Executive Summary

Brazil's commitment to combat climate change had already begun when the country hosted the United Nations Conference on Environment and Development, also known as the Rio Earth Summit, in June 1992. The resulting United Nations Framework Convention on Climate Change (UNFCCC) led to the creation of the Kyoto Protocol. Today, Brazil remains strongly committed to voluntarily reducing its carbon emissions. On December 1, 2008 President Luiz Inácio Lula da Silva launched the National Plan on Climate Change (PNMC), based on work of the Interministerial Committee on Climate Change, in collaboration with the Brazilian Forum on Climate Change and civil society organizations. The PNMC calls for a 70-percent reduction in deforestation by 2017, a particularly noteworthy goal given that Brazil has the world's second largest block of remaining native forest. On December 29, 2009 the Brazilian Parliament adopted Law 12.187, which institutes the National Climate Change Policy of Brazil and set a voluntary national greenhouse gas reduction target of between 36.1% and 38.9% of projected emissions by 2020.

As the world's largest tropical country, Brazil is unique in its greenhouse gas (GHG) emissions profile. **In prior decades, the availability of large volumes of land suitable for crop cultivation and pasture helped to transform agriculture and livestock into key sectors for sustaining the country's economic growth**. In the past decade alone, these two sectors accounted for an average of 25 percent of national GDP. The steady expansion of crop land and pasture has also required the conversion of more native land, **making land-use change the country's main source of GHG emissions today. At the same time, Brazil has used the abundant natural resources of its vast territory to explore and develop low-carbon renewable energy.**

Currently, per capita fossil fuel–based emissions in Brazil are much lower than those in other countries,[1] owing to the large role of renewable-energy sources for electricity and fuels. Hydropower represents more than three-fourths of installed electricity generation capacity, while ethanol substitutes for two-fifths of gasoline fuel. **Without the historically large investments in renewable energy, Brazil's current energy matrix would be far more carbon intensive. If Brazil's energy matrix reflected the worldwide average, energy-sector emissions would presumably be twice as high and total national emissions 17 percent greater. The energy and transport sectors in Brazil are, thus, already widely based on low-carbon alternatives and current efforts to keep the energy matrix clean must be acknowledged. However, the maintenance of a low-carbon development path in Brazil will continue to require larger investments in low-carbon options and additional measures to reduce emissions in the Brazilian energy sector may require increased efforts.**

Yet Brazil used to be one of the largest GHG emitters from deforestation and would probably continue to be so if not for the government's recent adoption of a series of measures to protect the forest. Although drastically reduced in recent years, deforestation could continue to be a potentially large emission source in the future. Exacerbating this outlook are expected growth in carbon-intensive sources of electric power, accelerated use of diesel-based transport, and a larger volume of methane (CH_4) emissions from expanded landfill development.

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1   Fossil fuel–based emissions amount to about 1.9 tCO_2 per year per capita or less than one-fifth of the OECD country average.

At the same time, Brazil is likely to suffer significantly from the adverse effects of climate change. Some advanced models suggest that much of the eastern part of the Brazilian Amazon region could be converted into a savannah-like ecosystem before the end of this century. A phenomenon known as the Amazon dieback, combined with the shorter-term effects of deforestation by fires, could reduce rainfall in the Central-West and Northeast regions, resulting in smaller crop yields and less available water for hydropower-based electricity[2]. Urgent solutions are thus needed to reduce Brazil's vulnerability to climate change **and to enable the implementation of adaptation actions in the country**.

Like many other developing countries, Brazil faces the dual challenge of encouraging development and reducing GHG emissions. President Lula echoed this concern in his introduction to the National Plan, stating that actions to avoid future GHG emissions should not adversely affect the development rights of the poor, who have done nothing to generate the problem. Efforts to mitigate GHG emissions should not add to the cost of development, but there are strong reasons to shift toward a low-carbon economy. Low-carbon alternatives would offer important development co-benefits, ranging from reduced congestion and air pollution in urban transport areas to better waste management, jobs creation and costs savings for industry, and biodiversity conservation. Countries that pursue low-carbon development are more likely to benefit from strategic and competitive advantages, such as the transfer of financial resources through the carbon market, new international financing instruments, and access to emerging global markets for low-carbon products. In the future this may create a competitive advantage for the production of goods and services, due to the lower emission indexes associated with the life cycle of products.

Study Overview

The overall aim of this study was to support Brazil's efforts to identify opportunities to reduce its emissions in ways that foster economic development. The primary objective was to provide the Brazilian government the technical inputs needed to assess the potential and conditions for low-carbon development in key emitting sectors.

To this end, the World Bank study adopted a programmatic approach in line with the Brazilian government's long-term development objectives, as follows: (i) anticipate the future evolution of Brazil's GHG emissions to establish a reference scenario; (ii) identify and quantify lower carbon-intensive options to mitigate emissions, as well as potential options for carbon uptake; (iii) assess the costs of these low-carbon options, identify barriers to their adoption, and explore measures to overcome them; and (iv) build a low-carbon emissions scenario that meets the same development expectations. The team also analyzed the macroeconomic effects of shifting from the reference scenario to the low-carbon one and the financing required.

To build on the best available knowledge and avoid duplicate effort, the study team undertook a broad consultative process, meeting with more than 70 recognized Brazilian experts, technicians, and government representatives covering most emitting sectors and surveying the copious literature available. This preparatory work informed the selection of four key areas with a large potential for low-carbon options: (i) land use, land-use change, and forestry (LULUCF), including deforestation; (ii) transport systems; (iii) energy production and use, particularly electricity and oil and gas; and (iv) solid and liquid urban waste.[3]

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2   "Assessment of the Risk of Amazon Dieback," World Bank, 2010.
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 by this study. Without a recent

In order to estimate the emissions Brazil would generate in these four key areas over the study period, the study team defined a "reference scenario" that is later compared with the projected "low-carbon scenario". It is worth noting that the reference scenario is based on a different methodology than the one used by the Brazilian government in its national GHG inventory. In particular, having focused on these four areas, the reference scenario built by this study does not cover 100 percent of all emission sources of the country and therefore, should not be considered as a simulation of future national emissions inventories.

