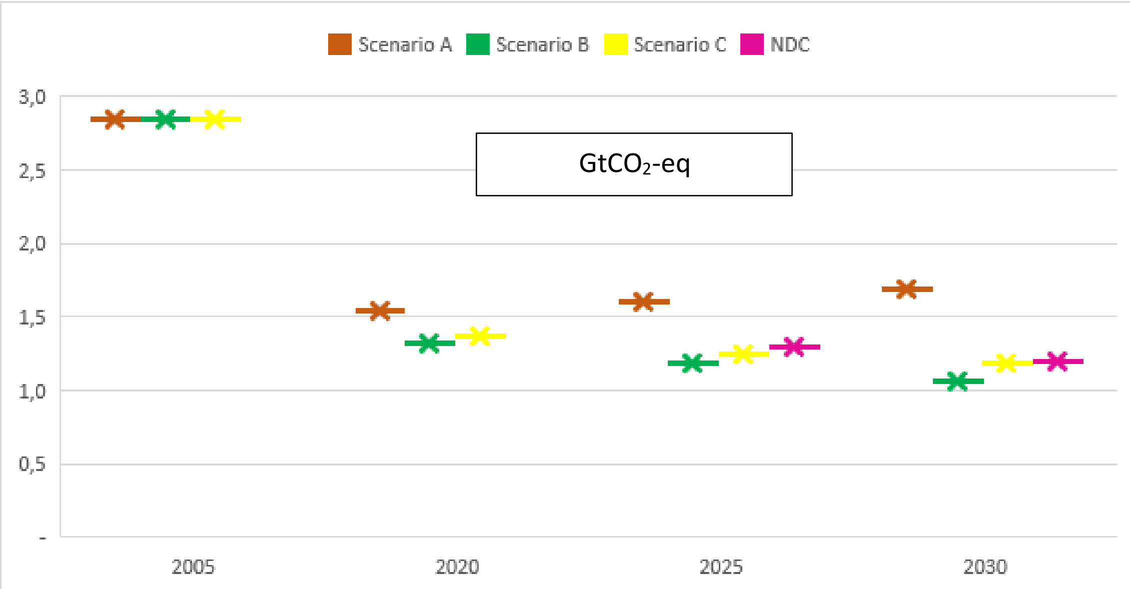
Resulting GHG emissions from the Waste sector in the three scenarios are presented in Table 31, split by solid waste and wastewater treatment facilities.

Table 31. Emissions from the Waste sector (solid waste and wastewater treatment) up to 2030 in Scenarios A, B and C ($MtCO_2$-eq)

Emission sources ($MtCO_2$-eq)	2010	2015	Scenario A			Scenario B			Scenario C		
			2020	2025	2030	2020	2025	2030	2020	2025	2030
MSW and ISW(II-A) landfilling		**56**	**65**	**73**	**81**	**64**	**63**	**69**	**64**	**55**	**59**
ISW and HSW incineration		0.20	0.20	0.20	0.30	0.20	0.20	0.30	0.20	0.20	0.30
Aerobic composting		0.10	0.10	0.05	0.04	0.10	0.20	0.40	0.10	0.20	0.40
Total solid waste ($MtCO_2$.eq)	**37**	**56**	**65**	**73**	**81**	**65**	**67**	**69**	**65**	**55**	**60**
Domestic wastewater	16	17	18	19	20	18	18	19	18	18	19
Industrial wastewater	17	19	19	23	27	19	23	27	18	22	26
Total wastewater ($MtCO_2$.eq)	**34**	**35**	**37**	**42**	**46**	**36**	**41**	**46**	**36**	**40**	**45**
Total Waste Sector ($MtCO_2$.eq)	**71**	**91**	**102**	**115**	**128**	**101**	**104**	**116**	**100**	**95**	**105**

2.6. Scenarios A, B and C - Consolidated Results

From an economy-wide perspective, Scenario A would not meet the NDC targets either in 2025 or in 2030. Figure 1 presents the total emissions in each scenario, showing that more mitigation efforts than those currently being implemented are required.



Note: GWP AR5

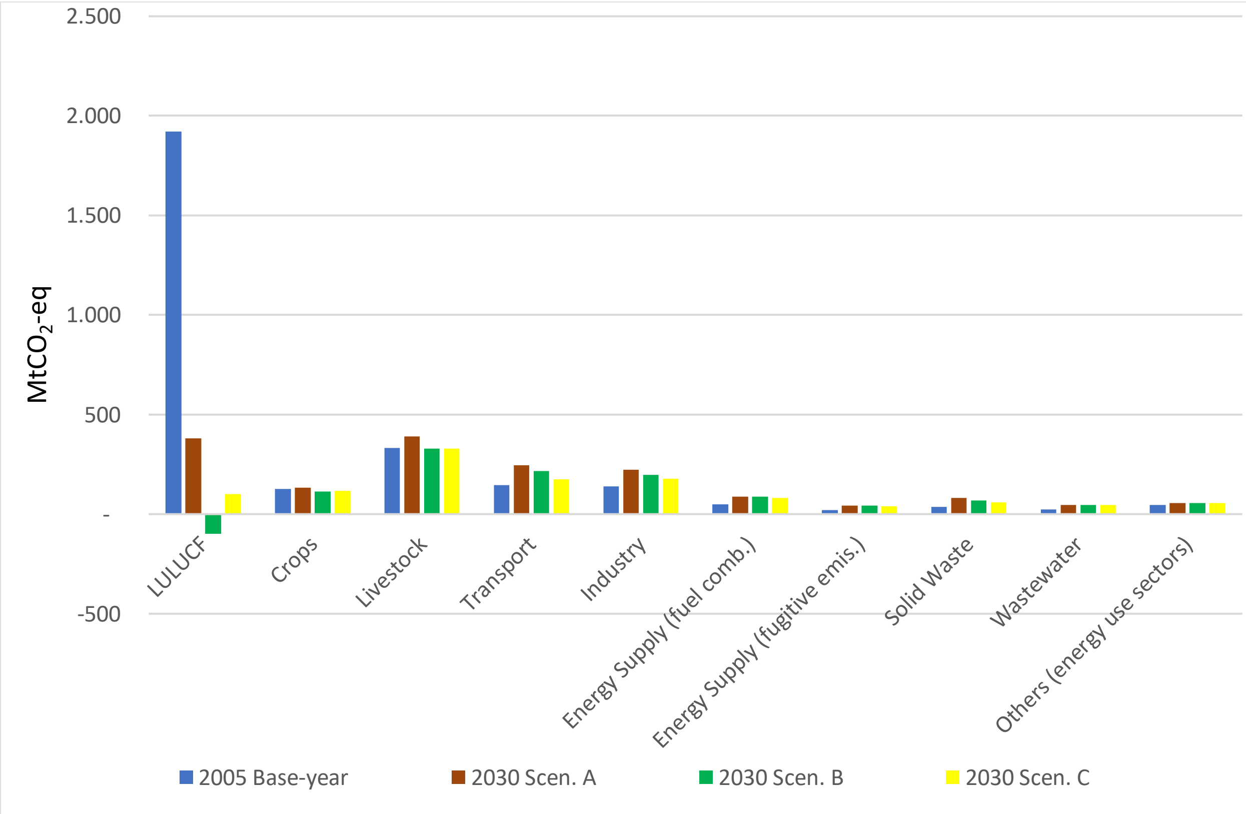
Figure 1. Total emissions in Scenarios A, B and C and NDC's targets (Gt CO_2-eq)

The emissions evolution obtained for Scenarios A, B and C in the model runs is presented by sectors in Figure 2. In Scenario A, we can see that there would be a strong reduction of emissions from Land Use, Land Use Change and Forestry (LULUCF) where both a reduction in deforestation rates and the extension of current levels of carbon removals in conservation units and indigenous lands would allow for a decrease of net emissions from this source up to 2030. All other sectors and sub-sectors present emissions in 2030 substantially higher than in 2005, jeopardizing the achievement of the NDC targets.

In scenario B, we reach negative net emissions from LULUCF in 2030, with both a reduction in deforestation rates and an increase in carbon removals in conservation units and indigenous lands that are particularly relevant to the overall mitigation targets. Emissions from agriculture also decrease along the period due to efficiency gains and a reduction of average cattle slaughtering age allows to curb down emissions from livestock at the end of the period.

Although all other sectors present increasing emissions, the success of strong mitigation efforts in the AFOLU sector would be decisive for Brazil to meet its Paris commitment with a good margin to increase its ambition in future updates of the NDC.

In Scenario C, we reach a substantial reduction in 2030 emissions from LULUCF, where both a reduction in deforestation rates and an increase in carbon removals in conservation units and indigenous lands, although to a lesser extent than in Scenario B, are again decisive. The agriculture and livestock sector also presents lower GHG emissions in 2030 than in 2005. Even with more mitigation efforts than in Scenario B, emissions from all other sectors would still be growing up to 2030. Again, from an economy-wide perspective, the efforts would be more than enough for Brazil to meet its Paris commitment, allowing to increase its ambition in future NDC updates.



Note: GWP AR5

Figure 2. Evolution of Emissions Sources in Scenarios A, B, C ($MtCO_2$-eq).

The scenarios values are also presented in Table 32

Table 32. Evolution of Emissions Sources in Scenarios A, B and C ($GtCO_2$-eq)

Sectors	2005	2010	2015	2020	2025	2005 - 2025	2030	2005 - 2030
	Mt CO_2-eq							
AFOLU								
Scenario A	2,381	828	935	899	887	-63%	894	-62%
Scenario B				679	500	-79%	320	-87%
Scenario C				741	614	-74%	533	-78%
Transportation								
Scenario A	144	178	203	208	223	54%	247	71%
Scenario B				204	211	46%	218	51%
Scenario C				201	193	34%	175	21%
Industry								
Scenario A	141	163	170	178	199	42%	222	58%
Scenario B				171	184	31%	197	40%
Scenario C				166	171	22%	178	26%
Other Energy Sectors								
Scenario A	46	47	47	51	54	17%	54	19%
Scenario B				51	54	19%	54	20%
Scenario C				51	54	19%	54	20%
Energy Supply								
Scenario A	69	81	122	97	113	64%	131	89%
Scenario B				96	111	59%	129	87%
Scenario C				95	107	55%	119	73%
Waste								
Scenario A	60	71	91	102	115	92%	128	114%
Scenario B				101	104	74%	116	93%
Scenario C				100	95	59%	105	74%
Total								
Scenario A	2,841	1,367	1,568	1,535	1,591	-44%	1,675	-41%
Scenario B				1,302	1,164	-59%	1,034	-64%
Scenario C				1,354	1,235	-57%	1,164	-59%

2.7. Comparative Analysis of Scenarios A, B and C – Total Avoided Emissions

Figures for the avoided emissions across scenarios and sectors are in Table 33. In 2030, economy-wide emissions in Scenario B are 37% lower than in Scenario A, mainly thanks to the strong mitigation efforts in AFOLU (89% of the total reduction), and particularly in LULUCF (77% of the total reduction).

In 2030, economy-wide emissions in Scenario C are 30% lower than in Scenario A. Again, the AFOLU sector provides a large majority (71%) of total avoided emissions, mainly thanks to the mitigation of LULUCF emissions (56%), although to a lesser extent than in Scenario B, according to the assumptions of lower ambition and success of mitigation policies and measures in AFOLU. However, this decrease is partially compensated by larger avoided emissions in other sectors, mainly Transport, reaching 14% of the total reductions in 2030, and Industry (9%).

Table 33. Comparative Analysis of GHG Emissions Across Scenarios and Sectors ($MtCO_2$-eq)

$MtCO_2$-eq	2020	2025	2030	2020	2025	2030	2020	2025	2030
	GHG Emissions in Scenario A – GHG Emissions in Scenario B			GHG Emissions in Scenario A – GHG Emissions in Scenario C			GHG Emissions in Scenario B – GHG Emissions in Scenario C		
AFOLU	**220**	**387**	**574**	**158**	**272**	**361**	**-62**	**-114**	**-213**
Land Use and Land Use Change and Forestry	215	356	484	159	252	284	-56	-104	-200
Cropping Systems	-0.03	8.5	20	-0.87	5	16	-0.8	-3.1	-4.4
Livestock	4.9	22	70	-0.10	15	61	-5.0	-7.1	-8.5
Transport	**4.0**	**12**	**28**	**7.1**	**30**	**71**	**3.1**	**18**	**43**
Industry	**7.2**	**16**	**25**	**13**	**28**	**44**	**5.6**	**13**	**19**
Energy Supply	0.72	2.9	1.6	2.0	6.6	11	1.3	3.7	9.9
Fuel Combustion	0.72	2.4	1.3	1.4	4.6	6.9	0.68	2.2	5.6
Fugitive Emissions	-	0.55	0.27	0.61	2.0	4.5	0.61	1.4	4.3
Waste	**0.9**	**11**	**13**	**1.9**	**20**	**24**	**1 .0**	**9.0**	**11**
Solid Waste	0.9	9.8	12	0.91	18	22	-	8.0	10
Wastewater	-	1.0	1.0	1.0	2.0	2.0	1.0	1.0	1.0
Others (energy use sectors)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Total	**232**	**429**	**643**	**182**	**357**	**511**	**-51**	**-71**	**-130**

* GWP AR5
Note: Negative figures describe an increase in emissions in Scenario C compared to Scenario A.

2.7.1. Comparative Analysis of Scenarios A and B

The amount of avoided emissions in Scenario B compared to Scenario A is split by main mitigation actions in Table 34. We can see that the reduction of deforestation alone is responsible for nearly half (47%) of the total avoided emissions in 2030. Overall, six mitigation actions in the AFOLU sector account for 90% of total avoided emissions in 2030. The most relevant single mitigation action in the other sectors is the increased use of biofuels, allowing for 2% of total avoided emissions in 2030.

Table 34. Consolidated Avoided Emissions by Mitigation Action – Comparative Analysis of Scenarios A and B ($MtCO_2$-eq and %)

MITIGATION ACTIONS	GHG Emissions in Scenario A – GHG Emissions in Scenario B					
	2020		2025		2030	
	Mt CO_2-eq	%	Mt CO_2-eq	%	Mt CO_2-eq	%
Reduction of Deforestation	160	69%	265	62%	293	46%
Increased Restoration of native forests	15	6%	40	9%	122	19%
Increase in livestock productivity	-	0%	15	4%	60	9%
Increase of protected areas (increased accounting of carbon sinks)	-	0%	28	7%	55	9%
Increased Restoration of pastureland	8.7	4%	17	4%	17	3%
Reduction in fertilizer application and in animal manure deposit on soil (due to a decrease in the average cattle slaughtering age)	0.0	0%	3.6	1%	14	2%
Increased use of biofuels	1.50	1%	6.7	2%	13	2%
HFCs leakage control and end-of-life recollection	3.91	2%	8.0	2%	12	2%
Increased disposal of USW in managed deep landfills with methane recovery for power generation	-	0%	5.8	1%	11	2%
Others in Transportation	2.3	1%	6.1	1%	17	3%
Others in Energy Supply	0.68	0%	3.0	1%	1.6	0%
Others in Industry	3.3	1%	7.5	2%	13	2%
Others in Waste	0.70	0%	5.7	1%	3.1	0%
Others in AFOLU	36	15%	18	4%	12	2%
TOTAL	**232**	100%	**429**	100%	**643**	100%

* GWP AR5

2.7.2. Comparative Analysis of Scenarios A and C

The amount of avoided emissions in Scenario C compared to Scenario A by main mitigation actions is in Table 35. Again, the reduction of deforestation alone is responsible for nearly half (49%) of the total avoided emissions in 2030. In an overall perspective, only five mitigation actions in the AFOLU sector still account for 75% of total avoided emissions in 2030, although less than in Scenario B. Mitigation actions in other sectors present higher relevance than in Scenario B, such as increased use of biofuels, energy efficiency in Industry and HFCs leakage control and end-of-life recollection, allowing for 5%, 4% and 3% respectively of total avoided emissions in 2030.

Table 35. Consolidated Avoided Emissions by Mitigation Action – Comparative Analysis of Scenarios A and C ($MtCO_2$-eq and %)

MITIGATION ACTIONS	GHG Emissions in Scenario A – GHG Emissions in Scenario C					
	2020		2025		2030	
	Mt CO_2-eq	%	Mt CO_2-eq	%	Mt CO_2-eq	%
Reduction of Deforestation	160	89%	242	68%	247	48%
Increase in livestock productivity	-	0%	15	4%	60	12%
Increase of protected areas (increased accounting of carbon sinks)	-	0%	14	4%	28	5%
Increased use of biofuels	1.5	1%	15	4%	27	5%
Increased Restoration of native forests	1.2	1%	3.0	1%	26	5%
Energy efficiency in the industry sector	4.6	3%	12	3%	19	4%
Increased disposal of USW in managed deep landfills with methane recovery for power generation	-	0%	8.6	2%	17	3%
HFCs leakage control and end-of-life recollection	5.3	3%	11	3%	16	3%
Reduction in fertilizer application and in animal manure deposit on soil (due to a decrease in the average cattle slaughtering age)	0.0	0%	3.6	1%	14	3%
Others in Transportation	5.9	3%	15	4%	44	9%
Others in Energy Supply	2.0	1%	6.6	2%	11	2%
Others in Industry	3.0	2%	5.5	2%	8.7	2%
Others in Waste	0.88	0%	11	3%	7.2	1%
Others in AFOLU	-3.9	-2%	-5.6	-2%	-14	-3%
TOTAL	**181**	100%	**358**	100%	**512**	100%

* GWP AR5
Note: Negative figures describe an increase in emissions in Scenario C compared to Scenario A.

2.7.3. Comparative Analysis of Scenarios B and C

The amount of avoided emissions in Scenario C compared to Scenario B is split by main mitigation actions in Table 36. Overall, the total avoided emissions in Scenario C compared to Scenario B are negative, as by design Scenario B is more ambitious than Scenario C in the AFOLU sector and the increased avoided emissions from mitigation actions in Scenario C only partially compensates for the decline in avoided emissions from AFOLU. We can see that Scenario C has tested a lower degree of success in increased restoration of native forests and in the reduction of deforestation, mainly, but also in the increase of protected areas, of commercial planted forests and of pastureland restoration.

In other sectors, the main increase in avoided emissions from single mitigation actions in Scenario C compared to Scenario B, have come from the increased use of biofuels, energy efficiency in Industry, expansion of the electric vehicles fleet, changes in freight transport patterns and infrastructure, increased disposal of USW in managed deep landfills with methane recovery and increased renewable power generation.

Table 36. Consolidated Avoided Emissions by Mitigation Action – Comparative Analysis of Scenarios B and C ($MtCO_2$-eq and %)

MITIGATION ACTIONS	GHG Emissions in Scenario B – GHG Emissions in Scenario C					
	2020		2025		2030	
	Mt CO_2-eq	%	Mt CO_2-eq	%	Mt CO_2-eq	%
Increased Restoration of native forests	-14	27%	-37	52%	-96	73%
Reduction of Deforestation	-	0%	-22	31%	-47	35%
Increase of protected areas (increased accounting of carbon sinks)	-	0%	-14	19%	-27	20%
Increase in commercial planted forests	-33	63%	-18	25%	-19	14%
Increased use of biofuels	-	0%	8.6	-12%	15	-11%
Increased Restoration of pastureland	-5.4	10%	-11	15%	-11	8%
Energy efficiency in the Industrial Sector	2.5	-5%	6.2	-9%	9.8	-7%
Increase of manure management (from cattle swine and others animals)	-5.0	10%	-7.1	10%	-8.5	6%
Expansion of the electric vehicles fleet (battery electric vehicles - BEV and hybrids)	0.10	0%	1.1	-2%	8.5	-6%
Others in Transportation	3.5	-7%	8.1	-11%	19	-14%
Others in Energy Supply	1.3	-2%	3.7	-5%	9.9	-7%
Others in Industry	3.2	-6%	6.5	-9%	9.1	-7%
Others in Waste	0.27	-1%	8.6	-12%	10.0	-8%
Others in AFOLU	-5.3	10%	-5.1	7%	-4.3	3%
TOTAL	**-52**	100%	**-71**	100%	**-132**	100%

* GWP AR5
Note 1: By design, AFOLU has increased mitigation ambition in Scenario B compared to Scenario C, but in all other sectors (Industry, Transport, Energy Supply and Waste), Scenario C has increased mitigation ambition compared to Scenario B.
Note 2: Negative figures describe an increase in emissions in Scenario C compared to Scenario B.

