ESMAP
Energy Sector Management Assistance Program

Briefing Note 005/10

Brazil Low Carbon Country Case Study

LOW CARBON GROWTH COUNTRY STUDIES PROGRAM

MITIGATING CLIMATE CHANGE THROUGH DEVELOPMENT

CARBON FINANCE ASSIST

LOW CARBON GROWTH COUNTRY STUDIES PROGRAM

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A COMMITMENT TO LOW CARBON DEVELOPMENT

Brazil demonstrated early commitment to climate action at the 1992 United Nations Conference on Environment and Development, also known as the Rio Earth Summit. Today, Brazil remains strongly committed to voluntary action to reduce greenhouse gas (GHG) emissions. Brazil launched the 2008 National Plan on Climate Change (PNMC) that calls for a 70 percent reduction in deforestation by 2017 and adopted a National Climate Change Policy in 2009 that lays out voluntary GHG reduction targets (a 36.1 percent to 38.9 percent reduction of projected emissions by 2020). The PNMC states that the development rights of the poor should not be adversely affected by actions to avoid future GHG emissions.

Brazil, the world's largest tropical country, has a unique GHG emissions profile. Agriculture and livestock, which account for 25 percent of national gross domestic product (GDP), have required the steady expansion of crop land and pasture leading to the conversion of native vegetation. Land-use change, in particular deforestation, is the main source of national GHG emissions in the country today. Brazil's abundant natural resources and vast territory have enabled the development of low carbon renewable energy. Historically, large investments in renewable energy—hydropower at 75 percent of installed generation capacity and sugar cane-based ethanol substituting 40 percent of gasoline fuel—have lowered the carbon intensity of Brazil's energy matrix[1] and reduced emissions from transport.

At the same time, it is important to recognize that Brazil is likely to be significantly impacted by climate change. A phenomenon known as the Amazon dieback, combined with shorter term deforestation due to fires, could reduce rainfall in the Central-West and Northeast regions, leading to smaller crop yields and less water for hydropower-based electricity.[2] Urgent solutions are needed to reduce Brazil's vulnerability and to enable adaptation.

[1] Fossil fuel–based emissions amount to about 1.9 tCO_2 per year per capita or less than one-fifth of the Organisation for Economic Co-operation and Development (OECD) country average.

[2] "Assessment of the Risk of Amazon Dieback," World Bank, 2010.

BOX 1.

Getting Started

Brazil Low Carbon Country Case Study was two years in the making based on a study by the World Bank assisted by the United Nations Development Programme (UNDP) and the Energy Sector Management Assistance Program (ESMAP). It supports Brazil's integrated effort towards reducing national and global-emissions GHG while promoting long-term development.

It builds on the best available knowledge and is underpinned by a broad consultative process and survey of available literature. The study was coordinated by Christophe de Gouvello, a Senior Energy Specialist in the Sustainable Development Department of the Latin American and the Caribbean Region. The study's scope was discussed with the Ministries of Foreign Affairs, Environment and Science and Technology, as well as representatives of the Ministries of Finance, Planning Agriculture, Transport, Mines and Energy, Development, Industry and Trade. Several public agencies and research centers participated in, or were consulted, including EMBRAPA, INT, EPE, CETESB, INPE, COPPE, UFMG, UNICAMP, and USP.

More than 15 technical reports and 4 synthesis reports have been commissioned in the course of this work. For a quick overview of priority issues, analysis is presented using reader-friendly charts, graphs, and annotations organized in chapters according to the four key emission sectors—land use, land-use change, and forestry (LULUCF), including deforestation; energy production and use, particularly electricity, oil and gas and bio-fuels; transport systems; and solid and liquid urban waste.

Christopher de Gouvello. (2010, June). "Brazil Low-Carbon Country Case Study." The World Bank.

OBJECTIVE AND APPROACH

The ***Brazil Low Carbon Country Case Study*** identifies opportunities to reduce GHG emissions while fostering economic development. It provides technical inputs on ways to assess mitigation potential and conditions for low carbon development in key GHG emitting sectors of the economy.

Consistent with long-term development objectives, the study (Table 1):

- Establishes a ***reference scenario*** by anticipating the future evolution of Brazil's GHG emissions
- Identifies and quantifies actions that could be taken to mitigate emissions and increase carbon uptake
- Assesses the costs of implementing low carbon actions, identifies potential implementation barriers, and explores measures to overcome them
- Builds a ***low carbon scenario*** that meets development expectations
- Analyzes the macroeconomic effects of shifting from the reference scenario to a lower carbon pathway and additional financing needs

More than 30 recognized Brazilian experts participated directly in the elaboration of this study and dozens more were consulted, including government representatives, to integrate the best available knowledge and avoid duplica-

Table 1. The Approach to Brazil's Low Carbon Country Case Study

STEP	LULUCF	ENERGY	TRANSPORT	WASTE
1. Build the reference scenario	Project land use and land-use change (consistent with projected liquid and solid biofuels; develop geospatially explicit, land-use modeling), deforestation (adapt existing modeling), and emissions.	Project energy demand (consistent with demand from other sectors; using MAED projections); optimized energy-supply mix (using MESSAGE projections); and emissions.	Project regional and urban transport demands, transport modes shares for regional and urban transport (using TRANSCAD modeling), fuel mix for transport modes, and emissions (using adaptation of COPERT modeling).	Project waste and effluent production, carbon content and methane (CH_4) potential, waste and effluent disposal mix, and emissions.
2. Explore mitigation and carbon uptake options	Analyze options to reduce deforestation pressure and protect forests, mitigate emissions from agriculture and livestock, and sequester carbon; conduct an economic (abatement cost) analysis of the proposed options.	Analyze options to manage demand and reduce carbon intensity of supply; conduct an economic analysis (abatement cost) of the proposed options.	Analyze options to improve regional transport efficiency and scale up low carbon interurban modes; improve urban transport efficiency and scale up low carbon urban modes; and switch to biofuels; conduct an economic analysis (abatement cost) of the proposed options.	Analyze options to reduce waste and effluent production and scale up collection and low carbon disposal modes; conduct an economic analysis (abatement cost) of the proposed options.
3. Assess the feasibility of the options identified	Identify barriers that limit or prevent implementation of the options analyzed, environmental and economic co-benefits, and measures to overcome the barriers.	Identify barriers that limit implementation of the energy-demand management and emissions-mitigation options analyzed, environmental and economic co-benefits, and measures to overcome the barriers.	Identify barriers that limit implementation of regional and urban transport efficiency and low carbon modes, environmental and economic co-benefits, and measures to overcome the barriers.	Identify barriers that limit implementation of waste and effluent production reduction and low carbon waste and effluents disposal modes, environmental and economic co-benefits, and measures to overcome the barriers.
4. Build the low carbon scenario	Project new land use and land-use changes (including added land needed for mitigation and carbon uptake options), estimate reduced deforestation, and project reduced emissions.	Revise energy demand (including new fuel mix from transport); define new and internally consistent, low carbon energy mix for energy supply; and project reduced emissions.	Project new transport demand (consistent with new land use), new modal distribution for regional and urban transport, new fuel mix, and reduced emissions.	Project new waste and effluent production, new carbon content and CH_4 potential, new waste and effluents disposal-mode mix, and reduced emissions.

tion of efforts. Together these actions informed the selection and the analysis of four areas with large potential to lower carbon emissions.[3]

- **Land Use, Land-Use Change, and Forestry** (LULUCF), including deforestation
- **Energy** production and use, particularly electricity, and oil and gas
- **Transport** systems
- **Waste Management,** specifically solid and liquid urban waste

THE REFERENCE SCENARIO

The reference scenario builds on these four areas and existing government plans, such as the Ministry of Mines and Energy's "2030 National Energy Plan (PNE 2030)" and the National Logistic and Transport Plan both launched in 2007, the Government Accelerated Growth Plan and other published policies and measures at the time the reference scenario was developed.[4] The study built its own reference scenarios where published plans were unavailable by either developing or adapting sector models that maintain consistency with the goals laid out in the PNE 2030. Key interfaces (e.g., determining the land needed for solid and liquid biofuel production used by transport and energy) were addressed jointly by the teams working in these areas. The reference scenario does not cover all of the country's emission sources and is not a simulation of future national emission inventories.

Deforestation remains the key driver of Brazil's future GHG emissions to 2030 in the reference scenario. Emissions from deforestation are projected to stabilize (at about 400–500 Mt CO_2 per year) after declining slightly in 2009-11. As the energy, transport, and waste management sectors continue to grow, the relative share of emissions from deforestation declines (from 40 to 30 percent between 2008 and 2030). Subsectors, such as urban transport, thermal power generation and industrial processes, which are dependent on fossil fuels, have high emissions

[3] Certain industrial sources of nitrous oxide (N_2O), hydroflourocarbons (HFCs), perflourocarbons (PFCs), sulfur hexafluoride (SF_6), and other non-Kyoto GHG gases are not covered in this study. Without a recent complete inventory, it is not possible to determine precisely the share of other sources in the national GHG balance. However, based on the first Brazil National Communication (1994), it is expected that they would not exceed 5% of total Kyoto GHG emissions. Not all agriculture activities were taken into account when estimating emissions from that sector; crops taken into account in LULUCF emissions calculations represent around 80% of the total crop area.