Since the objective of this study was not to simulate the future development of the Brazilian economy or to question the government's stated development objectives, this study has adhered, to the extent possible, to existing government plans to establish the reference scenario. Therefore, the 2030 National Energy Plan (PNE 2030), published by the Ministry of Mines and Energy (MME) in 2007, was adopted as the reference scenario for the energy sector. The study also took into account of Brazil's Government Accelerated Growth Plan (PAC) and the National Logistic and Transport Plan (PNLT), launched in 2007, and other policies and measures in other sectors that were already published by the time the reference scenario was established[4]. Where long term planning publications were unavailable, the team built its own reference scenarios, using sector models developed or adapted for the project, consistent with the main assumptions of the PNE 2030. Key interfaces (e.g., determining the land needed for solid and liquid biofuels production in the transport and energy sectors) were addressed jointly by the teams in charge of these sectors and the land-use modeling.

Reference-scenario results for these main areas show that deforestation remains the key driver of Brazil's future GHG emissions through 2030. Modeling results indicate that, after a slight decrease in 2009–11, deforestation emissions are expected to stabilize at an annual rate of about 400–500 Mt CO_2. Even so, the relative share declines to about 30 percent as emissions from the energy, transport, and waste-management sectors continue to grow. Since transport and energy consumption are both functions of economic growth, certain subsectors dependent on fossil fuels (e.g., urban bus systems or thermal power generation and industrial processes) have high emissions growth; for subsectors that depend on energy forms with a lower carbon intensity (e.g., bioethanol-powered vehicles or hydropower-generated electricity), levels of emission remain relatively stable. An annex of maps and an electronic database detail the results of the study by state.

Land Use and Land-use Change: Toward a New Dynamic

Despite its significant decline in the past four years, deforestation remains Brazil's largest source of carbon emissions, representing about two-fifths of national gross emissions (2008). Over the past 15 years, deforestation has contributed to reducing Brazil's

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 percent of total Kyoto GHG emissions. Not all agriculture activities were taken into account when estimating emissions from that sector; crops taken into account in the calculation of the emissions from agriculture 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 officially announced by the Brazilian Government in 2009 along with the voluntary commitment to reduce emissions, which are reflected in law 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. Noticably, the reference scenario was defined before the elaboration of the National Plan on Climate Change (PNMC) and the adoption of Law 12.187, which institutes the National Climate Change Policy of Brazil and set a voluntary national greenhouse gas reduction target.

carbon stock by about 6 billion metric tons, the equivalent of two-thirds of annual global emissions.[5] Without the Brazilian government's recent forest protection efforts, the current emissions pattern from deforestation would be significantly higher.[6] The drivers of deforestation occur at multiple levels. In the Amazon and Cerrado regions, for example, the spatial dynamics of agricultural and livestock expansion, new roads, and immigration determine the pattern of deforestation. At a national or international scale, broader market forces affecting the meat and crop sectors drive deforestation.

Agricultural production and livestock activities also produce direct emissions, together accounting for one-fourth of national gross emissions. Agricultural emissions mainly result from the use of fertilizer and mineralization of nitrogen (N) in the soil, cultivation of wetland irrigated rice, the burning of sugar cane, and use of fossil fuel–powered agricultural equipment. Livestock emissions result mainly from the digestive process of beef cattle, which releases of methane (CH_4) into the atmosphere.

Models and Reference-scenario Results

To estimate future demand for land and LULUCF emissions, the study developed two complementary models: i) Brazilian Land Use Model (BLUM) and (ii) Simulate Brazil (SIM Brazil). BLUM is an econometric model that estimates the allocation of land area and measures changes in land use resulting from supply-and-demand dynamics for major competing activities.[7] SIM Brazil, a geo-referenced spatialization model, estimates future land use over time under various scenarios. SIM Brazil does not alter BLUM data; it finds a place for land-use activities, taking into account such criteria as agricultural aptitude, distance to roads, urban attraction, cost of transport to ports, declivity, and distance to converted areas. SIM Brazil works at a definition level of 1 km^2, making it possible to generate detailed maps and tables.

Under the reference scenario, about 17 million ha of additional land are required to accommodate the expansion of all activities over the 2006–30 period. In Brazil as a whole, the total area allocated to productive uses, estimated at 257 million ha in 2008, is expected to grow 7 percent—to about 276 million ha—in 2030; 24 percent of that growth is expected to occur in the Amazon region. In 2030, as in 2008, pastures are expected to occupy most of this area (205 million ha in 2008 and 207 million in 2030). Growth of this total amount over time makes it necessary to convert native vegetation to productive use, which mainly occurs in frontier regions, the Amazon region, and, on a smaller scale, in Maranhão, Piaui, Tocantin, and Bahia.

To estimate the corresponding balance of annual emissions and carbon uptake over the next 20-year period, these and related models calculated land use and land-use change for each 1-km^2 plot at several levels.[8] Results showed that land-use change via deforestation accounts for the largest share of annual LULUCF emissions—up to 533 Mt CO_2e by 2030. Direct annual emissions from land use only (agriculture and livestock) increase over the period, with an average annual rate of 346 Mt CO_2e. Carbon uptake offsets less than 1 percent of gross LULUCF emissions, sequestering 29 Mt CO_2e in 2010, down to 20 Mt CO_2e in 2030. Over the 20-year period, LULUCF gross emissions increase one-fourth, reaching 916 Mt CO_2e by 2030. **The**

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

6   After peaking at 27,000 km^2 in 2004, deforestation rates have declined substantially, falling to 11,200 km^2 in 2007, the second lowest historical rate recorded by the PRODES deforestation observation program (INPE 2008).