3. Assessment of the Achievement of the NDC Economy-Wide Target

In Scenario A, total emissions would reach 1.6 Gt CO_2-eq in 2025 and 1.7 Gt CO_2-eq in 2030. The level reached in 2030 is above the Paris target commitment irrespectively of the metric adopted, using values from either the Second or the Third National Inventory as the base year. Therefore, the assessment of the potential results of current mitigation policies shows that they are not enough to meet Brazilian NDC targets for 2030.

Additional mitigation actions are required to put the country's GHG emission pathway back on track to meet the Brazilian commitment to the Paris agreement. According to the multiple stakeholders consulted by the Brazilian Forum on Climate Change during 2017, there are plenty of additional mitigation options that could be deployed to this end. Grouped in Scenarios B and C, they would allow not only to meet Brazilian Paris commitments, even under the stricter interpretation that sticks to the absolute emissions cap of 1.3 Gt CO_2-eq in 2025 and 1.2 Gt CO_2-eq in 2030, as illustrated by the results of Scenario C, but also to increase the ambition of next NDCs to reach even lower economy-wide emissions in 2025 (1.2 Gt CO_2-eq) and 2030 (1.0 Gt CO_2-eq), as illustrated by the results of Scenario B.

This scenario analysis also illustrates the crucial role of some key mitigation actions, as the reduction in deforestation. In Scenario C, that hits the NDC targets with an increased mitigation effort in other sectors than AFOLU, deforestation should emit no more than 0.6 Gt CO_2-eq in 2025 and 2030 (around half of the caps of 1.3 and 1.2 Gt CO_2-eq in 2025 and 2030, respectively), to meet the economy-wide targets. The translation of this deforestation emission level in different pathways of deforested surfaces in the main biomes as the Amazon and the Savannah ("Cerrado") is a good example of the type of MRV indicators required to track the progress achieved in Brazilian mitigation policies towards meeting the NDC targets, as it will be further explored in the next phase of the study. Table 37 presents the figures.

Table 37. Brazilian NDC economy-wide targets with figures related to the Second National communication and corrected by the Third National Communication ($MtCO_2$-eq and %)

$MtCO_2$-eq*	2005	2025	2030
Second National Communication	2.1	1.3	1.2
Third National Communication	2.8	1.8	1.6
	100%	-37%	-43%

* GWP AR5

Sources: 2005 values from Brazil (2010 and 2015). Decree values from Brazil (2010). Scenario A values, our estimates.

The next section presents the set of indicators proposed to track the progress towards the achievement of NDC targets.

4. Indicators for Monitoring Progress towards the Achievement of NDC Targets

4.1. AFOLU

4.1.1. NDC targets for the AFOLU Sector

In the AFOLU sector, the Brazilian NDC includes a series of mitigation actions as summarized below.

For Land use change and forestry:

i) strengthening and enforcing the implementation of the Forest Code, at federal, state and municipal levels;

ii) strengthening policies and measures with a view to achieving, in the Brazilian Amazonia, zero illegal deforestation by 2030 and compensating for greenhouse gas emissions from legal suppression of vegetation by 2030;

iii) restoring and reforesting 12 million hectares of forests by 2030, for multiple purposes;

iv) enhancing sustainable native forest management systems, through georeferencing and tracking systems applicable to native forest management, with a view to curbing illegal and unsustainable practices;

In the agriculture sector, the Brazilian NDC strengthens the Low Carbon Emission Agriculture Program (ABC) as the main strategy for sustainable agriculture development, including restoration of additional 15 million hectares of degraded pasturelands by 2030 and increase of 5 million hectares of integrated cropland-livestock-forestry systems (ICLFS) until 2030.

4.1.2. Indicators of Emission Drivers in the AFOLU sector

Since the 1970s, the National Institute for Spatial Research (INPE), the Brazilian Agricultural Research Corporation (EMBRAPA) and the Brazilian Institute of Geography and

Statistics (IBGE) have established and strengthened strategic partnerships to develop technologies and methodologies to monitor the Brazilian territory.

With the development of geoprocessing and remote sensing technologies, Brazil has become a benchmark in the development of land cover and land-use monitoring systems. The resulting knowledge on the dynamics of land-use change has been a key element for curbing deforestation in the Amazon biome.

Brazil has a consistent, credible, accurate and verifiable historical time series for annual gross deforestation in the Legal Amazon biome. The PRODES (Amazon Deforestation Estimation Project) is part of a larger program (Amazon Program) developed at INPE to monitor gross deforestation in areas of primary forest in the Legal Amazon making use of satellite imagery (BRAZIL, 2017).

Mapping and monitoring initiatives provide the government with official data regarding the remaining vegetation cover of the Brazilian biomes. The Ministry of the Environment (MMA), through the Project for the Conservation and Sustainable Use of Brazilian Biological Diversity (PROBIO), has conducted significant mappings based on satellite imagery, which were later refined under the Project of Satellite Deforestation Monitoring of the Brazilian Biomes (PMDBBS). This project carried out a series of assessments between 2008 and 2011 on the Cerrado, the Caatinga, the Pampa, the Pantanal and the Atlantic Forest biomes, taking the PROBIO map as a basis (BRAZIL, 2017).

Currently, there are five systems in place monitoring deforestation and forest degradation in Brazil: PRODES, DETER, QUEIMADAS, DEGRAD/DETEX and TerraClass. Through these initiatives, Brazil tracks the progress of the NDC targets (BRAZIL, 2017).

Concerning indicators related to agriculture, the Brazilian Institute of Geography and Statistics (IBGE) has made available agricultural data through its digital platform, since the '70s (for the main crops). The IBGE Automatic Recovery System - SIDRA contains historical data series of Municipal Agricultural Production (PAM), Production of Plant Extraction and Silviculture (PEVs) and Municipal Livestock Research (PPM). Indicators of production, average yield and areas planted and harvested by crop types; quantity and value of the main products and areas planted and harvested in forestry; as well as statistical information on herds are published annually for the whole national territory, with nationally aggregated information, Geographic Regions, Federation Units, Geographical Meso-regions, Geographical Microregions and Municipalities.

The National Supply Company (CONAB) is also an official source that publishes agricultural information and provides a platform with data on Brazilian grain crops, winter and summer crops, as well as coffee and sugarcane. They provide monthly data and information related to grain harvesting and the agricultural monitoring, while for coffee and sugar cane the periodicity is quarterly. Data since the ’70s are available by State.

Indicators related to the variation of carbon stock in protected areas, restored native forest areas, commercial forest areas, and integration systems (ICLF) can be obtained by private agencies and government agencies such as: Ministry of the Environment - National Registry of Conservation Units (SISNUC) and the Indian National Foundation (FUNAI); the National Plan for Native Vegetation Recovery (PLANAVEG); IBÁ, ABRAF and EMBRAPA (ICLF platform). The variation of carbon in pasture areas and areas under zero-tillage are provided by the Low Carbon Agriculture Observatory (ABC Plan Observatory) and the Brazilian Federation of Zero Tillage and Irrigation (FEBRAPDP).

There are also partnership projects between NGOs, universities and companies involving several specialists that aim to provide historical data and monitoring systems of land use in Brazil. An example is the online platform MapBiomas, which makes available Brazilian annual land cover and land use maps from 1985 to the present day. In addition to maps, information and statistic data are available on land use cover for each year, at various scales (municipality, state, biome), as well as land use changes from the previous year. Another example is the System for Greenhouse Gas Emissions and Removal Estimates (SEEG) developed by the Climate Observatory. This system estimates greenhouse gas (GHG) emissions in Brazil and provides analytical documents on the evolution of sectorial emissions including AFOLU (http://seeg.eco.br).

AFOLU indicators can be divided into those aimed at tracking emissions reduction (for example reduction of annual deforestation rate) and those aimed at monitoring CO_2 removals from the atmosphere (uptake increases) such as planting forests or the maintenance of forest stocks. Table 38 shows the mitigation actions of the AFOLU sector and the corresponding indicators.

Table 38. Mitigation actions and corresponding indicators in AFOLU

MITIGATION ACTION	INDICATORS
Emissions Reduction	
Land Use Change and Forestry	
Reduction of annual deforestation rate	Annual deforested area per biome (thousand ha/year)
Agriculture	
Increased livestock productivity (emission reduction in enteric fermentation	Number of cattle (units)
Increased area under Biological Nitrogen Fixation (replacement of chemical fertilizers)	Area under Biological Nitrogen Fixation (Mha/year)
Reduction in animal manure deposit on soil (due to a decrease in the cattle slaughtering age)	Number of cattle (units)
Increased manure management (from cattle, swine and other animals)	Volume of manure management (Mm^3)
Carbon uptake increases	
Land Use Change and Forestry	
Restoration of native forests	Restored area of native forest per biome (Mha/year)
Increased protected areas	Protected area per biome (Mha/year)
Planting commercial forests	Area of commercial planted forest (Mha/year)
Use of ICLF systems[1]	Area of integrated systems (Mha/year)
Restoration of pastureland	Recovered pasture area (Mha/year)
Agriculture	
Increased zero-tillage practices	Area under zero-tillage (Mha/year)

[1]ICLF = integrated cropping/livestock/forest systems, also including ILF = integrated livestock/forest systems, and ICF = integrated cropping/forest systems.

4.1.2.1. Emission drivers in LULUCF

A key emissions reduction indicator is the annual deforested area of the biomes. Deforestation is the main source of emissions from the AFOLU sector. In 2015 it was responsible for about 62% of the total gross AFOLU emissions. For example, the Amazon biome alone contributed with 49% of the gross emissions related to Land Use Change and Forestry, and Cerrado with 25%. Estimates of these emissions are directly related to the availability of data on deforested areas in these biomes. Therefore, monitoring the annual deforested area in the Brazilian biomes is extremely important in tracking the progress towards mitigation targets for 2020, 2025 and 2030.

Historical data about the annual deforested area in the Amazon biome provided by the project Amazonia deforestation satellite monitoring – PRODES, published by INPE, is used in this study <http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes>. This platform has historical data for the period 1988 - 2017.

Historical data about the annual deforested area in the Atlantic Forest biome are published by the SOS Mata Atlântica Foundation (https://www.sosma.org.br/projeto/atlas-da-mata-atlantica/dados-mais-recentes/). Between 2016 and 2017, deforestation decreased by 56.8% in relation to the previous period (2015-2016) when 29,075 ha were cleared. Last year, 12,562 hectares, or 125 km², were destroyed in the 17 states of the biome, the lowest total deforestation value of the historical monitoring series, carried out by the SOS Mata Atlântica Foundation and the National Institute for Spatial Research (INPE).

For the Cerrado, we used the annual deforestation data published by the project PMDBBS (IBAMA, 2013) until 2011. These data are supplemented by data published by INPE until 2017 (http://www.dpi.inpe.br/fipcerrado/dashboard/cerrado-rates.html). The results of the period 2016-2017 show a 38% reduction in the deforested area compared to the 2014-2015 period.

For the other biomes (Caatinga, Pampa and Pantanal) we used the annual deforestation data from the project Deforestation Monitor of the Brazilian Biomes by Satellite – PMDBBS until 2009 (IBAMA, 2013) (http://siscom.ibama.gov.br/monitora_biomas), and data estimated by SEEG for 2010. Due to a lack of recent annual deforestation data for the Caatinga, Pantanal and Pampa biomes, we used data from the last published year of the PMDBBS-IBAMA Project.

The estimates for the annual deforested area per biome in Scenarios A, B and C for 2020, 2025 and 2030 considered the targets included in Decree 7390, NDC and recommendations from the FBMC, as described in the Report 2 of this study. Table 39 shows the annual deforestation rate projected per biome in Scenarios A, B and C for 2020, 2025 and 2030.

Table 39. LULUCF Emission Drivers Indicator: Deforested area per biome – (Thousand ha/year)

Indicators (Thousand ha/year)	Data					Scenario A			Scenario B			Scenario C		
Annual Deforestation rate per biome	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Amazônia	1901	700	621	789	662	591	591	591	393	231	191	393	261	255
Cerrado	1764	647	948	948	948	838	838	838	838	838	838	838	838	838
Mata Atlântica	35	15	18	29	13	22	22	22	22	22	22	22	22	22
Caatinga	235	192	192	192	192	192	192	192	192	192	192	192	192	192
Pantanal	71	19	19	19	19	19	19	19	19	19	19	19	19	19
Pampa	36	33	33	33	33	33	33	33	33	33	33	33	33	33
Total	**4044**	**1606**	**1831**	**2010**	**1867**	**1696**	**1696**	**1696**	**1497**	**1335**	**1296**	**1497**	**1365**	**1360**

Sources 2005-2015: [1]INPE<http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes>;
[2]Ibama<http://www.dpi.inpe.br/fipcerrado/dashboard/cerrado-rates.html>;
[3]Mata Atlântica Foundation <https://www.sosma.org.br/projeto/atlas-da-mata-atlantica/dados-mais-recentes/>;
[4]Ibama <http://siscom.ibama.gov.br/monitora_biomas>.

NAMA's targets for 2020 are: annual deforested rate in the Amazon biome = 393 thousand ha/year and in Cerrado = 945 thousand ha/year.
NDC's target = zero illegal deforestation in the Amazon biome by 2030.

4.1.2.2. Emission drivers in Agriculture

In the agriculture sector, hey indicators are those related to the reduction of livestock GHG emissions. Enteric fermentation is the main emissions source, responsible in 2015 for 68% of the total emissions of this subsector (see Report 2). Indicators such as recovered pasture area and herd size are essential for monitoring these emissions.

Assumptions of 20% increase in herd productivity from 2020 in Scenarios B and C, restoration and improved management of pastureland, genetic improvements and reduction of the slaughtering age from 37 to 27 months, would result in a reduction of the herd size and therefore emissions, without affecting meat production.

Increasing the adoption of Biological Nitrogen Fixation (BNF) in croplands results in less use of synthetic nitrogen fertilizers and consequently in lower N_2O emissions. The area under Biological Nitrogen Fixation - BNF (planted with soybean and other grains) is the main indicator for monitoring emissions reduction by this mitigation action.

The amount of animal waste treated (manure management) is estimated considering data on the annual populations (number of cattle heads, swine and others animal categories) published by IBGE (2018) and the percentage of waste treated to produce fertilizers and energy.

Table 40 summarizes the evolution up to 2030 of these three indicators of emission drivers in Agriculture (herd size, area under BNF and volume of manure management) in scenarios A, B and C.

Table 40. Agriculture Emission Drivers Indicators (multiple units)

Emission drivers indicators	Unit	Data					Scenario A			Scenario B			Scenario C		
Agriculture		**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Number of cattle	Head of cattle (million)	228	210	215	208	209	210	213	218	210	204	182	210	204	182
Area under BNF[1]	Mha	23.4	23.3	32.2	NA	NA	33	36	38	33	39	42	33	39	41
Volume of manure management	Mm^3	N.A.	7.4	9.4	NA	NA	9.4	9.4	9.4	12	13	14	9.4	9.4	9.4

[1]BFN = Biological Nitrogen Fixation
NAMA's targets for 2020: Area under BNF = 28.8 Mha (5.5 Mha more than in the year 2010); Manure management = $11.8Mm^3$ ($4.4Mm^3$ more than in the year 2010).
NA = not available

4.1.2.3. Carbon uptake in LULUCF and Agriculture

Indicators that monitor increased CO_2 removals, such as the surface under the category of protected areas (Conservation Units and Indigenous Lands) and with restored native forest are very important due to the high mitigation potential of these areas. Areas of dedicated homogeneous plantations of Eucalyptus and Pinus forests, areas under integrated cropland-livestock-forestry systems (ICF+ILF+lCLF), recovered pasture area and areas managed under a zero-tillage system (agriculture) are also part of this group of indicators.

a) Land Use Change and Forestry

Protected Areas

The annual increment of carbon stocks in protected areas such as Conservation Units and Indigenous Lands is accounted in the total carbon removals since they are a category of managed forest areas in the IPCC guidelines (2006).

To estimate the Protected Area (Conservation Units and Indigenous Lands) for 2020 and in 2025 and 2030, we considered data from the III[rd] National Inventory (BRASIL, 2016), data available in the database of the National Indian Foundation - FUNAI (www.funai.com.br) and the National Register of Conservation Units (www.mma.gov.br/cadastro_uc).

Recommendations from the FBMC regarding the conversion of more land into the category of protected areas until 2030 were considered as described in Report 2 of this study. Table 41 shows the values per biome assumed up to 2030 in scenarios A, B and C.

Table 41. LULUCF Carbon Uptake Drivers Indicators: Protected area per biome (Mha/year)

Indicators	Data					Scenario A			Scenario B			Scenario C		
Protected area per biome (Mha/year)	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Amazônia	N.A.	170	N.A.	N.A.	214	214	214	214	214	232	248	214	223	232
Cerrado	N.A.	12	N.A.	N.A.	29	29	29	29	29	29	31	29	29	29
Mata Atlântica	N.A.	5	N.A.	N.A.	15	15	15	15	15	15	15	15	15	15
Caatinga	N.A.	4	N.A.	N.A.	9	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Pantanal	N.A.	0	N.A.	N.A.	1	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Pampa	N.A.	0	N.A.	N.A.	1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Total	N.A.	**191**	**247**	**258**	**269**	**269**	**269**	**269**	**269**	**287**	**305**	**269**	**278**	**287**

Sources:< http://www.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs.html>; <http://www.funai.br >

Note: differences in totals are due to rounding; NA = not available

Restored area of native forests

To estimate the native forests area covering all biomes (Amazon, Atlantic Forest, Cerrado, Caatinga, Pantanal and Pampa) to be restored in order to comply with the requirements due to liabilities resulting from the new Forest Code, we relied on the potentials obtained in the study published by Soares Filho (2013) and the values presented in the NDC (restoring and reforesting 12.0 million hectares of forests by 2030, for multiple purposes). Table 42 shows the Restored area of native forests projected in scenarios A, B and C.

Area of commercial planted forests

Commercial planted forest areas published by ABRAF (ABRAF, 2012) for the period 2005-2013 and IBA for 2014-2017 <http://iba.org/pt/dados-e-estatisticas> were our data sources. For scenarios A and C, we used the demand for forest plantations from the MATRIZ model outputs with biomass demand for energy purposes and other sectorial demands for wood (Report 2 of this study). For Scenario B we considered the values provided for 2020 by Decree 7390, and an increase for 2025 and 2030 according to the same trend. Table 42 shows the figures for scenarios A, B and C.

Area of integrated cropland-livestock-forestry systems

Data published by Embrapa (www.embrapa.br/web/rede-ilpf) are used to estimate additional forest plantation areas and related carbon removals up to 2030. Distinct types of integration systems are encompassed within this category: Crop-Livestock-Forest Systems; Crop-Forest Systems and Livestock-Forest Systems. Table 42 shows the area of integrated systems in scenarios A, B and C.

Recovered pasture areas

Data of pastureland restored in Brazil from 2010 to 2015 published by Observatório ABC (http://observatorioabc.com.br/publicacoes/) are used to estimate additional restored pasture area up to 2030. Table 42 shows the recovered pasture areas in scenarios A, B and C.

Table 42. Other LULUCF Carbon Uptake Drivers Indicators (Mha/year)

Carbon uptake drivers indicators						Scenario A			Scenario B			Scenario C		
Land use change	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Restored area of native forests	N.A.	N.A.	N.A.	N.A.	N.A.	0.4	0.9	1.4	1.3	3.4	9.0	0.4	1.1	3.0
Area of commercial planted forests[1]	5,3	6,5	6,9	7,2	7,3	6.3	6.7	7.4	7.8	8.6	9.5	6.2	6.6	6.9
Area of integrated systems[2] (ICLF*)	0,3	0,9	1,9	N.A.	N.A.	2.6	3.2	3.8	3.0	4.0	5.0	2.8	3.6	4.4
Recovered pasture area[3]	N.A.	N.A.	3,90	N.A.	N.A.	6.9	9.9	12	9.3	14	20	7.8	11	15

Sources: Planted forests: Abraf (2012) and Ibá <http://iba.org/pt/dados-e-estatisticas>;
Integrated systems: <http://www.embrapa.br/web/rede-ilpf >;
Recovered pasture area: <http://observatorioabc.com.br/publicacoes>

*ICLF = integrated cropping/livestock/forest systems, also including ILF = integrated livestock/forest systems, and ICF = integrated cropping/forest systems.

NAMA's targets for 2020: [1]Area of commercial planted forests = 9.5Mha (3 Mha more than in the year 2010); [2]Integrated ICLF systems: planting of 4 Mha; Recovered pasture area[3] = 15 Mha. NDC targets for 2030: [2]Integrated ICLF systems = planting of 4 Mha; [3]Recovered pasture area: 15 Mha.

N.A. = Not Available

b) Agriculture

Area under zero-tillage systems

Projections of the agricultural area under zero-tillage systems up to 2030 are based on the IBGE database and historical data about the adoption of this practice from 2005 to 2012, published by FEBRAPDP (2012). Table 43 shows the area under zero tillage in scenarios A, B and C.

