

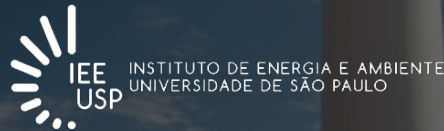


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BRIDGING THE GAP BETWEEN ENERGY AND CLIMATE POLICIES IN BRAZIL

Policy Options to Reduce Energy-Related GHG Emissions

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A child is playing in the ocean waves in the foreground. In the background, a large wind farm is visible against a clear sky. The scene is captured during the day, with the sun low on the horizon, creating a soft, golden light. The child is in the water, splashing, and the waves are breaking around them. The wind turbines are scattered across the horizon, some closer and some further away, creating a sense of depth. The overall atmosphere is peaceful and natural, highlighting the coexistence of nature and renewable energy.

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FOREWORD

Until recently Brazil's greenhouse gas emissions have been dominated by deforestation and land-use change. But good progress in reducing deforestation and rapid growth in energy use have shifted this balance so that emissions from land-use change and energy are roughly equal. This is leading to a greater focus on the potential role of the energy sector in Brazil's transition to a low-carbon economy.

Bridging the Gap Between Energy and Climate Policies in Brazil: Policy Options to Reduce Energy-Related GHG Emissions assesses trends in Brazil's energy sector and presents policy options for emissions reductions, with the goal of informing the national dialog on energy and climate change. The authors assess the impacts of existing energy and climate policies, as well as opportunities for further efficiency gains and emissions reductions, particularly in the post-2020 timeframe.

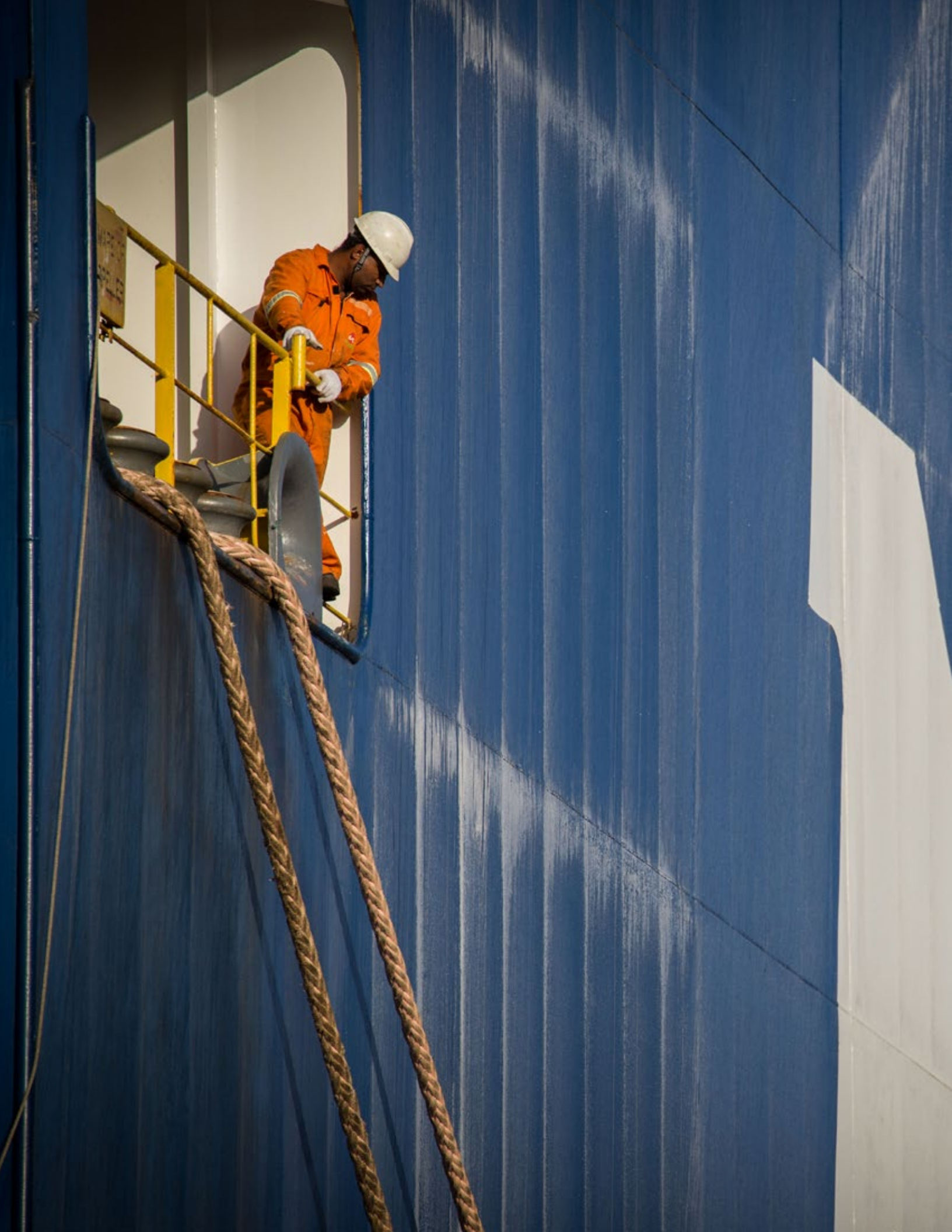
Emissions from energy in Brazil have traditionally been low due to strong reliance on hydroelectricity. But recently, even while renewable-sourced energy continues to grow, fossil-based energy has been growing much faster, leading to a strong upward trend in emissions. The good news is that Brazil

can reverse this trend. With nearly half of Brazil's energy emissions now coming from transportation, the report finds that Brazil can make significant headway by tapping its vast renewable energy potential, modernizing its vehicles, and encouraging mass electrification and hybridization of its transportation fleet. Such efforts would not only make a major contribution to Brazil's mitigation efforts, they would also deliver health co-benefits to its citizens and increase the livability and competitiveness of its cities.

Recent research from many countries around the world has shown that a bold shift toward a low-carbon economy need not involve large incremental costs. On the contrary, done right, it can lead to accelerated technological change, more jobs, a better quality of life, and faster economic growth. Brazil can position itself as a leader in this historic transformation.



Andrew Steer
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EXECUTIVE SUMMARY

Brazil is facing a series of important policy decisions that will determine its energy future over the next several decades, with important implications for the country's economic competitiveness, the well-being of its citizens, and the global climate. The decisions concern the direction of approximately 0.5 trillion U.S. dollars of anticipated investment in energy infrastructure over the next decade—which can either lock in carbon-intensive infrastructure, or advance Brazil's position as a leader in the low-carbon economy.

These decisions also include the role of large-scale hydropower projects, the pace of transition to modern renewables (biofuels that do not cause land-use change (LUC), biopower, wind power, solar power, and others), ambitious and widespread efficiency improvements, decentralized power generation, and its “smart” integration with the grid.

More recently, the economic crisis, a severe drought, regulatory uncertainty in the power sector, and management problems associated with the state-owned oil company have raised more concerns about investment diversion in the Brazilian energy sector. On the eve of the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), global environmental concerns add another important dimension to Brazil’s national decision-making process.

Energy decisions must be made against the backdrop of several important trends intersecting energy and climate. First, global greenhouse gas (GHG) emissions are increasing at a rate that threatens imminently to exceed physical global limits. Second, even as Brazil makes strides in reducing deforestation rates, emissions from its energy sector are increasing rapidly, as the economy grows and the country relies more on fossil-fuel-fired power generation—a departure from its history of relying primarily on renewable resources. As a result, Brazil will increasingly need to grapple with the climate implications of a sector that has historically enjoyed an especially large share of low-carbon energy sources. Under the UNFCCC, it becomes imperative that Brazil’s intended nationally determined contribution (INDC) for the 2015 Paris Agreement should reflect the post-2020 reality of the country’s emissions profile by taking on an ambitious national commitment that goes beyond forests and includes transformative actions, especially in the energy sector.

Therefore, *Bridging the Gap Between Energy and Climate Policies in Brazil: Policy Options to Reduce Energy-Related GHG Emissions* examines Brazil’s key energy-related GHG emitting sectors through a climate lens in order to offer recommendations for a more integrated approach that can more effectively reconcile energy and climate needs.

Bridging the Gap Between Energy and Climate Policies in Brazil: Policy Options to Reduce Energy-Related GHG Emissions begins with an overview of Brazil’s past energy and GHG emissions profiles, current pledges and future trends, and a discussion of the implications for a possible allocation of the remaining global carbon budget.

Next, it reviews available scenarios for Brazil’s energy-related GHG emissions in order to identify key drivers and results and compare them to a given allocation of the global carbon budget. It then focuses on the top-emitting subsectors—transport, industry, and power generation—to identify key abatement opportunities. The report concludes with recommendations regarding a portfolio of policies and measures that could achieve both climate and energy objectives.

Findings

The current trajectory of Brazil’s energy-related GHG emissions is not consistent with least-cost pathways to avoiding dangerous levels of climate change.

Although the allocation of the remaining carbon budget by country—and what Brazil’s share should be—is fundamentally a political question, the literature describes various approaches and proposals that are under consideration as possible means to determine Brazil’s economy-wide “fair share.” These approaches include historical responsibility, ethical allocation including rights of future generations, economic capability, and least possible cost (discussed in Annex 2). Generally, they present an upper emissions limit (a carbon budget) for Brazil’s non land-use change (LUC) sectors that ranges from approximately 20 to 26 GtCO₂e over the period 2010-2050. However, under current policies, Brazilian GHG emissions, especially energy-related GHG emissions, are likely to exceed that budget between 2024 and 2035.

GHG mitigation scenarios identify abatement opportunities for Brazil that are consistent with the need to limit global carbon emissions.

A review of a range of modeling scenarios for Brazil’s future GHG emissions, including those produced by the International Energy Agency, McKinsey, the World Bank, and others, identifies

opportunities for reductions in Brazil's energy-related GHG emissions that are significantly greater than those identified in Brazil's current energy plans. Many of these reductions would incur negative or low economic costs, with significant benefits in the form of energy security, mobility, health, and economic competitiveness.

Key abatement opportunities in energy-related GHG emissions exist primarily in the transport, industry, and power-generation sectors.

The following recommendations can help Brazil take advantage of these opportunities:

- **Improve fuel economy and invest in shifting to low-carbon modes of transport.** Transport is the largest contributor to energy-related GHG emissions in Brazil. Ambitious decarbonization of this sector can be achieved through the use of biofuels that do not cause negative land-use change, mass transportation, and non-motorized modes of transport. Appropriate regulatory signals and incentives can encourage the inclusion of advanced flex-fuel engine technologies, hybrids, and electrical vehicles in the energy transportation mix, as well as increase synergies between transport and power-generation. Fuel-economy standards in Brazil still lag in both stringency and implementation behind several other major economies. Likewise, with the exception of certain cities, Brazil has provided limited incentives to date to encourage shifts toward more efficient transportation modes, including rail and bus rapid transit. A series of reforms at federal, state, and local levels could help accelerate this shift.
- **Create incentives and systems for improving and gauging industrial efficiency by using carbon metrics.** These measures include implementing the planned Brazilian Market for Emission Reductions, developing life-cycle-assessment-based benchmarks to differentiate low-carbon from more carbon-intensive products; leveraging environmental licensing to improve efficiency; accelerating plans to switch to low-carbon fuels; and accelerating implementation of the measurement,

reporting, and verification (MRV) system for industrial carbon emissions.

- **Prioritize modern renewables, particularly solar and wind, while addressing the challenges concerning large hydropower projects.** There are significant untapped opportunities for Brazil to foster the deployment of modern renewables and to promote their interconnection with the grid. It would be necessary to remove harmful incentives for fossil fuels, leveling the playing field so that alternative energy solutions can compete in a free market. A commitment to increase the share of solar and wind in the national energy mix to 30 percent by 2030, as part of Brazil's intended nationally determined contribution (INDC), could be also a relevant strategy to advance the use of these clean energy sources.
- **Reconcile climate and energy policy and planning processes in national- and international-level policies.** Climate and energy policy and planning processes need to be more thoroughly integrated in Brazil. In the energy sector, this implies acknowledging the constraints imposed by the global carbon budget—as well as the sizable risk and cost of locking in carbon-intensive energy sources—in planning processes such as the National Energy Plan and the Ten-Year Energy Expansion Plan. In the context of climate policy, it includes setting ambitious and feasible GHG mitigation goals that consider the full range of cost-effective and beneficial abatement potential in the energy sector. Such goals set the pace of implementation, and address the practical challenges involved in transitioning to a sustainable low-carbon economy, including the need to grapple with intermittency challenges in modern renewables and the serious social and environmental issues concerning hydropower. Confronting the need to reconcile energy and climate priorities is the first step in mustering the political will and ingenuity necessary to overcome the barriers to the low-carbon pathway.



INTRODUCTION

The international climate negotiations have important implications for the way Brazil sources and uses energy. The size and expected growth of Brazil's economy, combined with the carbon intensification of its energy mix, have growing consequences for climate change.

In turn, decreasing stability and predictability in weather patterns resulting from global climate change pose a serious threat to the country's energy supply (EPE, 2014). Hydropower production and bioenergy crops depend on reliable water regimes. Wind power and solar energy have not been deployed at a sufficiently large scale and their integration is still an issue. Nuclear power is minimal and controversial. Fossil fuels are being considered as a short- and medium-term option, but the scale of foreseen investments in this sector is very likely to lock in the Brazilian energy infrastructure toward a long-term carbon-intensive pathway, inconsistent with climate-change mitigation goals.

Although Brazil's GHG emissions correspond to only about three percent of total global GHG emissions, the country will play a prominent position in future international negotiations. However, it risks losing this prominence if it persists with the current policy of investing heavily in fossil fuels. It may also lose the competitiveness race to more innovative, efficient, and decarbonized economies. In this sense, the relationship between Brazil's energy system and the global climate system makes it imperative that the country move toward an integrated approach to decision-making on these two key issues.

Historically, Brazil's energy mix has been dominated by an exceptionally high share of renewable sources (hydropower and bioenergy); renewables reached 47 percent of the total primary energy supply in 2009 (EPE, 2010), whereas the average world share of renewables in primary energy supply is approximately 13 percent (IEA, 2014). However, although the country still has a significant share of renewable sources in the energy mix—39.4 percent in 2014 (EPE, 2015)—and although renewables continue to grow in absolute terms, their share in the energy mix decreased by almost six percent over the past six years. Carbon-intensive forms of energy have gained a foothold in Brazil and are growing much faster than renewable energy sources, leading to an increase in the carbon intensity of the energy mix (MCTi, 2013; SEEG, 2014; EPE, 2015). Between 2014 and 2023, the government expects that more than 70 percent of the nearly 0.5 trillion U.S. dollars in projected energy investments will be directed to fossil fuels. In 2013, land use, land-use change and forestry (LULUCF) was the largest GHG emitter, representing approximately 34.8 percent of national GHG emissions, while GHG emissions from fossil energy (28.8 percent) edged out those from agriculture (26.8 percent) (SEEG 2014).



Under the Ministry of Energy (MME), the Energy Research Company (EPE) is the government research organization that handles long-term energy planning. EPE periodically issues the Long-term National Energy Plan (PNE), the annual National Energy Balance (BEN), and the annual Ten-Year Energy Expansion Plan (PDE), which together form the basis of Brazil's energy policies. The most recent long-term planning document, the PNE 2030 (EPE, 2007), was published before the global financial crisis, the launch of Brazil's national climate policy, and numerous other important developments. In a move to address the longer term, EPE is currently developing the 2050 National Energy Plan.

The 2050 PNE's Terms of Reference (TOR), the energy-demand studies, and the economic scenarios for the elaboration of the 2050 National Energy Plan have been already published. They take into consideration many issues and trade-offs facing the energy sector that will have implications for the country's strategies to reduce energy-related GHG emissions:

- The global financial crisis of 2008 and its continuing effects
- Vulnerability of the hydro system due to climate change impacts

- Inclusion of hybrids and electrical vehicles in the energy transportation mix
- National capacity to store energy to take advantage of the endowment of intermittent energy sources, especially wind and solar
- Trade-offs between promoting natural gas versus non-traditional renewable sources
- Distributed power generation, the role of self-generators, and implications for future power demand
- Role of thermal power plants running on biomass (instead of gas or coal)—including biomass from forests, which can fully substitute for fossil-fuel-fired power plants in a continuous process
- Advancement and improved competitiveness of bioenergy, regarding both biofuels and biopower
- Associated implications of bioenergy for land use
- Promotion of regional energy integration with bordering countries

However, the PNE 2050 does not take into account the rapid progress of modern renewables, and their integration and storage systems, which seem likely to become highly cost-competitive in the near future. Layered on top of these considerations is global climate change, but this issue has been only



marginally discussed in the PNE 2050 preliminary documents as a driver for new technologies and necessary adaptive measures. The issue of compatibility with the global carbon budget is similarly neglected.