7   These include six key crops (soybean, corn, cotton, rice, bean, and sugar cane), pasture, and production forests; the model also projects demand for various kinds of meat and corresponding needs for chaff and corn.

8   Microregion, state, and country.

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net balance between land use, land-use change, and carbon uptake results in increased emissions, which reach about 895 Mt CO$_2$e annually by 2030[9].

Low-carbon Options for Emissions Mitigation

Avoiding deforestation offers by far the largest opportunity for GHG mitigation in Brazil. Under the resulting low-carbon scenario, avoided emissions from deforestation would amount to about 6.2 Gt CO$_2$e over the 2010–30 period, or more than 295 Mt CO$_2$e per year.

Brazil has developed forest-protection policies and projects to counter the progression of pressure at the frontier and is experienced in economic activities compatible with forest sustainability. **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.**

To drastically reduce deforestation, this study proposed a dual strategy: (i) eliminate the structural causes of deforestation and (ii) protect the forest from illegal attempts to cut. 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 (chapter 7). **The potential to release and recover degraded pasture is enough to accommodate the most ambitious growth scenario**.

The combination of reducing pasture area and protecting forests can lead to a sharp decline in deforestation emissions. This was demonstrated in 2004–07, when new forest-protection efforts, combined with a slight contraction in the livestock sector and resultant pasture area,[10] led to a 60-percent reduction in deforestation (from 27,000 km^2 to 11,200 km^2). **Such a rapid reduction resulted from deforestation and its associated emissions being related to the *marginal expansion* of land for agriculture and livestock activities,[11] without which there would be no need to convert additional native vegetation and incidentally generate GHG emissions. If the effort to reduce pasture area and protect forests were neglected, emissions from deforestation would resume immediately. To protect against illegal cuts, the forest should be further protected against fraudulent interests**. The Brazilian government has made considerable efforts in this area, particularly under the 2004 Plan of Action for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAM).

Model-based projections indicate that, under the new land-use dynamic, deforestation would be reduced by more than two-thirds (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,

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9   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 109MtCO2 per year, thus reducing the net emissions.

10   The 2005–07 period witnessed the first decline in herd size (from 207 million to 201 million head), 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.

respectively. **Accordingly, in 2030, annual emissions from deforestation would be reduced nearly 63 percent (from about 530 Mt CO_2 to 190 Mt CO_2) compared to the *projected* reference scenario. In the Amazon, the level of deforestation would fall quickly to about 17 percent of the historic annual average of 19,500 km^2 *observed* in the recent past, thus complying with the PNMC goal of reducing deforestation in the Amazon region by 72% by 2017**[12].

The study also proposed ways to reduce direct emissions from agricultural production and livestock activities. For agriculture, the study proposed an accelerated dissemination of zero-tillage cultivation. Compared to conventional farming systems, zero-tillage involves far fewer operations and can thus reduce emissions caused by altering soil carbon stock and using equipment powered by fossil fuels. Done effectively, zero-tillage cultivation can help control soil temperature, improve soil structure, increase soil water-storage capacity, reduce soil loss, and enhance the nutrient retention of plants. For these reasons, expansion of zero-tillage cultivation is accelerated in the low-carbon scenario, reaching 100 percent by 2015 and delivering 356 Mt CO_2e of avoided emissions over the 2010–30 period.

To lower direct emissions from beef-cattle farming, the study proposed shifting to more intensive meat-production systems, as mentioned above. **It also proposed genetic-improvement options to reduce CH_4, including improved forage for herbivores and genetically superior bulls**, which have a shorter life cycle. The study projects that the combination of improved forage and bulls, along with increased productivity, would reduce direct livestock emissions from 272 to 240 Mt CO_2 per year by 2030; that is, maintain them close to the 2008 .

The study also explored two major carbon uptake options: (i) recovery of native forests and (ii) production forests for the iron and steel industry . For forest recovery, the low-carbon scenario considered compliance with legal actions for mandatory reconstitution, in accordance with the laws of riparian forests and legal reserves.[13] In this sense, the low-carbon scenario engendered a "Legal Scenario." Using these defined areas for reforestation, the study modeled their potential for CO_2 removal.[14] Results showed that the Legal Scenario has a high carbon-uptake potential: a cumulative total of 2.9 Gt CO_2e over the 20-year period or about 140 Mt CO_2e per year on average[15]. For production forests, the reference scenario assumed that the thermo-reduction process would be based on coke (66 percent), non-renewable plant charcoal (24 percent), and renewable plant charcoal (10 percent). The low-carbon scenario assumed total substitution of non-renewable plant charcoal by 2017 and use of renewable plant charcoal for up to 46 percent of total production of iron and steel ballast by 2030; the volume of sequestered emissions would total 377 Mt CO_2 in 2030, 62 Mt CO_2 more than in the reference scenario.

A New Dynamic for Land Use

Building a low-carbon scenario for land use involves more than adding emissions reductions associated with mitigation opportunities; it must also avoid the potential for carbon leakage. For example, increasing forest recovery leads to carbon uptake, but it also

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12   Over the 1996–2995 period, the historical rate of deforestation in the Amazon region was 1.95 million ha per year, according to the PNMC.

13   In areas with optimal conditions, forest recovery can remove 100 tC per ha on average in the Amazon Region. (Saatchi, 2007). In the reference scenario, its contribution is limited in terms of quantity.

14   The study model used meteorological and climatic variables (e.g., rainfall, dry season, and temperature) and edaphic (soil and topography) variables to estimate potential biomass.