Table 43. Agriculture Carbon Uptake Drivers Indicators (Mha)

Carbon Uptake drivers indicators (Mha)	Data					Scenario A			Scenario B			Scenario C		
Agriculture	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Area under zero-tillage[1]	26	31	34	N.A.	N.A.	39	43	45	39	45	48	39	45	48

[1]NAMA's targets for 2020: Area under zero-tillage = 38.8 Mha (8 Mha more than in the year 2010)

Note: NA = not available

4.1.3. Absolute Emissions Indicators in the AFOLU sector: Scenarios A, B and C pathways

Tables 44 summarizes the emissions and removals ($MtCO_2$-eq) achieved in Scenarios A, B and C in 2020, 2025 and 2030, resulting from the assumptions on the evolution of emission drivers and the implementation of mitigation actions in the AFOLU sector.

They allow for a comparison with some Decree 7390 targets for 2020.

Table 44. Emissions and Removals in the AFOLU sector ($MtCO_2$-eq)

Emissions and Removals ($MtCO_2$-eq)	***Scenario A***			***Scenario B***			***Scenario C***		
	2020	***2025***	***2030***	***2020***	***2025***	***2030***	***2020***	***2025***	***2030***
Emissions	***1370***	***1379***	***1393***	***1198***	***1078***	***1003***	***1204***	***1110***	***1063***
Land Use Change and Forestry	***896***	***896***	***896***	***729***	***622***	***592***	***729***	***645***	***640***
Annual deforestation	*896*	*896*	*896*	*729*	*622*	*592*	*729*	*645*	*640*
Agriculture	***474***	***483***	***497***	***469***	***456***	***411***	***475***	***465***	***423***
Livestock enteric fermentation	*349*	*355*	*364*	*349*	*340*	*304*	*349*	*340*	*304*
Chemical fertilizers	*21*	*22*	*22*	*21*	*20*	*20*	*22*	*22*	*23*
Animal manure deposit on soil	*86*	*87*	*90*	*86*	*84*	*76*	*86*	*84*	*76*
Manure management (from cattle, swine and other animals)	*18*	*19*	*21*	*13*	*12*	*11*	*18*	*19*	*20*
Removals	***533.8***	***554***	***565***	***584***	***642***	***751***	***527***	***560***	***599***
Land Use Change and Forestry	***517.8***	***538***	***554***	***568***	***622***	***735***	***511***	***540***	***583***
Restoration of native forests	*5.8*	*15*	*23*	*21*	*55*	*145*	*7*	*18*	*48*
Increased protected areas	*382*	*382*	*382*	*382*	*410*	*437*	*382*	*396*	*410*
Planting of commercial forests	*0*	*14*	*22*	*33*	*31*	*31*	*0*	*13*	*12*
Use of ICLF systems ILF+ICF+ICLF)	*15*	*15*	*15*	*25*	*25*	*24*	*20*	*20*	*20*
Restoration of pastureland	*25*	*22*	*22*	*34*	*39*	*39*	*29*	*29*	*29*
Carbon sinks in the natural regrowth of deforested areas	*90*	*90*	*90*	*73*	*62*	*59*	*73*	*64*	*64*
Agriculture	***16***	***16***	***11***	***16***	***20***	***16***	***16***	***20***	***16***
Increased zero-tillage practices	*16*	*16*	*11*	*16*	*20*	*16*	*16*	*20*	*16*
Emissions from other changes ($MtCO_2$--eq)	***44***	***46***	***48***	***45***	***48***	***51***	***45***	***47***	***51***
Liming for pH correction of agricultural soil	*12*	*14*	*15*	*13*	*16*	*17*	*13*	*15*	*16*
Burning of agriculture residues (in sugar cane pre-harvesting)	*3.4*	*3*	*2.8*	*3.4*	*3.1*	*3.1*	*3.7*	*3.5*	*3.5*
Returning of agriculture residues to agricultural soil	*14*	*16*	*18*	*14*	*16*	*19*	*14*	*16*	*19*
Rice cultivation	*10*	*8.2*	*6.9*	*10*	*8.2*	*6.9*	*10*	*8.2*	*6.9*
Organic Soils	*4.6*	*4.8*	*5.2*	*4.6*	*4.8*	*5.2*	*4.6*	*4.8*	*5.2*
Synthesis of AFOLU Emissions ($MtCO_2$-eq)									
Gross emissions from Land use change and forestry	***896***	***896***	***896***	***729***	***622***	***592***	***729***	***645***	***640***

Removals from Land use change and forestry	***518***	***538***	***554***	***568***	***622***	***735***	***511***	***540***	***583***
Net emissions from Land use change and forestry	***378***	***358***	***342***	***161***	***0***	***-143***	***218***	***105***	***57***
Emissions from Agriculture	***474***	***483***	***497***	***469***	***456***	***411***	***475***	***465***	***423***
Other Emissions	***44***	***46***	***48***	***45.2***	***47.6***	***51.3***	***45***	***47.2***	***50.7***
AFOLU total Gross Emissions	***1414***	***1425***	***1441***	***1243***	***1126***	***1054***	***1249***	***1157***	***1114***
AFOLU Total Net Emissions	***899***	***887***	***894***	***679***	***500***	***320***	***741***	***614***	***533***

Note: GWP AR5
Note: differences in totals are due to rounding

Gross emissions from Land Use Change and Forestry in 2020, amount to 925, 760 and 759 $MtCO_2$-eq in Scenarios A, B and C, respectively. Of this total, 94% comes from deforestation, mainly in the Amazon biome. As the target for emissions from deforestation in 2020 is set at 851 $MtCO_2$-eq, the Scenario A emissions pathway wouldn't meet the target set by Decree 7390 for 2020, while in Scenarios B and C emissions would be 17% below this target.

In the Amazon biome, according to PRODES/INPE (2018) data, the average annual deforestation rate was of 691 thousand hectares/year in 2015-2017. The Brazilian commitment (Decree 7390) is that this rate should not exceed 393 thousand ha in 2020, a reduction of 80% of the average observed in the 1996-2005 period. According to the previously presented indicators, the deforested area in 2020 would be of 591 thousand hectares in Scenario A and of 393 thousand hectares in scenarios B and C. Therefore, in scenarios B and C, emissions would be below the target established by Decree 7390.

In the case of the Cerrado biome, the Decree target will be reached by 2020 in all scenarios. The annual deforested area would be of 838 thousand ha in the period 2017 – 2030 (average of the period 2012-2016) while the Decree goal is of 942 thousand ha. The deforested area in Cerrado corresponds to emissions of 172 $MtCO_2$-eq in 2020 while the Decree goal is of 219 $MtCO_2$-eq.

The Brazilian NDC does not present any emission target for deforestation in 2025 and 2030. The document strengthened policies and measures with a view to achieving, in the Brazilian Amazon, zero illegal deforestation by 2030 and compensating for greenhouse gas emissions from legal suppression of vegetation by 2030 (BRASIL, 2015).

In Scenario A, there would be no reduction of emissions from annual deforestation in any biome between 2020 and 2030. In the Amazon Biome, in scenario B, there would be a reduction of 68% and in Scenario C of 56% compared to Scenario A by 2030. According to the assumptions based on FBMC recommendations (see Report 2), zero illegal deforestation by 2030 in this Biome is not feasible and therefore not projected. In Scenario B, describing a greater effort, we assume a reduction of 95% in the illegal deforestation rate while legal deforestation (5%) would still take place. We used the historical deforestation rate presented in Decree 7390 as the base-year period. In Scenario C, illegal deforestation would be reduced by 60%. For 2025, in both B and C scenarios, values are interpolated with an exponential function, due to the increasing marginal effort that would be required to control deforestation in sparse areas of the biome. Deforestation in the other biomes is the same in the three scenarios and is assumed to be constant over the 2020-2030 period. Table 45 shows the values.

Table 45. Annual Deforestation per Biome in Scenarios A, B and C (km^2/year)

Biome		Amazon	Cerrado	Atlantic Forest	Caatinga	Pantanal	Pampa	total
		(km²/year)						
Historical annual deforestation rate		19.630	15.700	NA	NA	NA	NA	NA
2005		19.010	17.640	350	2.350	710	360	40.440
2010		7.000	6.470	150	1.920	190	330	16.060
2011		6.420	7.240	140	1.920	190	330	16.240
2012		4.570	7.650	220	1.920	190	330	14.880
2013		5.890	7.650	240	1.920	190	330	16.220
2014		5.010	7.650	180	1.920	190	330	15.280
2015		6.210	9.480	180	1.920	190	330	18.310
2016		7.890	9.480	290	1.920	190	330	20.100
2017		6.620	9.480	130	1.920	190	330	18.670
2020	ScenA***	5.910	8.380	220	1.920	190	330	16.960
	ScenB	3.930	8.380	220	1.920	190	330	14.970
	ScenC	3.930	8.380	220	1.920	190	330	14.970
2025	ScenA	5.910	8.380	220	1.920	190	330	16.960
	ScenB	2.310	8.380	220	1.920	190	330	13.350
	ScenC	2.610	8.380	220	1.920	190	330	13.650
2030	ScenA	5.910	8.380	220	1.920	190	330	16.960
	ScenB	1.910	8.380	220	1.920	190	330	12.960
	ScenC	2.550	8.380	220	1.920	190	330	13.600

* average in the period 1996-2005 according to Decree 7390
** average in the period 1998-2008 according to Decree 7390
*** average in the period 2012-2016 according to FBMC assumptions
NA not available

According to the document "*Basis for the elaboration of the Intended Nationally Determined Contribution (INDC)*" (MMA, 2015) gross emissions from the Forestry and Land Use subsector were of 1,398 $MtCO_2$-eq in 2005 and would reach 392 $MtCO_2$-eq in 2025 and 143

$MtCO_2$-eq in 2030, an overall reduction of 90% in the 2005-2030 period. In terms of net emissions, they would go down from 1,187 $MtCO_2$-eq to 118 $MtCO_2$-eq in 2025 and a negative emission (= removal) of -131 $MtCO_2$-eq in 2030. Removals would reach 274 $MtCO_2$-eq/year by 2030.

It was not possible to reproduce the calculations underlying the projections in MMA (2015) since the document does not provide further details. Furthermore, the iNDC estimates rely on data from the Second National Inventory (2010) where emissions are far lower than those in the Third National Inventory (2016) that revised the historical series, with substantial discrepancies in 2005 values, with reasons not very clear yet. There are differences in the amounts of deforested areas, and in removal factors in protected areas (for example, IPCC defaults where replaced by national biome-specific factors). Emission factors for deforestation in several phytophysiognomies were also revised, resulting in higher emissions.

Additionally, it cannot be inferred whether the assumptions about mitigation actions adopted in this study were accounted for in the estimates of the MMA document (2015). Removals related to the recovery of degraded pasture and integration systems, for example, are included in agriculture and livestock subsector in the iNDC document, while in this study they are included in land use change and forestry subsector. The factors mentioned above explain the discrepancies between data from the different sources analyzed.

The most important removals related to land use change and forestry take place in protected areas. In total, removals include increased restoration of native forests, increase in commercial planted forests, increased use of ICLF systems, increased restoration of pastureland, and carbon sinks from natural regrowth of deforested areas. Scenario B shows the emissions pathway resulting from the highest assumptions on carbon removals.

Brazilian NDC does not mention any specific sectorial emissions target like, for example, the NAMA document. It proposes mitigation actions and refers to areas estimates (emission drivers targets) where these actions would be adopted by 2030: restore and reforest 12 million hectares of forests by 2030, for multiple purposes; increase sustainable native forest management systems; recover an additional 15 million hectares of degraded pasturelands by 2030; enhance 5 million hectares of integrated cropland-livestock-forestry systems (ICLF) by 2030.

In the agriculture sector, emissions in Scenario A amount to 491, 498 e 519 MtCO2-eq in 2020, 2025 and 2030 respectively using GWP-100 from IPCC-AR5. Using GWP from IPCC-SAR, emissions would be of 422, 429 and 448 MtCO2-eq in 2020, 2025 and 2030, respectively. Decree 7.390/2010 indicates emissions of 730 MtCO2-eq from Agriculture in 2020 (BRASIL, 2010b). However, this estimate was made under an assumption of average annual GDP growth of 5%. This discrepancy shows the need for a robust and periodic review process of climate policies and sectorial plans. Agriculture emissions in Scenarios B and C in 2020 would also be below the Decree 7390 target (730 MtCO2--eq).

The comparative analysis of each mitigation action in Agriculture scenarios and in Decree 7390 shows that the increase of zero-tillage practices and of Biological Nitrogen Fixation meet its targets in scenarios A, B and C. In contrast, targets for ICLF systems and the restoration of pastureland are not met in any scenario by 2020. This is due to the assumptions adopted about the penetration of these mitigation actions. Most of the mitigation in Agriculture takes place after 2020 in Scenarios B and C, due to an improvement of livestock productivity and the corresponding decrease in the herd size compared to Scenario A, keeping production levels and reducing emissions from enteric fermentation.

The Brazilian NDC submitted to the UNFCC doesn't set any specific sectorial emissions target for the agriculture sector in 2025 and 2030. The document strengthens the goals of the ABC Plan as the main strategy for sustainable agriculture development, including the restoration of additional 15 million hectares of degraded pasturelands and increase of 5 million hectares of integrated cropland-livestock-forestry systems by 2030. Considering the targets for the agriculture sector mentioned in the document "*Basis for the elaboration of the Intended Nationally Determined Contribution (INDC)"* (MMA, 2015), total emissions of the agriculture sector (GWP-100; IPCC-AR5) would be equivalent to 470 MtCO_2-eq in 2025 and to 489 MtCO_2-eq in 2030. In scenario A, emissions would exceed these targets, whereas in scenarios B and C emissions would be, respectively, 1% and 2% above 470 MtCO_2-eq in 2025 and below the target of 489 MtCO_2-eq in 2030. Table 46 presents the values.

Table 46. Emissions and Removals in Scenarios A, B and C , Decree 7390 and ABC Plan ($MtCO_2$-eq)

,	Emissions and Removals (Mton CO_2-eq)									
	Scenario A			**Scenario B**			**Scenario C**			**Governmental targets (Mton CO_2-eq)**
Emissions (positive figures) and Removals (negative figures) in AFOLU (Mton CO_2-eq)	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020 (Decree 7390 and ABC Plan)**
Annual Deforestation										
Amazônia biome	434	434	434	274	169	140	274	191	187	189*/286**
Cerrado biome	195	195	195	195	195	195	195	195	195	194*/219**
Other biomes	239	239	239	239	239	239	239	239	239	133*/346**
Total	868	868	868	708	604	575	708	626	621	516*/851**
Increased protected areas	-382	-382	-382	-382	-410	-437	-382	-396	-410	-
Increased Restoration of native forests	-5.8	-15	-23	-21	-55	-145	-6.9	-18	-48	-
Increased commercial planted forest	0	-14	-22	-33	-31	-31	0	-13	-12	-
Increased use of ICLF systems	-15	-15	-15	-25	-25	-24	-20	-20	-20	18-22***
Increased Restoration of pastureland	-25	-22	-22	-34	-39	-39	-29	-29	-29	83-104***
Increased zero-tillage practices	-16	-16	-11	-16	-20	-16	-16	-20	-15	16-20***
Fertilizers (considering an increase in Biological Nitrogen Fixation)	21	22	22	21	20	19	21	22	23	14-17***

* Emissions target for 2020 according to Decree 7390 and ABC Plan
** Emissions target for 2020 recalculated according to carbon stocks applied in this study
***data published by NAMA/UNFCCC (Brazil, 2010a)
**** as in PRODES.

4.2. Transportation

4.2.1. NDC targets for the Transportation Sector

According to the Brazilian NDC, there will be an "increase in the share of sustainable biofuels in the energy mix to approximately 18% by 2030, by expanding biofuel consumption, increasing ethanol supply, increasing the share of advanced biofuels (second generation), and increasing the share of biodiesel in the diesel mix". It also includes efficiency measures and improvement in transport infrastructure and public transportation in urban areas.

4.2.2. Indicators of Emission drivers in the Transportation Sector

This section presents the list of indicators identified for transportation, considering scenarios A, B and C and 2020, 2025 and 2030 milestones. To select the indicators, we examined the literature on MRV indicators that could be applicable to the sector, considering related articles and reports. As stressed by Bongardt et al. (2016), when assessing emissions from the transportation sector, it is necessary to study the nature of millions of small mobile sources, driven by a variety of energy sources (electricity, gasoline, diesel, kerosene, NGV, biofuels etc.) and operated by several individuals or companies. This phenomenon reflects the number of MRV indicators required to assess the entire sector.

In summary, MRV indicators were obtained from sectorial studies[5] and expert judgment. The selection criteria were based on the consistency of identified indicators with the outputs (variables) of the bottom-line and top-down approaches adopted to estimate energy consumption, transport activity and GHG emissions (see Report 2 for details on the modeling). Table 47 lists the selected indicators based on each mitigation action in decreasing order of impact on emissions.

[5] Such as: Bongardt et al. (2016), Asean (2016), Eichhorst and Bongardt (2015) and Capone and Velezmoro (2015).

Table 47. Mitigation actions and Emission driver indicators in Transportation

Mitigation actions	Indicator	Unit
Increased use of biofuels	Biofuels share in energy demand	%
	Market share of ethanol (flexible-fuel vehicles)	%
	Percentage of anhydrous ethanol in the mandatory blend (Gasoline C)	%
	Percentage of biodiesel in the mandatory blend (Bx)	%
	Percentage of biokerosene in the mandatory blend (Bx)	%
	Annual demand for ethanol equivalent	10^6 toe
	Annual demand for biodiesel	10^6 toe
	Annual demand for biokerosene	10^6 toe
	Annual demand for biomethane	10^6 toe
Changes in freight transport patterns and infrastructure	Road mode share in the modal split of freight transport	%
	Activity of rail transport	10^9 t -km
	Activity of water transport	10^9 t -km
Gains in energy efficiency in the transportation sector	Energy intensity of freight transport	MJ/t -km
	Energy intensity of passenger transport	MJ/pass-km
	Cumulative gains in energy efficiency - light vehicles	%
Expansion of the electric vehicles fleet (battery electric vehicles - BEV and hybrids)	Electricity share in transport energy consumption	%
	Electric power consumption (BEV vehicles)	TWh
	Electric vehicles share in the fleet	%
	Hybrid vehicles share in the fleet	%
	Number of BEV cars in the fleet	10^6 vehicles
	Number of hybrid cars in the fleet	10^6 vehicles
	Number of BEV urban buses in the fleet	10^6 vehicles
	Number of hybrid urban buses in the fleet	10^6 vehicles
	Number of BEV light commercial vehicles in the fleet	10^6 vehicles
	Number of hybrid light commercial vehicles in the fleet	10^6 vehicles
	Number of BEV motorcycles in the fleet	10^6 vehicles
	Number of BEV micro-buses in the fleet	10^6 vehicles
	Number of semi-light BEV trucks in the fleet	10^6 vehicles
	Number of light BEV trucks in the fleet	10^6 vehicles
	Number of medium-size BEV trucks in the fleet	10^6 vehicles
	Number of medium-size hybrid trucks in the fleet	10^6 vehicles
	Avoided emissions compared to Scenario A	Mt CO_2-eq
Improved logistics of freight transportation	Reduction in transport activity due to logistical optimization - road transportation	10^9 t-km
	Reduction in transport activity due to logistical optimization - rail transportation	10^9 t-km
Improved logistics of passenger transportation and increased active transportation	Increased active transport activity	10^9 pass-km
Increased use of mass transportation systems	Road mode share in the modal split of passenger transport	%
	Number of qualified urban buses in the fleet	10^6 vehicles
	Activity of rail transport	10^9 pass-km
	Activity of water transport	10^9 pass-km

In order to assess the avoided emissions potential of the mitigation actions in the transportation sector, we have selected the indicators with greater impact on GHG emissions. This step was also described in Report 2 when the penetration of mitigation actions was estimated, and in the comparative analysis of the three scenarios. In addition, we emphasize that Brazilian NDC mentions general targets related to transportation[6], which are difficult to compare across scenarios due to the lack of quantitative figures.

4.2.2.1. Increased use of biofuels

Table 48 shows the emission driver indicators for the mitigation action "Increased use of biofuels". In Scenario A, biofuels share in the energy demand is 22% by 2030, 13% lower than in Scenario C and 7% lower than in Scenario B. This difference can be explained by other indicators, such as "Market share of ethanol" – which is a Brazilian specificity due to the existence of flexible fuel vehicles (powered by ethanol-gasoline fuel blends). This indicator reaches 26% in Scenario A, in 2030. This value is 14% lower than in Scenario B and 34% lower than in Scenario C.