The threat of climate change has implications for the resilience of Brazil's energy sector and its economy more generally; it also implies limits to the amount of net GHG emissions that can safely be allowed at the global level. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013) has made clear that current emissions trends threaten the integrity of the global climate system and that the time available for action to maintain safe levels of average global temperature rise is running out. To limit the average global temperature increase to 2°C by the end of the century, cumulative global CO₂ emissions should stay within a “budget” of approximately 990 (510–1505) GtCO₂ over the period 2012–2100 (RCP2.6 scenarios, according to the IPCC, 2013). Scientists estimate that, ideally, global CO₂ emissions will need to reach net zero between 2050 and 2070 (UNEP, 2014) and should become negative over the remainder of the century to offset previous emissions. Global GHG emissions will need to reach net zero between 2080 and 2100 (IPCC, 2013).

If current trends continue unabated, humankind will burn through this budget within the next 30 years. How the remaining carbon budget is allocated by country—and what Brazil's share should be—was not addressed in the IPCC AR5; it is fundamentally a political question, but there are various approaches and proposals under consideration in the literature that could be used to determine Brazil's economy-wide “fair share.” These approaches include historical responsibility, ethical allocation including rights of future generations, economic capability, and least possible cost; they are discussed further in Annex 2 of this report. Policies and economic decisions made in the interest of pursuing such goals are likely to have serious implications for the economic viability of

investments in fossil fuels *vis a vis* investments in a more rapid deployment of energy efficiency and renewables-related infrastructure.

Objectives and Structure of the Report

The main objectives of this report are to:

- assess the key Brazilian energy-related GHG emitting sectors through a climate lens;
- present recommendations regarding how the Brazilian government could enhance implementation of existing energy policies; and
- identify potential policies that could effectively reconcile energy and climate needs in Brazil.

The report is focused on potential and realistic national policy recommendations that could assist the Brazilian government in promoting better integration of climate and energy considerations. It is based on the premise that most decarbonization and energy-efficiency efforts will occur at the necessary pace only with a strong policy signal to guide public and private investment. We have considered mostly specific sector-level approaches that the government could take to implement new policies, and to enhance effectiveness of existing policies, in order to reduce energy-related GHG emissions in Brazil.

The proposed policy recommendations address key energy-related GHG emission sectors (transport, industry, and power generation), as well as opportunities for improved integration between energy and climate policies. They are based on (i) policy literature specific to Brazil; (ii) international literature on best-practice policies in key energy sectors; (iii) analysis of existing GHG mitigation scenarios; and (iv) expert opinion elicited from energy and climate stakeholders.

This section has introduced some of the key national and global factors that are affecting the Brazilian energy sector in the context of the need to constrain GHG emissions, and has outlined the methodological approach of the report.

Background and Context describes the changing profile of Brazil's GHG emissions and discusses the implications of the global carbon budget for Brazil's energy-related GHG emissions and the measures that might need to be taken by the government to contribute to the joint effort of limiting global temperature rise to 2°C.

Scenario Analysis presents available GHG mitigation scenarios concerning Brazil's energy-related GHG emissions and analyzes their main findings in order to identify some key drivers of future GHG emissions and highlight key differences between those scenarios that are compatible with the global carbon budget and those that are not. It is important to note that this report compiles several different sources of information, from different dates. For this reason, base years may vary, as do the assumptions underlying different projections.

Policy Implications examines the policy implications for Brazil's energy subsectors with the highest GHG emissions—transport, industry, and power generation—and identifies technological options and key abatement opportunities. It discusses the practicality of these opportunities by looking at existing, available technologies and/or those that have not been widely implemented but present great potential to reduce GHG emissions. The section identifies policies that would be consistent with implementing those technologies, and proposes recommendations to increase the effectiveness of existing energy policies and/or climate policies related to energy-related GHG emissions in Brazil. It also makes recommendations on the implementation of new policies to spread the use of existing and potential low-carbon technologies in Brazil.

Finally, Conclusions and Recommendations presents conclusions and summarizes the main policy recommendations that concern the key energy subsector emitters. Because this report takes a qualitative approach to potential and realistic policies to be implemented or enhanced, the effects of each recommendation have not been quantified in the present analysis.

How the remaining carbon budget is allocated by country—and what Brazil's share should be...is fundamentally a political question, but there are various approaches and proposals under consideration in the literature that could be used to determine Brazil's economy-wide "fair share."



BACKGROUND AND CONTEXT

Historically, the vast majority of Brazil's GHG emissions¹ have stemmed from deforestation and forest degradation. The contribution from energy-related GHG emissions was relatively modest, because of heavy reliance on renewable energy sources (biofuels and hydropower). However, this scenario has changed and energy and agriculture represent the key sectors.

Brazil's Changing GHG Emissions Profile

Since 2005, the Brazilian government has prioritized command-and-control policies to reduce deforestation in the Legal Amazon (the socio-geographic division in Brazil that contains nine states in the Amazon Basin), through the Action Plan for Prevention and Control of Deforestation in the Legal Amazon—PPCDAM (MMA, 2004) and in the Cerrado savannah, through the Action Plan for the Prevention and Control of Deforestation and Forest Fires in the Cerrado—PPCerrado (MMA, 2010).

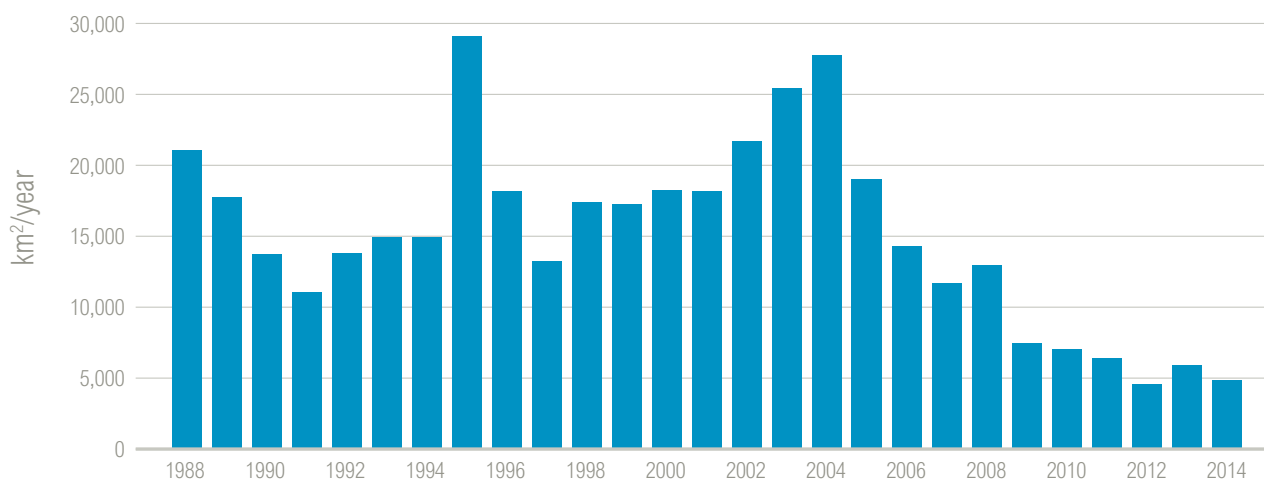
In December 2009, the Brazilian Government launched the National Policy on Climate Change (PNMC) through Federal Law No. 12.187/2009. In line with its submission to the UNFCCC, the PNMC pledged Brazil to a 36.1–38.9 percent reduction in GHG emissions by 2020, relative to a trend-line scenario, and established a reduction target for deforestation rates of 80 percent in the Legal Amazon and 40 percent in the Cerrado savannah. A year later, Decree 7.390 was established to regulate the PNMC, and stated that the 2020 commitments should be achieved through sectoral mitigation and adaptation plans. The Satellite Monitoring System of the Brazilian Amazon Forest (PRODES) provides the annual deforesta-

tion rates in the Legal Amazon, and the latest data (INPE PRODES, 2014) show that deforestation rates reached their lowest level in 2012. There was a one-year increase of 28 percent in 2013 over the previous year's rate but a return to the decreasing trend (18 percent) in 2014, as shown in Figure 1.

As Brazil's response to deforestation becomes more effective, and as reliance on fossil fuels for energy grows, the country's GHG emissions profile is undergoing a radical transformation.

The Ministry of Science, Technology and Innovation (MCTi) periodically publishes information on national GHG emissions divided into main sectors grouped according to their processes, sources, and sinks, as determined by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006): energy; industrial processes and product use (IPPU); waste; and agriculture, forestry, and other land use (AFOLU)—which includes agriculture, and land use, land-use change and forestry (LULUCF). Each sector comprises individual categories and sub-categories, and this report is focused on the energy-related GHG emissions from these sectors. The latest GHG emissions estimates for the five broad sectors (MCTi, 2013) are available up to the year 2011 (see Table 1.)

Figure 1 | Annual Deforestation Rates in the Legal Amazon (1988–2014)



Source: INPE PRODES, 2014.

Table 1 | **Brazilian GHG Emissions Estimates by Sector, 1990-2011**

SECTORS	MTCO ₂ EQ					CHANGE (PERCENT)	
	1990	1995	2000	2005	2011	1995-2005	2005-2011
Energy	188	228	299	328	408	44	24
Industrial Processes	53	63	72	78	86	24	11
Agriculture	304	336	348	416	450	24	8
LULUCF	816	1940	1343	1179	310	-39	-74
Waste	29	33	38	42	48	24	15
TOTAL	1389	2601	2100	2043	1302	-21	-36

Source: MCTi, 2014.

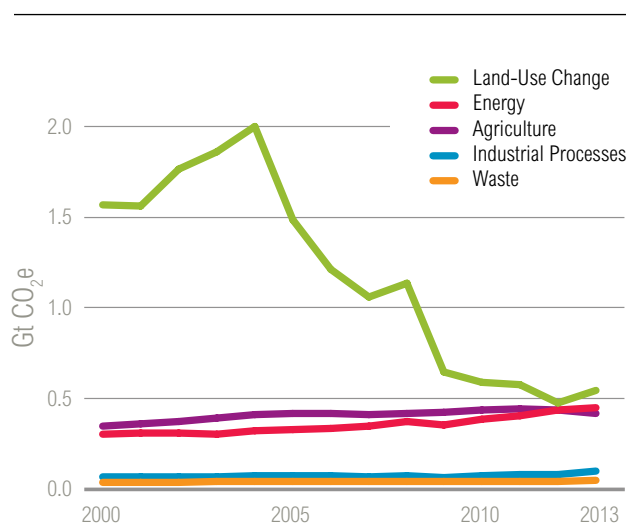
According to more recent estimates from the Brazilian Greenhouse Gas Emissions System (SEEG, 2014), in 2012, fossil-energy emissions for the first time surpassed those from agriculture (Figure 2), and they are expected to surpass those from land-use, land-use change and forestry (LULUCF) in the very near future.

It is important to highlight the difference in the methodological approach to estimating GHG emissions used by the Brazilian government and that used by independent data collection systems,

for example, the SEEG. Both of them are based on the IPCC guidelines for national inventories, but the Brazilian national inventories and periodic GHG emissions estimates published by the MCTi consider not only GHG emissions but also removals due to the increase of carbon stocks (that is, net GHG emissions). Methodologically, SEEG estimates consider gross GHG emissions (they do not account for GHG removals), and they also do not consider the offsets from GHG emission-reduction certificates originated by Clean Development Mechanism (CDM) projects in Brazil.

Because of the focus on land use as the key driver of climate change in Brazil, as well as the historically low-carbon content of key energy sources, there has been limited pressure on Brazil to explore energy efficiency and renewable energy (beyond hydropower and bioenergy) in response to climate change.

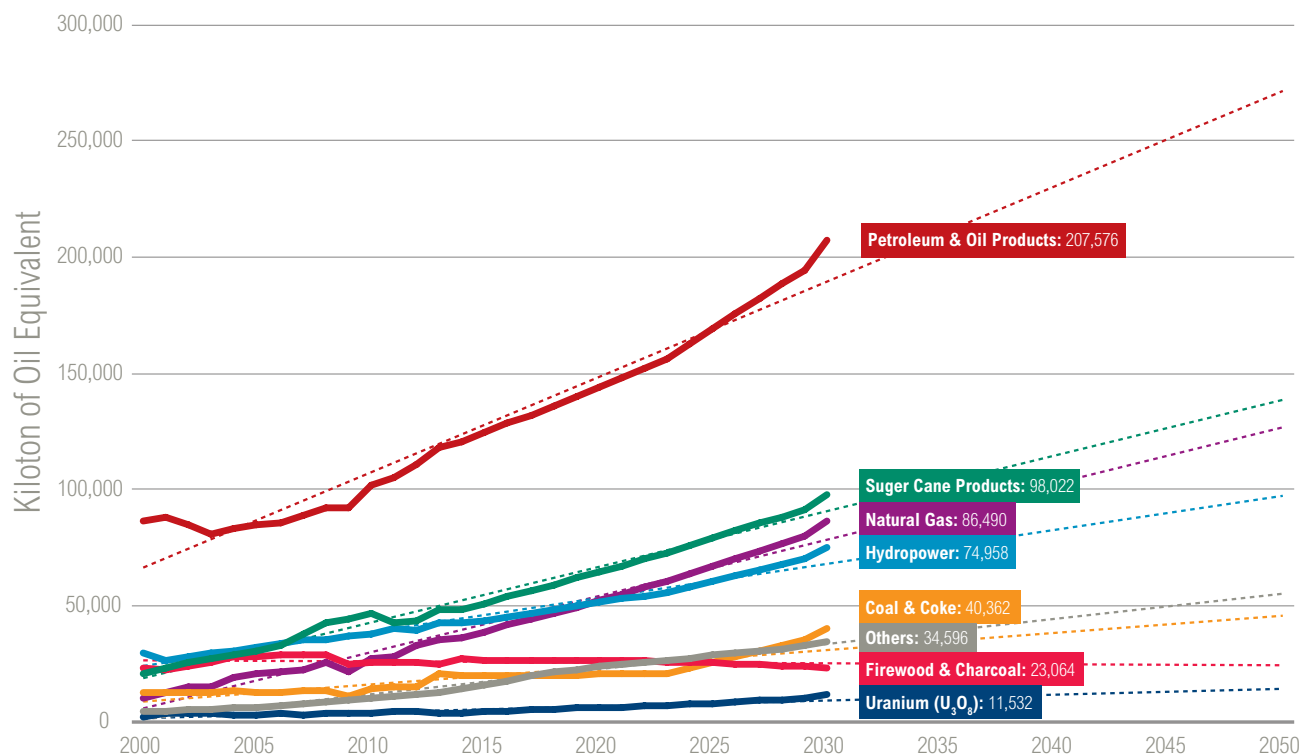
Figure 2 | **Brazilian GHG Emissions by Sector, 2000–2012**



Source: SEEG, 2014.

As previously mentioned, renewables accounted for 39.4 percent of Brazil’s total primary energy supply in 2014, while the world average was 13.2 percent (EPE, 2015). Although the Brazilian energy mix can be considered relatively “clean,” there are many opportunities to reduce energy-related GHG emissions (Schaeffer et al, 2012a). Furthermore, even as the absolute quantity of renewable energy continues to increase, its *share* of the total energy mix is on the decline. That is, non-renewable energy is growing faster than renewable energy (Figure 3).

Figure 3 | Brazilian Total Primary Energy Supply by Fuel (in thousand tonnes of oil equivalent—ktoe)



Source: Authors' extrapolation based on data from MME, 2014.

Official outlooks and investment patterns imply that the country is heading toward a carbon-intensive lock-in. Around 80 percent of the energy investments in Brazil between 2013 and 2022 (approximately 0.5 trillion U.S. dollars) will be allocated to fossil fuels, as shown in Figure 4.