15   If the carbon uptake from the natural regrowth of degraded forests were to be included, then the potential uptake would increase by 112MtCO2 per year on average.

reduces the land area otherwise available for expanding agriculture and livestock activities. This, in turn, could provoke an excess in demand for land use, which could generate deforestation, inducing a lower net balance of carbon uptake. To avoid a carbon leakage, ways must be found to reduce the global land demand for other activities, while maintaining the same level of products supply found in the reference scenario.

In the low-carbon scenario, the amount of additional land required for emissions mitigation and carbon uptake totals more than 53 million ha. Of that amount, more than 44 million ha—over twice the land expansion projected under the reference scenario—is for forest recovery. Together with the additional land required under the reference scenario, the total volume of additional land required is more than 70 million ha, more than twice the total amount of land planted with soybean (21.3 million ha) and sugar cane (8.2 million ha) in 2008 or more than twice the area of soybean projected for 2030 in the reference scenario (30.6 million ha) (table 1).

Table 1: Summary of Additional Land Needs in the Reference and Low-carbon Scenarios

Scenario	Additional land needed (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 non-renewable 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 additional hectares***

To increase livestock productivity to the level needed to release the required volume of pasture, the low-carbon scenario considered three options: (i) promote recovery of degraded pasture, (ii) stimulate the adoption of productive systems with feedlots for finishing, and (iii) encourage the adoption of crop-livestock systems. The increased carrying capacity that results from recovery of degraded areas, combined with more intensive integrated crop-livestock systems and feedlots for finishing are reflected in an accentuated reduction in demand for land, projected at about 138 million ha in the low-carbon scenario, versus 207 million ha in the reference scenario, for the year 2030. The difference would be enough to absorb the demand for additional land associated with both expanded agriculture and livestock activities in the reference scenario and expanded mitigation and carbon uptake in the low-carbon scenario.

Energy: Sustaining a Green Energy Matrix

The intensity of GHG emissions in Brazil's energy sector is comparatively low by international standards, owing to the significant role of renewable energy in the national energy matrix. Renewable energy accounts for nearly half of Brazil's domestic energy supply—more than three-quarters of it provided by hydroelectricity (MME 2007). In 2005, the country's energy sector accounted for just 1.2 percent of the world's 27 Gt CO_2, of fossil-fuel emissions, corresponding to an annual average per capita of 1.77 tCO_2, significantly less than annual global (4.22 tCO_2) and OECD-country (11.02 tCO_2) per-capita averages (IEA 2007). In 2010, emissions from energy production and consumption, excluding transport, represented about one-fifth of national emissions.

Reference Scenario: 97-percent Increase in Emissions

The PNE 2030, on which the sector reference scenario is based, reflects recent sector policies and basic market tendencies and features, including the dynamics of incorporating technology and the evolution of supply and demand[16]. The view toward long-term technical and economic consistency renders the PNE 2030 an important tool for creating the energy-sector reference scenario; however, for circumstantial reasons, (i.e. adverse hydrological conditions), Brazil's higher use of thermoelectric power in recent years was anticipated by the PNE 2030. If this were to continue over a longer term, the Brazilian grid's average emissions factor would be greater than that projected by the MME in 2007. If hydroelectricity proves substantially less than predicted, the reference scenario considered in this study would prove conservative.

Although the PNE 2030 assumes greater use of renewable energy sources over the 2010–30 study period, Brazil's energy matrix should result in higher emissions over time under the reference scenario. For 2030, the projected emissions figure, excluding fuels for transport, is just over 458 Mt CO_2, representing a 97-percent increase or more than one-fourth of national emissions. Cumulative sector emissions are estimated at 7.6 Gt CO_2 over the 20-year period.

Low-carbon Mitigation Potential: Less Than 20 Percent

To develop the low-carbon scenario, the study analyzed mitigation options for energy efficiency and fuel switching in industry, refining and gas-to-liquid (GTL), wind-energy generation and bagasse cogeneration, and high-efficiency appliances.[17] Since most of Brazil's main remaining large-hydropower potential will have been fully exploited by 2030 (PNE 2030), the study assumed no further opportunities to significantly reduce emissions via hydropower expansion beyond what was established in the reference scenario. Beyond options to reduce domestic emissions, the study considered two opportunities to reduce emissions abroad: (i) hydro-complementarity (to reduce CO_2 emissions of energy sectors in Brazil and Venezuela) and

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16   The reference scenario adopted in this study, the PNE2030, differs from the emissions projections for the energy sector officially announced by the Brazilian Government in 2009 along with the voluntary commitment to reduce emissions, which are reflected in law 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 in the PNE2030.

17   To avoid double counting, this study considered emissions reductions from vehicular fuel switching as transport-sector emissions reduction.

(ii) large-scale ethanol exports (to reduce fossil-fuel emissions of transport sectors worldwide).

Over the 2010–30 period, cumulative emissions reductions would amount to 1.8 Gt CO$_2$ or less than 25 percent of cumulative emissions of the sector in the reference scenario.[18] If all of the proposed low-carbon mitigation options were implemented, annual energy-sector emissions would be reduced by 35 percent in the year 2030.[19] Not surprisingly, the industrial sector, which still relies heavily on fossil fuels, would account for 75 percent of 2030 reductions (68 Mt CO$_2$ per year), followed by renewable charcoal for the steel industry (31 percent) and biomass cogeneration (9 percent). **Even so, energy-sector emissions under the low-carbon scenario would remain about 28 percent higher in 2030 than in 2008.**