The percentages of biodiesel and biokerosene in the mandatory blend are 17% and 5%, respectively, in Scenario C by 2030. Scenario A does not consider any increase in the ratio of biodiesel/biokerosene in blends. As stressed in Report 2, these indicators have significant impacts on the share of biofuels in energy demand.

In Brazil, tests with biodiesel blends in diesel oil started in 2005, but the blend was not mandatory. In 2010, the percentage of biodiesel in the mandatory blend was 5% (B5), increasing to 7% in 2015 (B7). As noted, blends with biokerosene in air transportation were not adopted in the past and remain uncertain in the future, being included in Scenario C only (from 2025).

The percentage of anhydrous ethanol in the mandatory blend remains the same in all scenarios (27%), the same since 2015 (20% in 2005 and 25% in 2010).

[6] For instance: to promote efficiency measures, improvements in transport infrastructure and public transport in urban areas.

Table 48. Increased use of Biofuels – Emission driver Indicators (multiple units)

		Data					Scenario A			Scenario B			Scenario C		
Indicator	**Unit**	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Biofuels share in energy demand	%	13%	19%	21%	20%	20%	21%	22%	22%	23%	25%	29%	23%	29%	35%
Market share of ethanol (flexible-fuel vehicles)	%	55%	53%	32%	26%	24%	25%	25%	26%	30%	30%	40%	30%	40%	60%
Percentage of anhydrous ethanol in the mandatory blend (Gasoline C)	%	25%	24%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%
Percentage of biodiesel in the mandatory blend (Bx)	%	0	5%	7%	7%	8%	10%	10%	10%	10%	15%	15%	10%	15%	17%
Percentage of biokerosene in the mandatory blend (Bx)	%	0	0	0	0	0	0	0	0	0	0	0	0%	1%	5%
Annual demand for ethanol equivalent	10^6 toe	7	12	15	NA	NA	14	16	18	14	17	22	15	19	24
Annual demand for biodiesel	10^6toe	0	1.5	2.5	NA	NA	3.8	4.1	4.6	3.8	6.3	6.8	3.8	6.0	7.0
Annual demand for biokerosene	10^6 toe	0	0	0	NA	NA	0	0	0	0	0	0	0	0	0.2
Annual demand for biomethane	10^6 toe	0	0	0	NA	NA	0	0	0	0	0	0	0	0.1	0.1

NA = not available

As proposed in the Brazilian NDC, the intention is to obtain a biofuel share of approximately 18% of the total energy demand by 2030, as well as to increase the percentage of biodiesels in the mandatory blend. In the transportation sector, the biofuels' target is achieved in the three Scenarios.

4.2.2.2. Changes in freight transport patterns and infrastructure

As presented in Table 49, the road mode share in the modal split of freight transport does not change in scenarios A and B. Although the transport activities of water and rail transportation increase, they are not enough to change transport patterns and the participation of road mode in the modal split.

In order to monitor energy efficiency in mobility, it is important to split the modals into freight and passenger transportation. The indicator "Road mode share in the modal split" for freight transportation is 54% of the total activity in Scenario A, by 2030. This result is the same as in Scenario B, but higher than Scenario C, in 2030 (49%). As noted, many transport indicators are closely related, making it difficult to assess each one individually. For instance, a more balanced modal split, observed in Scenario C, can be explained by the more intensive rail and water transportation activities. In 2030, 542,740 million t-km of rail transport are estimated for Scenario C, against 488,466 million t-km for Scenario A.

Table 49. Freight transport patterns and infrastructure – Emission driver Indicators (% and 10^9 t -km)

		Data					Scenario A			Scenario B			Scenario C		
Indicator	**Unit**	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Road mode share in the modal split of freight transport	%	55%	57%	60%	61%	59%	55%	54%	54%	55%	54%	54%	55%	53%	49%
Activity of rail transport	10^9 t -km	223	278	332	342	375	414	452	488	414	459	507	414	459	543
Activity of water transport	10^9 t -km	115	173	131	97	115	182	225	277	182	225	277	182	244	326

Scenario C presents significant changes in the modal split. Around 49% of the total transport activity is road transport (5% lower than in the other scenarios). Besides the expansion of rail and water networks with the completion of ongoing investment programs, which is a common assumption in the three scenarios, Scenario C also considers the adaptation of the existent railway network, increasing the capacity and better use of underused lines.

4.2.2.3. Gains in energy efficiency in the transportation sector

The indicators of energy intensity for freight and passenger transportation, as well as cumulative gains in energy efficiency, are presented in Table 50.

Table 50. Gains in energy efficiency – Emission driver Indicators (MJ/t -km and %))

		Data					Scenario A			Scenario B			Scenario C		
Indicator	**Unit**	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Energy intensity of freight transport	MJ/t -km	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	0.9	1.0	0.9	0.8
Energy intensity of passenger transport	MJ/pass-km	1.0	1.1	1.0	1.1	1.2	1.0	1.0	0.9	1.0	1.0	0.9	1.0	0.9	0.8
Cumulative gains in energy efficiency - light vehicles	%	-	-	-	-	-	2%	5%	7%	5%	10%	13%	7%	11%	15%

Investment in the enhancement of engine fuel efficiency (internal combustion engines) or traction system (BEV vehicles) collaborates to the reduction of energy intensity of freight and passenger transport. Energy intensity of freight transport is reduced in 2030 in Scenario B and in by 2025 and 2030 in Scenario C. Energy intensity of passenger transport is equally reduced in 2030 in Scenarios A and B, and from 2025 in Scenario C.

Cumulative energy efficiency gains for light vehicles in Scenario C are 15% in 2030 compared to 2017, against 7% in Scenario A and 13% in Scenario B. Part of this increased would be explained by the full implementation of Rota 2030 program.

4.2.2.4. Expansion of the electric vehicles fleet (battery electric vehicles - BEV and hybrids)

As summarized above, the energy intensity indicators (of freight and passenger) in Scenario C are slightly lower than the other scenarios, which is also partly due to an increase in the electric vehicle fleet. Table 51 shows the indicators for the “Expansion of the electric vehicles fleet” mitigation action.

Table 51. Expansion of the electric vehicles fleet (battery electric vehicles - BEV and hybrids) – Emission driver Indicators (multiple units)

		Historical data					Scenario A			Scenario B			Scenario C		
Indicator	**Unit**	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Electricity share in transport energy consumption (Road transport)	%	0%	0%	0%	0%	0%	0.1%	0.1%	0.2%	0.1%	0.2%	0.4%	0.1%	0.3%	1.1%
Electric vehicles share in the fleet	%	0%	0%	0%	0%	0%	0%	0.1%	0.2%	0%	0.4%	1.5%	0%	1.2%	4.9%
Hybrid vehicles share in the fleet	%	0%	0%	0%	0%	0%	0%	0.2%	0.7%	0.1%	0.3%	1.1%	0.1%	0.6%	1.6%
Electric power consumption (BEV vehicles)	TWh	0	0	0	NA	NA	0	0.2	0.5	0	0.7	3.0	0.1	2.3	10
Number of BEV cars in the fleet	10^3 vehicles	0	0	0	NA	NA	3.3	22	61	3.2	13	143	10	165	1,273
Number of hybrid cars in the fleet	10^3 vehicles	0	0	1	NA	NA	21	166	502	33	209	782	47	378	1,136
Number of BEV urban buses in the fleet	10^3 vehicles	0	0	0	NA	NA	0	0.4	2.1	0.3	5.7	24	0.9	12	53
Number of hybrid urban buses in the fleet	10^3 vehicles	0	0	0	NA	NA	0	0.1	0.8	0	0.7	3.3	0	1.3	7.3
Number of BEV commercial light vehicles in the fleet	10^3 vehicles	0	0	0	NA	NA	0.3	5.3	25	0.4	10	56	1.8	31	184
Number of hybrid commercial light vehicles in the fleet	10^3 vehicles	0	0	0	NA	NA	0	1.0	7.3	0.4	5.4	26	1.1	11	62
Number of BEV motorcycles in the fleet	10^3 vehicles	0	0	0	NA	NA	0.8	11	60	0.8	209	949	0.8	609	2,037
Number of BEV micro-buses in the fleet	10^3 vehicles	0	0	0	NA	NA	0	0.1	0.2	0	0.9	4.4	0.1	1.9	9.8
Number of semi-light BEVs trucks in the fleet	10^3 vehicles	0	0	0	NA	NA	0	0	0	0	0	0	0.1	0.9	10
Number of light BEV trucks in the fleet	10^3 vehicles	0	0	0	NA	NA	0	0	0	0	0	0	0.1	2.4	14
Number of medium-size BEV trucks in the fleet	10^3 vehicles	0	0	0	NA	NA	0	0	0	0	0	0	0	0.5	2.0
Number of medium-size hybrid trucks in the fleet	10^3 vehicles	0	0	0	NA	NA	0	0	0	0	0	0	0	1.3	4.6

The number of electric vehicles increases significantly in Scenario C, especially of cars, commercial light vehicles and motorcycles. The share of electric vehicles reaches 4.9% by 2030, much higher than in Scenario A (0.2%). The share of hybrid vehicles reaches 1.6% by 2030. As mentioned in the previous section, part of these incentives for this shift would come from the full implementation of the Rota 2030 program.

Despite the overall growth trend towards electrification, the electricity share in transport energy consumption is representative only in Scenario C (achieving 1.1% of the total), which is equivalent to the total electricity consumption of 10 TWh. The electric vehicle's energy consumption is of 0.5 TWh in Scenario A and of 3.0 TWh in Scenario B. This is due to the inertia in the scrapping of the fleet and to the investment made in the past on diesel/gasoline-powered vehicles, using conventional fuels with different biofuel blends.

4.2.2.5. Other mitigation actions

Table 52 shows the indicators for the following mitigation actions: (1) Improved logistics of freight transportation; (2) Improved logistics of passenger transportation and increased active transportation; (3) Increased use of mass transportation systems; and (4) General indicators.

Table 52. Other Mitigation Actions– Emission driver Indicators (multiple units)

			Historical data					Scenario A			Scenario B			Scenario C		
	Indicator	Unit	2005	2010	2015	2016	2017	2020	2025	2030	2020	2025	2030	2020	2025	2030
1	Reduction in freight transport activity due to logistical optimization - road transportation	10^9 t - km	NA	NA	NA	NA	NA	0	0	0	0	13	25	12	21	41
	Reduction in freight transport activity due to logistical optimization - rail transportation	10^9 t - km	NA	NA	NA	NA	NA	0	0	0	0	6.9	13	6.2	11	25
2	Increased active transport activity	10^9 pass-km	NA	NA	NA	NA	NA	0	0	0	0	22	38	20	45	76
3	Road mode share in the modal split of passenger transport	%	93%	92%	91%	92%	91%	92%	91%	91%	92%	91%	91%	92%	91%	90%
	Number of qualified urban buses in the fleet	10^6 vehicles	20	24	29	NA	NA	39	52	69	42	70	102	45	77	132
	Passenger water transport activity	10^9 pass-km	0.7	1.2	1.3	1.3	1.3	1.3	1.4	1.6	1.3	1.4	1.6	1.3	1.4	2.1
	Passenger rail transport activity	10^9 pass-km	18	27	38	38	38	39	45	54	39	45	54	39	47	67

Reductions in transport activity due to logistical optimization of freight transportation are observed from 2025 (in Scenario B) and from 2020 in Scenario C, accelerating in 2025-2030. The same trend is observed in the "Increased active transport activity" of passenger transportation, reaching 76 billion pass-km in 2030 (Scenario C) and 38 billion pass-km in Scenario B. These levels would be attained by the implementation of widespread sustainable programs for companies (private and public sectors) and cities (public sector).

4.2.3. Absolute Emission Indicators in the Transportation sector: Scenarios A, B and C

The absolute emission indicators for transportation are presented in table 53. In 2030, Scenario B, emissions are 12% below Scenario A and Scenario C emissions are 29% below Scenario A.

Table 53. Absolute emission indicators in the Transportation sector and milestones in Scenarios A, B and C ($MtCO_2$-eq)

Sector	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
	$MtCO_2$-eq											
Transportation	144	178	203	208	223	247	204	211	218	201	193	175
Road	**131**	**161**	**187**	**190**	**202**	**221**	**186**	**190**	**193**	**183**	**172**	**151**
Passengers	68	83	88	91	99	111	96	98	94	94	86	67
Private cars	*50*	*63*	*68*	71	77	86	73	74	66	71	62	39
Mass transportation	*18*	*20*	*19*	20	22	24	23	24	28	23	24	28
Freight	**63**	**78**	**99**	**99**	**103**	**110**	**90**	**92**	**99**	**89**	**86**	**83**
Light trucks	14	16	21	21	21	20	19	19	19	19	18	18
Medium trucks	11	10	10	7.7	7.2	6.7	7.0	6.4	6.1	7.0	6.3	5.7
Heavy trucks	38	52	68	70	75	84	64	67	74	63	62	60
Railways Freight	**2.8**	**3.3**	**2.8**	**3.2**	**3.5**	**3.7**	**3.2**	**3.3**	**3.5**	**3.1**	**3.3**	**3.6**
Airways	**6.4**	**9.8**	**11**	**10**	**13**	**16**	**10**	**12**	**14**	**10**	**12**	**14**
Passengers	4.8	8.8	9.6	8.9	11	13	9.0	11	13	9.0	11	12
Freight	1.5	1.1	1.5	1.6	2.1	2.5	1.5	1.5	1.6	1.5	1.5	1.5
Waterways	**3.6**	**4.5**	**3.1**	**4.2**	**5.1**	**6.2**	**4.2**	**5.1**	**6.1**	**4.2**	**5.5**	**7.2**
Passengers	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3
Freight	3.4	4.3	2.9	4.0	4.9	6.0	4.0	4.9	5.9	4.0	5.3	6.9

Note: differences in totals are due to rounding

4.3. Industry

4.3.1. NDC targets for the Industry Sector

The NDC mentions only one mitigation action applied to the Industry sector: "to promote new standards of clean technology and further enhance energy efficiency measures and low carbon infrastructure".

4.3.2. Indicators of Emission drivers in the Industry Sector

This section presents the indicators used to track the implementation of the mitigation actions adopted in the scenarios to reduce emissions of the Brazilian industrial sector. These indicators are designed to measure and monitor emissions, providing information on energy use and on GEE emissions in each industrial branch, based on past trends and in the identified potential of specific measures to reduce energy consumption and GEE emissions (IEA, 2007).

There isn't a single indicator for tracking and understanding the energy consumption and GEE emissions in the industry. The primary reason is the large variety of branches and uncountable products (in Food and Beverage, there are more than 400 products, for example).

The main indicator of the industry sector, by branch, is the emission intensity expressed in amount of GEE emissions per unit of industrial product (in physical and monetary terms as for example, per value added). Other indicators are required to complement the assessment: (i) the energy intensity expressed in amount of energy demand per unit of industrial product (also in physical and monetary terms) and (ii) the replacement of fossil fuels by renewable energy sources.

Measures that result in gains in energy efficiency (reduction of energy consumption per output) in the industrial branches are the main mitigation actions adopted in the scenarios. In the segments with a large variety of products, where the ratio between energy consumption and the amount of product cannot be adopted, the ratio between energy consumption and value added is a better indicator.

Changes in energy mix can also reduce GEE emissions in industrial branches. The percentage of renewable energy sources in the total energy consumed shows if the industry is replacing fossil fuels used in its production, and consequently emitting a lower amount of greenhouse gases.

When emissions are related to the type of industrial process and not to energy sources, other indicators can be adopted, such as the clinker-cement ratio in cement manufacturing. Clinker, the main component of cement, when produced emits huge amounts of CO_2 as a by-product. Therefore, when reducing the proportion of clinker in the cement also reduces CO_2 emissions.

Table 54 shows the annual emission drivers indicators adopted in the industrial sector for tracking the overall performance of mitigation actions in each scenario. We observed that between 2005 and 2015, total energy consumption increased by 16.9%, although the energy intensity remained almost the same. The share of biomass and electricity decreased slightly, resulting in a 2.7% increase in GHG emissions intensity. Up to 2030, energy consumption continues to grow in all three scenarios. As of 2015, it would increase by 22.0% in Scenario A, 15.2% in Scenario B and 9.6% in Scenario C. The share of biomass would decrease less in Scenario C (1.8%) than in Scenario B (5.4%) and Scenario A (7.1%), while the share of electricity would remain constant over time. Gains in energy efficiency would reach 19.7% in scenario C, 16.6% in scenario B and only 10.6% in scenario A. Emissions intensity of would decrease by 23.4% in scenario C, 15.2% in scenario B and 4.6% in scenario A.

Table 54. Emission drivers Indicators in the Industry sector (multiple units)

Indicator				Scenario A			Scenario B			Scenario C		
	2005	2010	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (Mtoe)	72.8	85.6	85.1	89.3	96.2	103.8	87.7	92.6	98.1	86.4	89.6	93.3
% of Biomass	33%	33%	31%	31%	30%	29%	31%	30%	29%	31%	31%	31%
% of Electricity	21%	20%	20%	21%	21%	21%	21%	21%	21%	21%	21%	21%
Value added (2015 R$ 1.00 x 10^6)	1,358	1,638	1,584	1,589	1,853	2,161	1,589	1,853	2,161	1,589	1,853	2,161
Energy intensity (ktep/ 2015 billion R$)	53.6	52.2	53.7	56.2	51.9	48.1	55.2	50.0	45.4	54.3	48.4	43.2
Emission intensity ($MtCO_2$-eq/2015 billion R$)	0.105	0.099	0.108	0.112	0.108	0.103	0.108	0.099	0.091	0.104	0.092	0.082

In the next sections, we present the emission drivers indicators for each industrial branch.

4.3.2.1. Cement Industry

Table 55 presents the annual indicators of the Cement Industry. Energy intensity decreased by 8.2% in 2015 compared to 2005. In Scenario A, estimates follow the decreasing trend, falling by 1.8% in 2030 compared to 2015. In Scenarios B and C, there would be an even greater decrease of 8.1% and 13.2%, respectively. The biomass share remains negligible.

Regarding the emissions intensity, this indicator decreased by 3.7%, between 2005 and 2015. In Scenario A, it would increase by 4.9% between 2015 and 2030. In scenarios B and C, the decrease would reach 8.8% and 12.9%, respectively. This would be possible not only due to energy intensity gains but also for the clinker/cement ration that would be reduced by 4%, 7.4% and 10.5%, in Scenarios A, B and C respectively, comparing 2030 to 2015 annual values.

Table 55. Indicators of the Cement industry (multiple units)

Cement industry indicators	2005	2010	2015	2016	2017	Scenario A			Scenario B			Scenario C		
						2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (Mtoe)	2.9	4.3	4.7	N.A	N.A	4.6	5.1	5.6	4.5	4.9	5.3	4.5	4.7	5.0
Total Production (Mt)	37	59	65	N.A	N.A	63	70	79	63	70	79	63	70	79
Clinker/cement ratio (t clinker/t cement)	0.67	0.69	0.68	0.7	0.7	0.66	0.65	0.64	0.66	0.64	0.63	0.65	0.63	0.61
Energy intensity (toe/10^3 t)	79	72	73	74	73	73	72	71	72	69	67	71	67	63
Emission intensity (tCO_{2}-eq/t)	0.63	0.62	0.61	0.6	0.6	0.60	0.59	0.58	0.59	0.57	0.56	0.58	0.56	0.53

Source: based on SNIC and EPE, 2018 and BRASIL, 2016.
NA = not available

4.3.2.2. Iron and Steel Industry

Table 56 presents the annual indicators of the Iron and Steel Industry. Energy intensity of the crude steel equivalent decreased of 6.1% between 2005 and 2015. In Scenario A, estimates follow the downward trend, falling by 2.8% between 2015 and 2030. In Scenario B and C, there would be an even greater reduction of 5.0% and 14.0 %, respectively, in the period.

Regarding emissions intensity, it increased by 4.4% between 2005 and 2015. In Scenario A, the increase would be of 4.1% between 2015 and 2030. In scenarios B and C there would be a decrease of 4.1% and 16.1%, respectively. The annual biomass share would only increase in Scenario C (6.1%), in the same period.