[4] As a result of the methodology used to establish this reference scenario, it differs from the projections of national and sectoral emissions, based mainly on extrapolation of past trends, officially announced by the Brazilian Government in 2009 along with the voluntary commitment to reduce emissions, which are reflected in Law 12.187. The difference between the reference scenario defined in this study and the one established by the Brazilian government on the basis of past trends reflects the positive impact on emission reductions of the policies already adopted at the time this study's reference scenario was established. Noticeably, the reference scenario was defined before the elaboration of the PNMC and the adoption of Law 12.187, which institutes the National Climate Change Policy of Brazil, and set a voluntary national GHG reduction target.

[5] From 1970 to 2007, the Amazon lost about 18% of its original forest cover; over the past 15 years, the Cerrado lost 20% of its original area while the Atlantic Forest, which had been largely deforested earlier, lost 8%.

[6] After peaking at 27,000 km² in 2004, deforestation rates have declined substantially, falling to 11,200 km² in 2007, the second lowest historical rate recorded by the Amazon Deforestation Monitoring Program (Programa de Cálculo do Desflorestamento da Amazônia).

growth to 2030 while emissions from subsectors dependant on less carbon intensive energy forms (e.g., bio-ethanol powered vehicles or hydropower generated electricity) remain relatively stable.

Land Use and Land-Use Change | *Towards a New Dynamic*

Deforestation is the largest source of emissions (about 40 percent in 2008), reducing Brazil's carbon stock by about 6 Gt over the past 15 years, the equivalent of two-thirds of annual global emissions.[5] Without recent action to protect forests, emissions would be significantly higher.[6] Deforestation in the Amazon and Cerrado regions is driven by agricultural and livestock expansion, new road construction, and related immigration while broader national and international market forces affect meat and crops demand that, in turn, contribute to deforestation.

Agricultural production and livestock account for 25 percent of Brazil's gross emissions. Fertilizer use, the mineralization of nitrogen in soil, the cultivation of wetland-irrigated rice, burning of sugar cane, and use of fossil fuel–powered

agricultural equipment drive agricultural emissions. Livestock emissions mostly result from the digestive processes of beef cattle.

Modeling Land Use, Land-Use Change, and Forestry

Future demand for land and land use, land-use change, and forestry (LULUCF) is projected using two models developed under this study *Brazilian Land Use Model (BLUM)*, an econometric model that estimates land allocations and measures changes in land use; and *Simulate Brazil* (SIM Brazil), a georeferenced spatialization model that estimates future land use over a period of time for various scenarios (Box 2).

Projecting Emissions in the Reference Scenario

An additional 17 million ha of land is estimated to be required in the 2010–30 reference scenario. Land allocated for productive uses grows 7 percent—from 257 to 276 million ha over 2008-30—with a quarter of this growth occurring in the Amazon region. In 2030, as in 2008, pastures occupy most of this area (rising from 205 to 207 million ha). Native vegetation is converted to productive use mostly in frontier regions like the Amazon region in the states of Maranhão, Piaui, Tocantins, and Bahia to accommodate this growth.

LULUCF emissions rise to about 895 Mt CO_2e per annum by 2030.[7] Land-use change via deforestation accounts for 533 Mt CO_2e of emissions per year by 2030. Direct emissions from agriculture and livestock increase over this period (346 Mt CO_2e per year on average to 2030). Less than one percent of gross LULUCF emissions are offset through carbon uptake.

Managing Emissions from Agriculture

Accelerated dissemination of zero-tillage cultivation can reduce net emissions caused by altering soil carbon stocks and using equipment powered by fossil fuels. Zero tillage cultivation can also help control soil temperature, improve soil structure, increase soil water-storage capacity, reduce soil loss, and enhance the nutrient retention of plants. In the low carbon scenario, if 100 percent zero-tillage is achieved in propitious areas by 2015, 356 Mt CO_2e of avoided emissions could be realized over the 2010–30 period (Figure 1).

Lowering Direct Emissions from Beef-Cattle Farming

Shifting to more intensive meat-production systems, implementing genetic-improvements, and improving forage for herbivores and genetically superior bulls with a shorter life cycle can reduce methane emissions from the digestive process of the cattle without reducing total meat production. With these measures, direct livestock emissions could decline from 272 to 240 Mt CO_2 per year by 2030, from the reference versus the low carbon scenario respectively (Figure 2).

[7] When calculating national carbon inventories, some countries consider the contribution of natural regrowth towards carbon uptake; therefore, although this study does not compute this contribution in the carbon balance of LULUCF activities, it would be fair to add that information for comparison purposes. If the carbon uptake from the natural regrowth of degraded forests were to be included, then the potential uptake would increase by 109 Mt CO_2 per year, thus reducing the net emissions.

BOX 2.

Modeling Future Land Use and Deforestation in Brazil

Exploring options for mitigating deforestation emissions requires projection of future deforestation. To simulate future land use and land-use changes in Brazil, the Low Carbon Growth Study team integrated two models:

1. ***Economic model:*** The Brazil Land Use Model (BLUM), developed by the Institute for International Trade Negotiations, is an economic modeling process that estimates the allocation of the country's area and measures land-use change as a result of the dynamics of supply and demand for all of the main products competing for land, such as soy, corn, rice, beans, cotton, sugar cane, pastures, and production forests.
2. ***Geo-referenced spatialization model:*** Simulate Brazil (SIM Brazil), developed by the Remote Sensing Center of the Cartography Department of the University of Minas Gerais, enables future land use to be spatially projected over time for the whole country according to different scenarios.

Both models were developed to meet the needs of this study. SIM Brazil does not alter the data from the BLUM economic model for the projection of land use; rather, it finds a place for them, taking into account a variety of criteria, such as agricultural aptitude, distance to roads, urban attraction, the cost of transport to ports, declivity, and distance to a converted area. SIM Brazil works at a definition level of 1 km^2, allowing for the generation of very detailed, dynamic maps. The methodology can be described as follows:

Step 1: Identify the areas suitable for expansion.

Step 2: Build an economic model to project the amount of land-use change within each activity (deforestation, livestock, and agriculture).

Step 3: Create a geographic model to distribute spatially the quantities of land required by each activity by year; hence, allocating where and how the land-use changes take place.

Step 4: Calculate the emissions resulting from changes in carbon stocks through conversion of native vegetation and soils, as well as direct emissions from cattle and agriculture operations.

The calculations are done twice, first for the reference scenario and then for the low carbon scenario. Emission abatements achieved under the low carbon scenario can then be compared to the emissions projected under the reference scenario.

Adapted from World Bank, "Brazil Low Carbon Country Case Study," June 2010.

Improving Carbon Uptake

Through measures that:

(i) *Recover native forests* by complying with legal actions for mandatory reconstitution laid out in laws for riparian forests and legal reserves.[8] This option has high carbon-uptake potential of about 140 Mt CO_2e per year on average.[9]

[8] In areas with optimal conditions, forest recovery can remove 100 tC per ha on average in the Amazon Region. In the reference scenario its contribution is limited in terms of quantity.

[9] If the carbon uptake from the natural re-growth of degraded forests were to be included the potential uptake would increase by 112 Mt CO_2 per year on average.

Figure 1: Emissions Avoided through Zero-Tillage Cultivation, Low Carbon Scenario (2010–30)

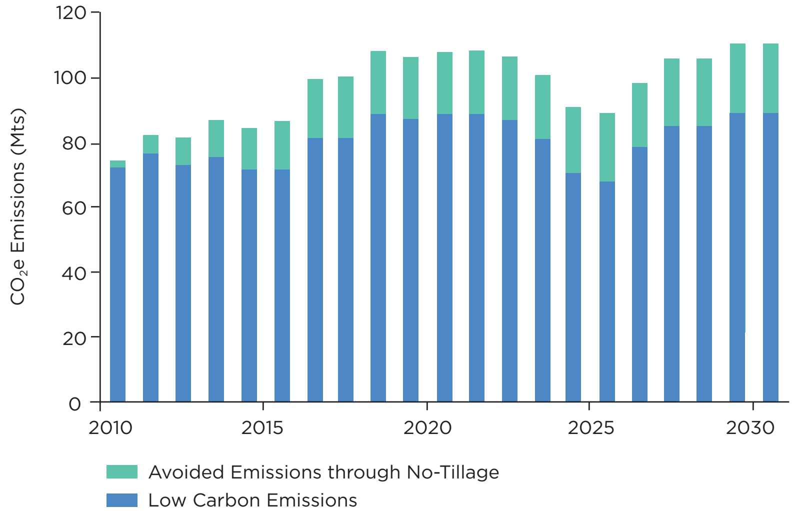
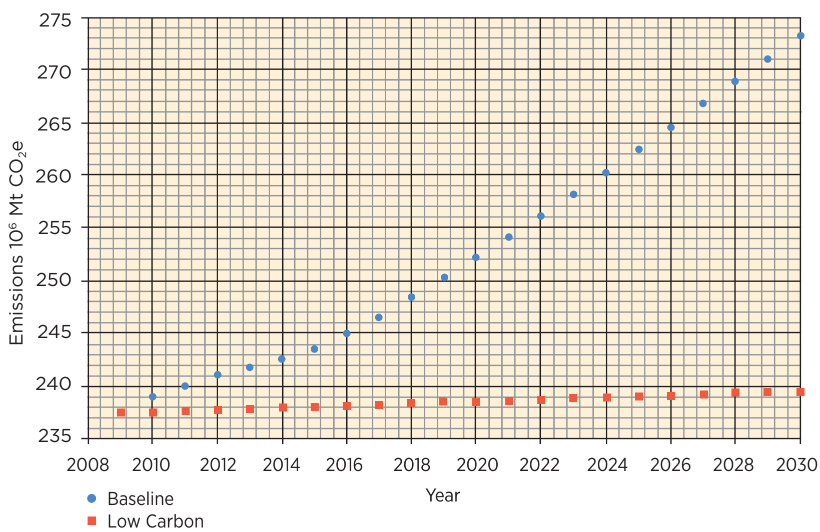


Figure 2: Comparing Methane Emission from Beef Cattle, 2008–30 ($MtCO_2e$ per year)



(ii) *Establish production forests* for the iron and steel industry. If total substitution of nonrenewable plant charcoal were effected by 2017 and 46 percent of iron and steel ballast production were based on renewable plant charcoal by 2030, sequestered emissions could amount to 377 Mt CO_2 in 2030—62 Mt CO_2 more than in the reference scenario.