Scaled-up Ethanol Exports: One-third Increase in Mitigation Potential

Brazil's success with bio-ethanol offers an opportunity to reduce global emissions by increasing ethanol exports. It terms of emissions, social costs, and economic production costs, ethanol from sugar in Brazil is superior to alternatives in others countries, reflecting a significant comparative advantage to serve the growing international demand for low-carbon vehicle fuels. Reducing or eliminating the high trade barriers and enormous subsidies currently in place in many countries would produce economic benefits for both Brazil and its trade partners, and reduce GHG emissions. While the size of such exports depends on counterfactual assumptions, this study adopted a 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 (equal to 10 percent of bio-ethanol demand to reach an average target of 20 percent ethanol blend in gasoline worldwide). This target corresponds to the lower bound of a recent study on the feasibility of scaled-up ethanol production for export.[20]

The added emissions reductions achieved via ethanol exports would reach 73 Mt CO$_2$ per year in 2030 and would amount to 667 Mt CO$_2$ over the 2010–30 period or about one-third of the total reduction in energy emissions. The additional ethanol would require increasing the area planted to sugar cane by 6.4 million ha in 2030 (from 12.7 to 19.1 million ha), still less than the current area planted to soybean (22.7 million ha in 2006) and one-tenth the current pasture area (210 million ha).[21] As explained above, it is assumed that, as long as the proposed goals for increasing livestock-raising productivity are met, sugar-cane expansion would not result in deforestation, either directly or indirectly through pasture expansion, and sugar-cane production would not occur on conservation lands.

Transport: Modal Shifts and Fuel Switching

Brazil's **transport sector has a lower carbon intensity compared to that of other countries because of the widespread use of ethanol as a fuel for vehicles.** Still, the transport sector accounts for more than half of the country's total fossil-fuel consumption. In 2008, the sector emissions were about 149 Mt CO$_2$e, representing 12 percent of national emissions.

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18   Excluding 667 Mt CO$_2$ of avoided emissions from ethanol exports and 28 Mt CO$_2$ from the transmission line between Venezuela and Brazil.

19   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.

20   NIPE/UNICAMP report for CGEE/MCT, Campinas, December 2007.

21   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.

Urban transport accounts for about 51 percent of direct sector emissions in 2008. The main causes are increased use of private cars, congestion, and inefficient mass transport systems. **The study revealed that a modal shift to Bus Rapid Transit (BRT) and Metro plus traffic management measures have a potential to reduce urban emissions by about 26 percent in 2030**; however, policy, coordination, and financing issues often prevent their implementation. The country's more than 5,000 municipalities administer their own transit and transport systems, making it difficult to mobilize resources where needed. In addition, mass transport systems are capital-intensive.

For regional transport, the study revealed a potential for reducing emissions by about 9 percent in 2030 via modal shifts for both passenger and freight transport. Simulations showed that expanding the high-speed passenger train between São Paulo and Rio de Janeiro, for example, can attract passengers from higher emitting transport modes (e.g., planes, cars, and buses). For freight transport, shifting from road- to water- and rail-based transport can reduce emissions significantly. Obstacles to making the shift include inadequate infrastructure for efficient inter-modal transfer and lack of coordination among public institutions.

Without bio-ethanol, which already contributes to the transport sector's low carbon intensity, 2030 transport emissions would be nearly 32 percent more than in the reference scenario and more than twice as much as current emissions. Because of the increase in flex-fuels vehicles and fuel switching from gasoline to bio-ethanol, emissions from light-duty vehicles are expected to stabilize over the next 25 years, despite a projected rise in the number of kilometers traveled. **Under the low-carbon scenario, this fuel switch could be further increased from 60 to 80 percent in 2030, thus delivering half of the emissions reductions in 2030 and more than one-third of the total emissions reductions 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 that objective. Because of volatile oil prices, an appropriate financial mechanism would be needed to absorb price shocks and maintain ethanol's attractiveness for vehicle owners.

Implementing the low-carbon scenario would mean reducing increased emissions of the transport sector from almost 65percent to less than 17%(from 149 Mt CO_2 in 2008 to 174Mt CO_2 instead of 245 Mt CO_2 per year in 2030). Total avoided emissions would amount to nearly 524Mt CO_2 over the 2010-2030 period, or about 35 Mt CO_2 per year on average, roughly equivalent to the combined emissions of Uruguay and El Salvador.

Waste Management: Leverage of Financial Resources

Brazil's waste-management sector has a history of underinvestment and little private-sector participation. This situation can be attributed, in part, to a lack of long-term planning, insufficient allocated funds, and lack of incentives. Both solid and liquid waste management face a high level of institutional complexity and decentralization, making it more difficult to leverage the required financial resources. **As of 2008, sector emissions were relatively limited, at 62 Mt CO_2e, representing 4.7 percent of national emissions**.

In modern landfills, where fermentation is anaerobic, methane (CH_4) is released into the atmosphere; emissions increase as waste collection and disposal sites continue to expand. Under the reference scenario, the CH_4 generated is a powerful end-of-pipe GHG, which is not necessarily destroyed. **The emissions are quickly boosted and could increase more than 50 percent over the study period as ever greater numbers of people begin to benefit from solid and**

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liquid waste-collection services. But given that CH_4 can easily be destroyed, incentives created by the carbon market under the low-carbon scenario could encourage participation in projects designed to destroy landfill gases. To meet the waste-management sector's challenges, it is imperative that the appropriate capacitation is developed in the municipalities with respect to long-term planning and project development capabilities, expanded awareness of and capacity to use the existing legal structure, regulations and procedures, and improving access to the available financing resources. In particular, inter-municipal and regional consortia should be created to handle waste treatment, and public-private partnerships (PPPs) should be developed via concessions under long-term contracts.

Implementing the low-carbon scenario would reduce annual sector emissions by 80 percent (from 99 Mt CO_2e to 19 Mt CO_2e in 2030). Over the 2010–30 period, total avoided emissions would equal 1,317 Mt CO_2 or an average of 63 Mt CO_2 per year, comparable to the annual emissions of Paraguay.