Table 56. Indicators of the Iron and Steel Industry (multiple units)

Iron and Steel Industry Indicators	2005	2010	2015	2016	2017	Scenario A			Scenario B			Scenario C		
						2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (M toe)	17	16	17	N.A.	N.A.	17	18	19	17	18	19	16	17	17
Energy demand in the blast furnace (M toe)	9.0	9.2	9.3	N.A.	N.A.	9.3	10.0	10.7	9.2	9.8	10.4	9.0	9.2	9.5
Total Production (Mt of crude steel equivalent)	32	33	33	N.A.	N.A.	33	36	39	33	36	39	33	36	39
Total Pig Iron Produced (Mt)	34	31	32	N.A.	N.A.	31	34	37	31	34	37	31	34	37
Share of pig iron produced using coke (%)	66.3%	76.8%	79.7%	N.A.	N.A.	80.2%	82.5%	84.5%	78.2%	78.2%	78.2%	77.4%	76.3%	75.1%
Share of pig iron produced using charcoal (%)	33.7%	23.2%	20.3%	N.A.	N.A.	19.8%	17.5%	15.5%	21.8%	21.8%	21.8%	22.6%	23.7%	24.9%
Biomass share (%)	28	21	18	0.2	0.2	15	13	12	17	17	18	17	18	19
Energy intensity (toe/10^3 t of crude steel equivalent)	535	499	502	502	500	498	493	488	495	486	477	481	456	432
Emission intensity (tCO_2e/t of crude steel equivalent)	1.4	1.4	1.4	1.3	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.3	1.2

Source: based on DNPM, IAB and EPE, 2018 and BRASIL, 2016.
NA = not available

4.3.2.3. Iron Alloy Industry

Table 57 presents the annual indicators of the Iron Alloy Industry. The annual energy intensity decreased by 45.8%, between 2005 and 2015. In Scenario A, there would be a decrease of 1.9% in 2030 compared to 2015. In Scenarios B and C, there would be a further decrease of 9.0% and 13.1% in the period.

In respect to the annual emissions intensity, it decreased by 49%, between 2005 and 2015. In Scenario A, there would be a 2.0% decrease between 2015 and 2030. In scenarios B and C the decrease would reach 9.0% and 22%, respectively, in the same period. This would be possible mainly due to reductions in the energy intensity.

Table 57. Indicators of the Iron alloy Industry (multiple units)

Iron alloy Industry Indicators	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (Mtoe)	1.6	1.6	1.2	1.7	2.1	2.6	1.6	2.0	2.4	1.6	1.9	2.3
Biomass share (%)	41	40	39	39	39	39	39	39	40	39	40	41
Total Production (Mt)	0.6	1.2	0.9	1.2	1.5	1.9	1.2	1.5	1.9	1.2	1.5	1.9
Energy intensity (toe/ t)	2.6	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.4	1.3	1.2
Emission intensity (tCO_{2}-eq/t)	2.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.1	1.0	0.88

Source: based on MME and EPE, 2018 and BRASIL, 2016.

4.3.2.4. Mining and Pelleting Industry

Table 58 presents the annual indicators of the Mining and Pelleting Industry. Regarding energy intensity, there was a 15.0% decrease, between 2005 and 2015. In Scenario A, estimates follow the downward trend, falling by 2.0% between 2015 and 2030. In Scenarios B and C, there would be an even greater reduction of 8.0% and 13.5%, in the period. The biomass share remains negligible.

In respect to the annual emissions intensity, it decreased by 22.0%, between 2005 and 2015. In Scenario A, it would decrease by 8.9%, in 2030 compared to 2015. In scenarios B and C the decrease would reach 14.5% and 21.2%, respectively.

Table 58. Indicators of the Mining and Pelleting Industry (multiple units)

Mining and Pelleting Industry Indicators	2005	2010	2015	2016	2017	Scenario A			Scenario B			Scenario C		
						2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (M toe)	2.8	3.2	3.3	NA	NA	4.0	4.6	5.4	3.9	4.4	5.0	3.8	4.3	4.7
Total Production (Mt)	356	463	506	NA	NA	602	710	830	602	710	830	602	710	830
Energy intensity (toe/10^3t)	7.8	6.9	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.3	6.1	6.3	6.0	5.7
Emission intensity (kg CO_2-eq/t)	19	16	15	11.0	14.0	14	14	14	14	13	13	13	13	12

Source: based on DNPM and EPE, 2018 and BRASIL, 2016
NA = not available

4.3.2.5. Chemical Industry

Table 59 presents the annual indicators of the chemical industry. Energy intensity decreased by 33.7% between 2005 and 2015. In Scenario A, estimates follow the downward trend but with a modest fall of 3.1% between 2015 and 2030. Scenario B is the same as A. In Scenario C, there would be a greater reduction of 15.1% in the period. The share of biomass remains constant throughout the period.

Regarding the intensity of annual emissions, it decreased by 52.0% between 2005 and 2015. In Scenario A, it would remain constant for the period 2015-2030. In scenarios B and C the fall would be of 7.1% and 15.8%, respectively.

Table 59. Indicators of the Chemical Industry (multiple units)

Chemical Industry Indicators	2005	2010	2015	2016	2017	Scenario A			Scenario B			Scenario C		
						2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (M toe)	7.1	7.2	6.9	NA	NA	7.0	7.0	7.1	6.8	6.7	6.6	6.7	6.4	6.2
Biomass share (%)	2%	2%	2%	NA	NA	2%	2%	2%	2%	2%	2%	2%	2%	2%

Total Production (Mt)	66	86	96	NA	NA	98	100	102	98	100	102	98	100	102
Energy intensity (toe/t)	108	84	72	71	70	71	70	69	69	67	65	68	64	61
Emission intensity (t CO_2-eq/t)	0.37	0.21	0.18	0.10	0.10	0.18	0.18	0.18	0.18	0.17	0.16	0.17	0.16	0.15

Source: based on IBGE and EPE, 2018 and BRASIL, 2016.
NA = not available

4.3.2.6. Non-Ferrous and Other Metals Industry

Table 60 presents the indicators of the Non-Ferrous Metals Industry. Annual energy intensity increased by 51.0% between 2005 and 2015. In Scenario A, values are constant in the period 20015-2030, with no gains in energy intensity. In Scenarios B and C, there would be a decline of 5.0% and 9.0%, respectively, in the period. Biomass share is marginal, therefore negligible.

Regarding the annual emissions intensity, it increased by 85.5%, between 2005 and 2015. In Scenario A, it would increase by 20.4% in the 2005-2030 period. In scenarios B and C the increase would reach 15.9% and 8.7%, respectively.

Table 60. Indicators of the Non-ferrous and other metals Industry (multiple units)

Indicator	2005	2010	2015	2016	2017	Scenario A			Scenario B			Scenario C		
						2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (M toe)	5.4	6.5	5.6	NA	NA	6.6	7.7	9.0	6.5	7.5	8.6	6.4	7.2	8.2
Total Production (Mt)	2.4	2.4	1.7	NA	NA	2.0	2.3	2.7	2.0	2.3	2.7	2.0	2.3	2.7
Energy intensity (ktoe/10^3t)	2.2	2.7	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.1	3.0
Emission intensity (t CO_2-eq/t)	4.6	5.9	8.5	8.3	8.3	9.9	10	10	9.8	9.9	9.8	9.5	9.4	9.2

Source: based on MME and EPE, 2018 and BRASIL, 2016.
NA = not available

4.3.2.7. Food and Beverage Industry

Table 61 presents the annual indicators of the Food and Beverage Industry. Annual energy intensity decreased by 28.4% between 2005 and 2015. In Scenario A, there would be a 2.5% reduction in the period 2015-2030. In Scenarios B and C, there would be a still greater reduction of 10.0% and 12.0%, respectively, in the period. The biomass share would remain very high throughout the period.

Regarding the annual emissions intensity, it reduced by 31.2%, between 2005 and 2015. In Scenario A, it would decrease by 10.3% in the 2005-2030 period. In scenarios B and C, the decrease would reach 17.2% and 19.1%, respectively.

Table 61. Indicators of the Food and Beverage Industry (multiple units)

Indicator	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (M toe)	17.9	23.2	21.5	22.4	23.3	24.3	21.8	22.1	22.4	21.6	21.8	21.9
Biomass share (%)	83%	84%	82%	84%	84%	84%	84%	84%	84%	84%	84%	84%
Total Production (10^9 R$)	336	331	562	591	620	652	591	620	652	591	620	652
Energy intensity (k toe/10^9 R$)	53.4	70.3	38.2	37.9	37.6	37.3	36.9	35.6	34.4	36.6	35.1	33.6
Emission intensity (Mt CO_2-eq /10^6 R$)	14.5	16.5	10.0	9.1	9.0	9.0	8.9	8.6	8.3	8.8	8.4	8.1

Source: based on IBGE and EPE, 2018 and BRASIL, 2016.

4.3.2.8. Pulp and Paper Industry

Table 62 presents the annual indicators of the Pulp and Paper Industry. Annual energy intensity increased by 3.9% between 2005 and 2015. In Scenario A, there would be no change in the period 2015-2030. In Scenarios B and C, there would be a decline of 5.0% and 8.0%, respectively. The biomass share would remain very high throughout the period.

Regarding the annual emissions intensity, the reduction was of 29.7%, between 2005 and 2015. In Scenario A, it would increase by 1.3% between 2005 and 2030. In scenarios B and C there would be a reduction 3.7% and 14.3%, respectively.

Table 62. Indicators of the Pulp and Paper Industry (multiple units)

Indicator	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (M toe)	7.7	10.1	11.7	13.0	14.5	16.0	12.8	14.0	15.2	12.7	13.7	14.8
Biomass share (%)	66%	70%	72%	72%	72%	72%	72%	72%	72%	73%	73%	73%
Total Production (Mt)	18.9	24.1	27.7	30.8	34.2	37.9	30.8	34.2	37.9	30.8	34.2	37.9
Energy intensity (toe/t)	0.41	0.42	0.42	0.42	0.42	0.42	0.42	0.41	0.40	0.41	0.40	0.39
Emission intensity (t CO_2-eq/t)	0.21	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13

Source: based on Indústria Brasileira de Árvores and EPE, 2018 and BRASIL, 2016.

4.3.2.9. Textile Industry

Table 63 presents the indicators of the Textile Industry. Regarding the annual energy intensity, there was a 23.7% decrease between 2005 and 2015. In Scenario A, there would be a 1.0% reduction in the period 2015-2030. In Scenarios B and C, there would be a greater decline of 8.0% and 10.0%, respectively. The biomass share remains constant throughout the period.

In respect to the annual emissions intensity, it reduced by 40.7%, between 2005 and 2015. In Scenario A, it would decrease by 5.6% in the 2015-2030 period. In scenarios B and C the decrease would reach 12.3% and 16.0%, respectively.

Table 63. Indicators of the Textile Industry (multiple units)

Indicator	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (M toe)	1.20	1.21	0.89	0.92	0.95	0.98	0.90	0.91	0.91	0.89	0.89	0.89
Biomass share (%)	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Total Production (10^9 R$)	53.2	58.6	51.8	53.7	55.6	57.5	53.7	55.6	57.5	53.7	55.6	57.5
Energy intensity (k toe/10^9 R$)	22.6	20.7	17.3	17.2	17.1	17.1	16.8	16.3	15.9	16.7	16.1	15.5
Emission intensity (kt CO_2-eq/R$10^6)	21.8	17.3	12.9	12.3	12.3	12.2	12.0	11.7	11.3	11.8	11.3	10.9

Source: based on IBGE and EPE, 2018 and BRASIL, 2016.

4.3.2.10. Ceramic Industry

Table 64 presents the annual indicators of the Ceramic Industry. Annual energy intensity increased by 7.6%, between 2005 and 2015. In Scenario A, there would be a decrease of 8.8% in the period 2015-2030. In Scenarios B and C, the decrease would be even greater reaching 14.8% and 17.6%, respectively, in the same period. In Scenario A, this share is kept constant in 48.7% up to 2030. However, in Scenario B the share increased by 50.7% and in Scenario C, 52.1%. The annual biomass share fluctuates around 50.0% throughout the period.

Regarding the annual emissions intensity, it reduced by 5.2%, between 2005 and 2015. In Scenario A, it would decrease by 7.6% in the 2015-2030 period. In scenarios B and C the decrease would reach 11.7% and 24.7%, respectively.

Table 64. Indicators of the Ceramic Industry (multiple units)

Indicator	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (Mtoe)	3.4	4.5	4.6	4.5	4.7	5.1	4.4	4.5	4.7	4.4	4.5	4.6
Biomass share (%)	50	51	49	49	49	49	49	50	51	51	52	52
Total Production (10^9 R$)	24.5	33.0	30.8	32.4	34.4	37.1	32.4	34.4	37.1	32.4	34.4	37.1
Energy intensity (ktoe/10^6 R$)	0.14	0.14	0.15	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12
Emission intensity (tCO_2-eq/10^3 R$)	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.13	0.12

Source: based on IBGE and EPE, 2018 and BRASIL, 2016.

4.3.2.11. Other Industries

Table 65 presents the annual indicators of the Other Industries Sector. Annual energy intensity increased by 3.6%, between 2005 and 2015. In Scenario A, there would be a 2.1% reduction in the period 2015-2030. In Scenarios B and C, there would be a decline of 7.0% and 12.0%, respectively, in the same period. The biomass share remains constant throughout the period.

Regarding the annual emissions intensity, it increased by 6.2%, between 2005 and 2015. In Scenario A, it would decrease by 7.8% in the 2005-2030 period. In scenarios B and C the decrease would reach 11.7% and 16.5%, respectively.

Table 65. Indicators of the Other Industries (multiple units)

Indicator	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Total energy demand (Mtoe)	5.8	7.2	7.9	8.1	8.3	8.6	8.0	8.0	8.1	7.8	7.7	7.7
Biomass share (%)	12%	12%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
Total Production (10^9R$)	167	285	218	226	234	242	226	234	242	226	234	242
Energy intensity (Mt /10^6 R$)	35	25	36	36	36	35	35	34	34	35	33	32
Emission intensity (MtCO_2-e/R$10^6)	35	28	37	35	35	35	35	34	33	34	33	31

Source: based on IBGE and EPE, 2018 and BRASIL, 2016.

4.3.2.12 Other Emission Sources

Other emission sources related to the industry sector are the chemical gases, HFCs and SF_6, and from the industrial branch of the Non-Metallic Minerals other than cement. The indicators are in table 66.

Table 66. Indicators of the Other Emission Sources (multiple units)

Indicator	2005	2010	2015	2016	2017	Scenario A			Scenario B			Scenario C		
						2020	2025	2030	2020	2025	2030	2020	2025	2030
Non Metallic Minerals														
Total Production (10^6 t)	24	33	26	NA	NA	25	28	31	25	28	31	25	28	31
Emission intensity ($MtCO_2$-e/Mt)	0.35	0.25	0.31	NA	NA	0.28	0.32	0.35	0.27	0.30	0.31	0.27	0.30	0.29
HFCs - Avoided emissions by replacement ($MtCO_2$-eq)	-	-	-	0.0	0.0	0.0	4.3	5.3	0.0	7.8	11	0.0	12	15
SF_6 - Maximun leakage (gx10^-6/kwh)	50	50	50	50	50	50	50	50	42	34	29	39	26	21

NA = not available

4.3.3. Absolute Emissions Indicators in the Industry sector: Scenarios A, B and C pathways

In total, emissions from the industrial sector would grow by 56% in scenario A, 39% in scenario B and 25% in scenario C, by 2030 compared to 2005.

It is important to highlight that apart from the Chemical and the Textile branches that would reduce absolute emissions in Scenario A, all other industrial branches would increase emissions, including the chemical gases (HFCs and SF_6). Emissions from the Iron and Steel industry would grow by 36% in 2030 compared to 2005 in Scenario A, 25% in Scenario B and 10% in Scenario C. From the Cement industry, growth would be of 98%, 88% and 80%, in Scenarios A, B and C respectively, in the same period. Non-Ferrous and Other Metals would have an even higher emissions growth reaching 147%, 137% and 123% in the three scenarios in the period. It is worth noting that the highest growth in emissions would occur through the consumption of HFC gases in scenario A, growing 577% in 2030 compared to 2005.

The absolute emissions indicators in the Industry sector are presented by branch and includes both sources: energy consumption and industrial processes, when applicable. They are presented in decreasing order considering Scenario A values, in 2030, as in Table 67.

Table 67. Absolute Emissions Indicators in the Industry sector ($MtCO_2$-eq)

Segment	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Iron and Steel	43	45	48	49	54	59	48	51	54	46	47	48
Cement	23	37	40	38	41	46	37	40	44	37	39	42
Non-Ferrous and Other Metals	11	14	14	20	23	28	19	23	27	19	22	25
HFCs	2,9	7,4	10	13	17	20	9,5	8,7	8,1	8	6	4,5
Chemicals	24	18	17	18	18	18	17	17	17	17	16	15
Mining and Pelleting	6,9	7,5	7,7	8,4	9,9	11	8,3	9,5	10,8	8,1	9	9,9
Mineral Industry (Cement excluded)	8,6	8,3	7,9	6,9	8,8	11	6,7	8,2	9,6	6,7	8,2	9,0
Other Industries	5,9	7,9	8,2	8,0	8,2	8,4	7,8	7,9	8	7,7	7,6	7,6
Food and Beverage	4,9	5,5	5,6	5,4	5,6	5,8	5,2	5,3	5,4	5,2	5,2	5,3
Ceramics	3,8	4,9	5,0	5,0	5,3	5,7	4,9	5,1	5,3	4,5	4,4	4,5
Pulp and Paper	4,0	3,9	4,1	4,6	5,1	5,6	4,5	4,9	5,4	4,2	4,4	4,8
Iron Alloy	1,4	1,3	0,97	1,3	1,7	2,1	1,3	1,6	2	1,3	1,4	1,7
Textile	1,2	1	0,67	0,66	0,68	0,7	0,64	0,65	0,65	0,63	0,63	0,62
SF6	0,14	0,17	0,21	0,24	0,27	0,3	0,2	0,19	0,17	0,19	0,15	0,13
Non-energy products	0,7	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,5	0,6	0,5	0,4
Total	**141**	**162**	**170**	**179**	**199**	**222**	**171**	**184**	**198**	**166**	**171**	**178**

Note: differences in totals are due to rounding

4.4. Energy Supply

4.4.1. NDC targets for the Energy Supply Sector

The Brazilian NDC has five specific targets for the energy sector in 2030:

- achieving 45% of renewables in the energy mix by 2030;
- expanded use of renewable energy sources other than hydropower in the total energy mix to between 28% and 33%;
- increased share of renewables (other than hydropower) in the power supply to at least 23% by 2030;

- increased share of sustainable biofuels in the Brazilian energy mix to approximately 18% by 2030; and
- achieving 10% efficiency gains in the electricity sector by 2030.

In this section, we present the results of selected energy indicators. Indicators are useful in monitoring progress towards specific country goals (IAEA, 2005). By analyzing the values projected in the scenarios and the historical data, it is possible to quantify the progress being made. Indicators are also useful to compare regions and countries. For instance, OECD (2017) compiles the Indicators for fuel combustion for over 150 countries and regions.

4.4.2. Indicators of Emission Drivers in the Energy Supply Sector

The first four of NDC's goals are the main indicators that can be used to monitor the mitigation actions in the energy sector. Those indicators can then be extended into other related indicators that compose the main indicator. For example: "share of renewables in the energy system" is composed of the share of each renewable source, such as wind, hydro, solar power and so on. The last NDC goal -efficiency gains in the electricity sector - is vaguely defined, without an accurate metrics, so it was not included in the indicators presented in table 68.

Table 68. Emission driver Indicators of Energy Supply (%)

Indicators of Renewables in the energy mix	Unit
Share of renewables in the energy mix	%
Share of hydropower in the energy mix	%
Share of renewables, other than hydropower, in the energy mix	%
Share of wind power in the energy mix	%
Share of solar power in the energy mix	%
Share of sugarcane products in the energy mix	%
Share of firewood and charcoal in the energy mix	%
Share of biodiesel and other biofuels in the energy mix	%
Share of other renewables in the energy mix	%
Indicators of Biofuels in the energy mix	
Share of biofuels in the energy mix	%
Share of sugarcane products in the energy mix	%
Share of biodiesel and other biofuels in the energy mix	%
Share of ethanol in the energy mix	%

Indicators of Renewables in the energy mix	Unit
Indicators of Renewables in power supply (electricity generation)	
Total electricity generation	TWh
Share of renewables, other than hydropower, in the power supply	%
Share of renewables in total electricity generation	%
Wind generation	TWh
Power generation from sugarcane products	TWh
Power generation from firewood	TWh
Distributed photovoltaic generation	TWh
Utility-scale photovoltaic generation	TWh
Hydropower generation	TWh
Indicators of Renewables in power supply (installed capacity)	
National installed capacity	GW
Total renewable installed capacity	GW
Wind power installed capacity	GW
Installed capacity of sugar cane products power plants	GW
Installed capacity of firewood power plants	GW
Distributed photovoltaic installed capacity	GW
Utility-scale photovoltaic installed capacity	GW
Hydropower installed capacity	GW
Indicators of electricity supply	
Electricity final consumption	TWh
National electricity generation	TWh
Total Electricity Supply (TES)	TWh

Table 69 shows the share of each renewable source in the energy mix. From all the renewable sources, the use of sugarcane products is the component with the highest increase in scenarios B and C.