Tackling Deforestation

Brazil has developed forest-protection policies and projects to counter the progression of pressure on forests at the expansion frontier and is experienced in economic activities compatible with forest sustainability. However, shifting to a low carbon scenario that ensures growth of agriculture and the meat industry—both important to the Brazilian economy—would also require acting on the primary cause of deforestation: demand for more land for agriculture and livestock.

Reducing Demand for Land through Improvements in Livestock Productivity
53 million ha of land, including more than 44 million ha for forest recovery, are required in the low carbon scenario to absorb land demand for agricultural and livestock activities. This increases to a total of 70 million ha—more than double the land planted with soybeans and sugar cane in 2008—when the additional land requirements under the reference scenario are taken into account (Table 2).

To drastically reduce deforestation, this study proposes a dual strategy:

(i) Eliminate the structural causes of deforestation by dramatically increasing livestock productivity

(ii)Protect the forest from illegal attempts to cut

Reducing Pasture Areas. Forest-protection policies, projects, and programs are already in place. Eliminating the structural causes of deforestation would require a dramatic increase in productivity per hectare. Increasing livestock productivity could free up large quantities of pasture. This option is technically possible since Brazil's livestock productivity is generally low and existing feedlots and crop-livestock systems could be scaled up. Use of more intensive production systems could trigger higher economic returns and a net gain for the sector economy. Releasing and recovering degraded pasture can accommodate the most ambitious growth scenario.

Table 2: Additional Land Needed in the Reference and Low Carbon Scenarios

SCENARIO	ADDITIONAL LAND NEEDS (2006–30)	
Reference Scenario: Additional volume of land required for the expansion of agriculture and livestock activities	Expansion of agriculture and livestock production to meet the needs anticipated in 2030	16.8 million ha
Low Carbon Scenario: Additional volume of land required for mitigation measures	Elimination of nonrenewable charcoal in 2017 and the participation of 46% of renewable planted charcoal for iron and steel production in 2030	2.7 million ha
	Expansion of sugar cane to increase gasoline substitution with ethanol to 80% in the domestic market and supply 10% of estimated global demand to achieve an average worldwide gasoline mixture of 20% ethanol by 2030	6.4 million ha
	Restoration of the environmental liability of "legal reserves" of forests, calculated at 44.3 million ha in 2030	44.3 million ha
Total		**70.4 million ha**

It is possible to reduce the demand by around 138 million ha by 2030 in the low carbon scenario through the increased livestock productivity measures below:

- Promote recovery of degraded pasture
- Stimulate the adoption of productive systems with feedlots for finishing
- Encourage the adoption of crop-livestock systems

Consolidating Forest Protection Measures. However, the model results show that the ebbing of additional demand for crops and livestock may not be enough to eliminate the complex dynamics that currently lead to forest clearing, either in protected forested areas or in areas where deforestation is still legally possible. These results reflect the need for additional measures to contain the process, at least in areas where deforestation is illegal, to thus achieve the goal set by the PNMC to reach zero illegal deforestation. Many measures have already been put into practice through the implementation of the Plan of Action for the Prevention and Control of Deforestation in the Legal Amazon, which increases the capacity for enforcement and consolidation of conservation policies for the Amazon rainforest.

The efficiency of this strategy has been demonstrated in 2004–07 when new forest-protection efforts, combined with a slight contraction in the livestock sector and pasture area,[10] led to a 60 percent reduction in deforestation (from 27,000 to 11,200 km²). This rapid reduction is due to a decline in the marginal land expansion for agriculture and livestock[11] and the conversion of native vegetation. However, if these efforts were to be neglected, emissions would resume immediately.

Broad implementation of such a strategy is projected to reduce deforestation by about 68 percent in 2030 compared to projected levels in the reference scenario; in the Atlantic Forest, the reduction would be about 90 percent while the Amazon region and Cerrado would see reductions of 68 percent and 64 percent, respectively (Figure 3).

In these ways, the result would be a net GHG emission of 331 Mt CO_2 per year from LULUCF in 2030 instead of the net of 816 Mt CO_2e per year, which was observed in 2008, and is expected to continue under the reference scenario.

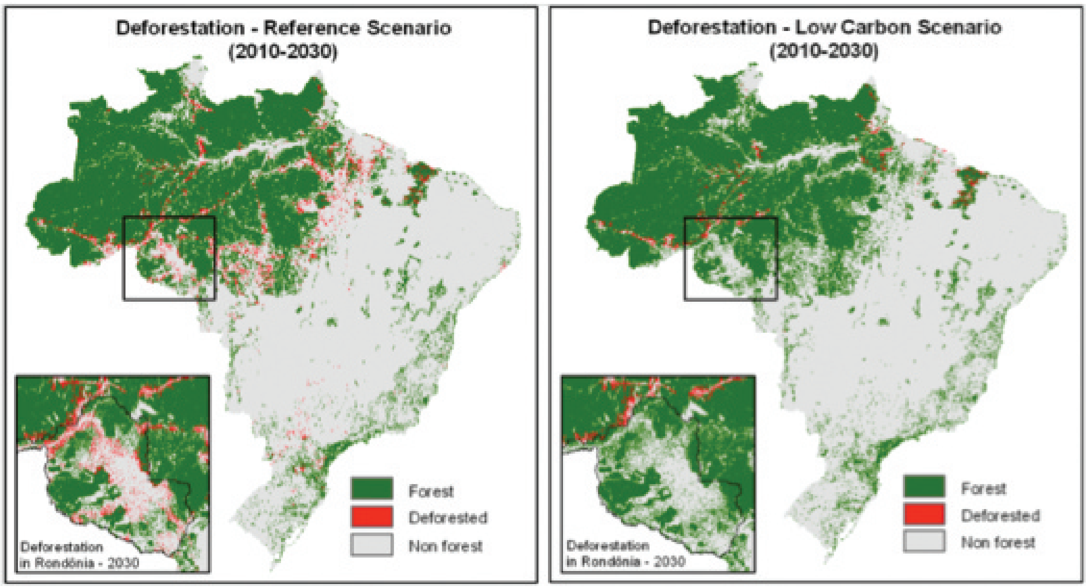
Energy | *Sustaining a Green Energy Matrix*

Energy production and consumption, excluding transport, contributed about 20 percent to Brazil's GHG emissions in 2010; mostly due to the large share of renewable energy (particularly hydropower) in the domestic energy mix. The GHG emission intensity of the energy sector is comparatively low by international standards: annual average emissions per capita from the energy sector were 1.77 tCO_2 in 2005 compared to an annual global per capita average of 4.22 tCO_2 and OECD country per capita average of 11.02 tCO_2 (Table 3). As a result, lowering emissions in the energy sector is more difficult in Brazil than in most of other countries.

[10] The 2005–07 period witnessed the first decline in herd size (from 207 million to 201 million heads), following a decade-long increase, together with a slight contraction in pasture area (from 210 million to 207 million ha).

[11] Unlike other sectors, whose energy-based emissions are usually proportional to the *full size* of the sector activity, emissions from deforestation are related only to the *marginal* expansion of agriculture and livestock activities.

Figure 3: Comparing Cumulative Deforestation | Reference and Low Carbon Scenarios (2007–30)



Reference Scenario Low Carbon Scenario

Energy Sector Emissions Rise by 97 Percent in the Reference Scenario

Most emissions, and most of the mitigation potential, depend on the technology used in industry, which continues to use mostly fossil fuels. While the PNE 2030 assumes greater use of renewable energy sources over 2010–30, GHG emissions from the energy sector rise 97 percent to 458 Mt CO_2 in 2030 (excluding fuels for transport) in the reference scenario (Figure 4). Cumulative GHG emissions from the energy sector are estimated at 7.6 Gt CO_2 over this 20-year period.