Economic Analysis of Mitigation Options

To inform the Brazilian government and larger society of the economic costs involved in shifting to a low-carbon development pathway, the study team conducted an economic analysis to determine the financial conditions under which the proposed mitigation and carbon uptake options might be implemented. The economic analysis was also used to select the mitigation options that could be retained in a low-carbon scenario. **Two complementary levels of economic analysis were undertaken: (i) a microeconomic assessment of the options considered from both social and private-sector perspectives and (ii) a macroeconomic assessment of the impacts of these options**, either individually or collectively, on the national economy using an input-output (I-O) model.

The social approach provided a cross-sectoral comparison of the cost-effectiveness of the mitigation and carbon uptake options considered for the overall society. For that purpose, a marginal abatement cost (MAC) was calculated 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), which permits a quick reading of how the various measures compare in terms of cost and volume of GHG emissions.

The private-sector approach explored the conditions under which the proposed measures would become attractive to individual project developers. It corresponds to the same principle underlying the cap-and-trade approach adopted in the Kyoto Protocol: providing additional revenues to economic agents who opt for carbon-intensive solutions that are less intensive than those in the baseline. This approach aims at estimating the minimum economic incentive—the "break-even carbon price"—that should be provided for the proposed mitigation measure to become attractive. This approach is based on the expected rates of return from real economic agents in the considered sectors, as observed by the major financing institutions consulted in Brazil.

Because the rates of return expected by the private sector are generally higher than the social discount rate, the break-even carbon price is usually higher than the MAC. In certain 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.
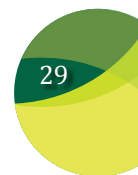
The total volume of incentives needed over the study period would amount to US$445 billion or US$21billion per year on average. .

The incentive for the measures proposed to avoid deforestation-related emissions is estimated at about US$34 billion over the period, equivalent to US$1.6 billion per year and US$6 per tCO_2 (including forest protection costs of $24 billion over the period). For 80 percent of the mitigation and carbon uptake potential under the low-carbon scenario—that is, more than 9 Gt CO_2—the required level of incentives is US$6 per tCO_2e or less.

The economic incentive to be provided is not necessarily through the sale of carbon credits. Other incentives, such as capital subsidies for low-carbon technologies, investment financing conditions, tax credits, regulations, or other instruments can sometimes be more effective in making the low-carbon option preferable to project developers.

The macroeconomic effects of the mitigation options considered were estimated individually and collectively, with the incremental impact of the low-carbon scenario calculated in comparison to the reference scenario using a simple Input-Output (IO) modeling. While results should be viewed with caution, used only to 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. Rather, both GDP and employment might improve slightly, owing to economy-wide spillover from the low-carbon investment**. It is estimated that GDP could increase 0.5 percent per year on average over the 2010–30 period, while employment could increase an average of 1.13 percent annually over the same period.

Based on this two-level economic analysis, the study selected the mitigation and carbon uptake options retained for a low-carbon scenario for Brazil over the 2010–30 period. The criteria adopted were that the MAC, which represents the social perspective usually adopted in government planning exercises, should not exceed US$50, except for the options triggered more by large expected co-benefits and their positive macroeconomic impacts, which would balance the higher MAC. This is typically the case for most of the measures proposed by the transport and waste sectors.

A National Low-carbon Scenario

The low-carbon scenario constructed for Brazil under this study is an aggregate of the low-carbon scenarios developed for each of the four sectors considered in this study. In each sector, the most significant opportunities to mitigate and sequester GHGs were analyzed, while less promising or fully exploited options in the reference scenario were not further considered. In short, this national low-carbon scenario is derived from a bottom-up, technology-driven simulation for single subsectors (e.g., energy conservation in the industry or landfill gas collection and destruction), based on in-depth technical and economic assessments of feasible options in the Brazilian context, and sector-level optimization for two of the four main sectors (land use and transport).

This national low-carbon scenario has been built in a coordinated way to ensure full consistency among the four main sectors considered. To ensure transparency, the methods and results were presented and discussed on various occasions with a range of government representatives.[22] **But this low-carbon scenario is not presumed to have explored all possible mitigation options or represent a preferred recommended mix. This scenario,**

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22   Three seminars were held over the past several years (September 14–16, 2007; April 30, 2008; and March 19, 2009) to present and discuss the study methodology, intermediate results, and near-final results with representatives of 10 ministries. Sectoral teams also interacted on various occasions with technical-area and public-agency representatives.

which simulates the combined result of all the options retained under this study, should be considered modular—as a menu of options—and not prescriptive, especially since the political economy between sectors or regions may differ significantly, making certain mitigation options that at first appear more expensive easier to harvest than others that initially appear more attractive economically.

This low-carbon scenario represents a 37-percent reduction in gross GHG emissions compared to the reference scenario over the 2010–30 period. The total cumulative emissions reduction over the period amounts to more than 11.1 Gt CO_2e, equal to approximately 37 percent of the cumulative emissions observed under the reference scenario. Projected gross emissions in 2030 are 40 percent lower under the low-carbon scenario (1,023 Mt CO_2e per year) compared to the reference scenario (1,718Mt CO_2e per year) and 20 percent lower than in 2008 (1,288 Mt CO_2e per year) (table 2, figure 1). In addition, forest plantations and recovery of legal reserves will sequestrate the equivalent of 16 percent of reference-scenario emissions in 2030 (213 Mt CO_2e per year)[23].