Table 69. Renewables in the energy mix – Emission driver Indicators of Energy Supply (%)

Indicator	Unit	Historical data					Scenario A			Scenario B			Scenario C			NDC
		2005	2010	2015	2016	2017	2020	2025	2030	2020	2025	2030	2020	2025	2030	2030
Share of renewables in the energy mix	%	44.1%	44.7%	41.3%	43.5%	43.2%	45.2%	45.1%	43.9%	45.6%	47.0%	46.9%	46.2%	48.7%	50.4%	45.0%
Share of hydropower in the energy mix	%	14.9%	14.0%	11.3%	12.6%	11.9%	13.5%	12.7%	12.1%	13.4%	12.8%	12.0%	13.3%	12.9%	12.3%	
Share of renewables other than hydropower, in the energy mix	%	29.2%	30.7%	30.0%	30.9%	31.2%	31.7%	32.4%	31.8%	32.1%	34.2%	34.9%	32.9%	35.8%	38.0%	28.0%
Share of wind power in the energy mix	%	0.0%	0.1%	0.6%	1.0%	1.2%	1.8%	2.0%	2.1%	1.8%	2.0%	2.1%	1.8%	2.1%	2.3%	
Share of solar power in the energy mix	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.4%	0.5%	0.3%	0.4%	0.5%	0.3%	0.4%	0.6%	
Share of sugarcane products in the energy mix	%	13.8%	17.5%	16.9%	17.5%	17.4%	17.3%	18.0%	17.5%	17.7%	18.5%	19.1%	18.4%	20.0%	21.7%	
Share of firewood and charcoal in the energy mix	%	13.1%	9.7%	8.3%	8.0%	8.0%	7.0%	6.5%	6.2%	7.0%	6.5%	6.4%	7.1%	6.7%	6.4%	
Share of biodiesel and other biofuels in the energy mix	%	0.0%	0.7%	1.0%	1.0%	1.2%	1.3%	1.3%	1.3%	1.3%	1.9%	1.9%	1.3%	1.9%	2.0%	
Share of other renewables in the energy mix	%	2.3%	2.7%	3.1%	3.4%	3.4%	4.1%	4.3%	4.3%	4.1%	4.8%	4.9%	4.1%	4.9%	5.0%	

Table 70 shows the shares of biofuels in the energy mix, including ethanol.

Table 70. Share of biofuels in the energy mix - Emission driver Indicators of Energy Supply (%)

Indicator	Unit	Historical data					Scenario A			Scenario B			Scenario C			NDC
		2005	2010	2015	2016	2017	2020	2025	2030	2020	2025	2030	2020	2025	2030	2030
Share of biofuels in the energy mix	%	13.8%	18.2%	17.9%	18.5%	18.6%	18.6%	19.3%	<u>18.7%</u>	19.0%	20.4%	<u>21.0%</u>	19.7%	21.8%	<u>23.7%</u>	<u>18.0%</u>
Share of sugarcane products in the energy mix	%	13.8%	17.5%	16.9%	17.5%	17.4%	17.3%	18.0%	17.5%	17.7%	18.5%	19.1%	18.4%	20.0%	21.7%	
Share of biodiesel and other biofuels in the energy mix	%	0.0%	0.7%	1.0%	1.0%	1.2%	1.3%	1.3%	1.3%	1.3%	1.9%	1.9%	1.3%	1.9%	2.0%	
Share of ethanol in the energy mix	%	3.4%	4.7%	5.3%	5.0%	4.9%	5.1%	5.4%	5.6%	5.3%	5.8%	6.6%	5.7%	6.6%	7.6%	

Concerning power generation, Tables 71 and 72 show the share of renewables in power supply. The first table shows electricity generation from each source and the second, the installed capacity. All sources, except hydropower, increase their share in the power supply. Wind power more than doubles its expected generation in 2030 compared to 2017.

Table 71. Renewables in power supply (electricity generation) – Emission drivers Indicators of Energy Supply (% and TWh)

		Historical data					Scenario A			Scenario B			Scenario C			NDC
Indicator	**Unit**	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2030**
Total electricity generation	TWh	442.1	550.4	615.7	619.7	624.3	677.4	751.8	828.3	672.2	740.3	811.2	668.6	735.3	810.1	
Share of renewables other than hydropower, in the power supply	%	3.1%	6.1%	11.5%	13.7%	15.1%	18.9%	22.1%	23.3%	19.0%	21.9%	23.4%	19.1%	22.3%	24.8%	**23.0%**
Share of renewables in national electricity generation	%	79.4%	79.4%	70.0%	75.1%	74.5%	83.3%	83.6%	82.6%	83.4%	83.7%	82.3%	83.5%	84.0%	83.2%	
Wind generation	TWh	0.1	2.2	21.6	33.5	42.4	62.1	76.9	88.0	62.1	76.9	88.0	62.1	76.9	91.7	
Power generation from sugarcane products	TWh	7.7	22.4	34.2	35.2	35.7	49.4	59.8	59.8	49.4	59.8	59.8	49.4	59.8	70.2	
Power generation from firewood	TWh	0.6	1.7	2.2	2.0	2.0	2.4	4.9	10.7	1.8	2.3	9.3	2.0	2.6	5.2	
Distributed photovoltaic generation	TWh	0.0	0.0	0.0	0.1	0.2	0.7	5.4	11.8	0.7	5.4	11.8	0.7	5.6	12.3	
Utility scale photovoltaic generation	TWh	0.0	0.0	0.0	0.0	0.7	8.1	9.3	10.4	8.1	9.3	10.4	8.1	10.0	12.7	
National hydropower generation	TWh	337.5	403.3	359.7	380.9	370.9	436.1	462.6	491.6	433.1	458.1	477.6	430.1	454.0	472.7	

Table 72. Renewables in power supply (installed capacity) – Emission driver Indicators of Energy Supply (GW)

		Historical data					Scenario A			Scenario B			Scenario C		
Indicator	**Unit**	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Total installed capacity	GW	96.2	121.3	154.1	164.4	125.6	168.7	181.0	197.3	168.7	180.8	194.1	168.7	181.8	199.6
National renewable installed capacity	GW	73.6	88.2	110.6	118.7	N.A.	143.1	155.9	168.8	143.1	155.9	165.7	143.1	156.9	173.6
Wind power installed capacity (average CF: 40%)	GW	0.0	0.9	7.6	10.1	12.3	16.8	20.8	23.8	16.8	20.8	23.8	16.8	20.8	24.8
Sugar cane products power plant installed capacity (average CF: 42%)	GW	2.3	6.2	10.6	11	11.2	12.8	15.5	15.5	12.8	15.5	15.5	12.8	15.5	18.2
Firewood powerplant installed capacity (average CF: 35%)	GW	0.2	0.4	0.7	0.7	0.7	0.8	1.0	2.2	0.8	1.0	1.9	0.8	1.6	3.1
Distributed photovoltaic installed capacity (average CF: 18%)	GW	0.0	0.0	0.0	0.1	0.2	0.4	3.4	7.5	0.4	3.4	7.5	0.4	3.6	7.9
Utility scale photovoltaic installed capacity (average CF: 25%)	GW	0.0	0.0	0.0	0	0.9	3.7	4.2	4.7	3.7	4.2	4.7	3.7	4.5	5.7
National Hydropower installed capacity (average CF: 48%)	GW	71.1	80.7	91.7	96.9	100.3	108.6	111.0	115.1	108.6	111.0	112.3	108.6	111.0	114.0

NA = not available

Table 73 shows Indicators related to the NDC goal of "10% efficiency gains in the electricity sector". National electricity generation is higher than the consumption due to the losses in the transmission system. Total Electricity Supply (TES) includes imports[7] from other countries and excludes exports. One possible metrics for "efficiency in the electricity sector" might be the ratio between electricity consumption and TES, reflecting the reduction of transmission and distribution and losses. This ratio was of 85% in 2005 and reaches 87% in 2030 across all the three scenarios, showing a reduction of overall grid losses from 15% to 13%. Anyway, the metrics of this indicator should be clarified in the future.

7 Almost all imported electricity by Brazil comes from the Paraguayan share of Itaipu hydropower plant that is not absorbed by the Paraguayan market and is sold to Brazil.

Electricity consumption is lower in Scenario B than in Scenario A due to better efficiency. In Scenario C, assumptions about increase of energy efficiency are higher than in Scenario B and electricity demand is lower until 2025. But the demand is higher in Scenario C for 2030. This is due to the higher penetration of electric vehicles. This phenomenon also explains the higher share of electricity in total demand in Scenario C.

Table 73. Electricity Supply and Consumption Indicators (TWh).

Indicator	Unit	Historical data					Scenario A			Scenario B			Scenario C		
		2005	2010	2015	2016	2017	2020	2025	2030	2020	2025	2030	2020	2025	2030
Electricity final consumption	TWh	375.2	464.7	524.6	521.4	526.2	584.6	652.8	720.3	580.1	643.7	705.3	577.1	638.4	704.5
National electricity generation	TWh	403.0	515.8	581.2	578.9	588.0	646.3	724.5	806.3	641.1	714.1	789.3	637.5	708.1	788.1
Total Electricity Supply (TES)	TWh	442.1	550.4	615.7	619.7	624.3	677.4	751.8	828.3	672.6	741.3	811.2	668.6	735.3	810.1

Table 74 below highlights the indicators selected in the NDC (already presented above along with other more specific indicators). It shows that NDC goals in the Energy Supply Sector are achieved in all three scenarios, except in the case of the share of renewables in the energy mix in 2030 for Scenario A, which misses the target by 1.1% (43.9% instead of 45%). This is mainly due to the fact that in Scenario A, compared to the other scenarios, there is less demand for biofuels and electricity in the transportation sector. In addition, Scenario A has a higher electricity demand and higher installed capacity of power plants fired by fossil fuels.

Table 74. Brazilian NDC energy goals - Indicators of Energy Supply (% and GW)

Indicator	Unit	Historical data					Scenario A			Scenario B			Scenario C			NDC
		2005	2010	2015	2016	2017	2020	2025	2030	2020	2025	2030	2020	2025	2030	2030
Share of renewables in the energy mix	%	44.1%	44.7%	41.3%	43.5%	43.2%	45.2%	45.1%	**43.9%**	45.6%	47.0%	**46.9%**	46.2%	48.7%	**50.4%**	**45.0%**
Share of renewables, other than hydropower, in the energy mix	%	29.2%	30.7%	30.0%	30.9%	31.2%	31.7%	32.4%	**31.8%**	32.1%	34.2%	**34.9%**	32.9%	35.8%	**38.0%**	**28.0%**
Share of biofuels in the energy mix	%	13.8%	18.2%	17.9%	18.5%	18.6%	18.6%	19.3%	**18.7%**	19.0%	20.4%	**21.0%**	19.7%	21.8%	**23.7%**	**18.0%**
Share of renewables, other than hydropower, in total power supply	%	3.1%	6.1%	11.5%	13.7%	15.1%	18.9%	22.1%	**23.3%**	19.0%	21.9%	**23.4%**	19.1%	22.3%	24.8%	**23.0%**
Share of renewables, other than hydropower, in national power supply	%	3.4%	6.5%	12.2%	16.6%	16.1%	19.9%	22.9%	23.9%	19.9%	22.7%	24.0%	20.1%	23.2%	25.5%	
Renewables installed capacity, other than hydropower	GW	2.6	7.5	18.9	21.8	-	34.5	44.9	53.7	34.5	44.9	53.2	34.5	45.9	59.6	

4.4.3. Absolute Emissions Indicators in the Energy Supply sector

Table 75 shows the absolute GHG emission indicators of energy supply in Scenarios A, B and C (excluding fugitive emissions), considering the emissions from all energy demand, including transportation, industry and other sectors.

Table 75. Absolute Emissions indicators of Energy Supply ($MtCO_2$- eq)

Indicator	Unit	Historical data					Scenario A			Scenario B			Scenario C		
		2005	2010	2015	2016	2017	2020	2025	2030	2020	2025	2030	2020	2025	2030
Emissions from power generation	$MtCO_2$-eq	27	37	68	-	-	41	47	55	41	46	55	40	44	50
Emissions from the energy sector consumption	$MtCO_2$- eq	22	24	30	-	-	28	30	34	28	30	32	27	29	31
Emissions from total energy consumption	$MtCO_2$- eq	320	378	445	-	-	429	469	518	423	450	482	417	425	423
Emissions from charcoal kilns	$MtCO_2$-eq	1.0	0.7	0.6	-	-	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.6

4.4.4. NDCs targets for the energy sector – Fugitive emissions

The Brazilian NDC does not specify targets for the reduction of fugitive emissions.

4.4.5. Indicators of Emission drivers of Fugitive Emissions

In Exploration and Production (E&P) of Oil and Natural Gas (O&G), emissions from flaring depend on the nature of the activity (exploration or production), field, location, operator, among others. Data on flaring, venting, equipment leaks and accidental losses on platforms, refineries and gas processing units (UPGN) are important for an effective Oil and Gas emissions monitoring system. Other relevant information is the flare combustion efficiency in the platforms and the amount of vented gases. The information on these parameters is not reported by oil companies and these data are not available. Therefore, based on available data, the proposed emission driver indicator for E&P is the ratio of natural gas flaring to the Brazilian natural gas production.

In the refineries, information is even less detailed, and no information on the percentage of emissions due to flaring, venting, equipment leaks, and accidental releases is available. Therefore, the emission driver indicator adopted is the ratio of CH_4 emissions to oil processing in refineries.

As in the Oil and Gas industry, for the Coal industry detailed information is not available. Data of annual emissions from surface and underground mines, or mining, post-mining, abandoned mining, CH_4 recovery and utilization would be useful to improve the design indicators. In the absence of specific mitigation action, the proposed indicator is the annual energy output from coal production, tracking its variation over time.

The emission driver indicators of fugitive emissions are presented in Table 76.

Table 76. Emission driver indicators of fugitive emissions (multiple units)

Indicator	Description	Unit
Flaring in E&P	Natural gas production sent to flare	%
CH_4 Emission intensity in refineries	Methane emissions per processed oil in refineries	t CH_4/bpd
Coal production	Coal mining production	M toe

The proposed emission driver indicators of fugitive emissions are presented in Table 77.

Table 77. Emission Driver Indicators of Fugitive Emissions (multiple units)

						Scenario A			Scenario B			Scenario C		
Indicator	**2005**	**2010**	**2015**	**2016**	**2017**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**	**2020**	**2025**	**2030**
Natural Gas flaring in Oil and Gas E&P (%)	14.0	10.5	4.0	3.9	3.4	3.2	3.0	3.0	3.2	3.0	3.0	3.2	2.6	2.0
Methane emissions per processed O&G (tCH_4/bpd)	5.1	5.4	6.1	6.1	5.3	5.3	5.3	5.3	5.3	5.3	5.3	3.8	3.7	3.6
Coal mining production (M toe)	2.3	2.1	2.5	2.6	1.9	3.4	3.3	3.6	3.4	3.0	3.4	3.3	3.1	2.9

4.4.6. Absolute Emissions Indicators in Fugitive Emissions: Scenarios A, B and C pathways

The absolute emissions indicators of fugitive emissions are presented in Table 78.

Table 78. Absolute Emissions Indicators of Fugitive Emissions, Scenarios A, B and C ($MtCO_2$-eq – GWP AR5)

	2005	**2010**	**2015**	**2020**	**2025**	**2030**
$MtCO_2$-eq						
Scenario A				28	35	42
Scenario B	20	20	23	28	35	42
Scenario C				27	33	38

Note: differences in totals are due to rounding; NA = not available

4.5. Waste Management

4.5.1. NDCs targets for the Waste Management Sector

The Brazilian NDC does not specify targets for the waste management sector. We have thus considered the goals set in the National Solid Waste Plan (PLANARES, 2012) and in the Basic Sanitation Plan (PLANSAB, 2013) as a reference for the analysis, as well as the inputs received from the Brazilian Forum on Climate Change (for details, see report 2).

4.5.2. Indicators of Emission Drivers in the Waste Management Sector

This section presents the list of indicators identified for the waste management sector. We have assessed investments that are most likely to take place in the country, as expressed in the sectorial policies and proposed by the Brazilian Forum on Climate Change. We have estimated the amount of methane that would be released from the technologies applied and assumed different levels of methane capture and destruction in flares or use in the replacement of fossil fuels. Table 79 lists the selected indicators based on each mitigation action associated with the investments in the sector.

Table 79. Emissions drivers and respective indicators in Waste Management (multiple units)

Solid Waste Emission Drivers		Indicators
Solid waste generation - municipal (MSW) and industrial (ISW)		Total amount of waste generated (Mt /year)
MSW and ISW collected and sent to disposal sites		Amount of collected waste (Mt /year)
Disposal Sites	Unmanaged Shallow	Amount of collected waste disposed in open dumps (Mt /year)
Disposal Sites	Unmanaged deep	Amount of collected waste disposed in unmanaged landfills (Mt /year)
Disposal Sites	Managed (landfills)	Amount of collected waste disposed in managed landfills (Mt /year)
Disposal Sites	% of landfill methane destruction	Methane generated in managed landfills converted to biogenic CO_2 in flares or used to replace fossils fuels (%/year)
Not collected (uncategorized)		Amount of not collected waste (Mt /year)
Aerobic composting		Amount of waste converted to composting (Mt /year)
Paper Recycling		Amount of recycled paper (Mt /year)
Wastewater Emission Drivers		**Indicators**
Urban wastewater generation		**Amount of wastewater generated, expressed in million t of Biodegradable Oxygen Demand (Mt BOD/year)**
Sewage treatment plants		**Amount of collected wastewater (Mt BOD/year)**
Treatment	Emission-free processes	Amount of collected wastewater treated by emission-free processes (MtBOD/year)
Treatment	Activated sludge	Amount of collected wastewater treated by activated sludge (MtBOD/year)
Treatment	Facultative lagoons	Amount of collected wastewater treated in facultative lagoons (MtBOD/year)
Treatment	Other unspecified treatments	Amount of collected wastewater treated by other treatments (MtBOD/year)
Treatment	Anaerobic Treatments	Amount of collected wastewater treated by anaerobic treatments (MtBOD/year)
Treatment	Biogas flaring in anaerobic urban plants (55% efficiency rate)	Methane generated in anaerobic plants converted to biogenic CO_2 in flares (%/year)
Septic tank		Amount of wastewater that is not collected but treated in septic tanks (MtBOD/year)
Rudimentary tank		Amount of wastewater that is not collected but treated in rudimentary tanks (MtBOD/year)
Launch in water bodies		Amount of wastewater not collected and launched in water bodies (MtBOD/year)
% of total Industrial wastewater in anaerobic plants with biogas used for electricity generation		Methane generated in anaerobic plants that is converted to biogenic CO_2 in power plants (%)

Tables 80 and 81 summarize the solid waste and wastewater emission driver indicators, respectively, and their evolution in Scenarios A, B and C from 2020 to 2030.