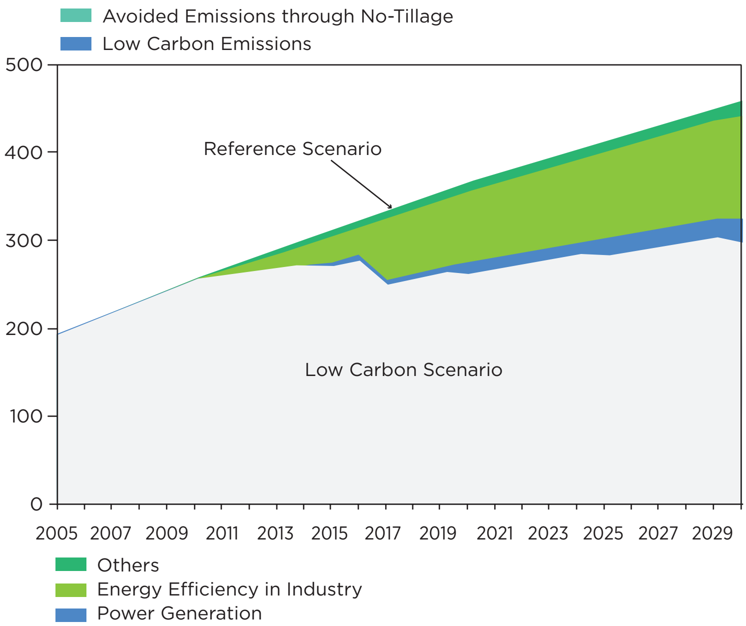
Limited Potential for Emission Reduction in the Low Carbon Scenario

Brazil could reduce annual energy sector emissions by 35 percent in the year 2030[12] compared to the reference scenario, with most actions being taken by the industrial sector, if the following measures were implemented:

- *Domestic Action:* Energy efficiency and fuel switching in industry, refining and gas-to-liquid (GTL), wind-energy generation, bagasse-based cogeneration and high-efficiency appliances. Most of Brazil's large-hydropower potential will have been exploited by 2030 under the reference scenario and hydropower expansion opportunities are not considered in the low carbon scenario.
- *Action Abroad:* Hydro-complementarities to reduce CO_2 emissions of energy sectors in Brazil and Venezuela and large-scale ethanol exports to reduce fossil-fuel emissions of transport sectors worldwide.

[12] In 2030, annual emissions would be reduced from 458 to 297 Mt CO_2 (excluding transport) or from 735 to 480 Mt CO_2 (including transport); that is, an annual reduction similar to Argentina's emissions in 2000.

Figure 4: Energy Sector Reference Scenario and CO_2 Emissions Mitigation Potential in the Energy Sector 2005-30, Reference Scenario (PNE 2030)



Even so, energy sector emissions in the low carbon scenario remain about 28 percent higher in 2030 than in 2008.

Scaling-Up of Ethanol Exports

By increasing ethanol exports Brazil could serve the growing international demand for low carbon vehicle fuels and deliver economic benefits for Brazil and its trade partners, as well as reduced GHG emissions. This opportunity could be realized by reducing or eliminating trade barriers and subsidies in many countries. This study adopted an export target of 70 billion liters by 2030; 57 billion more than in the PNE 2030 reference scenario and slightly more than 2 percent of estimated global gasoline consumption for that year. This would result in GHG emission reductions of 73 Mt CO_2 per year in 2030 or 667 Mt CO_2 over the 2010–30 period. An additional 6.4 million ha of land would be required in 2030 for sugar cane plantations (from 12.7 to 19.1 million ha).[13] If ethanol production does not outpace the implementation of the dual strategy proposed for freeing up pastures and protecting forests, additional land required for sugar cane expansion would not result in deforestation.

Transport | *Modal Shifts and Fuel Switching*

Brazil's transport sector has a lower carbon intensity compared to that of most other countries because of its widespread use of ethanol as a fuel for vehicles. As a consequence, the potential for emissions reduction appears relatively limited. For this reason, the study simulated the sector emissions that would result

[13] The measures proposed to reduce deforestation under the low carbon scenario considered the added land required for planting sugar cane for ethanol export to avoid carbon leakage.

Table 3: Energy Sector Emission Reduction Potential (2010–30)

LOW CARBON MITIGATION OPTIONS	EMISSION REDUCTIONS 2010–30 (MtCO₂)	%
Demand Side	**1,407**	**77**
Electricity	**28**	**2**
Solar heating	3	0
Air conditioning	3	0
Air conditioning ("PROCEL Seal")	0	
Refrigerators	10	1
Refrigerators (low-income populations)	6	0
Motor	2	0
Residential lighting	3	0
Industrial lighting	1	0
Commercial lighting	2	0
Fossil Fuels	**1,378**	**75**
Fuel combustion optimization	105	6
Heat recovery systems	19	1
Steam recovery	37	2
Oven heat recovery	283	15
New processes	135	7
Other efficient energy use measures	18	
Thermal solar energy	26	1
Recycling	75	4
Natural gas substitution (including ducts)	44	
Biomass substitution	69	4
Substitution of nonrenewable biomass with charcoal from tree plantings	567	31
Supply Side	**423**	**23**
Power Generation	**177**	**10**
Wind generation	19	1
Biomass cogeneration	158	9
Oil and Gas	**246**	**13**
GTL	128	7
Refining		
Improved energy use in existing refinery units (heat integration)	52	3
Improved energy use in existing refinery units (fouling mitigation)	7	0
Improved energy use in existing refinery units (advanced control)	7	0
Optimized design of new refineries	52	3
Total	**1,830**	**100**

if biofuels were substituted by fossil fuels (mainly gasoline). In that case, reference scenario emissions would be inflated by 50 percent in 2030 (Figure 7).

Despite the low emission intensity of Brazil's transport sector, the sector still accounts for more than half the country's fossil fuel consumption.

Transport sector emissions were about 149 Mt CO_2e in 2008 (12 percent of national emissions) with 51 percent linked to urban transportation and the increased use of private cars, congestion, and inefficient mass transportation systems. However, the increased use of flex-fuel vehicles and the switch from gasoline to bio-ethanol are expected to stabilize GHG emissions from light-duty vehicles over the next 25 years despite a projected rise in the number of kilometers traveled (Figure 5).

The low carbon scenario estimates transport sector emissions at 174 Mt CO_2 per year in 2030 (rather than 245 Mt CO_2 per year in 2030 under the reference scenario; Figure7). Total avoided emissions over the 2010-30 period are nearly 524 Mt CO_2, roughly equivalent to the combined emissions of Uruguay and El Salvador. Emissions could be reduced through the following mitigation options:

- *Urban.* Encouraging a shift to Bus Rapid Transit (BRT) and Metro, and implanting traffic management measures can reduce emissions by about 26 percent in 2030 (Figure 6); however, policy, coordination, and financing issues for capital intensive mass transit options often prevent and/or delay their implementation. Decentralized administration—more than 5,000 municipalities oversee transit and transport systems—makes resource mobilization difficult.
- *Regional.* Modal shifts for passenger and freight transport—such as expansion of high-speed passenger trains between São Paulo and Rio de Janeiro to replace the use of planes, cars, and buses, or increased use of water and rail transit for freight—could reduce emissions by about 9 percent in 2030. Inadequate infrastructure for efficient intermodal transfer and a lack of coordination among public institutions present barriers.
- *Fuel.* Increasing the switch from gasoline to bio-ethanol fuels from 60 percent in the reference scenario to 80 percent in 2030 could deliver more than one-third of total emissions reduction targeted for the transport sector over the period (nearly 176 Mt CO_2). The key challenge is to ensure that market price signals are aligned with this objective; an appropriate financial mechanism would be needed to absorb price shocks and maintain ethanol's attractiveness for vehicle owners.

Waste Management | *Financial Resources*

Emissions from Brazil's waste management sector amounted to 62 Mt CO_2e in 2008 (4.7 percent of national emissions). In the reference scenario, GHG emissions are projected to rise to 99 Mt CO_2e per year in 2030 as more people benefit from solid and liquid waste collection services—as a result of the government's plans for the universalization of basic sanitation services. In the low carbon scenario, annual emissions could be reduced by 80 percent in 2030 (to 19 Mt CO_2e per year comparable to Paraguay's annual emissions) avoiding 1,317 Mt CO_2 over 2010-30. The following actions are envisaged in the low carbon scenario:

- Carbon market incentives through the Clean Development Mechanism to encourage participation in projects designed to destroy landfill gases
- Developing municipal capacity for long-term planning and project development; raising awareness and use of existing legal structures, regulations, and procedures; and improving access to financing resources
- Creating intermunicipal and regional consortia to handle waste treatment
- Developing public-private partnerships through concessions under long-term contracts