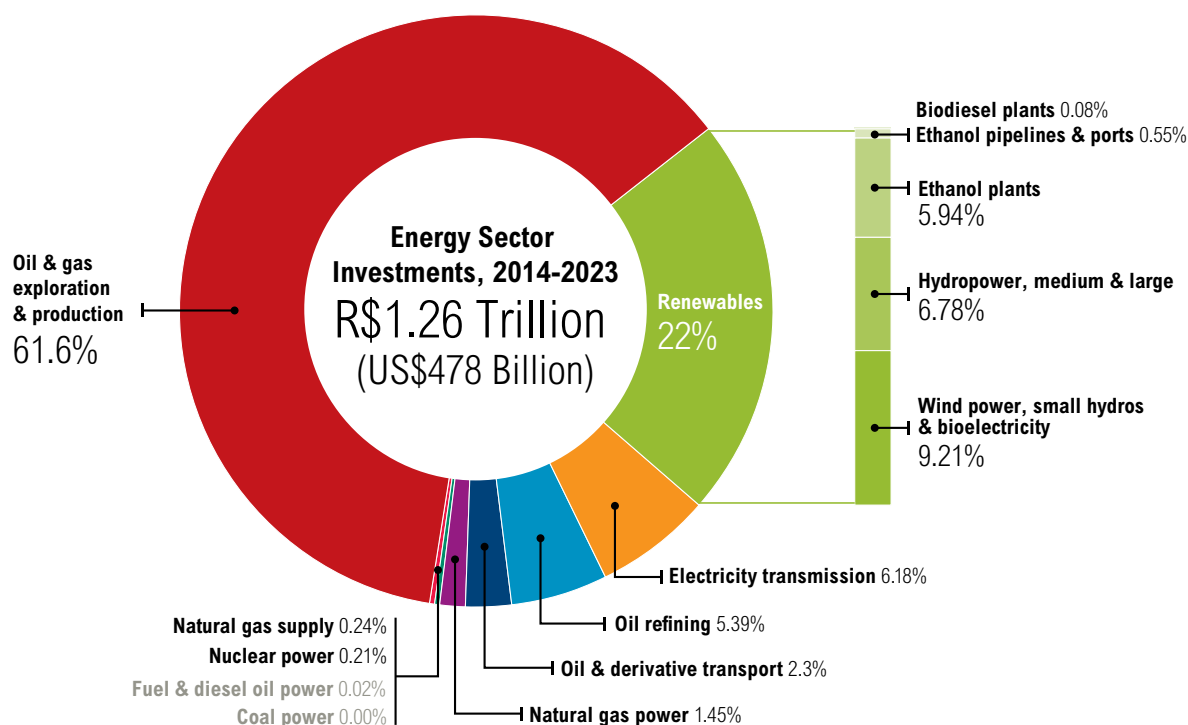
The lock-in stems also from economic factors. Subsidies for fossil fuels and carbon-intensive sectors were used to curb inflation and are still widespread, resulting in artificially low prices to the consumer for diesel oil, gasoline, and electricity from natural gas. The 2015 economic crisis has forced the government to review these directives, but there are still several unclear and uncertain rules that reduce the attractiveness of investments in renewable energy. Artificial energy prices plus the promotion of mass consumption of private cars and appliances with obsolete technologies inhibit energy-efficiency measures. Until recently, energy investments and policies relied on likely revenues

from the export (and import substitution) of conventional fossil fuels—chiefly oil from the Pre-salt offshore basin. Recently, plunging international oil prices have highlighted the vulnerability of the economy in Brazil (and many other countries) to such unexpected revenue swings.

Adding to the uncertainties of energy planning and of the economy as a whole, the multilateral environmental scene remains somewhat unclear. Under the UNFCCC, nations are defining, and in a process of announcing, their intended nationally determined contributions (INDCs) for the 21st Conference of the Parties, to be held in December 2015. The so-called “Paris Agreement” is intended to reflect ambitious national commitments in terms of GHG emissions reductions.

In the case of Brazil, a range of GHG mitigation scenarios and forecasts (Annex 1) shows that such pledges have to go beyond avoided deforestation

Figure 4 | Allocation of Energy Sector Investments in the Period 2014–2023



Source: Authors' elaboration from EPE, 2014.

in the Amazon region (and land use as a whole), and include necessarily long-term transformative actions in the energy sector.

Adaptation is another important topic for Brazil, helping to preserve the country's economic competitiveness, given its heavy dependence on climate-sensitive natural resources. Moreover, the country's infrastructure—power transmission lines, roads, and human settlements—is not sufficiently resilient to the threats posed by climate change. Considering that adaptation costs increase with climate change impacts, it should be in the interest of Brazil to achieve as soon as possible an ambitious global agreement that stabilizes global temperatures at safe levels.

The reasons for action are not only ethical but also economic. Factoring in climate change, Brazilian GDP estimates for year 2050 are lowered by

0.5–2.3 percent, compared to baseline projections. In present value, using an annual discount rate of one percent, the cost of inaction regarding GHG emissions could be between roughly USD 240 billion and USD 1.2 trillion, which would be equivalent to wasting at least one whole year of growth over the coming 40 years (Marcovitch, Dubeux, and Margulis, 2011).

To this end, Brazil will need to change course, in terms of technology, policies, and international diplomacy. The country has achieved a considerable level of mitigation over the last decade thanks to the control of deforestation. Nevertheless, further progress is required to reduce emissions in non-LUC sectors—in particular energy—which are growing rapidly. The use of scenarios (Annex 1) and carbon budgets (Annex 2) can help guide this process.



SCENARIO ANALYSIS

Scenario-building and analysis is an important tool in energy planning and policymaking. The results and conclusions drawn from scenarios depend upon the assumptions employed for their development; the approach can thus help scientists and policymakers to forecast the results of a hypothetical situation and make policy choices that are more likely to deliver a specific goal. A modeling exercise can serve as a robust guide for decision-makers as they try to understand what would happen if the assumptions were to become concrete (Kwon and Østergaard, 2012; Schaeffer et al., 2012b).

BOX 1 | SCENARIO ANALYSIS: POSSIBLE FUTURES FOR BRAZIL'S CO₂ EMISSIONS FROM THE ENERGY SECTOR

The National Energy Plan—PNE 2030 (2007)

shows basically four scenarios, covering a broad range of possibilities. Uncertainties are high and the assumptions made in 2007 are now being revised for the 2050 outlook, still not published.

McKinsey (2009) launched a study utilizing marginal abatement cost curves (MACC) to produce low-carbon pathways for all domestic sectors in year 2030. The publication has a very low level of detail, and data are not traceable.

World Bank—De Gouvello et al. (2010) analysis is another MACC study, based on the intermediate reference scenario from Brazil's National Energy Plan (PNE) 2030, which assumes an average economic growth rate for Brazil. Using a higher level of detail, it identifies a Low-Carbon Scenario which uses mitigation options such as hybrid cars and carbon capture and storage.

The (PNMCs) **Brazil 2020 Pledge (2010)** considers only implemented and adopted policies in Brazil, and adopts the annual Ten-Year Energy Plan as the sectoral plan for mitigation and adaptation in the energy sector, with projected 2020 emissions using a considerably inflated trendline as discussed in pages 60 and 61.

The IEA's **Energy Technology Perspectives—ETP (2012)** defines three scenarios for the Brazilian Energy sector, consistent with the 2°C, 4°C, and 6°C pathways respectively by 2100. The study projects that even after compliance with the Brazilian Nationally Appropriated Mitigation Actions (NAMAs), proposed emission reductions would exceed even the 6°C trajectory.

La Rovere et al (2013) shows the energy sector as the major source of emissions for Brazil post-2020 and presents three projections based on existing policies, more ambitious policies, and advanced strategies.

Greenpeace (2013) presents an ambitious low-carbon highly renewable scenario, with decentralized and integrated solutions, plus phase-outs of fossil fuels and nuclear power.

The IEA's **World Energy Outlook WEO (2014)** includes the Current Policies Scenario (formally enacted as of mid-2014); the New Policies (with the enactment of all improved policies under consideration by the government); and the 450 (ppm) scenario (bolder and consistent with a proposed allocation of the global carbon budget from the IPCC AR5).

Integrating and analyzing climate data through the use of scenarios can lay out a range of possible futures facing a country's energy sector and demonstrate the relationships between technologies, policies, energy supply/demand, and GHG emissions. When analyzed alongside a given global carbon budget, scenarios can help scientists and policymakers to understand which combinations of technology and policy choices are consistent with such a budget cap, if adopted, and which are not. In the case of Brazil, analysis of the GHG emissions contributed by each energy subsector in the latest Ten-Year Plan 2023 (approved in December 2014), for example, enables the evaluation of trends in sectoral emissions from 2014 to 2023, and can serve as a relevant input to the formulation of mitigation policies in Brazil.

The scenarios examined were developed for various purposes, and were based on a range of methodologies and assumptions. The present study is limited to publications that meet the following criteria:

- Official and independent modeling of supply and demand in the energy sector in Brazil that presents outlooks for future GHG emissions.
- Official and independent modeling that is sufficiently recent (not older than five to six years and extending at least through 2020) to reflect Brazil's latest energy-planning developments and to ensure that modeling parameters are relatively up to date. The exception was the National Energy Plan (PNE 2030) that was published in 2007, but it was included in the analysis because it is the current official plan adopted by the federal government. PNE 2030 will ultimately be replaced by PNE 2050, for which Terms of Reference and some economic premises were published in 2013 and 2014, but PNE 2050 is still under development and cannot therefore serve as the basis for this analysis.

Annex 1 of this report details GHG mitigation scenarios and pathways that have been published in recent years. It explores in detail the various projections of future energy-related GHG emissions in Brazil and compares the assumptions underlying each projection. Annex 1 also identifies the key factors that differentiate these scenarios in terms of their consistency, or lack of consistency, with a given carbon budget. This is explained in more detail

in Annex 2. It is important to note that this report compiles several different sources of information, from different dates. For this reason, the base years and the underlying assumptions adopted in different projections will vary.

A brief summary of these scenarios is provided in Box 1.

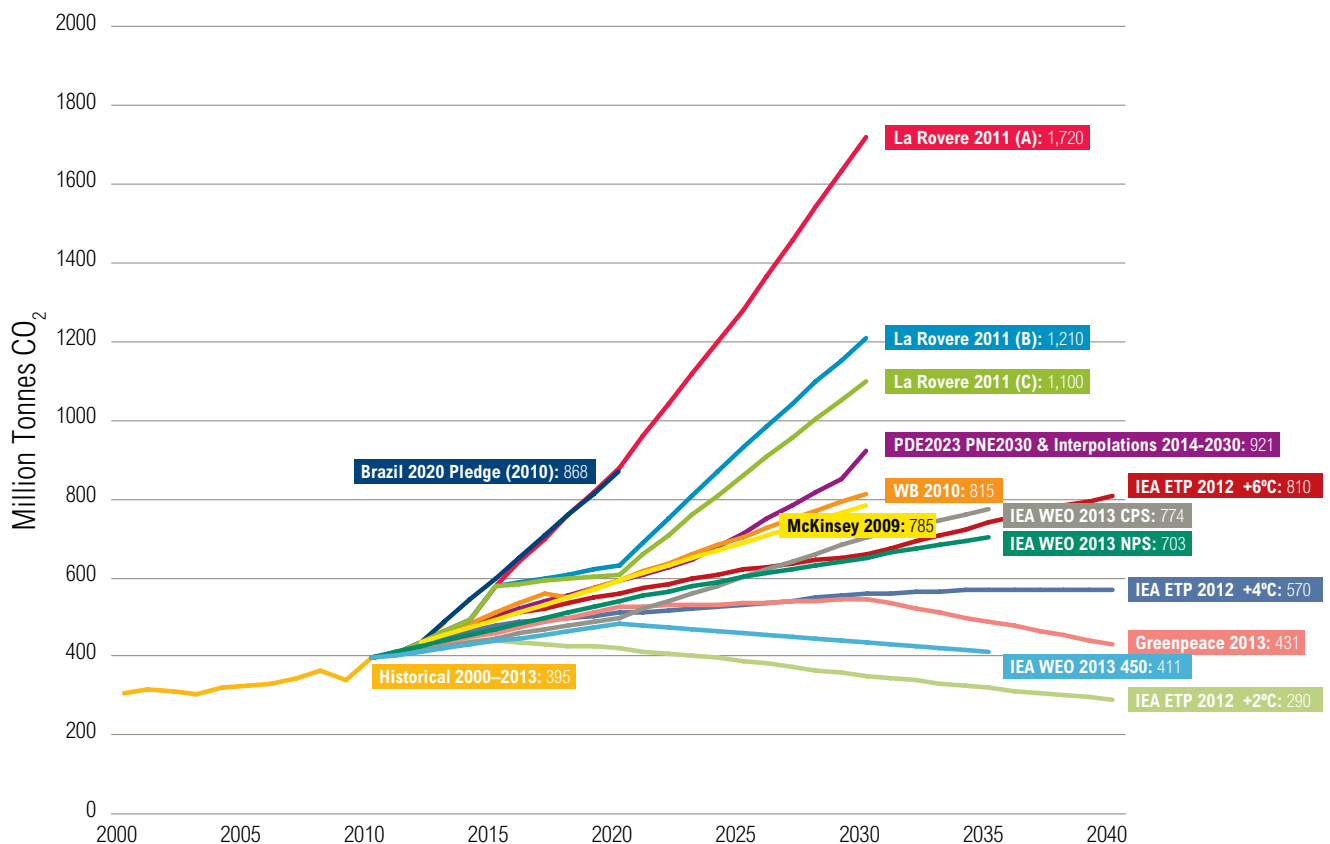
Collectively, the scenarios paint a picture of a range of possible futures for Brazil, against which current policies and alternative approaches can be examined. The scenarios provide alternatives to a reference scenario, which assumes the maintenance of existing trends (without considering potential policy changes). This contrast between the reference or “business-as-usual” scenario and the alternative scenarios is an important tool, not only to explain the implications of the long-term strategies

to be adopted, but also to evaluate the credibility of alternative scenarios (Schaeffer et al., 2012a).

The results of the comparative analysis of published GHG emission scenarios for Brazil are presented in Figure 5, which shows the historical trendline of emissions reported to 2013, and various extrapolations based on the alternative scenario studies.

In terms of adjusting the estimates and projections, the PDE 2023 (reference case scenario) estimates and projections for GHG emissions resulting from the energy sector in Brazil are as follows: 329 MtCO₂e in 2005, 483 MtCO₂e in 2014 (most recent historical figure), 537 MtCO₂e in 2017; 601 MtCO₂e in 2020; and 660 MtCO₂e in 2023.

Figure 5 | **Brazilian CO₂ Emissions from the Energy Sector: Scenario Comparison**



Source: NAMA, PDE 2023, PNE 2030, alternative scenarios.



POLICY IMPLICATIONS FOR KEY ENERGY- RELATED GHG EMISSIONS

As already mentioned, the Brazilian national GHG emissions are estimated by major economic sectors, each grouped according to its processes, sources, and sinks, as determined by the 2006 IPCC Guidelines for National GHG (IPCC, 2006): energy, industrial processes, waste, agriculture, and LULUCF. Each sector comprises individual categories and sub-categories, and this report is focused on the energy-related GHG emissions from these sectors.

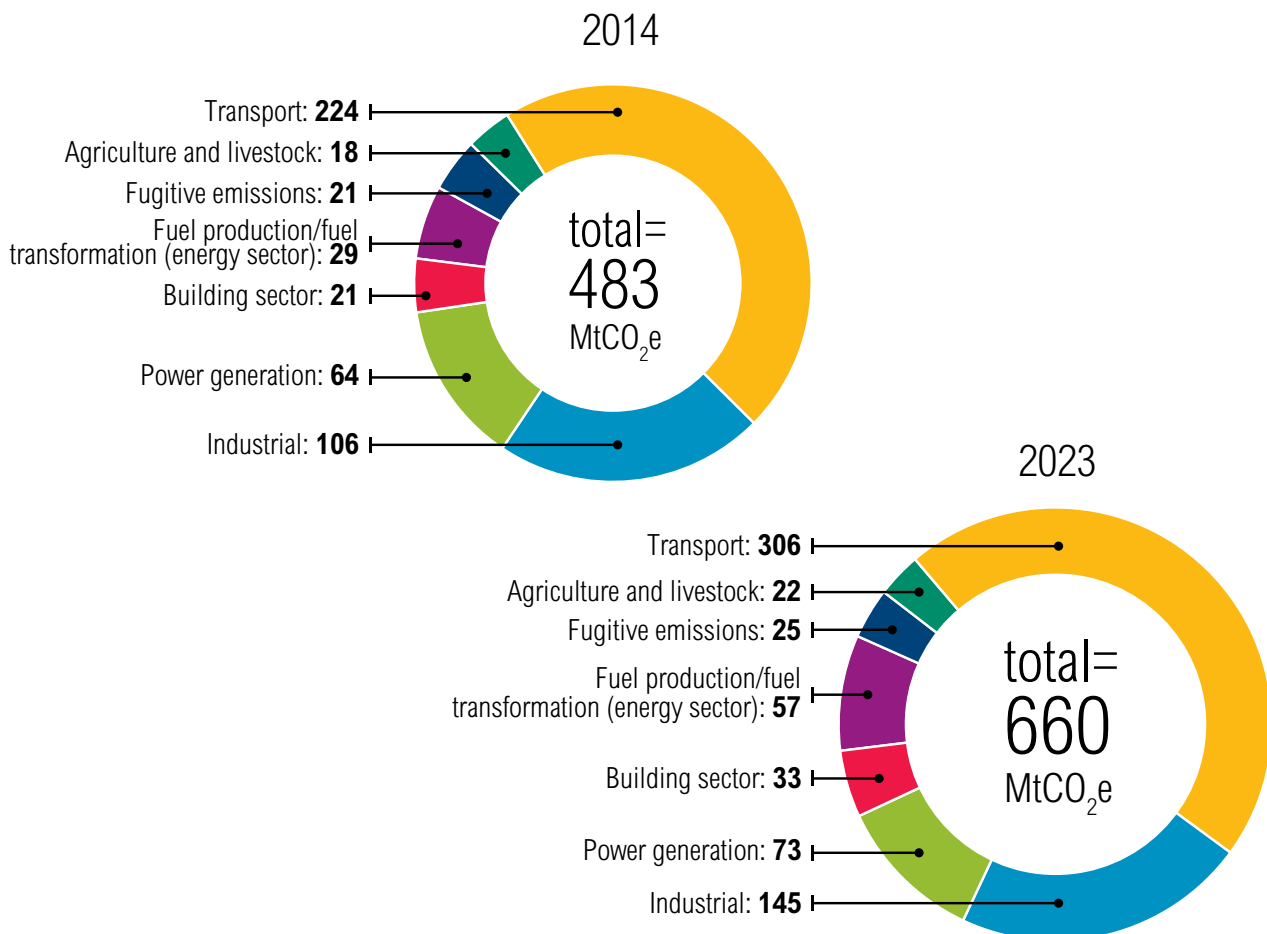
Energy-related GHG emissions in Brazil can be divided into the following categories, from the highest to the lowest emitters: (1) transport (2) industry (3) power-generation sector (or simply power sector) (4) fuel production/fuel transformation (also known as energy sector) (5) fugitive emissions (6) buildings (residential, public, and commercial), and (7) agriculture and livestock.