Table 2: Comparison of Emissions Distribution among Sectors in the Reference and Low-carbon Scenarios, 2008–30

Sector	Reference scenario, 2008		Reference scenario, 2030		Low-carbon scenario, 2030	
	Mt CO_2e	%	MT CO_2e	%	Mt CO_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)

The two areas where the proposed low-carbon scenario succeeds most in reducing net emissions are reducing deforestation and increasing carbon uptake. The main drivers are (i) reduction of total land area needed, via significant gains in livestock productivity, to accommodate expanded agriculture and meat production and (ii) restoration of legal forest reserves and production forests for producing renewable charcoal for the steel industry. By 2017, the proposed low-carbon scenario would reduce deforestation by more than 80 percent compared to the 1996–2005 average, thereby ensuring compliance with the Brazilian government's December 2008 commitment.

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23   If the carbon uptake from the natural regrowth of degraded forests were to be included, then the potential uptake would increase by 112MtCO2 per year on average, thus reducing the net emissions.

Figure 1: GHG Mitigation Wedges in the Low-carbon Scenario, 2008–30
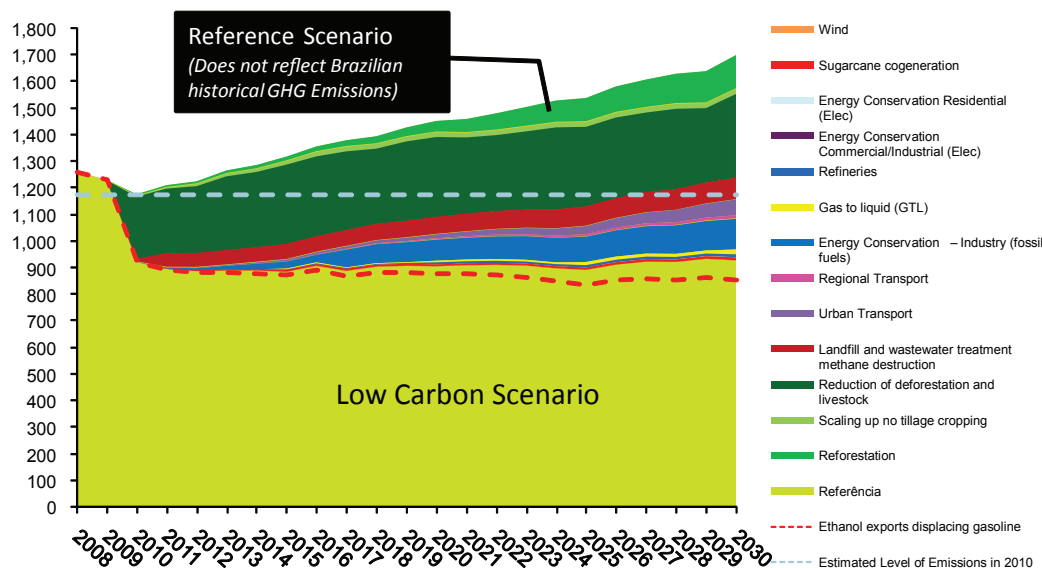
In the energy and transport sectors, it is more difficult to reduce emissions since they are already low by international standards, owing mainly to hydroelectricity for power generation and bioethanol as a fuel substitute for gasoline in the current energy matrix. As a result, these sectors' relative share of national emissions increases more in the low-carbon scenario than in the reference scenario.

Assessment of Financing Needs

Implementing the low-carbon scenario options would require more than twice the volume of financing needed for the alternatives in the reference scenario—about US$725 billion in real terms versus US$336 billion over the 2010–30 period. The per-sector distribution is US$344 billion for energy, $157 billion for land use and land-use change, $141 billion for transport, and $84 billion for waste management.

An average of US$20 billion in added annual investment would be required. This would represent less than 10 percent of the annual $250 billion in national investments in 2008 (at approximately 19 percent of GDP[24]), or less than half of the $42 billion in loan disbursements by the BNDES and two-thirds of the US$30 billion in FDI in Brazil during 2008. These requirements also compare well with Brazil's Government Accelerated Growth Plan (PAC), which anticipated spending $504 billion in 2007–10.

To implement the reference and low-carbon scenarios, both public and private investments are necessary. Under either scenario, the transport and waste sectors require more private-sector investments than today, while the energy sector continues to benefit from significant public sector participation; potential implementation of new rules or modification of existing ones may favor better use of resources (such as GTL). For the land-use sector, reducing emissions from deforestation continues to require public-sector intervention, albeit in the form of special funds, such as the Amazon Fund, and legal enforcement; while increased livestock productivity relies on better access to both public- and private-sector financing. Similarly, restoration of forests via compliance with the Legal Reserve Law requires public-sector

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24   GDP of $1.573 trillion per the CIA the World Factbook

enforcement and potentially greater private-sector participation.

To mobilize the private investment, incentives would be required to turn the low carbon options attractive when compared with more conventional options. Transport mitigation options would require the greatest amount of average annual incentives at approximately $9 billion, followed by energy at $7 billion, waste at $3 billion and LULUCF at $2.2 billion. However, most of energy efficiency measures would not require incentives.

Few of Brazil's many economic financing mechanisms and instruments currently in place target climate change–related activities. Non-climate financing mechanisms might be applicable to low-carbon options, as they would to reference-scenario alternatives. However, their availability, reach, configuration, and scale may be limited, especially when applied to unconventional alternatives. Although the overall costs may not appear exorbitant for implementing a low-carbon development scenario, the available resources for implementing mitigation activities at the site-specific level may not be as easily identifiable or sufficient, or financing mechanisms may not be appropriately defined for such options. **Thus, specific financing instruments and new sources that promote implementation of the proposed mitigation activities would be required.**

Meeting the Challenge of the Low-carbon Scenario

Implementing the proposed low-carbon scenario requires tackling a variety of challenges in each of the four areas considered. The combined strategy of releasing pasture and protecting forests to reduce deforestation to 83 percent of historically observed levels involves five major challenges. **First, productive livestock systems are far more capital-intensive, both at the investment stage and in terms of working capital.** Having farmers shift to these systems would require offering them a large volume of attractive financing far beyond current lending levels. Thus, a large volume of financial incentives, along with more flexible lending criteria, would be needed to make such financing viable for both farmers and the banking system. A first attempt to estimate the volume of incentives required indicates an order of magnitude of US$1.6 billion per year, or US$34 billion during the period. **Second, these systems require higher qualifications than traditional extensive farming**, which is used to move on to new areas as soon as pasture productivity has degraded, eventually converting more native vegetation into pasture. Therefore, the financing effort should be accompanied by intensive development of extension services.