Table 80. Solid waste emission driver indicators in Scenarios A, B and C (Mt waste)

Million t of waste (Mt)		2005	2010	2015	Scenario A			Scenario B			Scenario C		
					2020	2025	2030	2020	2025	2030	2020	2025	2030
Solid waste generation - municipal (MSW) and industrial (ISW)		63.3	71.2	79.8	85	92.3	99.7	85	92.3	99.7	85	92.3	99.7
MSW and ISW collected and sent to disposal sites		52.9	63.4	72.5	77.1	83.4	89.6	76.8	82	86.9	76.8	82	86.9
Disposal Sites	Unmanaged Shallow	14.1	11.5	12.5	11.4	11.5	11.6	11.2	11	10.8	11.2	11	10.8
	Unmanaged deep	14.4	15.4	17.5	14.8	14.3	13.9	16.2	14.5	10.9	16.2	14.5	10.9
	Managed (landfills)	24.4	36.5	42.6	50.8	57.6	64.1	49.4	56.5	65.2	49.4	56.5	65.2
	% of landfill methane destruction								18%	18%		50%	50%
Not collected (uncategorized)		6.4	3.3	1.7	1.3	1.2	1.1	1.3	1.2	1.1	1.3	1.2	1.1
Aerobic composting		0.6	0.4	0.3	0.3	0.2	0.2	0.2	1.0	1.9	0.2	1.0	1.9
Paper Recycling		3.4	4.1	5.3	6.3	7.5	8.7	6.5	8.0	9.7	6.5	8.0	9.7

Note: differences in totals are due to rounding

Table 81. Wastewater emission driver indicators in Scenarios A, B and C (Mt BOD)

Activity Level (MtBOD - biochemical oxygen demand)		2005	2010	2015	Scenario A			Scenario B			Scenario C		
					2020	2025	2030	2020	2025	2030	2020	2025	2030
Urban wastewater generation		**3.02**	**3.14**	**3.33**	**3.55**	**3.64**	**3.74**	**3.55**	**3.64**	**3.74**	**3.55**	**3.64**	**3.74**
Wastewater in treatment plant		**0.52**	**0.94**	**1.33**	**1.55**	**1.64**	**1.74**	**1.55**	**1.64**	**1.94**	**1.55**	**1.64**	**1.94**
Treatment	Emission-free processes	0.1	0.1	0.05	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0,04
	Activated sludge	0.2	0.4	0.5	0.6	0.6	0.7	0.6	0.6	0.7	0.6	0.6	0,7
	Facultative lagoons	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0,1
	Other treatments. unspecified	0.02	0.04	0.08	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0,1
	Anaerobic Treatments	0.1	0.3	0.6	0.7	0.8	0.8	0.7	0.8	1	0.7	0.8	1,0
	Biogas flaring in urban plants (55% efficiency rate)	N.A.	N.A.	N.A.	60%	60%	60%	60%	65%	70%	60%	70%	80%
Wastewater in septic tank		**0.3**	**0.3**	**0.4**	**0.5**	**0.6**	**0.1**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Wastewater in rudimentary tank		**0.5**	**0.4**	**0.4**	**0.3**	**0.2**	**0.7**	**0.3**	**0.2**	**0.1**	**0.3**	**0.2**	**0.1**
Wastewater launched in water bodies		**1.7**	**1.5**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.3**	**1.2**	**1.2**	**1.3**	**1.2**
Industrial Wastewater treated in anaerobic plants with CH4 used for electricity generation (% of total CH_4)		-	-	-	**40%**	**42%**	**43%**	**42%**	**44%**	**45%**	**44%**	**45%**	**47%**

Note: differences in totals are due to rounding

4.5.3. Absolute Emissions Indicators in the Waste Management Sector: Scenarios A, B and C pathways

The absolute emissions indicators of waste management are presented in Table 82.

Table 82. Waste management absolute emission indicators and milestones in Scenarios A, B and C ($MtCO_2$-eq)

Sector	2005	2010	2015	Scenario A			Scenario B			Scenario C		
				2020	2025	2030	2020	2025	2030	2020	2025	2030
Waste	**60**	**71**	**91**	**102**	**115**	**128**	**101**	**104**	**115**	**101**	**96**	**105**
Solid Waste	35	37	56	65	73	81	65	63	70	65	55	60
Urban Solid Wastes	-	-	56	65	73	81	64	63	69	64	55	59
Others	-	-	0.25	0.24	0.27	0.29	0.33	0.47	0.64	0.33	0.47	0.64
Wastewater Treatment and Discharge	25	34	35	37	42	46	36	41	45	36	40	45
Domestic Wastewater	14	16	17	18	19	20	18	18	19	18	18	19
Industrial Wastewater	11	17	18	19	23	27	19	23	27	18	22	26

Note: differences in totals are due to rounding

5. Synthesis of MRV Indicators: Board Panel to Track the Achievement of NDC Targets

The main emission indicators framework is presented in Table 83.

Table 83. Main emission indicators framework

AFOLU		Transportation				Industry			Energy Supply		Waste	
LULUCF	**Agriculture**	**Road**	**Railways**	**Airways**	**Waterways**	**Energy + IPPU**	**Energy**	**IPPU**	**Fuel Combustion**	**Fugitive Emissions**	**Solid Waste**	**Wastewater Treatment and Discharge**
Gross Emissions	Livestock	Passenger	Freight	Passenger		Cement			Energy Sector Consumption	E&P	Urban	Domestic
Deforestation and other land use changes	Enteric Fermentation	Private Cars		Freight		Iron and steel			Power Plants	Oil Refining	***Other***	Industrial
Amazon	Manure management	Mass transportation			Inland	Non-ferrous and other metals (aluminum included)		Aluminum and other non-ferrous and other metals	Other energy consumption sectors	***Other***		***Other***
Cerrado	Crop Systems	Freight			Cabotage	Chemicals			Residential			
Other Biomes	Agricultural Soils	Light trucks				Mining/Pelletization			Commercial & Public			
Removals	Zero Tillage	Medium trucks				Food and Beverage			Agriculture			
Planted Forests	***Other***	Heavy trucks				Pulp & Paper			***Other***			
Restoration of Native Forest		***Other***				Ceramics						
Recovery of Degraded Pasturelands						HFCs		HFCs				
Livestock-Forest Systems						Other Industries						
Protected Areas and Indigenous Lands						***Other***						
Other												

The proposed framework of MRV indicators for the monitoring of NDC targets is structured in two levels: (1) Absolute GHG emissions indicators and (2) Emission driver indicators. A third group includes the intensity indicators and still needs further development.

5.1. Absolute GHG emission indicators ($MtCO_2$-eq / year)

Over time, annual emissions will constitute the country's emissions pathway, disaggregated by sectors and subsectors according to the general GHG emissions inventory as suggested by IPCC guidelines. The effect of mitigation actions translates into the GHG emissions pathway of each sector and subsector. According to the scope and performance of mitigation actions, economy-wide, sectorial and subsectorial emissions pathways will achieve NDC targets or not. Generally speaking, as Scenarios B and C meet NDC targets, if the recorded emissions pathway of each sector/subsector follows the milestones of Scenarios B or C then the country will be on track to meet the emissions-wide NDC target. On the other hand, if the emissions indicator of a sector/subsector is not in the range of the Scenarios B and C milestones, deviating towards Scenario A emissions pathway, it may jeopardize the achievement of NDC targets. The follow-up of this set of emissions indicators will allow the planner to check **where** (in which sectors and subsectors) mitigation actions are on track to meet NDC targets ("green lights"), **where** they are going in the good direction but are still insufficient ("yellow lights") and **where** they are not able to prevent the emissions pathway going in the opposite direction of the expected NDC pathway ("red lights").

Table 84. AFOLU emission indicators and milestones in Scenarios A, B and C ($MtCO_2$-eq)

Sector	2005	2010	2015	2020		2025		2030	
				Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C
	$MtCO_2$-eq								
AFOLU (Agriculture, Forestry and Other Land Use)	**2,381**	**828**	**935**	**899**	**679 to 741**	**887**	**500 to 614**	**894**	**320 to 533**
Land Use, Land Use Change and Forestry (net emissions)	**1,922**	**355**	**413**	**408**	**193 to 249**	**388**	**33 to 137**	**375**	**-109 to 91**
Gross Emissions	2,171	668	913	925	760 to 759	927	655 to 677	928	626 to 673
Deforestation and other land use changes	-	-	883	896	729	896	622 to 645	896	592 to 640
Liming and forest residues	-	-	30	30	31 to 30	31	33 to 32	32	35 to 33
Removals	-249	-313	-500	-518	-567 to -510	-538	-622 to -540	-553	-735 to -582
Planted Forests	-	-	-12	-	-33 to 0	-14	-31 to -13	-22	-31 to -12
Restoration of Native Forest	-	-	-	-5,8	-21 to -7	-15	-55 to -18	-23	-145 to -48
Recovery of Degraded Pasturelands	-	-	-14	-25	-34 to -29	-22	-39 to -29	-22	-39 to -29
Livestock-Forest Systems	-	-	-25	-15	-25 to -20	-15	-25 to -20	-15	-24 to -20
Protected Areas and Indigenous Lands	-	-	-354	-382	-382	-382	-410 to -396	-382	-437 to -410
Secondary forests	0	0	-95	-90	-73	-90	-62 to -64	-90	-59 to -64
Agriculture	**460**	**473**	**522**	**491**	**486 to 492**	**498**	**468 to 478**	**519**	**429 to 442**

Livestock	333	333	379	368	363	374	352 to 359	385	315 to 324
Enteric Fermentation	-	312	358	349	349	355	340	364	304
Manure management	0	21	22	18	13 to 18	19	12 to 19	21	11 to 20
Cropping Systems	127	139	143	124	124	124	116 to 119	134	113 to 118
Agricultural Soils	-	120	129	126	126 to 127	130	125 to 127	135	120 to 123
Rice Cultivation	-	13	14	10	10	8.2	8.2	6.9	6.9
Burning of Agricultural Residues	-	6.5	6.6	3.4	3.4 to 3.7	3.0	3.1 to 3.5	2.8	3.1 to 3.5
Zero Tillage	-	-	-6.1	-16	-16	-16	-20	-11	-16

Note: differences in totals are due to rounding

Table 85. Transportation emission indicators and milestones in Scenarios A, B and C ($MtCO_2$-eq)

Sector	2005	2010	2015	2020		2025		2030	
				Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C
	$MtCO_2$-eq								
Transportation	**144**	**178**	**203**	**208**	**204 to 201**	**223**	**211 to93**	**247**	**218 to 175**
Road	**132**	**160**	**186**	**190**	**186 to 183**	**202**	**190 to 172**	**221**	**193 to 151**
Passengers	68	83	88	91	96 to 94	99	98 to 86	111	94 to 67
Private cars	50	63	68	71	73 to71	77	74 to 62	86	66 to 39
Mass transportation	18	20	19	20	23	22	24	24	28
Freight	**63**	**77**	**99**	**99**	**90 to 89**	**103**	**92 to 86**	**110**	**99 to 83**
Light trucks	14	16	21	21	19 to 19	21	19 to 18	20	19 to 18
Medium trucks	11	10	10	7.7	7.0	7.2	6.4 to 6.3	6.7	6.1 to 5.7
Heavy trucks	38	52	68	70	64 to 63	75	67 to 62	84	74 to 60
Railways Freight	**2.8**	**3.3**	**2.8**	**3.2**	**3.2 to 3.1**	**3.5**	**3.3**	**3.7**	**3.5 to 3.6**
Airways	**6.4**	**9.8**	**11**	**10**	10	**13**	**12**	**16**	**14**
Passengers	4.8	8.8	9.6	8.9	9.0	11	11	13	13 to 12
Freight	1.5	1.1	1.5	1.6	1.5	2.1	1.5	2.5	1.6 to 1.5
Waterways	**3.6**	**4.5**	**3.1**	**4.2**	**4.2**	**5.1**	**5.1 to 5.5**	**6.2**	**6.1 to 7.2**
Passengers	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2 to 0.3
Freight	3.4	4.3	2.9	4.0	4.0	4.9	4.9 to 5.3	6.0	5.9 to 6.9

Note: differences in totals are due to rounding

Table 86. Industry emission indicators and milestones in Scenarios A, B and C ($MtCO_2$-eq)

Sector	2005	2010	2015	2020		2025		2030	
				Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C
	$MtCO_2$-eq								
Industry (Energy + IPPU)	**141**	**162**	**170**	**179**	**171 to 166**	**199**	**184 to 171**	**222**	**198 to 178**
Iron & Steel	43	45	48	49	48 to 46	54	51 to 47	59	54 to 47
Cement	23	37	40	38	37	42	42 to 40	46	44 to 42
Non-ferrous and other metals	11	14	14	20	19	23	23 to 22	28	27 to 25
HFCs and SF6	3.0	7.6	10.2	13	9.5 to 8.0	17	8.7 to 6.0	20	8.1 to 4.5
Chemical	24	18	17	18	17	18	17 to 16	18	17 to 15
Mining and Pelleting	6.9	7.5	7.7	8.4	8.3 to 8.0	9.8	9.5 to 8.9	11	11 to 9.9
Mineral Industry (Cement excluded)	8.6	8.3	7.9	6.9	6.7	8.8	8.2	11	9.6 to 9.0
Other Industries	5.9	7.9	8.2	7.9	7.8 to 7.6	8.1	7.9 to 7.6	8.4	8.0 to 7.5

Food and Beverage	4.9	5.5	5.6	5.4	5.2	5.6	5.3 to 5.2	5.8	5.4 to 5.3
Ceramic	3.8	4.9	5.0	4.9	4.8 to 4.4	5.2	5.0 to 4.3	5.5	5.2 to 4.4
Pulp and Paper	4.0	3.9	4.1	4.3	4.2 to 3.9	4.8	4.6 to 4.1	5.3	5.1 to 4.5
Other	3.3	3.0	3.1	2.6	2.6 to 2.5	3.0	2.8 to 2.6	3.4	3.1 to 2.7
Industry (Energy)	62	72	73	74	72 to 70	80	76 to 72	86	81 to 74
Cement	9.2	15	16	16	15	17	17 to 16	19	18 to 17
Chemical	15	14	14	14	14 to 13	14	14 to 13	14	13 to 12
Mining/Pelletization	6.7	7.3	7.7	8.4	8.3 to 8.0	9.8	9.5 to 8.9	11	11 to 9.9
Non-Ferrous/Other Metallurgical	4.9	5.5	5.5	6.4	6.3 to 6.1	7.5	7.2 to 6.7	8.8	8.3 to 7.5
Other industries	6.3	8.3	8.2	7.9	7.8 to 7.6	8.1	7.9 to 7.6	8.4	8.0 to 7.5
Iron and steel	5.3	5.6	5.6	5.7	5.5 to 5.7	6.1	6.0 to 5.6	6.5	6.4 to 5.8
Food and Beverage	5.0	5.5	5.6	5.4	5.2	5.6	5.3 to 5.2	5.8	5.4 to 5.3
Ceramics	4.0	5.2	5.0	4.9	4.8 to 4.4	5.2	5.0 to 4.3	5.5	5.2 to 4.4
Pulp & Paper	4.2	4.2	4.1	4.3	4.2 to 3.9	4.8	4.6 to 4.1	5.3	5.1 to 4.5
Other	1.4	1.1	0.76	0.78	0.77 to 0.75	0.84	0.80 to 0.77	0.90	0.84 to 0.80
IPPU	79	91	98	105	99 to 96	120	108 to 99	136	116 to 104
Iron and Steel	37	40	42	43	42 to 41	48	45 to 41	52	48 to 42
Cement	13	22	24	22	22	25	25 to 24	27	26 to 25
HFCs	3.0	7.0	10	13	9.0 to 8.0	16.5	8.7 to 6.0	20	8.0 to 4.5
Mineral Industry (Cement excluded)	9.0	8.0	8.0	7.0	7.0 to 7.0	9.0	8.0	11	10 to 9.0
Aluminum	3.4	3.1	3.1	6.4	6.4 to 6.3	8.0	8.0 to 7.7	10	10 to 9.1
Non-ferrous and other metals	2.9	5.4	5.7	6.8	6.6 to 6.5	7.9	7.6 to 7.4	9.2	8.8 to 8.4
Chemical industry	9.3	3.3	3.2	3.6	3.6	3.7	3.6 to 3.4	3.9	3.6 to 3.3
Other	2.0	2.5	1.7	2.6	2.3 to 1.9	2.7	2.3 to 2.0	2.8	2.4 to 2.0

Note: differences in totals are due to rounding

Table 87. Energy supply and other energy sectors emission indicators and milestones in Scenarios A, B and C ($MtCO_2$-eq)

Sector	2005	2010	2015	2020		2025		2030	
				Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C
	$MtCO_2$-eq								
Energy Supply	115	128	168	148	147 to 146	167	164 to 160	185	184 to 174
Fuel Combustion	49	61	99	68	69 to 68	78	75 to 74	89	88 to 82
Energy Sector Consumption	22	24	30	28	28 to 27	30	30 to 29	34	32 to 31
Transformation Centers	28	37	69	41	41 to 40	48	46 to 45	55	55 to 51
Power Plants	27	37	68	41	41 to 40	47	46 to 44	55	55 to 50
Charcoal Production	1	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.6
Fugitive Emissions	20	20	23	28	28 to 27	35	35 to 33	42	42 to 38
E&P	10	10	11	13	13	21	21 to 20	26	25 to 24
Oil Refining	6.8	7.4	8.3	10	10 to 9.2	10	10 to 9.1	11	11 to 10
Fuel Transport	0.3	0.3	0.3	0.4	0.4	0.6	0.6	0.8	0.7 to 0.8
Coal Production	2.9	3	3	4.8	4.6 to 4.8	4.8	4.1 to 4.6	5.2	4.7
Other Energy Sectors	45	47	47	51	51	54	54	54	54
Residential	26	26	26	29	29	31	31	32	32
Commercial & Public	3.7	2.8	2.6	2.9	2.9	3.6	3.6	4.2	4.2
Agriculture	16	18	18	19	19	19	19	18	18

Note: differences in totals are due to rounding

Table 88. Waste management emission indicators and milestones in Scenarios A, B and C ($MtCO_2$-eq)

Sector	2005	2010	2015	2020		2025		2030	
				Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C	Scen. A	Range from Scen. B to Scen. C
	$MtCO_2$-eq								
Waste	**60**	**71**	**91**	**102**	**101 to 100**	**115**	**104 to 95**	**128**	**116 to 105**
Solid Waste	35	37	56	65	65	73	63 to 55	81	70 to 60
Urban Solid Wastes	-	-	56	65	64	73	63 to 55	81	69 to 59
Others	-	-	0.25	0.24	0.33	0.27	0.47	0.29	0.64
Wastewater Treatment and Discharge	25	34	35	37	36	42	41 to 40	46	45
Domestic Wastewater	14	16	17	18	18	19	18	20	19
Industrial Wastewater	11	17	18	19	19 to 18	23	23 to 22	27	27 to 26

Note: differences in totals are due to rounding

5.2. Emission driver indicators (in different units/year)

Emission driver indicators track the evolution of key driving forces determining the annual emission levels of each sector/subsector. For example, annual deforested area in the Amazon and in the Cerrado biomes (in million hectares/year) are key factors behind the annual gross emissions subsector of LULUCF. Again, if an emission driver indicator of a sector/subsector is not in the range of the Scenarios B and C milestones, deviating towards the Scenario A emissions driver pathway, it may jeopardize the achievement of NDC targets. The follow-up of this set of emissions indicators will allow the planner to check **why** (what driving forces) mitigation actions are on track to meet NDC targets ("green lights"), **why** they are going in the good direction but are still insufficient ("yellow lights") and **why** they are not able to prevent the emissions pathway going in the opposite direction of the expected NDC pathway ("red lights").

Besides the economy-wide GHG emissions reductions in 2025 and 2030, the NDC already specifies several emission driver indicators for the AFOLU and Energy sectors:

- in the Brazilian Amazonia, zero illegal deforestation by 2030 and compensating for greenhouse gas emissions from legal suppression of vegetation by 2030;
- 12 million hectares of forests restored and reforested by 2030;
- in the agriculture sector, restoring an additional 15 million hectares of degraded pasturelands by 2030 and enhancing 5 million hectares of integrated cropland-livestock-forestry systems (ICLFS) by 2030;
- share of sustainable biofuels (ethanol + advanced biofuels + biodiesel) in the Brazilian energy mix = 18% by 2030;
- share of renewables in the energy mix = 45% by 2030;
- share of renewable energy sources other than hydropower in the total energy mix = 28% to 33% by 2030;
- share of renewables (other than hydropower) in the power supply = 23% by 2030; and
- 10% efficiency gains in the electricity sector by 2030.

Our proposal extends this list of emission driver indicators to cover the more relevant factors determining GHG emissions in all sectors and subsectors as in table 89.