The latest EPE annual report, published at the end of 2014 (EPE, 2014), indicates that almost half of the energy-related GHG emissions in Brazil come from the transportation sector (46 percent), followed by industry (22 percent), and the power-generation sector (13 percent). EPE estimates that these shares will remain roughly the same over the next decade (Figure 6).

Figure 7 disaggregates GHG emissions by energy end use from 1970 to 2023. These data were calculated on the basis of different official governmental reports (MME, 2014; EPE, 2014; MCTi, 2010) by applying emission factors to estimates of fuel consumption. The results highlight the relevance of particular energy-related GHG emission categories to climate policies, especially transport, industry, and the power-generation sector.

Lampraia et al.(2011) consider a number of energy-related technologies and identify levels of feasibility for their widespread deployment in Brazil by 2030, as well as key barriers that would need to be addressed to foster the use of such technologies. The selection of technologies was based on a litera-

Figure 6 | **Energy-related GHG Emissions in 2014 and Projected for 2023**

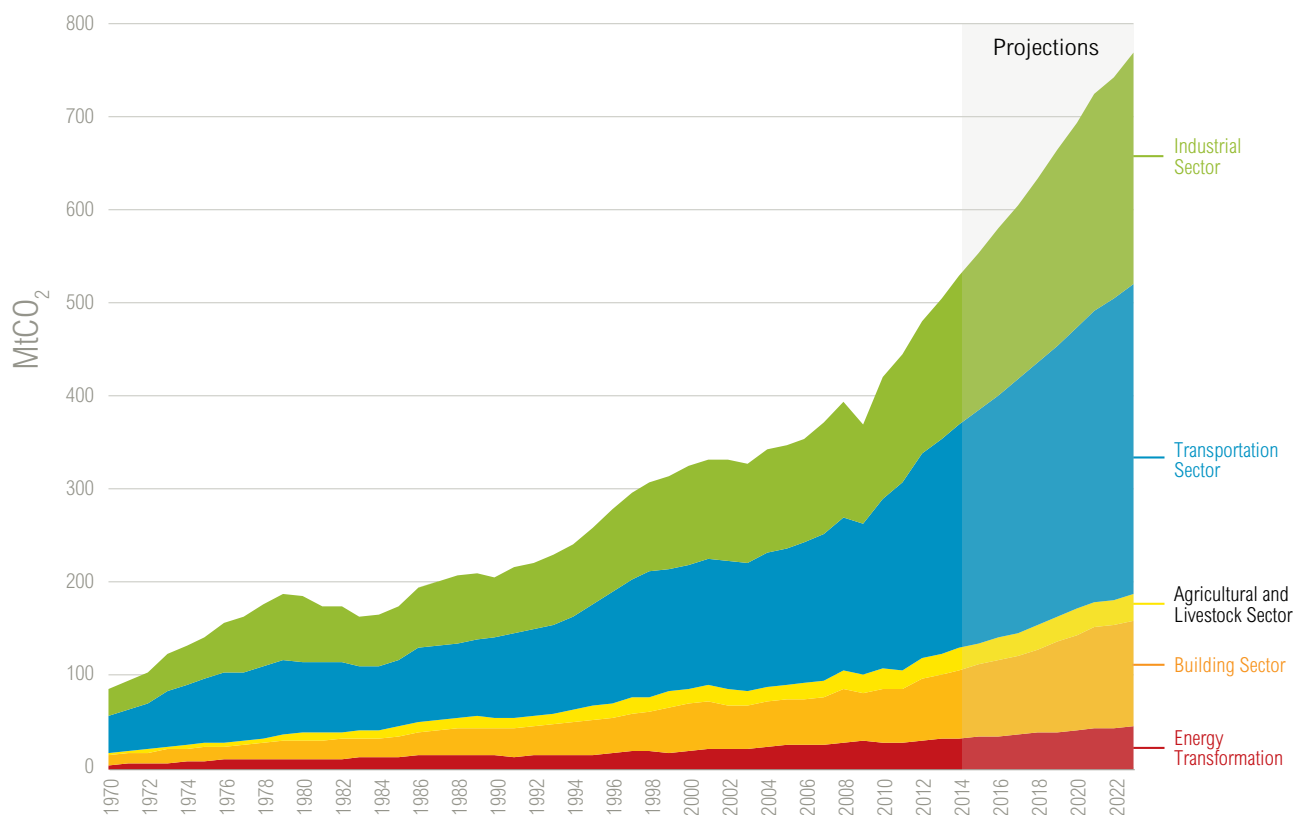


Source: EPE, 2014.

ture review of development scenarios and ongoing governmental plans. Table 2 presents a synthesis of the study’s results; however, the level of feasibility (low, medium, or high) has been updated by the authors of this report, based on analysis of recent official energy planning documents, scenarios, and conversations with experts. Lampreia et al. (2011) do not estimate the potential quantified contribution of each technology, but such estimates can be found in the minimum assessment cost studies covered in the scenario analysis.



Figure 7 | **Brazilian Energy-related GHG Emissions: Historical and Projected GHG Emissions Disaggregated by End Use**



Source: Authors' elaboration, from MME 2014, EPE 2014, MCT 2010.

Table 2 | **Summary of the Feasibility of Low-Carbon Technological Developments in the Energy Sector in Brazil by 2030**

LOW-CARBON TECHNOLOGY OPTIONS	KEY BARRIERS	FEASIBILITY OF WIDE DEPLOYMENT BY 2030
Small hydropower	Initial investments and possible land-use conflicts	High
Liquid biofuels	Land-use conflicts and logistics	High
Solid biomass	Droughts, lack of incentives, logistics, costs, and cultural inertia	High
Biogas	Technological upgrade lag and costs, small scale	High
Transport fuel switching	Fossil-fuel lobby, lack of adequate technologies	High
Wind energy and biopower	Connection to the grid, lack of incentives, financing constraints	High
End-use fuel efficiency	Upfront costs of modern equipment	Medium to high
End-use power efficiency	Upfront costs of modern equipment	Medium to high
Energy recovery from waste	Logistics, education, and permitting regulations for incinerators	Medium
Hydro power	Costs, water-level variations and permitting conflicts	Medium
Transport sector efficiency	Technological delay and costs	Medium
Solid biomass (iron, steel)	Lack of control over deforestation in charcoal production and logistics	Medium
End-use fuel switching	Fossil-fuel lobby, variation in natural gas supply	Medium
Power efficiency	Costs and lack of incentives	Medium to high
Solar photovoltaics	Intermittency and lack of incentives	Medium to high
Concentrated Solar Power	Costs of technology, energy storage	Low
CCS offshore, CO ₂ injection	Costs of technology and regulatory issues	Low
CCS with bioenergy (BECCS)	Costs of technology and regulatory issues	Low
CCS other	Higher costs, lack of incentives and regulation	Low
Hydrogen technologies	Costs, lack of incentives, know-how and infrastructure	Low
Nuclear energy	Social conflicts, potential risks, regulatory delays and high costs	Low
Microalgae biofuels	Initial costs, need for R&D and cultural inertia, small scale	Low

Source: Adapted from Lampreia et al., 2011.

The following chapter provides a deeper focus on the major GHG-emitting energy subsectors in Brazil—transport, industry, and power generation—examines the main trends, and recommends policies to meet energy needs in ways that are consistent with global climate goals. These recommendations are based largely on (i) policy literature specific to Brazil; (ii) international literature on best-practice policies in key energy sectors; (iii) analysis of existing GHG scenarios; and (iv) expert opinion elicited from energy and climate stakeholders.

Transport

Context and trends

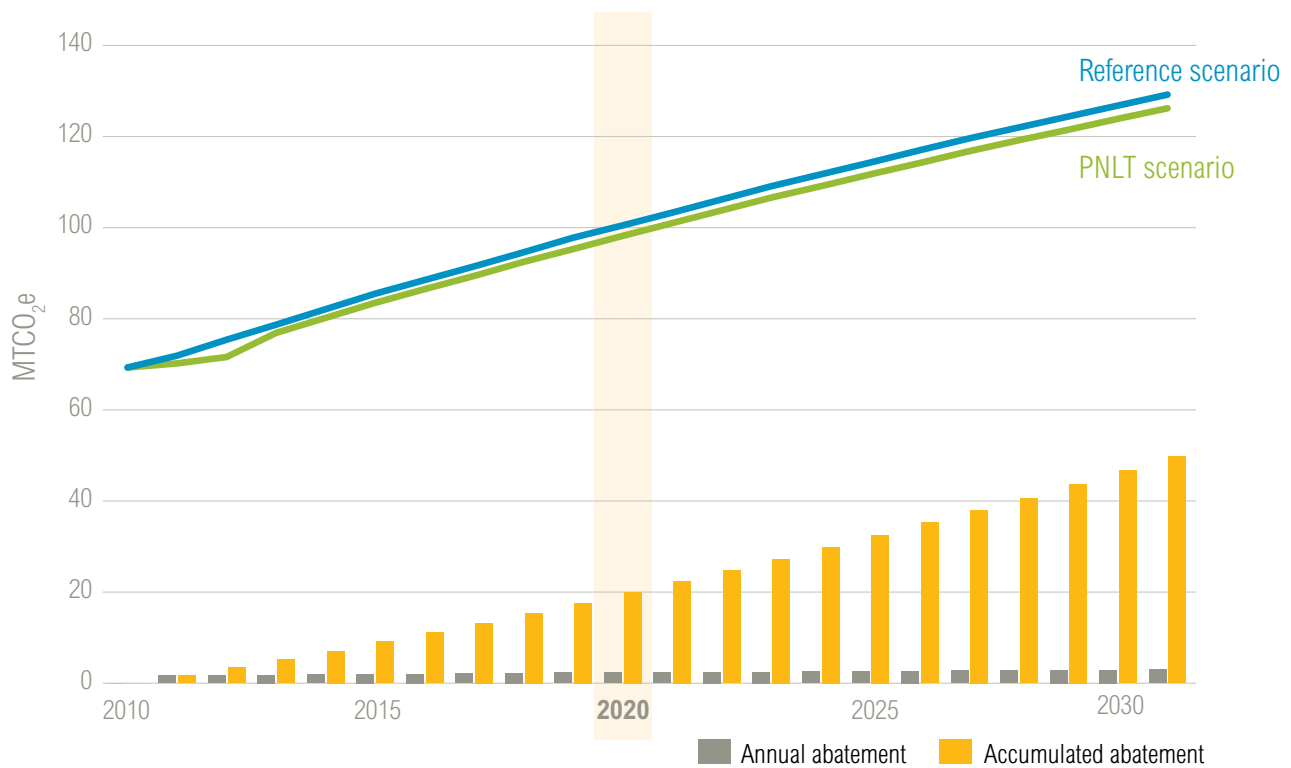
From the GHG-emissions standpoint, transportation is one of the most urgent Brazilian energy subsectors to address, and the various scenarios discussed above identified it as the key energy subsector to be decarbonized. As already mentioned, in 2013, transportation was responsible for nearly half of Brazil's energy emissions (46 percent or 224 MtCO₂e) (EPE, 2014), and in EPE's outlook this share is projected to be maintained over the next decade. By 2023, overall energy emissions are expected to increase from 483 MtCO₂e to 660 MtCO₂e, of which transportation will account for 306 MtCO₂e (EPE 2014).

Initiatives to reduce GHG emissions from the Brazilian transportation sector have taken a variety of approaches. Under the Sectoral Plan for Transport and Urban Mobility for the Mitigation of Climate Change (PSTM), a proposal to develop energy-efficiency standards for the light- and heavy-duty vehicle fleets was developed in 2012 (MMA, 2012). The so-called *Inovar-Auto* program was established to support technology development, innovation, safety, environmental protection, energy efficiency, and the quality of vehicles. This program, however, lacks ambition to bring Brazilian vehicle standards into line with international best practices. Moreover, future steps for this initiative are not clearly defined as of July 2015, which creates uncertainty for investors and undoubtedly delays manufacturers' investment plans concerning advanced technologies. Another challenge is how to induce car-makers to develop the flex-fuel technology necessary to incorporate ethanol fuel efficiently in new hybrid electric vehicles. Heavy-duty diesel-fueled engines are also not prepared to run on high blends of bio-diesel covered by the manufacturers' guarantees.

Contrary to any reasonable climate and energy efficiency policy, the government decided, in 2012, to discontinue the Tax on Industrialized Goods



Figure 8 | CO₂ Emissions from Freight Transportation and Emission Reductions from 2011 to 2031



Source: MMA PSTM, 2013a.

(IPI) on cars, which resulted in a reduction in the price of new vehicles and a consequent increase in car sales volumes. This measure contributed not only to increasing GHG emissions from vehicles but also to worsening traffic conditions and urban mobility. The decision was finally reversed in January 2015, when the federal government restored the IPI on vehicles to discourage the increase in private car transportation. Another problem was the “artificial” price of gasoline established by the government. This price control policy was implemented to curb inflation, as part of a government attempt to avoid transferring to consumers the instability of fuel prices caused by the short-term volatility in international oil prices. The gasoline subsidies encouraged flex-fuel vehicle owners to choose the fossil option over ethanol, and consequently reduce market share and incentives for flex-fuel hybrids, as further discussed in this section.

Under current policies, Brazil foresees only a modest abatement in GHG emissions from the transport sector over the coming decades. The National Plan of Logistics and Transport (PNLT) and the PSTM encompass only the relatively conservative assumptions of the Ten-Year Energy Plan (PDE 2020). They envision only business-as-usual (0.6 percent/year) gains in the energy efficiency of light- and heavy-duty vehicles. Regarding freight, the measures would result in a two percent reduction relative to the reference case out to 2030 (Figure 8). Clearly, current policies need to be revised as a matter of urgency.

The PNLT is reflected in the 2013 Climate Sectoral Plan for Transport (MMA, 2013a), but this translates to relatively weak abatements on the order of 20 MtCO₂e by 2020 and 50 MtCO₂e by 2031 in

freight transport, and 19.5–20 MtCO₂e by 2020 for all modes of passenger transport. (By contrast, 1,255 MtCO₂e of abatement is foreseen for 2020 in the Decree 7.390/2010 described previously.)

Further abatement potential

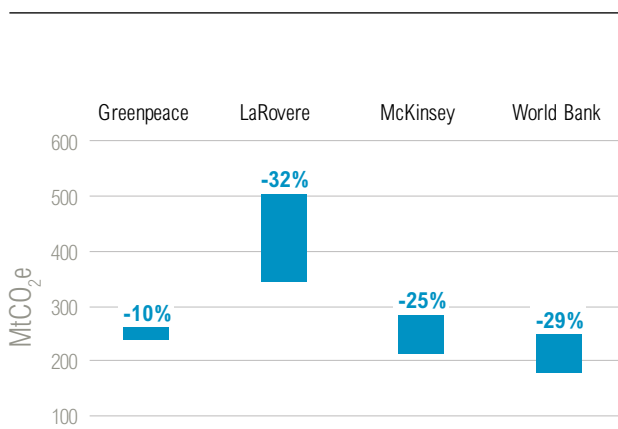
There is room for Brazil to go significantly beyond these plans (reference scenarios), resulting not only in enhanced GHG mitigation, but also—in some cases—in improved mobility and reduced air pollution, as shown in abatement scenarios in Figure 9.