Figure 5: Linking Regional and Urban Transport to Fuel Consumption

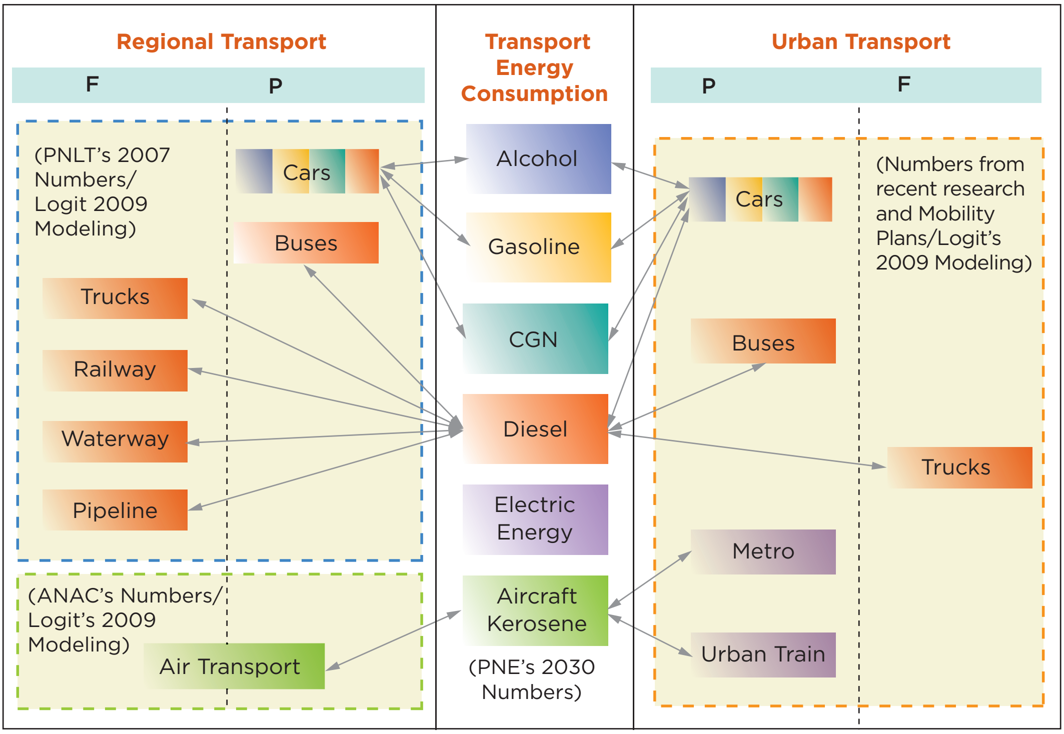


Figure 6: Example of Modal Shift for Urban Transport—Belo Horizonte, Brazil

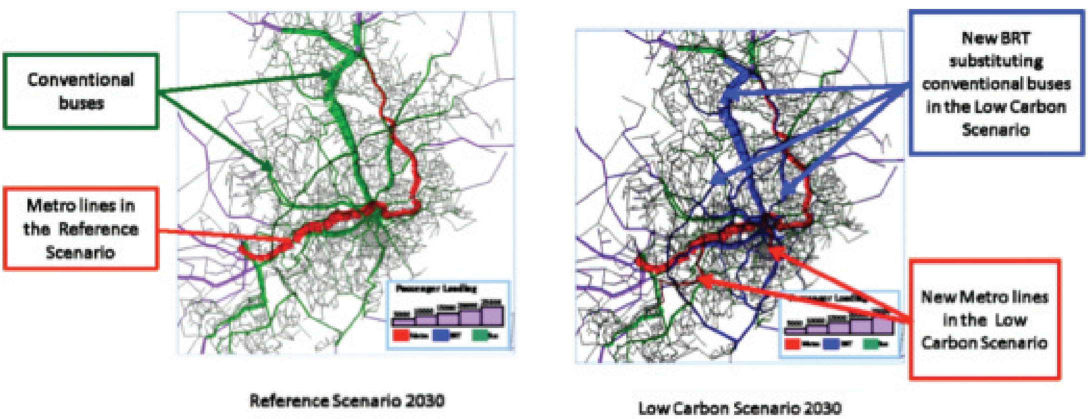
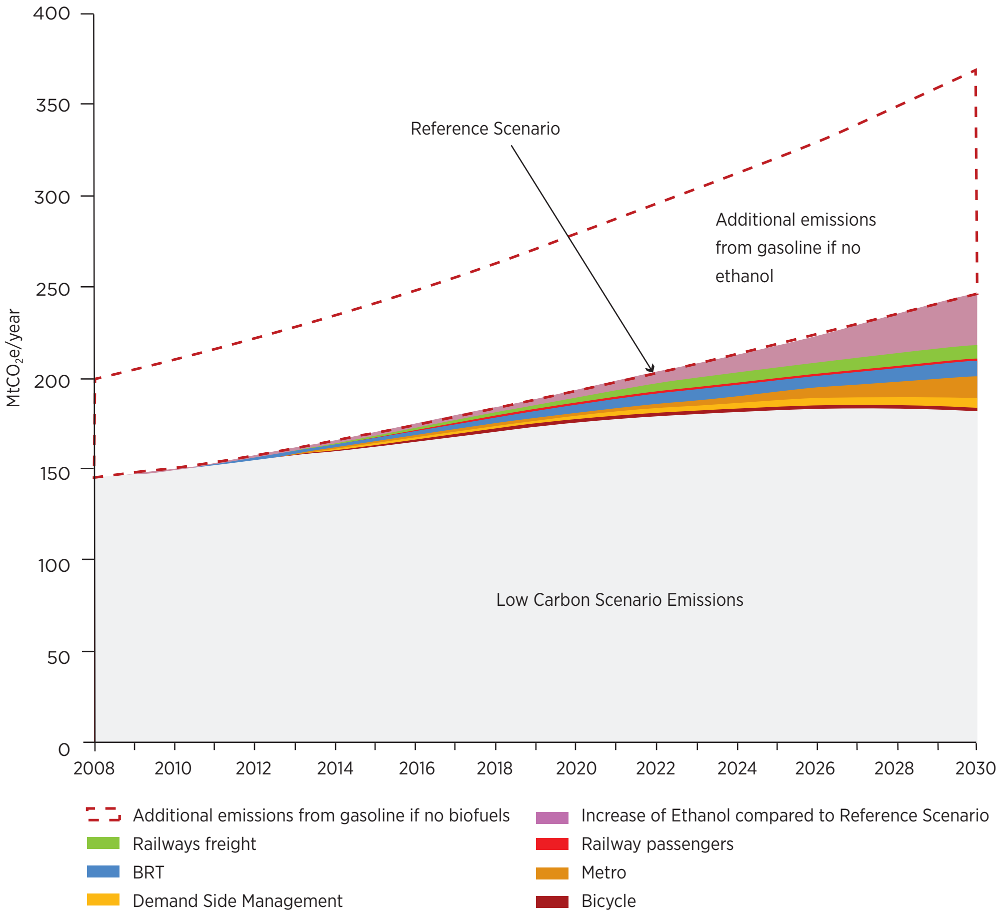


Figure 7: Emission Reduction Potential in the Transport Sector and Comparison of Emissions in Reference, Low Carbon, and "Fossil-Fuel" Scenarios, 2008–30



ECONOMIC ANALYSIS

The economic analysis looked at the financial conditions under which proposed mitigation and carbon uptake measures might be implemented and prioritized. Two complementary economic analyses were undertaken:

- *A microeconomic assessment* of the options considered from both social and private sector perspectives
- *A macroeconomic assessment* of the impacts of these options, either individually or collectively, on the national economy using an input-output (IO) model

The social approach compared the cost-effectiveness of mitigation and carbon uptake measures for society overall, calculating a marginal abatement cost (MAC) for each measure using a social discount rate of 8 percent. Results were sorted by increasing value and plotted in a single graph, known as the marginal abatement cost curve (MACC), to permit a quick comparison of the associated costs and volumes of GHG emissions (Figure 8). The study prioritized and selected mitigation and carbon uptake options for Brazil's 2010–30 low carbon scenario. The following criteria were used: the MAC, which represents the social perspective adopted in most government planning exercises, should not exceed US$50, except for options with large cobenefits and positive macroeconomic impacts (often seen in transport and waste sectors).

The private sector approach explored the conditions under which the proposed measures would become attractive to individual project developers. It estimates the minimum economic incentive—the "break-even carbon price"—that should be provided for the proposed mitigation measure to become attractive using the expected rates of return from existing economic agents in each sector as observed by major financing institutions in Brazil. The required rates of return for the private sector are generally higher than the social discount rate and hence the break-even carbon price is higher than the MAC. In some cases the MAC is negative and the break-even carbon price is positive (e.g., cogeneration from sugar cane, measures to prevent deforestation, fuel substitution with natural gas, electric lighting and motors or GTL), which helps one to understand why a measure with a negative MAC is not automatically implemented. Most mitigation and carbon uptake options presume an incentive to become attractive, with the exception of energy efficiency measures.

The total volume of incentives needed over the 2010-30 period is US$445 billion or US$21billion per year on average. Of this, about US$34 billion over the period 2010-30, or the equivalent of US$1.6 billion per year (US$6 per tCO_2),[14] is needed for measures that reduce deforestation (Figure 8). Under the low carbon scenario, more than 9 Gt CO_2 (80 percent) of emission reduction potential requires incentives of US$6 per tCO_2e or less (Figure 9). Economic incentives can be provided through a variety of means that includes—but is not limited to—the sale of carbon credits, capital subsidies for low carbon technologies, investment financing conditions, and tax credits.

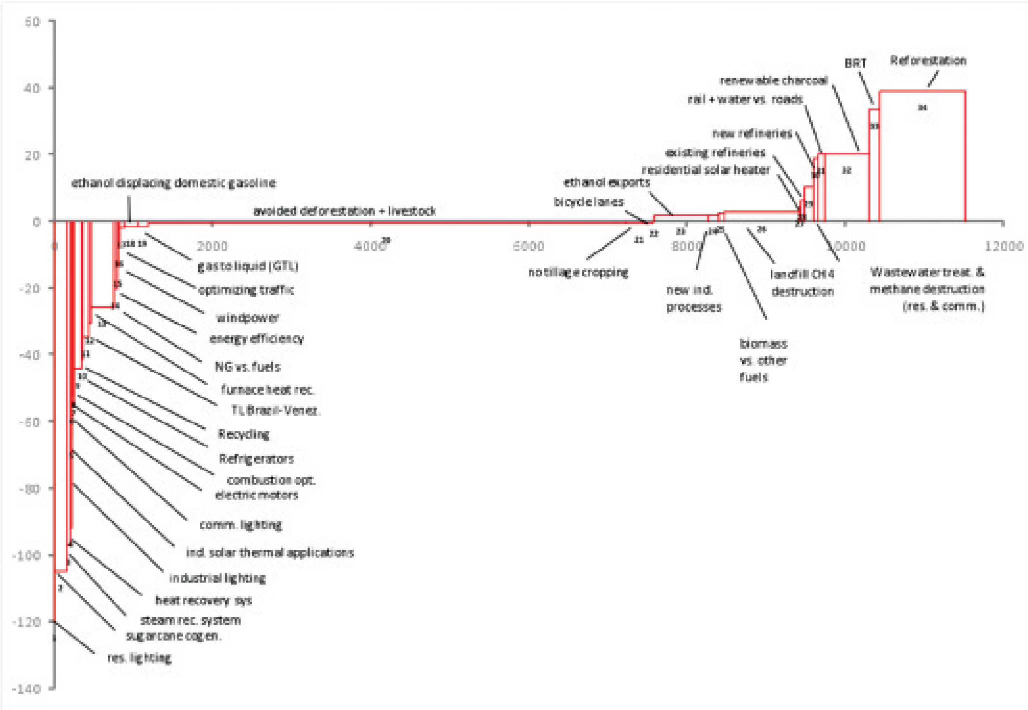
A simple Input-Output (IO) model was used to estimate the individual and collective macroeconomic effects of mitigation and carbon uptake measures and compared the low carbon and reference scenarios. While results only suggest the magnitude of the impact, the IO-based simulation indicates that investment under the low carbon scenario is not expected to negatively affect economic growth. Over 2010-30, slight improvement could be expected in GDP (0.5 percent per year) and employment (average 1.13 percent annually) due to economy-wide spillover effects associated with low carbon investments.