Table 89. Selected Emission Driver Indicators

Sector	Units	2005	2010	2015	2016	2017	2020			2025			2030		
							Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
AFOLU – Agriculture, Forestry and Other Land Use															
Land Use, Land Use Change and Forestry															
Deforestation	**Km²/year**	**40,436**	**16,062**	**18,312**	**20,104**	**18,670**	**16,950**	**15,000**	**15,000**	**16,960**	**13,350**	**13,650**	**16,950**	**12,950**	**13,590**
Amazônia	Km²/year	19,014	7,000	6,207	7,893	6,624	5,910	3,930	3,930	5,910	2,310	2,610	5,910	1,910	2,550
Cerrado	Km²/year	17,643	6,470	9,480	9,480	9,480	8,380	8,380	8,380	8,380	8,380	8,380	8,380	8,380	8,380
Other biomes	Km²/year	3,779	2,592	2,625	2,731	2,566	2,660	2,660	2,660	2,660	2,660	2,660	2,660	2,660	2,660
Area of commercial planted forests	**Mha/year**	**5.3**	**6.5**	**6.9**	**7.2**	**7.3**	**6.3**	**7.8**	**6.2**	**6.7**	**8.6**	**6.6**	**7.4**	**9.5**	**6.9**
Restored area of native forests	**Mha/year**	**NA**	**NA**	**NA**	**NA**	**NA**	**0.4**	**1.3**	**0.4**	**0.9**	**3.4**	**1.1**	**1.4**	**9.0**	**3.0**
Area of integrated systems (ICLF)	**Mha/year**	**0.3**	**0.9**	**1.9**	**NA**	**NA**	**2.6**	**3.0**	**2.8**	**3.2**	**4.0**	**3.6**	**3.8**	**5.0**	**4.4**
Recovered pasture area[3]	**Mha/year**	**NA**	**NA**	**3.9**	**NA**	**NA**	**6.9**	**9.3**	**7.8**	**9.9**	**14**	**11**	**12**	**20**	**15**
Protected Areas and Indigenous Lands	**Mha/year**	**NA**	**191**	**247**	**258**	**269**	**269**	**269**	**269**	**269**	**287**	**278**	**269**	**305**	**287**
Amazônia	Mha/year	NA	170	NA	NA	214	214	214	214	214	232	223	214	248	232
Cerrado	Mha/year	NA	12	NA	NA	29	29	29	29	29	29	29	29	31	29
Other biomes	Mha/year	NA	9	NA	NA	26	26	26	26	26	26	26	26	26	26

Sector	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Agriculture															
Livestock															
Number of cattle	Head of cattle (million)	228	210	215	208	209	210	210	210	213	204	204	218	182	182
Average slaughter age	months	37	37	37	37	37	37	37	37	37	27	27	37	27	27
Volume of manure management	Mm^3	NA	7.4	9.4	NA	NA	9.4	12	9.4	9.4	13	9.4	9.4	14	9.4
Crops															
Area under BNF	Mha	NA	23	32	NA	NA	33	33	33	36	39	39	38	42	41
Area under zero-tillage	Mha	NA	31	34	NA	NA	39	39	39	43	45	45	45	48	48
Transport															
Increased use of biofuels															
Biofuels share in energy demand	%	13%	19%	21%	20%	20%	21%	23%	23%	22%	25%	29%	22%	29%	35%
Market share of ethanol (flexible-fuel vehicles)	%	55%	53%	32%	26%	24%	25%	30%	30%	25%	30%	40%	26%	40%	60%
Percentage of anhydrous ethanol in the mandatory blend (Gasoline C)	%	25%	24%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%
Percentage of biodiesel in the mandatory blend (Bx)	%	0%	5%	7%	7%	8%	10%	10%	10%	10%	15%	15%	10%	15%	17%
Percentage of biokerosene in the mandatory blend (Bx)	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	5%
Changes in freight transport patterns and infrastructure															

Sector	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Road mode share in the modal split of freight transport	%	55%	57%	60%	61%	59%	55%	55%	55%	54%	54%	53%	54%	54%	49%
Activity of rail transport	10^9 t -km	223	278	332	342	375	414	414	414	452	459	459	488	507	543
Activity of water transport	10^9 t -km	115	173	131	97	115	182	182	182	225	225	244	277	277	326
Gains in energy efficiency in the transportation sector															
Energy intensity of freight transport	MJ/t -km	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	0.9	1.0	0.9	0.8
Energy intensity of passenger transport	MJ/pass-km	1.0	1.1	1.0	1.1	1.2	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8
Cumulative gains in energy efficiency - light vehicles	%	-	-	-	-	-	0.02	0.05	0.07	0.05	0.1	0.11	0.07	0.13	0.15
Expansion of the electric vehicles fleet (battery electric vehicles - BEV and hybrids)															
Electricity share in transport energy consumption (road transportation)	%	0%	0%	0%	0%	0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.2%	0.4%	1.1%
Electric vehicles share in the fleet	%	0%	0%	0%	0%	0%	0%	0%	0%	0.1%	0.4%	1.2%	0.2%	1.5%	4.9%
Hybrid vehicles share in the fleet	%	0%	0%	0%	0%	0%	0%	0.1%	0.1%	0.2%	0.3%	0.6%	0.7%	1.1%	1.6%
Increased use of mass transportation systems															
Road mode share in the modal split of passenger transport	%	93%	92%	91%	92%	91%	92%	92%	92%	91%	91%	91%	91%	91%	90%
Activity of water transport	10^9 pass-km	0.7	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.6	1.6	2.1
Activity of rail transport	10^9 pass-km	18	27	38	38	38	39	39	39	45	45	47	54	54	67
Industry															

Sector	Units	2005	2010	2015	2016	2017	2020			2025			2030		
							Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Cement															
Energy intensity	ktoe/10^6t of product	79	72	72	74	73	73	72	71	73	69	67	71	67	63
Emissions intensity	t CO_2-eq /t of product	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5
Ratio Clinker/cement	t clinker/t cement	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
Iron & Steel															
Energy intensity	ktoe/10^6t of crude steel eq.	535	499	502	502	500	498	495	481	493	486	456	488	47	432
Emission intensity	t CO_2-eq /t of crude steel eq.	1.4	1.4	1.4	1.3	1.4	1.5	1.4	1.4	1.5	1.4	1.3	1.5	1.4	1.2
Biomass share	%	28.4%	20.5%	17.9%	0.2%	0.2%	15.1%	17.0%	17.3%	13.4%	17.4%	18.1%	11.8%	17.8%	19.0%
Mining and Pelleting															
Energy intensity	ktoe/10^6t of product	7.8	6.9	6.6	6.6	6.6	6.6	6.5	6.3	6.5	6.3	6.0	6.5	6.1	5.7
Emission intensity	Kg CO_2-eq/t of product	19	16	15	11	14	14	14	13	14	13	13	14	13	12
Emission intensity	kg CO_2-eq/t of iron ore	18	15	14	10	13	13	13	12	13	12	12	13	12	11
Non-ferrous and other metals															
Energy intensity	ktoe/10^6t of product	2.2	2.7	3.3	3.3	3.3	3.3	3.3	3.2	3.3	3.2	3.1	3.3	3.2	3.0
Emission intensity	t CO_2-eq /t of product	4.6	5.9	8.5	8.3	8.3	9.9	9.8	9.5	10.1	9.9	9.4	10.2	9.8	9.2
Emission intensity	kg CO_2-eq /t of aluminum	5.5	6.6	11	10	11	14	14	13	14	14	13	14	14	13
Chemical															
Energy intensity	ktoe/10^3t of product	108	84	72	71	70	71	69	68	70	67	64	69	65	61
Emission intensity	t CO_2-eq /t of product	0.4	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Sector	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Emission intensiity	t CO_2-eq / t of etene	1.5	0.9	0.9	0.8	0.8	0.9	0.9	0.8	0.9	0.8	0.8	0.9	0.8	0.7
Chemical gases															
Amount of HFC replaced	$MtCO_2$-eq/year	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	7.8	11.7	5.3	10.5	15.2
Maximum SF6 leakage	gx10^-6/kwh	50	50	50	50	50	50	42	39	50	34	26	50	59	51
Energy Supply and Other Sectors															
Renewables															
Renewables in the energy mix															
Share of renewables in the energy mix	%	44.1%	44.7%	41.3%	43.5%	43.2%	45.2%	45.6%	46.2%	45.1%	47.0%	48.7%	43.9%	46.9%	50.4%
Share of hydropower in the energy mix	%	14.9%	14.0%	11.3%	12.6%	11.9%	13.5%	13.4%	13.3%	12.7%	12.8%	12.9%	12.1%	12.0%	12.3%
Share of renewables, other than hydropower, in the energy mix	%	29.2%	30.7%	30.0%	30.9%	31.2%	31.7%	32.1%	32.9%	32.4%	34.2%	35.8%	31.8%	34.9%	38.0%
Share of wind power in the energy mix	%	0.0%	0.1%	0.6%	1.0%	1.2%	1.80%	1.80%	1.8%	2.0%	2.0%	2.1%	2.1%	2.1%	2.3%
Share of solar power in the energy mix	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	0.6%
Share of sugarcane products in the energy mix	%	13.8%	17.5%	16.9%	17.5%	17.4%	17.3%	17.7%	18.4%	18.0%	18.5%	20.0%	17.5%	19.1%	21.7%
Share of firewood and charcoal in the energy mix	%	13.1%	9.7%	8.3%	8.0%	8.0%	7.0%	7.0%	7.1%	6.5%	6.5%	6.7%	6.2%	6.4%	6.4%
Share of biodiesel and other biofuels in the energy mix	%	0.0%	0.7%	1.0%	1.0%	1.2%	1.3%	1.3%	1.3%	1.3%	1.9%	1.9%	1.3%	1.9%	2.0%

Sector	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Share of other renewables in the energy mix	%	2.3%	2.7%	3.1%	3.4%	3.4%	4.1%	4.1%	4.1%	4.3%	4.8%	4.9%	4.3%	4.9%	5.0%
Share of ethanol in the energy mix	%	3.4%	4.7%	5.3%	5.0%	4.9%	5.1%	5.3%	5.7%	5.4%	5.8%	6.6%	5.6%	6.6%	7.6%
Renewables in power supply (electricity generation)															
Share of renewables, other than hydropower, in the power supply	%	3.4%	6.5%	12.2%	16.6%	16.1%	19.9%	19.9%	20.1%	22.9%	22.7%	23.2%	23.9%	24.0%	25.5%
Share of renewables in national electricity generation	%	87.1%	84.7%	74.1%	80.4%	79.2%	87.3%	87.5%	87.5%	86.7%	86.8%	87.3%	84.8%	84.6%	85.5%
Renewables in power supply (installed capacity)															
Total renewable installed capacity	GW	74	88	111	119	126	143	143	143	156	156	157	169	166	174
Wind power installed capacity (average CF: 40%)	GW	0	0.9	7.6	10	12	17	17	17	21	21	21	24	24	25
Sugar cane products power plant installed capacity (average CF: 42%)	GW	2.3	6.2	11	11	11	13	13	13	16	16	16	16	16	18
Firewood powerplant installed capacity (average CF: 35%)	GW	0.2	0.4	0.7	0.7	0.7	0.8	0.8	0.8	1.0	1.0	1.6	2.2	1.9	3.1
Distributed photovoltaic installed capacity (average CF: 18%)	GW	0	0	0	0.1	0.2	0.4	0.4	0.4	3.4	3.4	3.6	7.5	7.5	7.9
Utility scale photovoltaic istalled capacity (average CF: 25%)	GW	0	0	0	0	0.9	3.7	3.7	3.7	4.2	4.2	4.5	4.7	4.7	5.7

Sector	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Hydropower installed capacity (average CF: 48%)	GW	71	81	92	97	100	109	109	109	111	111	111	115	112	114
Fugitive Emissions															
Percentage of gas flaring in the oil and gas E&P	%	14	11	4	3.9	3.4	3.2	3.2	3.2	3.0	3.0	2.6	3.0	3.0	2.0
Methane emissions in oil refineries and in natural gas processing plants	tCH_4/bpd	5.1	5.4	6.1	6.1	5.3	5.3	5.3	3.8	5.3	5.3	3.7	5.3	5.3	3.6
Waste															
Solid Waste															
Solid Waste Deposited in Managed Landfills	Mt	24	37	43	NA	NA	51	49	49	58	57	57	64	65	65
Total methane converted to biogenic CO_2	%	0	0	0	0	0	0	0	0	0	9.3	17	0	11	20
Urban wastewater generation															
Biogas flaring in urban wastewater treatment plants (55% efficiency rate)	%	0	0	0	0	0	60%	60%	60%	60%	65%	70%	60%	70%	80%

Note: differences in totals are due to rounding; NA = not available

5.3. Intensity Indicators

Intensity indicators are another kind of helpful indicators. This study has selected a few representative intensity indicators to illustrate this point. A more complete set of intensity indicators can be further developed in the future, as it was beyond the scope of this study.

The selected intensity indicators are presented in Table 90.

Table 90. Selected Intensity Indicators

Intensity Indicators	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
General Indicators															
National per capita emissions	**t/hab.**	**12.86**	**4.23**	**4.57**	**NA**	**NA**	**4.24**	**3.20**	**3.49**	**4.06**	**2.29**	**2.81**	**4.01**	**1.43**	**2.39**
Carbon intensity of GDP	**Kg CO_2-eq/R$1.00**	**0.51**	**0.14**	**0.16**	**NA**	**NA**	**0.15**	**0.11**	**0.12**	**0.12**	**0.07**	**0.08**	**0.11**	**0.04**	**0.06**
AFOLU – Agriculture, Forestry and Other Land Use															
Land Use Change and Forestry															
Gross Emissions from LULUCF/Annual deforestation (all biomes)	kt CO_2-eq/km^2	**NA**	**NA**	**48.2**	**54.5**	**46.3**	**52.8**	**48.7**	**48.7**	**52.8**	**46.6**	**47.2**	**52.8**	**45.7**	**47.1**
Gross Emissions from LULUCF/Annual deforestation (Amazon Biome)	kt CO_2-eq/km^2	NA	NA	73.4	73.4	73.4	75.7	71.1	71.1	75.7	75.5	75.6	75.7	75.7	75.6
Gross Emissions from LULUCF/Annual deforestation (Cerrado Biome)	kt CO_2-eq/km^2	NA	NA	23.3	23.3	23.3	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0

Intensity Indicators	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Gross Emissions from LULUCF/Annual deforestation (Other Biomes)		NA	NA	78.9	108.2	61.7	92.8	92.7	92.7	92.4	92.7	92.7	92.8	92.7	92.7
Gross annual deforestation per biome / Brazilian GDP	10^{3}ha/Billion R$	NA	NA	149.5	155.1	153.6	142.6	142.6	142.6	121.8	121.8	121.8	104.1	104.1	104.1
Net Emissions from LULUCF/Annual deforestation (all biomes)	kt CO_2-eq/km^{2}	NA	NA	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Net annual deforestation per biome / Brazilian GDP	10^{3}ha/Billion R$	NA	NA	69.9	72.5	71.8	66.7	66.7	66.7	57.0	57.0	57.0	48.7	48.7	48.7
Agriculture															
Livestock Emission/ Meat production (carcass weight)	MtCO^{2}-eq/Mt CWE	35	36	40	0	0	37	36	37	34	32	32	30	27	27
Meat production (carcass weight)/ GDP from Agriculture	Mt CWE/ Billion R$	0.0394	0.0303	0.0290	0.0302	0.0291	0.0279	0.0279	0.0279	0.0265	0.0265	0.0265	0.0241	0.0241	0.0241
Livestock Emissions / GDP from Agriculture	$MtCO_2$-eq/ Billion R$	1.37	1.08	1.15	NA	NA	1.02	1.01	1.02	0.89	0.84	0.85	0.73	0.64	0.66
Meat production (carcass weight)/ Pastureland Area	kt CWE/ Mha	52.5	54.5	55.6	58.3	57.4	60.9	60.9	60.9	68.0	71.8	71.4	72.5	89.6	88.3
Livestock / Pastureland Area	Heads of cattle / Mha	1,25	1,22	1,25	1,26	1,26	1,27	1,27	1,28	1,30	1,32	1,31	1,33	1,37	1,36
Pastureland area / GDP from Agriculture	Mha / Billion R$	0.75	0.56	0.52	0.52	0.51	0.46	0.46	0.46	0.39	0.37	0.37	0.33	0.27	0.27

Intensity Indicators	Units	2005	2010	2015	2016	2017	2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
AFOLU Gross Emission/Agricultural Production	$MtCO_2$-eq /Mt Product	5.27	1.44	1.65	0.46	0.48	1.55	1.28	1.30	1.43	1.00	1.04	1.26	0.69	0.79
AFOLU Net Emission/Agricultural Production	$MtCO_2$-eq /Mt Product	4.77	1.07	1.20	NA	NA	1.09	0.82	0.86	1.00	0.55	0.63	0.88	0.29	0.45
Agricultural Production/GDP from Agriculture	Mt product / Billion R$	2.0	2.5	2.4	2.5	2.5	2.3	2.3	2.4	2.1	2.2	2.3	2.1	2.2	2.4
AFOLU Gross Emission/ GDP from Agriculture;	$MtCO_2$-eq/ Billion R$	10.80	3.59	3.91	1.14	1.17	3.57	2.95	3.13	3.02	2.17	2.40	2.59	1.54	1.92
AFOLU Net Emission/GDP from Agriculture		9.78	2.68	2.84	0.00	0.00	2.50	1.89	2.06	2.11	1.19	1.46	1.82	0.65	1.08
Agricultural Production / Agricultural area	Mt Product/Mha	2.1	3.4	3.3	3.5	3.5	3.6	3.6	3.8	3.8	4.0	4.3	4.3	5.2	5.7
Agricultural area /GDP from Agriculture	Mha/Billion R$	0.98	0.74	0.72	0.71	0.69	0.63	0.64	0.63	0.55	0.54	0.54	0.47	0.42	0.42
Transportation															
Carbon intensity of freight transport	g CO_2-eq /t -km	80	77	85	76	75	73	73	70	72	64	61	68	61	53
Carbon intensity of passenger transport	g CO_2-eq /pass-km	61	57	47	54	53	50	50	50	47	47	41	46	40	30
Carbon intensity of road freight transport	g CO_2-eq /t -km	121	122	132	119	116	120	120	116	119	107	102	110	101	94
Carbon intensity of road passenger transport	g CO_2-eq /pass-km	61	56	46	52	52	49	49	49	46	46	40	46	39	28
GHG Emissions/ Transport GDP	tCO_2.eq/10^6 R$	65	44	38	39	40	38	38	37	34	32	30	32	28	23

Intensity Indicators	Units						2020			2025			2030		
		2005	2010	2015	2016	2017	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Industry															
Emission intensity per value added of the industry sector	$tCO_2.eq/10^6$ R$	105	99	108	NA	NA	112	108	104	108	99	92	103	91	82
Emission intensity per value added of the industry branch Food and beverage	$tCO_2.eq/10^6$ R$	64.5	51.9	47.2	49.3	44.8	45.0	43.9	43.5	45.0	42.3	41.7	44.0	40.9	40.0
Emission intensity per value added of the industry branch Iron and steel	$tCO_2.eq/10^6$ R$	1,263	1,914	2,212	2,963	2,954	2,516	2,451	2,361	1,919	1,815	1,668	1,460	1,344	1,177
Emission intensity per value added of the industry branch non ferrous and other metals	$tCO_2.eq/10^6$ R$	1,154	1,076	901	925	955	955	938	915	955	922	876	955	906	840
Emission intensity per value added of the industry branch Paper and pulp	$tCO_2.eq/10^6$ R$	240	189	188	180	174	173	171	159	174	168	150	174	166	147
Energy Supply and Use															
Use of Electricity															
Electricity final consumption over GDP;	MWh/MR$	80.2	79.7	88.9	0.0	0.0	94.4	93.8	93.2	90.0	88.8	88.1	84.9	83.2	83.1
Total electricity supply over GDP	MWh/MR$	94.5	94.4	104.3	0.0	0.0	109.4	108.7	108.0	103.7	102.3	101.4	97.7	95.7	95.5

Intensity Indicators	Units	2005	2010	2015	2016	2017	2020			2025			2030		
							Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C	Scen. A	Scen. B	Scen. C
Share of electricity in total energy demand	%	0.165	0.166	0.173	0.175	0.174	0.186	0.186	0.185	0.188	0.188	0.190	0.189	0.190	0.197
Energy Supply															
Grid emission factor (electricity final consumption);	kg CO_2-eq /MWh	71.1	78.7	130.0	NA	NA	70.1	69.8	69.3	72.4	70.8	69.0	76.1	77.4	71.4
Grid emission factor (total electricity supply)		66.2	70.9	117.3	NA	NA	63.4	63.1	62.7	65.2	63.8	62.2	68.0	69.2	63.8
Total Primary Energy Suppluy (TPES)/GDP	toe/MR$	46.5	46.1	50.7	50.7	51.1	48.2	48.0	48.0	45.7	45.1	44.4	43.2	42.2	40.7
Emissions from total energy consumption over TPES	tCO_2-eq/toe	1.7	1.6	1.6	NA	NA	1.6	1.6	1.6	1.6	1.5	1.5	1.6	1.5	1.4
Emissions from total energy consumption over GDP	tCO_2-eq /MR$	77.3	72.8	83.5	NA	NA	77.8	76.5	75.2	72.8	69.8	65.7	68.6	63.8	56.1
GHG Emissions from all sectors/TPES	tCO_2.eq/toe	13.0	5.1	5.2	NA	NA	5.1	4.4	4.6	4.8	3.6	3.8	4.6	2.9	3.4
TPES / capita	toe/capita	1.2	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.5

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ICAT Brazil Project

CBC – Centro Brasil no Clima

Report 3

Indicators for Progress Monitoring in the Achievement of NDC Targets in Brazil

PPE-21314

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