The scenarios indicate that, for example, a combination of reduced energy demand through technology improvements and modal shift, along with a larger role for biofuels, could result in a GHG abatement of approximately 10 to 30 percent in 2030, relative to reference cases (Figure 9).

The key opportunities for further emissions-reduction potential in the transportation sector are discussed below.

There is room for Brazil to go significantly beyond these plans... resulting not only in enhanced GHG mitigation, but also—in some cases—in improved mobility and reduced air pollution.

Figure 9 | **GHG Emission Reduction in the Transportation Sector in 2030 in Reference and Abatement Scenarios**



Source: Authors' assessment based on various GHG emission mitigation scenarios.

Encouraging Modal Shift

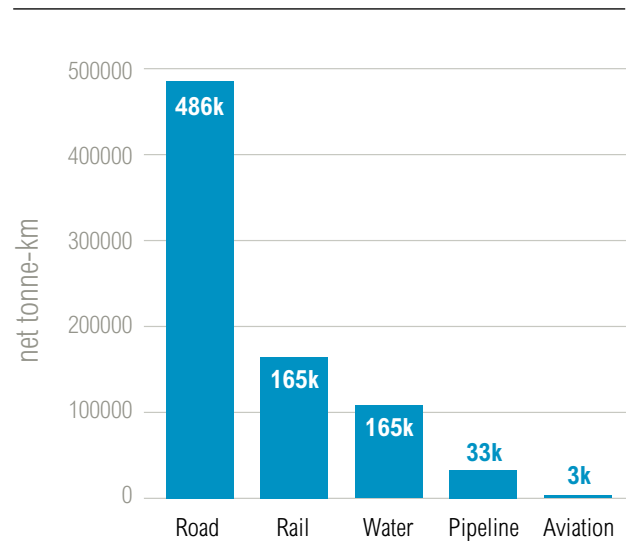
Diversifying and integrating modal transportation systems: freight transport

One of the main reasons for the inefficiency of freight transport in Brazil is the inappropriate use of different modes of transportation (Erhart and Palm, 2006). The lack of sufficient lines and terminals to integrate rail and road transport routes results in an overload of road transport. The relatively low price of building the highway system also represents an obstacle to the expansion of other modes.

Although more efficient modes (for example, rail and waterways) are currently growing more quickly than road transport their role remains limited and modal shift is not being pursued aggressively by the government. Rail and water transportation are



Figure 10 | **Brazilian Freight Transportation by Mode**



Source: CNIT, 2013.

impeded by the complicated bureaucratic procedures involved in obtaining environmental licensing, high costs of constructing infrastructure, and lack of governmental attention (MMA, 2013b).

Freight transportation in Brazil comprises 61.1 percent road transport and only 20.7 percent rail transport in terms of tonne-kms (tonnes of freight transported over one kilometer) (ANTT, 2013) (Figure 10); in other countries, the shares of road and rail modes are generally more evenly divided, and rail modes provide additional direct benefits to society because they transport passengers as well as freight. In Brazil, rail modes are generally not focused on passengers and the main beneficiary is the mining sector (freight transportation).

Because most freight travels by road, and because diesel constitutes the main fuel used for road freight transportation, freight transportation contributes significantly to GHG emissions. Freight transportation in Brazil released approximately 100 MtCO₂e in 2013, which corresponds to almost half of all transport-sector emissions (SEEG, 2014).

Historically, Brazilian transportation policies have paid relatively little attention to social and environmental sustainability issues (Santos and Kahn, 2013), but systemic changes to shift transport

toward less energy- and carbon-intensive modes in Brazil have become a crucial issue in the context of enhancing the quality of life of citizens, especially in big cities. With regard to environmental licenses for key rail and waterway projects, the current environmental regulatory framework in Brazil requires a range of licenses, resulting in high fees to get a final license. Considering the multi-level nature of Brazilian environmental licensing laws, many projects face overlapping environmental jurisdictions at the federal and state levels.

The costs increase even more if environmental licensing is delayed (Soito and Freitas, 2011). The Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), as the administrative body with responsibility for implementing and regulating Brazilian Environment National Policy under the Ministry of the Environment (MMA), could streamline licensing without compromising environmental integrity. This could be achieved not by reducing the number of safeguards but by providing clearer rules and reducing regulatory uncertainties.

According to Machado (2008), the key challenge lies not in dealing with each transportation mode individually, but in promoting the integration of road, rail, water, pipelines, and air transportation

modes, and creating storage spaces for freight. It would be important for the federal government to invest in more actions to maximize the use of the available capacity of transportation modes, and in more efficient modes (ANTT, 2014).

Encouraging modal shift and promoting multi-modal transportation systems in Brazil would reduce the high reliance on road transport and lead to better integrated planning, especially in terms of land use in urban centers. In pursuit of these goals, freight transport vehicles need to be larger, carry a bigger load, and operate more quickly. Ports must be prepared for such demands via land and water, and this requires significant government effort.

As for the high costs of infrastructure, financial resources have not been sufficient to plan and implement a national system of integrated surface transport. Governments have been struggling to balance investments in transportation with other pressing needs (eliminating poverty, improving health conditions, and combating hunger, among others). However, it is possible to achieve substantial improvements in all modes and in their integration, even with existing resources. Federal plans, especially the National Mobility Plan (Plan-Mob) do not currently provide strong support for shifting transportation modes (for example, road to rail), and a greater integration between transport regulatory agencies could help with establishing measures to integrate modal transportation systems.

Diversifying and integrating modal transportation systems: passenger transport

Integrating and optimizing existing routes and transport modes for public transport of passengers could not only reduce GHG emissions, but also increase local quality of life by reducing road traffic from individual transportation modes. The benefits of investing in mass-passenger transport within major urban centers include reduced air pollution and improved traffic flow, as well as improved management and operation of transportation to optimize routes.

The Ministry of Transport could prioritize public transportation through exploring high-speed rail to displace the use of individual modes of transportation for long distances, and also by developing high-capacity bus and rail transport systems in high-demand areas, as suggested by Machado (2008). The Ministry of Cities, under the National Secretary of Transport and Urban Mobility (SeMob), could offer municipalities incentives to create local mass-transport plans under the National Mobility Plan (Plan-Mob). As measures to discourage individual transportation, local governments could create and/or improve strategies that limit the use of private cars, such as restrictive parking policies in downtown areas or license-plate-rationing schemes, similar to those used in São Paulo, Quito, and Los Angeles, among other cities. Municipalities could also create and/or



improve strategies that reduce the emissions impact of private vehicles, such as compulsory inspections and maintenance programs for heavy vehicles that could be linked to annual licensing, and voluntary inspection and maintenance programs for light vehicles.

Municipal governments of major cities could also invest in solutions to manage traffic flow and reduce congestion delays, focusing their policies on mass

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passenger transportation systems. Increasing the frequency and punctuality of public transportation (especially local buses), and increasing the number of bus corridors, for example, could save travel time, reduce operational costs, improve urban mobility, and decrease traffic congestion, all while reducing GHG emissions from the transportation sector. The most common options in major urban centers are Bus Rapid Transit (BRT) systems and metro lines. Because BRT systems are less costly and can be implemented more quickly (Conselho de Arquitetura e Urbanismo, 2015), local governments could prioritize the use of BRTs by introducing bus-only lanes to improve the speed and comfort of travel and reduce traffic congestion. Those cities that already have metro and rail systems (such as São Paulo and Rio de Janeiro) could improve the quality of rail and subway services and expand the existing lines.

A survey recently conducted among residents of São Paulo City, for example, identified that the level of satisfaction with local transportation has increased over the past year. One of the reasons is the increasing number of bicycle lanes (Embarq Brasil, 2015). However, while this is an important achievement, the overall shift is still very modest and could receive much more attention and investment from local governors. Local governments could create and expand bike lanes, especially in major cities; create more bicycle parking facilities; enhance the quality, attractiveness, and safety of sidewalks; and incorporate bicycle path networks into public-transport policies and systems. Such measures could lead to additional national benefits, such as reduced energy costs, fewer road accidents, less traffic, better mobility, and less pollution.

Promoting Vehicle Efficiency

The predominance of road transport is likely to persist but the introduction of new vehicle technologies, particularly those that increase the energy efficiency of heavy vehicles, can play an important role in mitigating GHG emissions. In fact, there is already competition among manufacturers to offer more fuel-efficient trucks for freight transportation because fuel expenses represent a high portion of freight operating costs. Major investments in infrastructure to increase storage capacity at dispatching and receiving locations and better

Table 3 | **Range of Vehicle Efficiencies and Emissions in Brazil**
(lower and upper limits, 329 new models in urban cycle with gasohol (E22), 2010)

ENGINE (VOLUME)	MJ/KM	GCO ₂ /KM	PROPOSED EMISSION TARGETS BY 2020 GCO ₂ /KM
1.0	1.7–2.6	120–190	100–120
1.3–1.5	1.8–2.8	140–210	100–120
1.6–1.8	2.1–3.2	150–230	100–120
2.0–3.85	2.2–4.0	160–310	100–120

Source: Adapted from Nigro 2012.

logistics planning—at both the supply chain level and on road and rail networks to avoid the need for long distance transport—could reduce unnecessary tonne-kms and result in efficiency gains of more than 75 percent in tons CO₂ per kilometer (CEFIC, 2012; EPE, 2011; SP, 2010; Filho, 2010).

According to the New European Driving Cycle (NEDC) test cycle (adapted from ICCT 2012), improved efficiency standards could result in a 30–50 percent increase in efficiency for a new fleet of light-duty vehicles.

Table 3 shows how national vehicle efficiencies vary among different models of the same sized engine.

Hence, considerable savings—ranging from one third to one half of fuel consumption—could be achieved by selecting more efficient models. However, it should be noted that the entire vehicle fleet cannot be replaced at once, and it will take time to transition the fleet. A complementary measure is the widespread adoption of vehicle inspection and maintenance (I/M) schemes, which induce better calibration, resulting in more efficient fuel burning and thus mitigating GHGs, as well as abating black carbon and other pollutants.

The regulation of CO₂ emissions through efficiency standards is a powerful tool and can lead to efficiency, innovation, and competitiveness in the automotive industry, but Brazilian average vehicle efficiency targets fall short of those established

in the world’s largest economies. The Vehicle Air Pollution Control Program (PROCONVE IBAMA), responsible for such regulations, could improve this situation by mandating limits on CO₂ emissions in exhaust pipes of all vehicle models with all fuels (even the vehicles that are fueled with renewable energy sources). Ambitious technological efficiency standards that result in lower CO₂ emissions per distance travelled would lead not only to more efficiency, but also to less pollution from carbon monoxide (CO), nitrogen oxides (NO_x), particulate materials etc.

Cars in Brazil could be set emission targets on the order of 100–120 gCO₂/km by 2020, compared to around 180 in 2014 and to the target of 137 gCO₂/km proposed for 2017.² Car manufacturers utilize international efficiency standards. Even in the United States, manufacturers voluntarily exceeded the standard, reaching 178 gCO₂ in 2012. The 2016 target is 155 gCO₂/km (ICCT, 2012). A carbon tax is another option that could lead consumers to buy more efficient vehicles, but the federal government still gives low priority to this subject, as further discussed in Policy Implications.

There are no historic values for vehicle efficiency targets in Brazil because CO₂ standards were first implemented only in 2012 with the *Inovar-Auto* Program (applicable in the period 2013–2017). There is no previous database and, as mentioned, nothing yet foreseen as a next phase.

Investing in Electrical and Hybrid Vehicles and Increasing Synergies between Transport and the Power Sector

Fostering the development of new end-use technologies such as electric vehicles and hybrid vehicles (electricity and ethanol, for example), as well as the production of more efficient vehicles that demand less fuel and consequently reduce GHG emissions, represents one of the key strategies to decarbonize the transportation sector in Brazil (Greenpeace, 2013). The diffusion of hybrid and electric vehicles provides practical energy efficiency over time, and the notion of a hybrid system becomes even more tangible in Brazil because consumers are already used to a flex-fuel system, and it might facilitate an eventual transition to electric light vehicles and even to hybrid-drive buses (Johnson and Semida, 2014). In the case of public transportation, Almeida, Kahn and Cristiane (2013) state that the use of hybrid-drive buses is a promising option, and that state governments should consider the use of hybrid vehicles (diesel-electric or ethanol-electric) and fuel-cell electric vehicles (hydrogen-powered).

However, the penetration of hybrid and electric vehicles in the national market in Brazil is still slow, as stated in the terms of reference of the 2050 PNE (EPE, 2013). Questions of technical and economic feasibility, and the lack of governmental

incentives, have limited their growth to less than 600 units, and it is estimated that by 2023 they will represent only 4.2 percent of new licensed vehicles (EPE, 2013). In spite of the various challenges and the relatively low support from the government, a few initiatives exist to foster their dissemination. In 2012, for example, the local government from Curitiba established the “Hibribus,” an electric-biodiesel-fueled public bus that operates with two motors (in parallel or independently), leading to a reduction in GHG emissions of 35 percent (URBS, 2012). The electric motor is also used as a power generator during braking. Each time the brakes are applied, the energy of deceleration is used to charge the batteries. In 2013, Renault and Itaipu Binational signed an agreement (EPE, 2013) to jointly invest in research and development of electric vehicles. The agreement includes studies to analyze the feasibility of producing some key components nationally (instead of importing them). An example of such a component is batteries, which can account for approximately 50 percent of the total costs to produce hybrid vehicles (Sector Value, 2013).

Brazil could become a prime candidate for mass electrification of part of its transport fleet, if the country’s vast untapped renewable energy potential is explored. However, it is important to recall that electricity is increasingly being generated by fossil fuels. If this trend continues, it is possible



that incentives to encourage the growth of electric vehicles could actually stimulate the demand for fossil fuels in power generation. Any decision to promote electric vehicles should emphasize co-benefits, such as lowered local air pollution. It is also important to consider the increasing role that biofuels can play in the transport sector, ultimately leading to lower carbon emissions than under an “electrified” scenario.

By increasing the share of renewable energy in the electricity mix, a major shift toward electricity consumption in the transport sector in Brazil could be very important to help the load curve (which is the variation in energy demand from a specific source at a specific time). The big payoff will result from shifting to renewable electricity, rather than gasoline and ethanol, to power transport fleets, and such a shift could also reduce the pressure on distillation capacity for liquid fuels and on land use for ethanol production.

Nevertheless, disseminating the technologies and realizing the cost savings from increasing the use of hybrid and electric light and heavy vehicles will be achieved only in the long term, according to projections. The same is true for deploying the necessary infrastructure that will allow these vehicles to be competitive in the market (EPE, 2013). It is estimated that the fleet of regular buses, especially urban buses, will migrate to hybrid or electric

fleets only by 2050, but these estimates are based on current (low) incentives to spread the use of such technology. If better incentives are provided, this migration could occur by 2030. Considering that development of the power infrastructure for transport and all the distributed energy options can bring additional benefits, especially for the domestic industrial capacity of the country, the federal government could provide incentives to encourage the inclusion of hybrids and electrical vehicles in the energy transportation mix in the next 15 years. Such incentive should also cover electric motorcycles, scooters, and even bicycles, which are in the end dematerialized vehicles (vehicles whose construction requires less material and energy than regular vehicles).

Because current Brazilian law offers few opportunities to introduce these kinds of incentive, the federal government could provide tax relief (reductions in IPI, PIS, and COFINS) to increase production of hybrid and electric vehicles, while local governments could provide tax relief (IPVA exemption) to increase the sales of such vehicles. In some states, for example, Maranhão, Pernambuco, Ceará, Rio Grande do Norte, Rio Grande do Sul, and Sergipe, there is already a tax exemption (IPVA) for hybrid vehicles. In São Paulo, the license-plate-rationing scheme does not apply to electric vehicles (Stocco, 2013).





Promoting the Use of Biofuels in the Transportation Sector

The production of sugarcane ethanol in Brazil is considered highly efficient in capturing and converting solar energy relative to other types of ethanol. The net energy balance (the output ratio of energy contained in a certain volume of the fuel divided by the input ratio of energy required for its production) of sugarcane first-generation ethanol is high (8 to 10), while the net energy balance in the production of maize ethanol in the United States, for example, is about 1.3 to 1.6 (Shapouri, 2002; Macedo, 2004; Goldemberg, 2008). The efficiency of sugarcane ethanol can be even higher with recent developments on cellulosic ethanol (second generation made by grasses, wood etc.) that might improve the output/input ratio yields.