A NATIONAL LOW CARBON SCENARIO

The ***Brazil Low Carbon Country Case Study*** constructs a national low carbon scenario by consistently integrating the low carbon scenarios for each of the four areas described and taking into account the macroeconomic analysis. The methods and results were presented and discussed on various occasions with a range of government representatives to facilitate cross-sector coordination and transparency (Box 3).

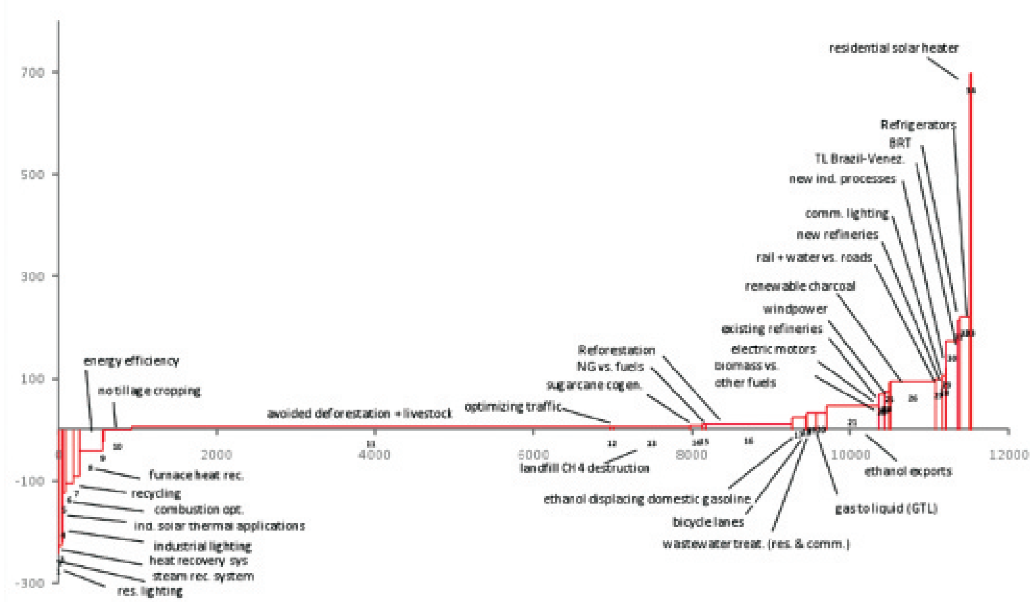
[14] Includes forest protection costs of US$24 billion over 2010-30.

Figure 8: Marginal Abatement Cost Curves for Mitigation Measures with MACs below US$50 per tCO_2e (8% Social Discount Rate)



Note: The assumption for oil prices is that of the PNE 2030 (US$45 per barrel on average), which is low compared to current prices (US$70 per barrel); thus, a sensitivity analysis is required, particularly for options that avoid oil and gas (e.g., gasoline substitution with bio-ethanol).

Figure 9: Break-Even Carbon Price of the Mitigation and Carbon Uptake Measures with MACs below US$50



BOX 3.

Brazil: Collaboration in the Public Sphere

Initial stakeholder engagement included a series of consultations and three organizational meetings.

Series of consultations: February–May 2007. Intensive discussions were held with about 60 people from government, private, academic, and NGO communities to explain, test, and adjust the study concept. Stakeholder committees were formed to map out the study process, including identification of state-of-the-art technical information and tools, preparation of an inventory of current local knowledge, setting priorities for investment of resources, and mapping human resources (both national and within the development community). Relevant official government plans were also identified together with areas for significant mitigation potential (axis for study and project boundary) and where additional study was required in light of currently available information (incremental information).

First meeting: September 2007. This meeting developed the foundation for the study. The meeting took place over three days and involved about 60–70 people, including NGOs, 10 government ministries, and academia. It built government ownership of the study; strengthened partnerships with the Ministries of Foreign Affairs, Science and Technology, and Environment; and helped to establish the study as an interactive process taking place in Brazil's public sphere. Local experts presented their views on the study design at the meeting.

Second meeting: April 2008. A presentation was made to the special committee tasked with preparing a national climate change plan in a one-day event that involved key local experts. Important feedback was gleaned at this meeting that also discussed inclusion of a legality scenario: What are climate mitigation gains if all relevant laws are enforced? The team was tasked with delivering early results to the committee for their feedback.

Third meeting: March 2009. A presentation was made of the emerging results to representatives of 10 ministries.

Series of Consultations: October 2009-March 2010. Technical details, final results and recommendations were widely discussed with representatives of several ministries and agencies, leading to a better understanding among government authorities and a significant improvement of conclusions.

Adapted from: "Low Carbon Growth Country Studies—Getting Started: Experience from Six Countries." Briefing Note 001/09. Energy Sector Management Assistance Program.

This national low carbon scenario does not explore all possible mitigation options or represent a recommended mix. Instead, it simulates the combined result of all prioritized measures examined under this study. It should be considered as a menu of options and not prescriptive since the political economy between sectors or regions may differ significantly making some mitigation options that at first appear more expensive easier to harvest than others that initially may appear more economically attractive.

The national low carbon scenario presented below reduces estimated gross GHG emissions by 37 percent over the 2010-30 projected period when compared to the reference scenario,[15] avoiding more than 11.1 Gt CO_2e. Projected gross

[15] See note 4.

Table 4: Sectoral Emissions Distribution in the Reference and Low Carbon Scenarios, 2008–30

	REF. SCENARIO 2008		REF. SCENARIO 2030		LOW CARBON SCENARIO, 2030	
	($MtCO_2e$)	%	($MtCO_2e$)	%	($MtCO_2e$)	%
Energy	232	18	458	27	297	29
Transport	149	12	245	14	174	17
Waste	62	5	99	6	18	2
Deforestation	536	42	533	31	196	19
Livestock	237	18	272	16	249	24
Agriculture	72	6	111	6	89	9
Total	**1,288**	**100**	**1,718**	**100**	**1,023**	**100**
Carbon uptake	-29	(2)	-21	(1)	-213	(21)

emissions in 2030 are 40 percent lower in the low carbon scenario (1,023 Mt CO_2e per year) than the reference scenario (1,718 Mt CO_2e per year) and 20 percent lower than total emissions in 2008 (1,288 Mt CO_2e per year; Table 4; Figure 10).

Measures to reduce deforestation and increase carbon uptake proved to be the most effective to reduce emissions in the low carbon scenario. Deforestation could be reduced by more than 80 percent by 2017, compared to the 1996–2005 average, and would ensure compliance with Brazil's recent voluntary commitment to reduce both deforestation and national emissions. The implementation of forest plantations and the recovery of legal reserves could further sequester the equivalent of 16 percent of reference scenario emissions in 2030 (213 Mt CO_2e per year).[16]

In the energy and transport sectors, it is more difficult to reduce emissions since they are already low by international standards. As a result, these sectors' relative share of national emissions increases more in the low carbon scenario than in the reference scenario (Figure 11).

FINANCING

In addition to the financial incentives detailed above, the investment needed to implement the low carbon options would be more than twice the level of investments required in the reference scenario; about US$725 billion in real terms versus US$336 billion over 2010–30. Of this, US$344 billion is needed for the energy sector, US$157 billion for land use and land-use change, US$141 billion for transport, and US$84 billion for waste management (Table 5). Overall this represents an average of US$20 billion in added annual investments. This is equivalent to less than 10 percent of national investments in 2008 (about 19 percent of GDP[17]), less than half the US$42 billion in loan disbursements by the Brazilian Development Bank in 2008, and two-thirds of the US$30 billion foreign direct investment in 2008.

Public and private investments are needed to implement the reference and low carbon scenarios. Under both scenarios, the transport and waste sectors require

[16] If the carbon uptake from the natural regrowth of degraded forests were to be included, then the potential uptake would increase by 112 Mt CO_2 per year on average, thus reducing the net emissions.

[17] GDP of US$1.573 trillion per the CIA the World Factbook.