A third challenge is preventing a rebound effect: The higher profitability of needing less land to produce the same volume of meat might trigger an incentive to produce more meat and eventually convert more native forest into pasture. Such a risk is especially high in areas where new roads have been opened or paved. Therefore, the incentive provided should be selective, especially in the Amazon region. It should be given only when it is clearly established, based on valid and geo-referenced land ownership title, that the project will include neither conversion of native vegetation nor areas converted in recent years (e.g., less than 5 years).

Fourth, several attractive options in the low-carbon scenario to mitigate emissions or increase carbon uptake amplify the requirement of freeing up pasture to prevent carbon leakage. For example, while replanting the forest to comply with the Legal Reserve Law would remove a large amount of carbon dioxide (CO_2) from the atmosphere, this area would no longer be available for other activities. The equivalent additional amount of pasture would need to be freed up; otherwise, a portion of production would have to be reduced or more native forest
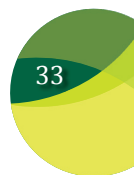
would eventually be destroyed elsewhere. **A more flexible legal obligation regarding forest reserves would make the goal of accommodating all agriculture, livestock and forestry activities without deforestation less difficult, but it might also mean less carbon uptake.**

For urban transport, the major challenge is not technological, although some efficiency gains can still result from technology innovations. Mass-transport technologies, non-motorized transport options, and demand management measures are all available and road-tested. **Rather, the main challenge centers on a lack of financing and need for more institutional coordination.** For example, Brazil's more than 5,000 municipalities independently administer their transit and transport systems, making it difficult to harmonize nationwide plans and policies. In addition, mass transport systems in urban areas are capital-intensive, which prevents many municipalities from implementing them. One way to overcome the limited investment capacity of the public sector is to promote PPPs.

For regional transport, meeting the freight transport targets under the low-carbon scenario requires better integration and partnerships among rail concessionaires and between concessionaires and government, including regulatory authorities. The various transport modes are generally operated privately; thus, their efficient integration requires new infrastructure and terminals, calling for more coordination of and support from public authorities. Regarding the Amazon region, the opening of new roads in Amazon forests can lead to increased deforestation and thus emissions. For policies involving intermodal-transfer projects to succeed and mitigate negative impacts, there must be adequate planning, appropriate allocation of resources, as well as measures to facilitate the financing of the large investments required to build and adapt the needed infrastructure.

Regarding further substitution of gasoline by bio-ethanol, the key challenge is how to ensure that market price signals are aligned with this objective. Most new cars produced in Brazil are flex-fuel vehicles, which, by definition, can switch continuously from gasoline to ethanol and vice-versa. Market price signals are key determinants of ethanol's high market share. Because of the high volatility of oil prices, a financial mechanism would need to be designed and implemented to absorb price shocks and maintain the attractiveness of ethanol for vehicle owners.

For the energy sector, the main challenges to emissions mitigation involve not only implementation of the measures proposed in the low-carbon scenario; certain assumptions that underpin the reference scenario also require significant efforts. In the low-carbon scenario, the energy sector's low carbon intensity results, in large part, from the already low carbon intensity of the reference scenario for that sector. The PNE 2030 projects that hydroelectricity will represent more than 70 percent of power generation in 2030, which implies increasing hydropower generation capacity at a pace not yet observed.

The participation of hydro-energy at new energy auctions has been limited by the environmental licensing process. As a result, the participation of fuel oil, diesel, and even coal-based power plants, which often face less difficulty in obtaining environmental licenses, has increased. Measures to improve the efficiency of the environmental licensing process for hydropower generation could include (i) ensuring that the design of electricity-sector plans, programs, and policies take social and environmental factors into account, along with economic, financial, and technical factors; (ii) promoting and establishing mechanisms to resolve disputes among players in the licensing process; (iii) preparing an operations guide, which defines the approaches used during the process; and (iv) building technical capacity and upgrading and

diversifying the professional skills of environmental agencies.[25]

Harnessing the mitigation potential of energy efficiency under the low-carbon scenario requires fully exploring the options offered by the existing framework. Progress, albeit slow, has been made in implementing the energy efficiency law, and several available mechanisms promoting energy efficiency 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 problems to address are: (i) price distortions that introduce disincentives for energy conservation and (ii) 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.

For bagasse cogeneration and wind energy, the main barrier to implementation is the cost of interconnecting with the sometimes distant or capacity-constrained sub-transmission grid. If this cost continues to be fully borne by the respective 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. An ambitious smart-grid development program would help to optimize the exploration of this promising but distributed low-carbon generation potential.

With regard to the waste sector, **both solid and liquid waste management face a high level of institutional complexity and decentralization, making it more difficult to leverage the large amount of required financial resources.** Scaling up appropriate collection, treatment and disposal, together with emissions avoidance, would require more inter-municipal coordination, clear regulationsand PPPs, along with a continuation of carbon-based incentives to destroy or use landfill gas.

Final Remarks

Brazil harbors large opportunities for GHG emissions mitigation and carbon uptake.. This positions the country as one of the key players to tackle the challenge posed by global climate change. This study has demonstrated that a series of mitigation and carbon uptake measures are technically feasible and that promising efforts are already under way. **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.**

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