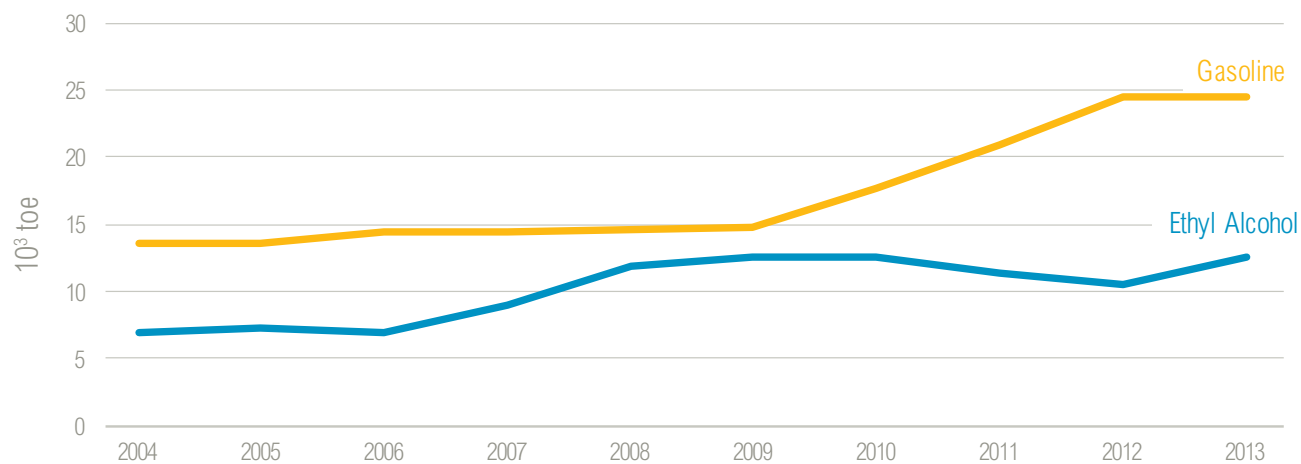
Another option could be that federal and local authorities prioritize, at least in the short and medium term, the development and operation of hybrid public buses (ethanol-electric, biodiesel-electric, or diesel-electric) in place of hybrid light vehicles. Because this technology is considered more appropriate to congested, large traffic urban zones, it would be easier to create fixed infrastructure to recharge such vehicles (Almeida, Kahn, and Cristiane, 2013). If the government establishes a sectoral ethanol fund, as further discussed below, part of the resources could be focused on research and development to foster the deployment of hybrid vehicles that are capable of making efficient use of biofuels—a genuine Brazilian technology.

However, while these alternative options to replace fossil fuels in public transportation are relevant in terms of GHG emissions, it is important to consider the negative effects in terms of the higher infrastructural costs of the system; increased fees and fares would make public transportation less accessible to the population. Because public transport in Brazil is currently priced with a tariff, it is recommended that the relevant authorities subsidize such measures to avoid increasing the cost of tariffs because of the burden it places on citizens. It is also recommended that subsidies to diesel are ended,³ to level the playing field with biofuels.

The energy balance associated with sugarcane ethanol results in considerably reduced GHG emissions: while maize ethanol reduces GHG emissions by only 18 percent relative to gasoline, sugarcane ethanol in Brazil reduces GHG emissions by 91 percent when it replaces gasoline (Macedo, 2008; Goldemberg, 2008). The World Bank estimates that the use of ethanol rather than fossil fuels in Brazil results in avoided emissions of approximately 50MtCO₂e per year (World Bank, 2010).

Despite these mitigation benefits, there is an important debate concerning the land-use change (LUC) associated with the production of biofuels, and the relationships between food, energy, and environmental sustainability (Souza et al., 2015). There is considerable controversy surrounding the amount of land-use change globally that can be linked to the production of biofuel (Tyner and Taheripour, 2013; Searchinger and Heimlich, 2015). In the case of Brazil, robust literature reviews show that the expansion of sugarcane in recent years has occurred mostly at the expense of extensive pasturelands and other temporary crops, without leading to perceivable indirect land-use change related to deforestation (Walter et al. 2011; Souza et al, 2015). There is virtually no sugarcane in the Amazon; sugarcane expansion occurred outside the Amazonian forest because of the practical difficulties of growing sugarcane crops in hot and humid areas. The expansion in the Cerrado has occurred mainly on pastures,

Figure 11 | Final Energy Consumption by Fuel Source



Source: BEN, 2014.

many of them degraded (Pacca and Moreira, 2009). Furthermore, life cycle analyses (LCA) of the main biofuels feedstocks in Brazil show that, while they considerably reduce GHG emissions, their production in the country does not pose risks of invasiveness (Horta Nogueira and Capaz, 2013), and that ecosystem services can be adequately maintained with appropriate agricultural practices.

Nevertheless, one of the main environmental challenges facing future biofuel production will be to ensure that it does not cause harmful land-use changes, and it will be imperative to address and reconcile concerns about the role of biofuels and food security. If there is to be no increase in the demand for pastureland for biofuel production, this implies that yields for biofuel crops will have to increase at the same rate as the increase in biofuel demand. If, on the other hand, demand for pasture land for food production increases, because of rising demand for Brazilian meat and dairy products that is not met by productivity improvements, the pressure to increase biofuel yields will be greater still: biofuel yields will have to increase at a faster rate, to compensate for the reduced area of pastureland land available for biofuel production.

Despite the significant role of sugarcane ethanol in the transport sector, the relatively low price of gasoline (as a result of subsidies) has reduced the share of the biofuel in consumption. In 2009, ethanol represented about one third of the fuels market for light-duty vehicles in terms of energy content, but between 2009 and 2012, the share of ethanol in the fuel market for light-duty vehicles in terms of energy consumption of road passenger transport, for example, decreased from 33.4 percent to 22.3 percent, while demand for gasoline increased (BEN, 2014), Figure 11.

In general, biofuels (especially ethanol) lost competitiveness in recent years because of several factors, including: (i) the use of gasoline subsidies designed by the federal government in an attempt to curb inflation; (ii) reduction of investments in the bioenergy sector following the 2008 financial crisis; (iii) loss of agricultural productivity due to climate impacts that reduced the yields of sugarcane in recent years; and (iv) higher international sugar prices, which diverted sugarcane to uses other than ethanol production. In order to increase the share of biofuel in the energy mix, some existing and potential policies are discussed below.

Phasing out fossil-fuel subsidies

Price controls on fossil fuels subsidize their consumption and affect the competitiveness of renewable energy. In Brazil, this is a case of gasoline against ethanol (and, to a lesser extent, of diesel against biodiesel). Investments prioritizing oil (and gas) infrastructure are other forms of “hidden” subsidies. Price-control policy is part of the government’s efforts to curb inflation, an attempt to avoid transferring to consumers the short-term volatility in international oil prices (Aidar and Serigati, 2015; Fattouh et al., 2015). This leads to relatively lower gasoline prices, compared to the “rule of thumb” break-even price. It is known from consumer behavior studies that ethanol is only preferable if the cost per liter is 70 percent of the cost of gasoline at the pump, or lower. As a result, flex-fuel vehicle owners choose the fossil option over ethanol, and consequently reduce market share and incentives for flex-fuel hybrids.

The federal government finally adjusted and raised the price of gasoline in 2013; the increase had originally been planned for 2007. The government also announced an increase in the mandated level

of ethanol (anhydrous alcohol mixture) from 20 percent to 25 percent, and unveiled a set of tax cuts for the ethanol industry.

Instead of providing fossil-fuel subsidies, it would be more useful to increase the subsidies to renewable-energy sources (Goldemberg, 2012). In this spirit, when the government recently fully reestablished the CIDE for gasoline, it created incentives to enhance the production of biodiesel, by reducing some federal taxes on the production of renewable fuel. They include the CIDE tax, the Industrialized Products Tax (IPI), the Contribution to the Social Integration Program and Civil Service Asset Formation Program (PIS/Pasep), and the Contribution to Social Security Financing (COFINS). The government also offered low-cost credit to biofuel producers, as well as some subsidies that cover the higher cost of biofuels relative to diesel. In November 2014, the federal government established the Normative Instruction no 1.514, suspending the levy of PIS/Pasep and COFINS on the acquisition of raw materials that are used for biodiesel production, which translates to a tax reduction of 0.825 percent and 3.8 percent respectively.



Investing in more R&D and creating a sectoral biofuel fund

Additional measures are necessary to induce continued long-term technological progress on biofuels. It is important to coordinate financing lines and programs in science, technology, and innovation (ST&I) and continuous research and development (R&D) to keep the national market abreast of new trends in the energy sector. Second-generation ethanol production, for example, allows the use of new biomass, including forest and agricultural residues (sugarcane bagasse), and is an innovation in the sector that could help Brazil maintain its place at the forefront of biofuel production (Nova Cana, 2013). The federal, state, and local governments could create more financial incentives to stimulate the production of new domestic technologies on biofuels that could increase the number of patents in Brazil and decrease production costs. The government could establish a sectoral biofuel fund to invest in R&D in specific programs to increase efficiency in motors fueled by ethanol (first and second generation) and biodiesel, and in programs to foster the deployment of hybrid vehicles, as discussed further below.

Increasing the mandatory blend of biofuel and encouraging 100-percent-biofueled public buses

While taking care that future biofuel production does not cause negative land-use changes, the Ministry of Transport (MT) could increase the level of the mandatory blend of biodiesel to diesel for heavy vehicles and the mandatory blend of anhydrous ethanol to gasoline for light vehicles. Local governments could also encourage urban bus operators to use more biofuel blends. Some cities in Brazil, for example, are already starting to operate with low-carbon-emission public buses. In 2012, Rio de Janeiro City launched the “Sugarcane Diesel Project” to test the addition of 30 percent sugarcane in the blend of diesel (AFCP, 2012). São Paulo City has also invested in a pilot project called “Ecofrota,” to test “B20” public buses (buses fueled by a 20 percent biofuel mix) (AFCP, 2012; SPtrans, 2012).

Besides requesting higher levels of ethanol and biodiesel in the fuel market in Brazil, local governments could incentivize 100-percent-biofuel (ethanol or biodiesel) public buses. In 2007, São

Instead of providing fossil-fuel subsidies, it would be more useful to increase the subsidies to renewable-energy sources (Goldemberg, 2012).

Paulo City began testing public buses powered by 100-percent ethanol, as part of an international initiative of the Bio Ethanol for Sustainable Transport (BEST) project, led by the Brazilian National Reference Center of Biomass (CENBIO) (São Paulo, 2007). In 2009, the local government from Curitiba established, through a private-public partnership (PPP), the “B100 Biodiesel Project” to test public buses operated with “B-100” fuel (100-percent-soy biodiesel), which can lead to 30 percent reductions in GHG emissions. This kind of bus involves higher costs (an increase of 20 to 30 percent) compared to regular fossil-fueled buses, and has been subsidized by the local government, but the environmental benefits include not only GHG emission reductions, but also improved air quality in terms of lower emissions of particulates and sulfur (URBS, 2009; BiodieselBr, 2010). Soybean production is more extensive than sugarcane in terms of land and requires adequate management and prioritization in the uses of biodiesel—the case of urban buses, which have lower fleets (relative to trucks) and run in populated areas. However, the number of such buses in operation is still very modest (SPtrans, 2012), and the need for more incentives is crucial.

Establishing sustainable public procurement that prioritizes biofuels

Public procurement accounts for a large share of a national economy (estimates range between eight percent and 25 percent of GDP) (IPEA, 2010).



Governments are large-scale consumers and can drive innovation by increasing the demand for more sustainable production and consumption. Therefore, sustainable public procurement constitutes a relevant tool with great potential to promote environmental and social policies. In 2010, Federal Law no. 12.349 altered Federal Law no. 8666 of 1993 to establish sustainable development as a principle of public procurement. It also provides guidelines for purchasing green products, including fuels and vehicles. At the ministerial level, there is already some experience with procurement of goods and services that follow sustainability criteria, such as the leasing of biofuel vehicles in the Ministry of the Environment (MMA, 2015). The Integrated System for General Services Administration (SIASG), managed by the Ministry of Planning and Budget (MPOG), also included one category for “biofuel vehicles” in its registration system (Portal Brazil, 2012). However, the number of sustainable tenders involving biofuel remains very low in Brazil. Public procurement constitutes 10 percent of Brazil’s GDP and, with due regard for environmentally responsible land use, the federal government could exert real influence by developing guidelines and establishing requirements for public procurement that prioritize biofuels in place of fossil fuels in the transportation sector.

Establishing a Price on Carbon

A carbon price signal could induce GHG reductions across various sectors of the economy. In the case of energy-related GHG emissions, carbon pricing

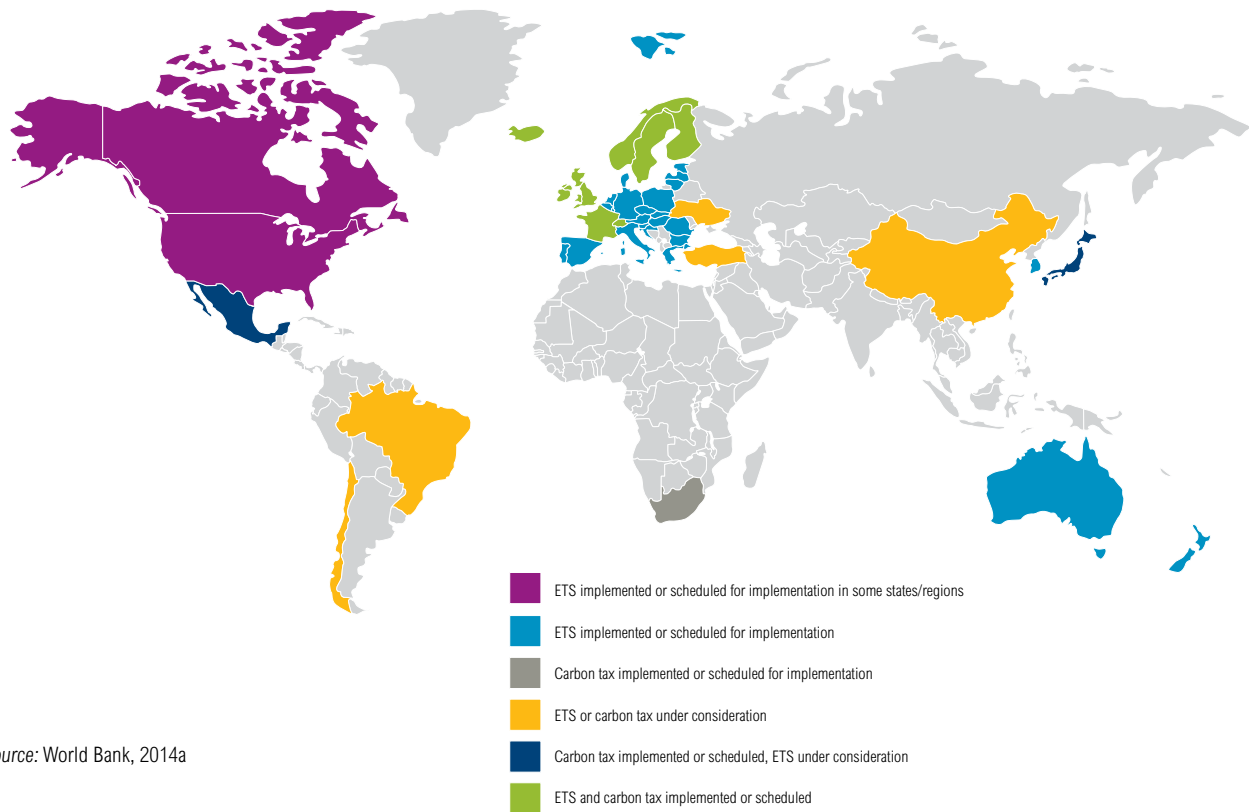
could comprise a tax rate on GHG emissions or on the carbon content of fossil fuels. Such an instrument might be an important tool to tackle climate change as part of a package of effective and cost-efficient policies.

Several countries have already established carbon pricing, including the world’s two largest GHG emitters (China and the United States), as shown in Figure 12. About 40 national and over 20 sub-national jurisdictions have implemented or are considering (with different degrees of priority) an emissions trading system (ETS); together, they cover almost six GtCO₂e or about 12 percent of annual global GHG emissions (World Bank, 2014a).

Prices vary significantly among carbon-pricing schemes (ranging from USD 1/tCO₂e in Mexico to USD 168/tCO₂ in Sweden). For business leaders, the discrepancies between the prices can affect competitiveness, which indicates the relevance of the creation of a global carbon-pricing system (Ethos, 2015). However, a low price on carbon will not necessarily result in net GHG reductions from business as usual (BAU) projections.

In Brazil, the Ministry of Finance could establish a carbon-pricing system, based on metrics such as CO₂ per ton of oil equivalent or per kilometer (distance traveled), but the issue of establishing a CO₂ tax in Brazil is still the subject of controversial debate at present. The Ministry of Finance is conducting a study to explore the impact of a CO₂

Figure 12 | Existing, Emerging, and Potential Carbon Pricing Instruments



Source: World Bank, 2014a

tax on the national economy, and the subject has also been discussed inside the National Congress through the Mixed Commission for Climate Change (Câmara dos Deputados, 2014). A national pricing mechanism would open an opportunity to transform lower carbon emissions from energy into competitive advantage, and a tax could encourage emissions reductions (Agência Gestão CT&I, 2015). However, the federal government is more focused on economic incentives to encourage GHG emission reductions than on carbon taxes. Given the high tax burden in Brazil, the challenges to establishing new taxes are very significant.