Figure 10: GHG Mitigation Wedges in the Low Carbon Scenario, 2008–30

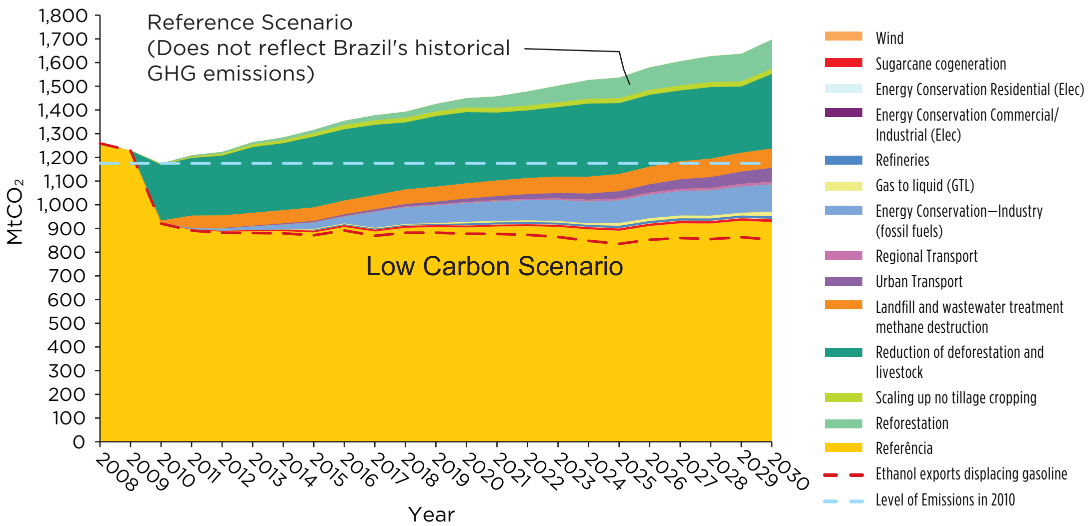
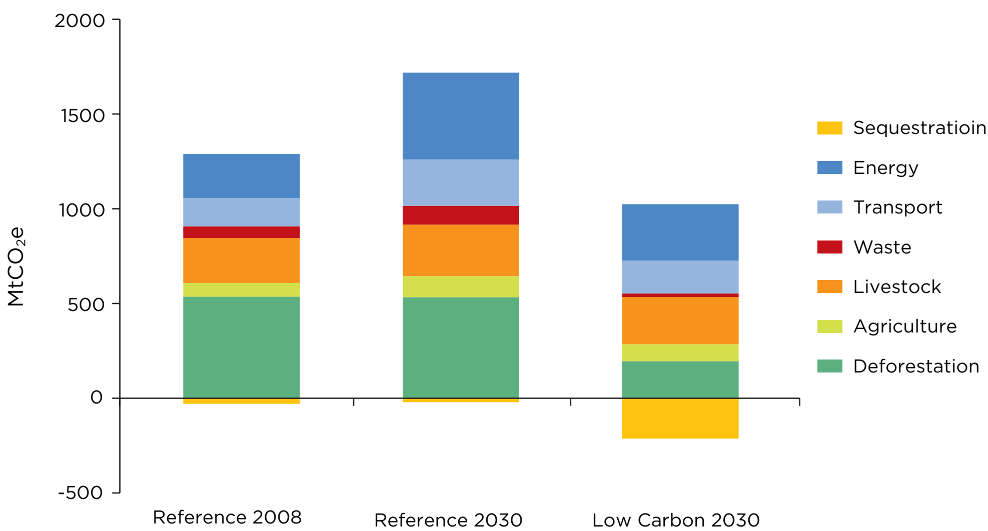


Figure 11: Comparing Gross Emissions Distribution among Sectors in the Reference and Low Carbon Scenarios, 2008–30



higher levels of private sector investments than today while the energy sector continues to benefit from significant public sector participation. For land use, public sector intervention would be required to reduce emissions from deforestation, albeit in the form of special funds like the Amazon Fund, and for legal enforcement while increased livestock productivity relies on better access to both public and private sector financing. Public sector enforcement and potentially greater private sector participation are needed to support forest restoration for compliance with the Legal Reserve Law.

Incentives would be needed to mobilize private sector investment in low carbon measures. The transport sector requires the greatest amount of annual incentives

Table 5: Comparing Sectoral Investment Requirements for the Reference and Low Carbon Scenarios, 2010-30

SECTOR/ ABATEMENT MEASURE	ABATEMENT POTENTIAL ($MtCO_2e$)	ANNUAL ABATEMENT POTENTIAL ($MtCO_2e$)	REFERENCE-SCENARIO INVESTMENT (BILLION US$)	LOW CARBON SCENARIO INVESTMENT (BILLION US$)	LOW CARBON INVESTMENT DIFFERENTIAL (BILLION US$)	ANNUAL DIFFERENTIAL (BILLION US$)
Land Use and Land-Use Change						
Reforestation	1,085	52	-	54.140	54.140	2.578
Scaled-up zero-tillage cropping	355	17	0.215	0.153	(0.062)	(0.003)
Avoided deforestation plus livestock	6,041	288	41.845	102.420	60.575	2.885
Total Land Use and Land-Use Change	**7,481**	**356**	**42.060**	**156.713**	**114.653**	**5.460**
Energy						
Electricity generation						
Transmission line (Brazil-Venezuela)	28	1	1.676	0.455	(1.221)	(0.058)
Sugar-cane cogeneration	158	8	16.756	52.264	35.508	1.691
Wind	19	1	4.287	12.898	8.611	0.410
Electricity conservation						
Residential solar heater	3	0	3.439	4.605	1.166	0.056
Residential lighting	3	0	0.903	1.197	0.294	0.014
Refrigerators (air conditioning)	10	0	42.734	48.785	6.051	0.288
Commercial lighting	1	0	0.265	0.748	0.483	0.023
Electric motors	2	0	3.399	4.601	1.202	0.057
Industrial lighting	1	0	0.108	0.286	0.178	0.008
Recycling	75	4	-	0.249	0.249	0.012
Fossil-fuel production						
Gas-to-liquid (GTL)	128	6	2.310	6.986	4.676	0.223
New refineries	52	2	116.753	120.908	4.155	0.198
Existing refineries (energy integration)	52	2	-	4.028	4.028	0.192
Existing refineries (incrustation control)	7	0	-	-	-	
Existing refineries (advanced controls)	7	0	-	1.492	1.492	0.071
Fossil-fuel conservation						
Combustion optimization	105	5	-	2.215	2.215	0.105
Heat-recovery system	19	1	-	0.323	0.323	0.015
Steam-recovery system	37	2	-	0.819	0.819	0.039
Furnace heat-recovery system	283	13	-	8.074	8.074	0.384
New industrial processes	135	6	-	37.995	37.995	1.809
Other energy-efficiency measures	18	1	-	0.827	0.827	0.039
Fossil-fuel substitution						
Solar thermal energy	26	1	-	1.482	1.482	0.071
Renewable charcoal displacement of nonrenewable charcoal	567	27	-	8.794	8.794	0.419
Natural gas displacement of other fuels	44	2	-	4.088	4.088	0.195
Ethanol exports displacement of gasoline abroad	667	32	3.817	19.680	15.863	0.755
Total Energy	**2,447**	**117**	**196.447**	**343.799**	**147.352**	**7.017**
Transport						
Regional						
Ethanol displacement of domestic gasoline	176	8	9.992	20.158	10.166	0.484
Rail and waterways investment vs. roads	63	3	32.074	41.707	9.633	0.459
Bullet train (São Paulo-Rio de Janeiro)	12	1	-	28.759	28.759	1.369
Urban		***0***				
Metro and bus rapid transit (BRT)	174	8	6.562	49.182	42.620	2.030
Traffic optimization	45	2	-	1.050	1.050	0.050
Bike lane investment	17	1	-	0.303	0.303	0.014
Total Transport	**487**	**23**	**48.628**	**141.159**	**92.531**	**4.406**
Waste Management						
Landfill methane destruction	963	46	1.984	5.687	3.703	0.176
Wastewater treatment plus methane destruction (residential and commercial)	116	6	40.075	41.678	1.603	0.076
Wastewater treatment plus methane destruction (ind.)	238	11	7.314	36.569	29.255	1.393
Total Waste Management	**1,317**	**63**	**49.373**	**83.934**	**34.561**	**1.646**
Total	**11,732**	**559**	**336.508**	**725.605**	**389.097**	**18.528**

Note: Excludes Air Conditioning and BRT alone.

on average (approximately US$9 billion) compared to energy (US$7 billion), waste (US$3 billion), and LULUCF (US$2.2 billion; Figures 12, 13). Most energy efficiency measures would not require additional incentives. Specific financing instruments and new sources of finance would be required to successfully promote the implementation of low carbon measures.

IMPLEMENTATION CHALLENGES

The implementation of a national low carbon scenario faces a number of challenges.