The introduction of a carbon price need not increase tax revenue. There are a number of options regarding how a carbon tax could be implemented without harm to the country’s economy. One option would be to adhere to “revenue neutrality,” which involves using the increased tax revenue to offset the recessionary effect of carbon taxation. Finland and the United Kingdom are examples of countries that have adopted tax neutrality as part

of their carbon tax strategy, and their approach has generated some political support (Câmara dos Deputados, 2014). Another option to reduce political resistance and economic impacts would involve a gradual implementation of the carbon tax. It would be important to use the tax to induce behavior change by establishing different levels for different economic sectors.

Industry

Context and trends

The Brazilian industry sector is very diverse, in terms of both subsectors and fuels. GHG emissions from industrial energy use, however, have been dominated by iron and steel production, followed by cement. Between 1990 and 2013, GHG emissions from the iron and steel subsector increased by 61 percent, and at present they account for 46 percent of emissions from industrial processes. Cement production, the second-largest emitter in the subsector, accounted for approximately 30 percent of industrial GHG emissions in 2013 (SEEG, 2014).

GHG emissions from industrial energy use...have been dominated by iron and steel production, followed by cement.

Although Brazil's **iron and steel** industry is already very efficient, the subsector is expected to be responsible for the greatest share of GHG emissions in the industry sector until 2022, and growth in this subsector is expected to lead to considerable increases in the consumption of coal, coal coke, and coke oven gas, with implications for future emissions. The majority of Brazilian iron and steel (76 percent in 2012) is produced in blast furnaces/basic oxygen furnaces (IAB, 2013; CNI, 2012). National average energy intensities in 2007-2011 ranged between 20.1 and 20.8 GJ/t steel, while actual best technologies reached 14.8 GJ/t steel, with further potential energy savings of 4.7 GJ/t steel (WSA, 2012; IAB, 2013; Henriques Jr, 2010; Worrel et al., 2008; IEA, 2010).

Cement: Brazilian cement production relies on the relatively efficient dry processing approach. Average energy intensity of production in 2007 was 3.7 GJ/t clinker, which was slightly better than the global average (4.1 GJ/t clinker), but worse than the best available technology (2.85 GJ/t clinker) (Henriques Jr. 2010; IEA 2007). The profile of fuel consumption in the cement industry has changed dramatically from fuel oil to coal and petroleum coke, which has led to more efficiency in the industry.

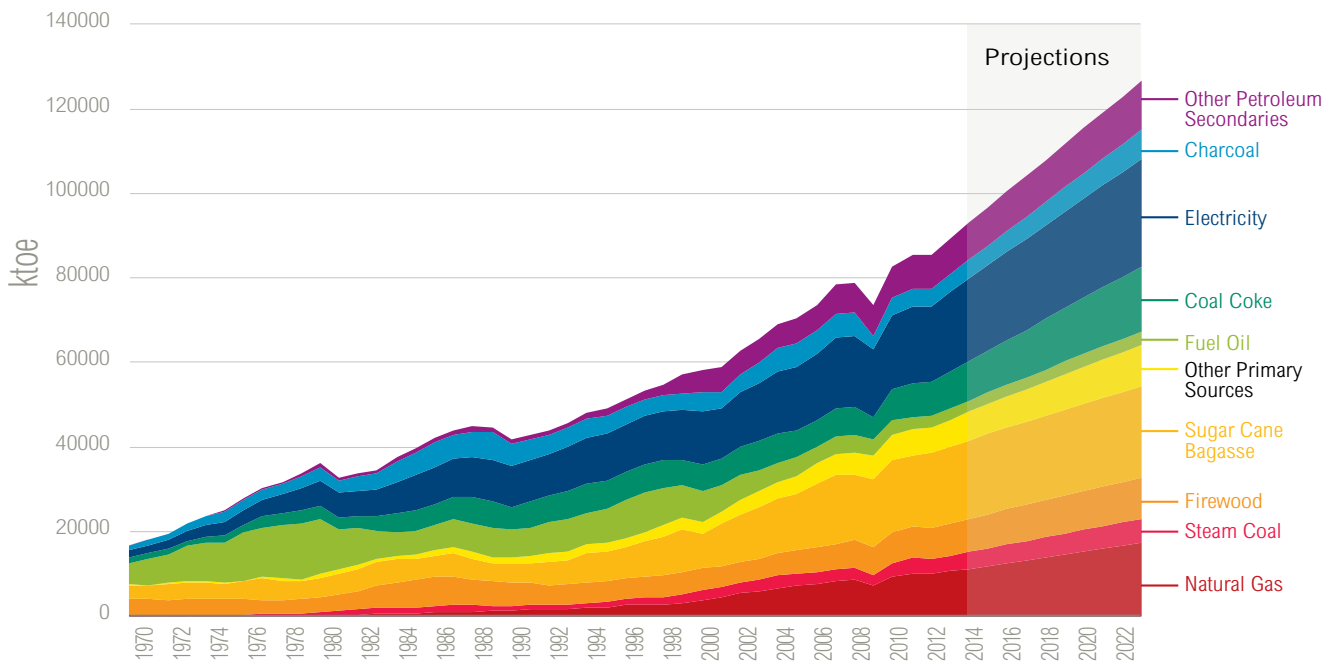
Non-ferrous metals: Non-ferrous metals (ferroalloys) include aluminum, zinc, copper, and other metals. This subsector draws primarily on charcoal, firewood, and electricity to meet its growing energy needs. Aluminum is the most electricity-intensive output from this subsector; its electricity intensity can be reduced by up to 95 percent through waste-heat recycling in Brazil (OECD, 2013).

Chemicals: The chemical industry involves a vast array of products and manufacturing processes, from the production of simple substances to the complex petrochemical and fine chemical industries. Its energy mix is also diverse and changing. The most energy-intensive products are ethylene (or ethene), ammonia, methanol, chlorine, sodium hydroxide (or caustic soda), and sulfuric acid. Energy-intensive subsectors are petrochemical,

fertilizer, and chlorine-alkali production, which together are responsible for 70 percent of total energy consumption in the chemicals industry. Some groups (elastomers, resins, plastics, and fine chemicals) make specific products involving higher energy intensity, but these are less relevant given their small share of total energy consumption.

The various scenarios for the Brazilian energy sector presented in Scenario Analysis show that industry is the second largest emitter in the energy sector and therefore must be the second top priority in terms of reducing GHG emissions. One of the main proposals of the McKinsey (2009) scenario for decarbonizing the energy sector in Brazil is to improve industrial efficiency. The reference scenario (PNE, 2030) emphasizes the need to phase out the use of fossil fuels in industry by 2030. La Rovere et al. (2013) show that more efficient and cleaner technologies will result in lower emissions from industrial processes. A reduction in SF₆ emissions and cooling gases as a result of mitigation actions in industrial processes was also assumed as a consequence of redesigned equipment and more advanced techniques in gas collection during maintenance activities.

Figure 13 | **Evolution of the Brazilian Industry Sector: Subsectors by Fuel Source** (process emissions not included)



Source: Authors' elaboration, from MME 2013, EPE 2014, MCT 2010.

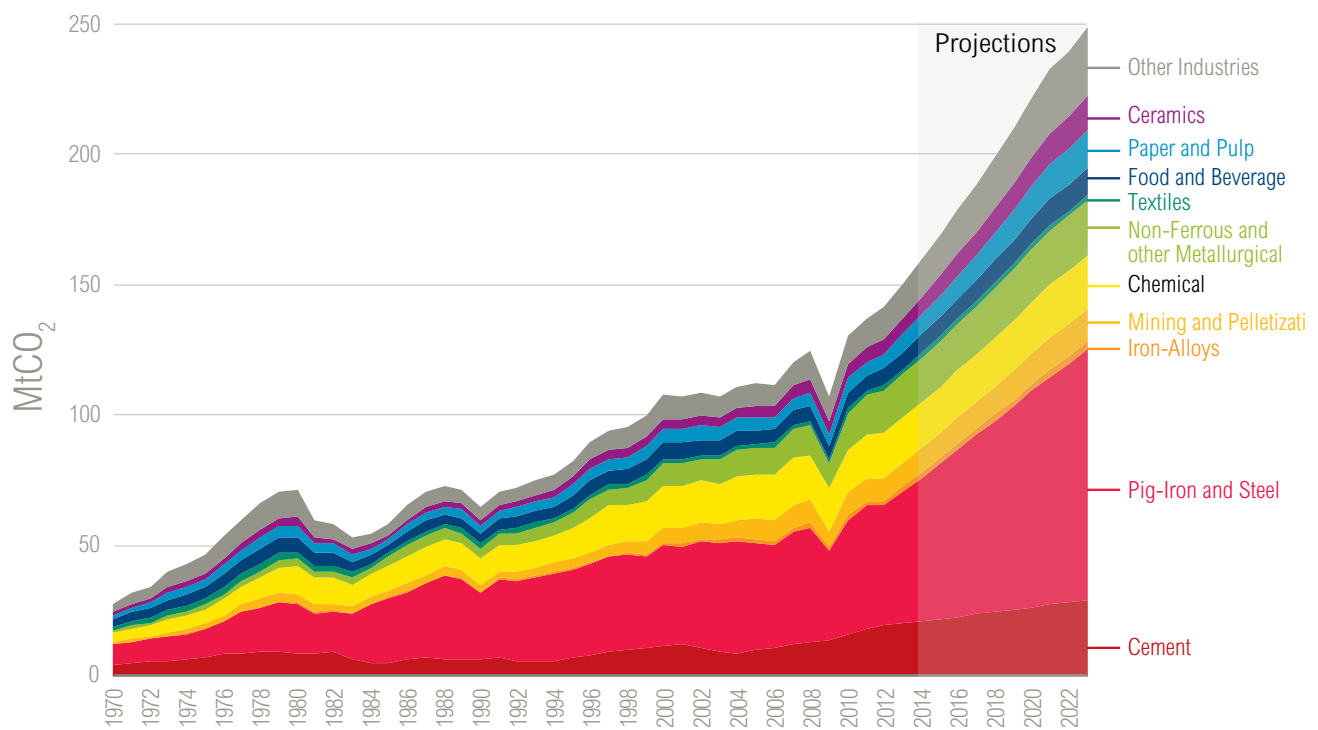
Greenpeace (2013) states that final industrial energy consumption can be reduced by 22 percent, through the use of solar, biomass, biogas, and bioelectricity, contributing to an overall reduction in final energy demand,⁴ achieved by more rational use in the buildings, industry, and transport sectors. While the Ten-Year Energy Plan does not break down future projected energy use by subsector, it is possible to estimate this information based on certain subsectoral characteristics (like dedicated use of certain fuels) and a few simplified assumptions (like constant shares of each subsector over time).⁵ Industry in Brazil encompasses a wide variety of subsectors fueled by diverse energy sources, as shown in Figure 13. Together, they contribute approximately one quarter of Brazil's Gross Domestic Product (World Bank, 2014b).

GHG emissions from industry, however, as already mentioned, are concentrated in the iron and steel, cement, and chemicals subsectors (Figure 14).

Current policies

In 2013, the Ministry of Development, Industry, and Foreign Commerce (MDIC) published a Sectoral Plan on Climate Change Mitigation and Adaptation for the Consolidation of a Low-Carbon Economy in the Manufacturing Industry-Industry Plan, (MDIC, 2013) as mandated under Decree 7.390 (Brazil, 2010), regulating the Climate Law. The plan covers aluminum, cement, pulp and paper, and chemicals during its first phase, after which iron and steel, lime, and glass are expected to be considered (a separate plan for the steel sector is under development).

Figure 14 | **Energy-Related GHG Emissions from the Industry Sector, 1970–2022** (process emissions not included)



Source: Authors' elaboration, from MME 2013, EPE 2014, MCT 2010.

According to the Industry Plan, the aim is to achieve a five percent reduction below the emissions level projected for 2020, and its main goal is to reduce all industry-related GHG emissions and prepare the sector for the challenges and opportunities of a low-carbon economy. More specifically, the Industry Plan is built on three pillars:

- the gradual implementation of a measurement, reporting, and verification (MRV) system;
- the creation of an action plan with a set of measures and tools to encourage energy efficiency and the reduction of GHG emissions in the industry; and
- the creation of a Technical Commission on the Industry Plan (CTPIIn), responsible for detailing, monitoring, and reviewing the plan's activities.

The CTPIIn was established by Ministerial Decree No 207 and has taken the lead in promoting the

interaction between public and private entities to implement, monitor, and review the Industry Plan. The Climate Fund already provides specific funds to finance business projects related to the goals of the Industry Plan; however, the Commission has been struggling to establish a robust MRV system of industrial-process emissions and energy use in the sectors included in the Industry Plan. Additionally, industries have indicated that the Industry Plan is not adequately integrated with other sectoral plans and a better coordination among them is essential to their success.

Further abatement potential

Although the EPE estimates that industry will account for an important share of the economy in 2050, the 2050 National Energy Planning estimates that industry will contribute a decreasing share of total Brazilian GDP (EPE, 2014). This trend, in

turn, might reduce the relative share of industry's energy consumption over the long term, and consequently its relative contribution to total GHG emissions.

The scenarios analyzed in Annex 1 suggest that a gradual increase in the energy efficiency of materials used in infrastructure, especially in the construction of industrial facilities, is a key opportunity for further emissions reduction. The expansion of more efficient power plants and the decommissioning of inefficient plants could also reduce the projected acceleration of energy demand out to 2050. The PNE 2050 estimates that overall energy efficiency across all industry sectors can contribute to reducing energy consumption by approximately 20 percent by 2050 (EPE, 2014). The various scenarios analyzed in Annex 1 also indicate that a combination of energy efficiency and the use of low-carbon technologies (such as solar, wind, carbon capture and storage etc.) can result in GHG abatement of approximately 20–43 percent in 2030, relative to reference cases.

Increasing incentives for low-carbon fuels, which effectively can cause a drop in GHG emissions, is one option but these fuels often require adequate technologies, supply logistics, and dependability. The policies listed below could advance abatement in the industry sector.

Establishing a Mandatory and Bottom-Up MRV System in Brazil

The Technical Commission on the Industry Plan (CTPIIn) has established a Working Group on Inventories (WG inventories) to set parameters for reporting GHG emissions from industrial sectors. The Ministry of the Environment, under the Federal Joint Center for the Climate, also created, in 2013, a Working Group on GHG Registry (Registry WG) that aims to propose recommendations for an MRV System and a mandatory bottom-up GHG Registry. The Registry WG convenes stakeholders from the various levels of government, academia, and civil society, and intends to assist Brazilian states and the federal government to create and/or harmonize GHG Registries and to set them on an implementation path based on robust and effective international best practices. However, the Inter-Ministerial Commission on Climate Change (CIM) has not yet analyzed the recommendations provided, in 2013,

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by the Working Group on GHG Registry for the creation of a MRV System in Brazil; it could therefore review and approve the document as a first step toward establishing such a system in Brazil.

Implementing the Brazilian Market for Emissions Reduction (MBRE)

One of the aims of the 2009 National Policy on Climate Change (PNMC) is to encourage the development of the Brazilian Market for Emissions Reduction (MBRE). According to the PNMC, the MBRE will be operationalized in stock exchanges authorized by the Brazilian Securities and Exchange Commission (CVM) to trade GHG emission-reduction certificates. This market could serve as an important tool to reduce GHG emissions in Brazil. In 2011, the Working Group on Carbon Markets, coordinated by the Ministry of Finance (MF) and comprising representatives from various ministries, was established by the Inter-Ministerial Commission on Climate Change (CIM). Its goal was to analyze the feasibility and requirements for the implementation of the MBRE and support

the CIMGC on decision-making to implement the MBRE (MMA, 2011). The working group also studied the trade-offs between alternative market instruments, such as the creation of a carbon tax in Brazil, and prepared a feasibility assessment report for the implementation and operation of the MBRE, as well as an assessment of the potential and cost-effectiveness of market-based instruments for reducing emissions in Brazil. However, the MBRE has not yet been developed, because the federal government has not yet officially approved the final report on the establishment of the MBRE. The CIM could review and approve the report to help foster the creation and implementation of such market.

Labeling the Energy and/or GHG Intensity of Products and Processes

The Ministry of Development, Industry, and Foreign Trade (MDIC) could improve sectoral policies for industry through the requirement for life cycle analysis (LCA) of major industrial products, in order to identify the best intervention points to reduce GHG emissions. Life cycle analysis could provide additional reduction options ranging from the selection of new materials to the choice of logistics that benefit the overall reduction of GHG emissions. The MDIC could create methods and metrics to distinguish among industrialized products according to their GHG intensity. This measure would differentiate similar and substitute products available in the market according to the GHG emissions that resulted from their production processes. This labeling measure

could encourage competition among industries for the production of less carbon-intensive products.