Land Use and Land-Use Change. Four main challenges and areas require support:

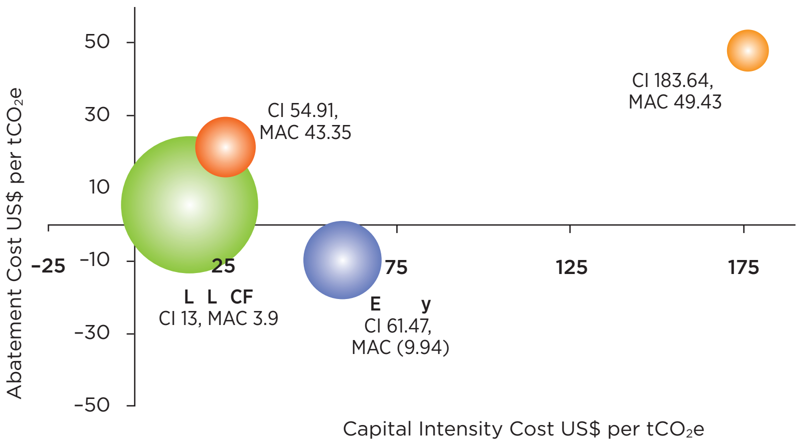
- *Productive livestock systems* are capital-intensive at the investment stage and in terms of working capital. Farmers and the banking system need financial incentives and more flexible lending terms to implement the low carbon scenario. An order of mangnitude estimate of the volume of incentives required is US$1.6 billion per year or US$34 billion during 2010–30.
- *Extension services* require intensive development.
- *Rebound effect.* Improved livestock productivity might trigger increased production of meat and the conversion of more native forest into pasture. This risk is especially high in areas where new roads have been opened or paved. Incentives need to be selective, especially in the Amazon region. Incentives should be clearly established, based on valid and georeferenced land ownership title, and include conditions regarding land conversion.
- *Carbon leakage.* For example, replanting forest under the Legal Reserve Law would remove a large amount of CO_2 from the atmosphere but the area would not be available for other activities. An equivalent additional amount of pasture, therefore, needs to be freed up to avoid reducing production or the destruction of native forest elsewhere. A more flexible legal obligation for forest reserves could make the goal of accommodating all agriculture, livestock, and forestry activities without deforestation less difficult but it might also mean less carbon uptake.

Energy. Significant effort is needed to implement measures in the reference and low carbon scenarios:

- *Generation.* PNE 2030 projects that hydroelectricity will represent more than 70 percent of power generation in 2030; hydropower generation capacity will need to increase at a pace not yet observed. The environmental licensing process has constrained the participation of hydro-energy at new energy auctions and fossil fuel-based generation has increased as a result. Licensing processes would need to be improved.[18]
- *Transmission.* The main barrier for bagasse cogeneration and wind energy is the cost of interconnecting with the sometimes distant or capacity-constrained subtransmission grid. If this cost continues to be fully borne by the respective

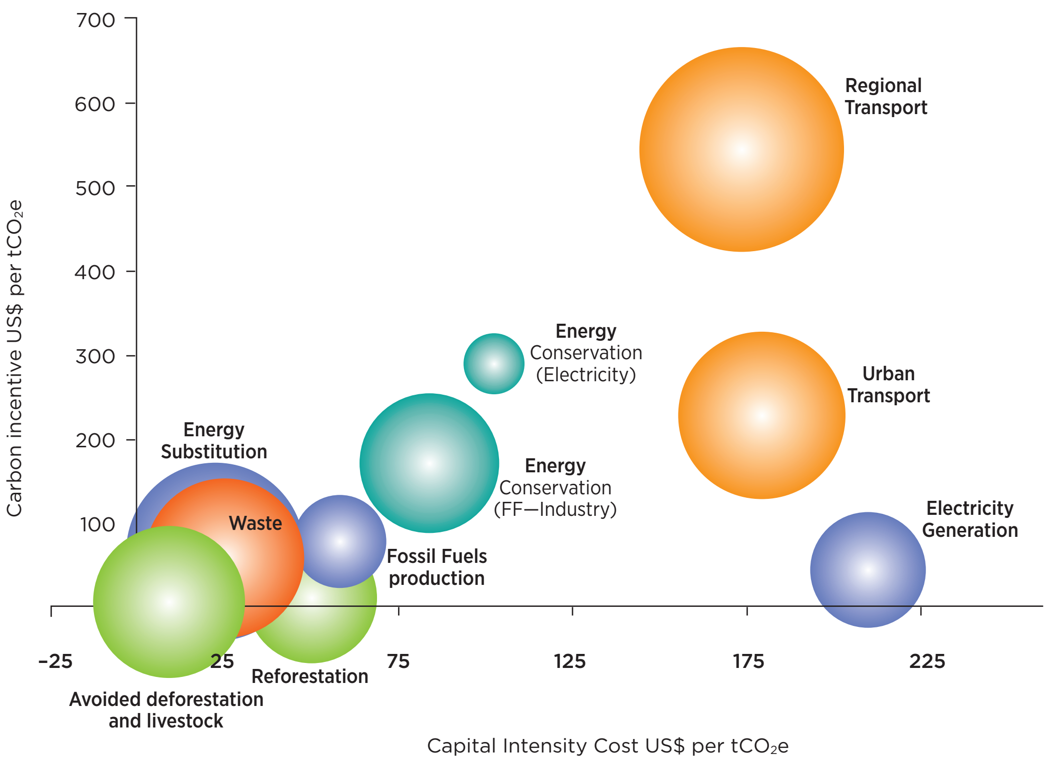
[18] See "Environmental Licensing for Hydroelectric Projects in Brazil: A Contribution to the Debate," Summary Report. World Bank Country Management Unit, March 28, 2008.

Figure 12: Evaluating Marginal Abatement Costs, Capital Intensity, and Potential for Emissions Reduction, by Sector



Note: Bubble size corresponds to the amount of avoided emissions.

Figure 13: Evaluating Required Incentives and Capital Intensity, by Subsector



Note: Bubble size corresponds to the sum of annual incentive plus annual incremental investment required in US$.

sugar mills and wind-farm developers, the contribution of cogeneration and wind energy will likely remain low, resulting in the entry of more fossil fuel–based alternatives. The key question is how to finance the required grid connection. An ambitious smart-grid development program would help to optimize the exploration of this promising but distributed low carbon generation potential.

- *Energy Efficiency.* Progress has been made in implementing the energy efficiency law and a number of existing mechanisms address the needs of all consumer groups (e.g., PROCEL, CONPET, and EPE planned auctions). These initiatives offer the possibility of creating a sustainable energy-efficiency market. Key issues to address are: price distortions that introduce disincentives for energy conservation and the separation of the energy-efficiency efforts of power and oil-and-gas institutions. Better institutional coordination might be achieved via a committee responsible for the development of both programs.

Transport. The main challenges for urban transport center on financing constraints and institutional coordination. Over 5,000 municipalities independently administer transportation systems, making it difficult to harmonize nationwide plans and policies, and urban mass transport systems are capital intensive. Public-private partnerships (PPPs) could be one option to overcome financing constraints.

Better integration and improved partnerships are needed among rail concessionaires and between concessionaires and government (including regulatory authorities) to promote regional transport measures. Most transport modes are operated by the private sector and public support is needed to ensure efficient integration and the construction of new infrastructure and terminals. Adequate planning, resource allocation and measures to facilitate large investment financing are needed to build and adapt intermodal transfer projects and mitigate negative impacts (e.g., when opening new roads in Amazon forests).

The key challenge for switching from gasoline by bio-ethanol fuel is the alignment of market price signals since most new cars produced in Brazil are flex-fuel vehicles. A financial mechanism needs to be designed and implemented to absorb oil price shocks and maintain the attractiveness of ethanol for vehicle owners.

Waste Management. Institutional complexities and decentralized structures make it more difficult to leverage large financial resources. Intermunicipal coordination, clear regulations, and PPPs, as well as the continuation of carbon-based incentives for landfill gas recovery/use are needed to scale up the collection, treatment, and disposal of waste and avoid emissions.

Brazil harbors large opportunities for GHG emissions mitigation and carbon uptake and is thus a key player in tackling global climate challenges. ***The Brazil Low Carbon Country Case Study*** demonstrates technically feasible measures to reduce overall GHG emissions. Yet implementing these proposed measures would require large volumes of investment and incentives, which may exceed a strictly national response and require international financial support. Moreover, for Brazil to harvest the full range of opportunities to mitigate GHG emissions, market mechanisms would not be sufficient. Public policies and planning would be pivotal, with management of land competition and forest protection at the center.

ACRONYMS AND ABBREVIATIONS

BLUM	Brazil Land Use Model
BRT	Bus Rapid Transit
C	Carbon
Ce	Carbon equivalent
CETESB	São Paulo State Waste Management Agency (Companhia de Tecnologia de Saneamento Ambiental)
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CONPET	National Program for the Rationalization of the Use of Oil and Natural Gas Derivatives (Programa Nacional de Racionalização do Uso dos Derivados de Petróleo e Gás Natural)
COPERT	Model to calculate air pollutant emissions from transport
COPPE	Post-graduate engineering programs coordination
EMBRAPA	Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agrícola)
EPE	Energy planning company (Empresa de Planejamento Energético)
ESMAP	Energy Sector Management Assistance Program
GDP	Gross domestic product
GHG	Greenhouse gas
Gt	Billions of tons
GTL	Gas-to-liquid
ha	Hectare
HFC	Hydrofluorocarbon
INPE	National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais)
INT	National Technological Institute (Instituto Nacional de Tecnologia)
IO	Input-output
km^2	Square kilometer
LULUCF	Land use, land-use change, and forestry
MAC	Marginal abatement cost
MACC	Marginal abatement cost curve
MAED	Model for Analysis of Energy Demand
MESSAGE	Systems engineering optimization model
Mt	Millions of tons
N_2O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PFC	Perfluorocarbon
PNE	National Energy Plan (Plano Nacional de Energia)
PNMC	National Plan on Climate Change (Plano Nacional sobre Mudança do Clima)
PPP	Public-private partnership
PROCEL	National Electrical Energy Conservation Program (Programa de Combate ao Desperdício de Energia Elétrica)
SF_6	Sulphurhexafluoride
SIM Brazil	Simulate Brazil
t	Tonnes
TRANSCAD	Planning and travel demand model
UFMG	Federal University of Minas Gerais (Universidade Federal de Minas Gerais)
UNDP	United Nations Development Programme
UNICAMP	State University of Campinas
US$	United States dollar
USP	University of São Paulo

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