Implementing a consumption regime based on energy intensity standards is a more difficult task, because trade barrier claims can be raised; such a step would require concerted and intense legal efforts. Globally, these measures have, for the most part, been implemented as part of voluntary private certification schemes, and governmental support is still very limited (International Trade Center, 2012). Energy intensity standards are a very controversial issue because of the risk that they might be interpreted or used as trade barriers against emerging or less developed countries (ApexBrasil, 2012), but the benefits of such measures to promote sustainable development might outweigh these risks.

Benchmarking to Increase Energy Efficiency

Environmental licensing through regulatory reforms applied by the Brazilian National Environmental Council (CONAMA) could require increased energy-efficiency measures. This measure would make permits dependent on meeting industry-wide efficiency benchmarks that could boost performance (increase efficiency) without inhibiting production. Benchmarking has been used widely in the European Union—in combination with other industrial policies—and has reduced energy intensity significantly over the period 1990 to 2007. Energy intensity has declined by 12 percent in the paper sector, 27 percent in cement and steel, and



55 percent in the chemical sector (Ernst & Young 2012). In Brazil, industrial energy intensity could be improved by 4–10 percent over the period 2011–2021 (MME, 2013; MMA, 2013b). For instance, subsectoral analyses can allow for more detailed *benchmark curves*. However, in the long term, many other sectors could reap benefits through improved processes, fuel switching, and waste recovery/recycling. Efficiency gains could reach above 50 percent for the glass sector, 30 percent for steel, and to clarify that category: 20 percent for cement, lime, pelleting and chemicals (ethene and ammonia), 15 percent for paper, ceramics and textiles and even 10 percent in the already efficient aluminum sector 2021 (MME, 2013; MMA, 2013b).

Replacing Coal with Renewable Charcoal

One form of sequestering carbon is through planting forests, and charcoal produced from such forests can provide an alternative, low-carbon fuel that could help decarbonize sectors such as iron and steel. With adequate supply chain logistics, in which biomass for charcoal is planted, harvested, and transported sustainably, renewable and sustainable charcoal can be one of the top solutions to decarbonize some industry sectors (CGEE, 2014). The share of fuelwood in the total energy mix is expected to decline from 8.2 percent to 6.0 percent between 2013 and 2022 (EPE, 2013). Switching from coal and charcoal obtained through deforestation to charcoal from planted forests represents an important step in the decarbonization of the iron and steel subsector. This study recommends that the iron and steel industry move toward the replacement of coal (which is highly polluting and mostly imported) with renewable charcoal.⁶ The industry involves relatively few process units, which makes control and enforcement easier, at least in theory. However, replacing coal with renewable charcoal would require new facilities and/or major renovations of existing facilities (furnaces designed for coal burning do not operate with charcoal), as well as new energy supply infrastructure, which would ultimately result in higher input costs (CNI 2012). The federal government, through its climate sectoral plans, could consider expanding charcoal use beyond the mere replacement of the fuel produced from deforestation, to include replacing coal and other fossil fuels used mainly by industry. We



recommend that the updated version of the 2008 National Plan on Climate Change, which is still under review, should consider this option.

Power-Generation Sector

Context and trends

Brazil's power-generation sector is undergoing a major transformation. Historically dominated by hydropower, a growing share of power is now generated from thermal electricity processes, including from fossil fuels (coal, natural gas, fuel oil, and diesel), biomass (sugarcane bagasse in particular) and, to a lesser extent, uranium. At the same time, the PDE 2023 projects significant growth in Brazil's electricity demand over the next decade, resulting in the need for around six GW of additional installed capacity per year through 2023 (EPE, 2014). Taken together, the trend toward a more carbon-intensive power sector, coupled with a higher demand for energy, would result in a significant increase in GHG emissions. These trends, however, are not inevitable: estimates of growth in power demand were inflated in the PDE, and Brazil has significant renewable-energy potential, offering opportunities to green the power-generation sector.

The scenarios reviewed above identify opportunities for both supply- and demand-side GHG reductions in the power sector. McKinsey (2009) considers the power sector only peripherally, but nonetheless identifies opportunities for 11 percent (190 MtCO₂) potential emissions reductions in the power sector relative to official plans for 2030 (PNE2030). De Gouvello et al. (2011) examine supply-side mitigation options (wind and biomass cogeneration, fuel replacement by biomass/ethanol, and oil refining and gas-to-liquids), as well as demand-side options (such as energy efficiency in electricity consumption and reductions from industrial use of fossil fuels).⁷ The abatement potential for the power sector is estimated at 11.7 Gt CO₂e (between 2010 and 2030) or an average of 560 MtCO₂e annually. Greenpeace (2013) indicates that the necessary GHG emission reductions will be possible if thermal-power plants running on fossil fuels are replaced by non-fossil-fuel powered plants as the energy supply is expanded. IEA's Energy Technology Perspectives (ETP) suggest that, to achieve the 2°C pathway, key mitigation strategies in the power sector include decarbonization through investments in low-carbon technologies such as wind and solar, energy efficiency, and carbon capture and storage (CCS).

Policy options and implications for the technologies discussed in these various scenarios—including hydropower and interconnected renewables (for example, wind complementing hydropower)—are discussed below.

Increasing the Share of Wind and Solar in the Electricity Mix

Investing in modern renewable energy sources (especially wind and solar) can enhance energy security, reduce GHG emissions, and create more jobs in Brazil (Pao and Fu, 2013). However, despite signals in the latest auctions that wind can compete with fossil sources and win (Fidelis da Silva et al., 2012), these energy sources have received limited support in Brazil. Although the Terms of Reference for the upcoming National Energy Plan (PNE 2050), elaborated by the Governmental Energy Research Company (EPE), indicate the relevance of investing in modern renewable energies such as wind and solar, the plan contrarily estimates a relative increase in energy supply from thermal power plants fueled by natural gas and coal.

With regard to solar energy, as of 2015, photovoltaic solar energy contributes only 15 MW of installed capacity in Brazil (ANEEL, 2015). The high cost of solar energy per MWh is one of the greatest obstacles to the widespread use of solar PV in Brazil. The cost of solar PV energy was estimated at R\$ 280.00 to R\$ 300.00/MWh in 2013 (Scalambrini, 2013). Other key challenges are related to the intermittency of renewable energy sources in Brazil (EPE, 2012; OESP, 2013; Oak and Sauer, 2012), and the lack of adequate incentives in Brazilian energy policy to disseminate the use of solar power. The Ten Year Energy Plan 2013–2022, for example, forecasts the generation of only 1,400 MW of distributed generation via solar PV by 2022 (PDE, 2014). However, the opportunity to invest in photovoltaic solar energy in Brazil is significant, not only because of the high incidence of solar radiation, but also because of the increasing efficiency

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and decreasing costs involved in implementing photovoltaic systems at the international and national levels (ABINEE, 2012). In 2015, tax levies on solar PV decentralized electricity are being removed, which in turn decreases the implementation costs of solar PV and accelerates the grid parity process.

There are significant untapped opportunities for Brazil in this field: high solar irradiance, plunging costs, and a strong interaction of the photovoltaics sector with electronic components industries in terms of value chain. Electronic components are particularly important, both in terms of Brazil's balance of trade and innovation. Semiconductors can be produced from the purification of electronics-grade silicon, with many co-benefits for other industrial sectors in the country. A suboptimal solution could be to produce silicon of lower quality (solar grade) through the metallurgical process, which is less energy intensive. But to achieve large-scale production, it is necessary to foster both supply and demand, motivating stakeholders to take advantage of the possible opportunities of assimilating new technology and the added value in local production at all supply chains.

There is an intense debate over whether Brazil should develop a vertically integrated solar panels industry (including production of cells) or whether efforts should be concentrated in assembling modules and installing systems. On the supply side, it is necessary to have systemic measures to reduce capital, operational, and maintenance costs, including subsidies and other incentives (for cells, modules, and components); research and development (for example, for thin films or crystalline cells working under high temperatures); funding (for example, Fundo Clima and other BNDES funds); and robust standards, norms and regulation to avoid variable quality among regions (ABINEE, 2012). On the demand side, strong action is required from public agents, especially from the Ministry of Mines and Energy (MMA), Ministry of Finance (MF), Ministry of Science, Technology and Innovation (MCTi), ANEEL, and EPE, with specific bidding and relevant volumes of contracts, to provide more economies of scale. The regulatory environment must be favorable, with measures such as feed-in tariffs (FIT) and net metering schemes, as well as simplified procedures for grid access (for example, dispensing consultations and access reports, with swift processes concerning contracts and environmental permits).

Concentrated Solar Power (CSP) has also vast potential in the arid regions of Brazil (Lucena et al., 2015), with a theoretical annual production of around 1900 TWh (Burgi, 2013). There is a growing literature about the prospects for CSP growth in Brazil. With storage or hybridization (the process of combining two complementary sources, such as CSP and biogas production systems) CSP could solve most of the problems of intermittency, but to date no projects have been initiated. The technology of CSP allows for energy storage using, for example, molten salts, which can be an advantage for intermittency reduction (Lodi, 2011). Thermal collectors for domestic hot water are already a mature technology, but one that is still not widely deployed because of barriers including initial capital costs and lack of a trained workforce to build installations. Collectors can also provide heat for commercial cooling systems, heating swimming pools, and for other types of thermal comfort (Souza et al., 2010). All of these options are still seen by the government as peripheral, remaining outside mainstream measures (Silva, 2015).

With regard to wind energy, several studies indicate the high potential of wind power in Brazil, but its contribution is still very modest—despite the highly competitive prices in the latest energy auctions. There are currently 242 installed windmills in Brazil, which contribute 4.9 GW of installed capacity or 3.6 percent of the electricity supply (EPE, 2015),

and account for avoided emissions of roughly five MtCO₂e per year. The declining costs of generating wind energy in Brazil already demonstrate its potential and competitiveness when compared with natural gas and coal sources (Ricosti and Sauer, 2013). Wind farms in Brazil have suffered from grid connection delays, a problem that has been addressed more recently. Technology is evolving rapidly, and the results of the latest auctions indicated a considerable fall in the price of wind energy per MWh (Fidelis da Silva et al., 2012).

Nevertheless, it is expected that modern renewable sources (mostly wind) will grow only from 4.3 percent to 5.2 percent between 2013 and 2022 (EPE, 2012), because natural gas or coal-fired power plants are still prioritized to meet baseload power needs (ACENDE, 2014).

High costs have long been a major obstacle to renewable electricity expansion in Brazil, which is now being overcome, notably by wind power (The Economist, 2013; EPE, 2012). However, uncertainty over the rules that regulate renewable electricity generation—and, until recently, artificially low prices to the consumer—have reduced the attractiveness of investments in renewable energy and discouraged end-user energy-efficiency measures. In 2015, soaring electricity prices are changing these equations, but many policymakers still consider the installation of more fossil-fueled power



plants, located near urban centers, to be the default choice. Given the delays in expanding the grid to include wind and solar energy sources, and the need to increase energy security, the government has decreased the share of renewable new capacity auctioned. At the same time, it has been increasing energy production from fossil-fuel power plants, especially coal-fired power plants, because they are relatively fast to build and connect to the grid. They also represent reliable (non-intermittent) sources that can provide energy over a longer time period.

In order to increase the share of wind and solar PV sources in the Brazilian electricity mix, the government has improved the auction system with source-dedicated rounds, as part of an energy, climate, and industrial innovation policy instrument. In the case of photovoltaic energy, although costs are still high, the contracted volume of energy could represent a minimum guaranteed demand to underpin the scale requirements for local installation of productive units, mainly modules. Auctions serve as an efficient instrument to identify the most cost-effective technologies in Brazil, and could be further improved by factoring in the many co-benefits from modern renewable energy sources.

With the joint climate announcement by Presidents Barack Obama and Dilma Rousseff in June 2015, the United States and Brazil reinforced the urgency of tackling climate change and committed to increase the share of renewables (beyond hydropower) to 20 percent by 2030 in their electricity mixes (The White House, 2015). However, the announced commitments from Brazil appear not to be very ambitious. Reaching the target does not represent a major effort because of the direction in which Brazil is already moving (the PDE2023, for example, already forecasts a 20 percent share for non-hydro renewables in the electricity mix by 2023 (EPE, 2014)). Therefore, the federal government could consider committing to increase the share of solar and wind to 30 percent by 2030 as part of Brazil's intended nationally determined contribution (INDC) under the UNFCCC 2015 Paris Agreement.

The government could also consider exempting foreign equipment and components for solar PV power generation from the Tax on Imports levy, and providing new lines of financing for solar PV genera-

tion equipment. Several countries, for example, the United States, are creating a series of incentives to encourage the broad expansion of the photovoltaic industry chain. The benefits include increasing local economic development, creating jobs, increasing access to renewable energy sources and, thereby, supporting national climate policies. These incentives usually take the form of loans, financing, and tax cuts (ABINEE, 2012). The ANEEL Resolution 482 of 2012, for example, established important incentives to encourage solar energy in small installations, including exemption from taxes and charges that are normally associated with independent production and electricity consumption. Providing financial mechanisms adapted to small generation of photovoltaic modules could allow the expansion of these opportunities, scaling them up and reducing production costs for the necessary equipment. The BNDES could make available credit lines, including the existing lines under the Climate Fund Program of the Ministry of the Environment (MMA), which includes, as one of its objectives, supporting investment in solar power generation.

Promoting Grid Interconnection of Renewables

Modern renewable electricity, integrated through smart grids, represents a key option to increase efficiency, decrease costs, and reduce GHG emissions from the power sector in Brazil. Interconnected renewables (modern renewable electricity complementing hydropower), especially wind and solar, could help to address many of the barriers—mentioned in previous sections—to increasing the share of wind and solar in the electricity mix. In particular, grid interconnection could help to overcome the problem of energy intermittence.

Reducing vulnerability to climate variability in the power sector is highly dependent on the integration of different sources of energy, and resilience is also a key issue for energy infrastructure. This problem rose in prominence after severe droughts in 2001, 2010, 2014, and 2015, which affected bioenergy supply. As a result, considerable amounts of liquefied natural gas (LNG) had to be shipped to Brazilian ports at spot market prices (which means higher and volatile prices), in order to back up electricity generation (Gomes, 2014).

New opportunities have been created with smaller and integrated power plant stations systems, such as plants based on small streams and small waterfalls, the reuse of biomass residues, and offshore wind farms (Soito and Freitas, 2011). While relying only on intermittent renewable energy sources, such as wind and solar, might not guarantee energy supply over the year, they could be used as a complementary power source or backup system. A wind-hydro hybrid scheme, for example, is a reasonable option that could be further explored in Brazil, because wind power potential in Brazil is comparable in scale to hydropower, and because Brazil has strong winds throughout the year, in contrast to the seasonal nature of water flow (Pau and Fu, 2013; Pimenta and Assireu, 2015). Wind power in the Northeast coast, for example, could complement hydropower supply during the dry season in that region (Alvim et al., 2005; Riscosti and Sauer, 2013).

A key policy recommendation to increase the share of wind and solar in the electricity mix and to promote grid interconnection of renewables is that the federal government should remove harmful incentives for fossil fuels, leveling the playing field so that alternative energy solutions can compete in a free market.

As integration among sources is improved, hydropower dispatch can be shifted from baseload to peak shaving, and intermittent sources become more stable as contributions to the grid from different regions smooth out variabilities. Smart grids and net metering⁸ can take this situation to another level, where data systems can also forecast variabilities more efficiently and in a more resilient way. A first measure to achieve this is to break out from the conventional generation-transmission-distribution schemes by means of regulations that reduce bureaucracy and administrative barriers to decentralized electricity generation.

A key policy recommendation to increase the share of wind and solar in the electricity mix and to promote grid interconnection of renewables is that the federal government should remove harmful incentives for fossil fuels, leveling the playing field so that alternative energy solutions can compete in a free market. The federal government could also encourage more investments in infrastructure for energy distribution and technological development aimed at local competitiveness, by creating more incentives to reduce production costs, and promoting deployment of manufacturing equipment in Brazil. These actions could increase the installed capacity of such sources and reduce production costs. Through better regulation and fair pricing (following the principle of the affordability tariff as defined by ANEEL, where even low-income consumers have the ability to access electricity and pay for it), wind and solar energy sources could be boosted to levels consistent with long-term low-carbon pathways. Such policy options could offer important prospects for better energy integration and use of smart grids, with several co-benefits like job creation and improved environmental health. It would be important to provide more long-term loans for investments in wind and solar, and improve infrastructure to expand the grid with wind farms, as well as prioritize clean energy sources in energy auctions held by the Brazilian Chamber of Electric Energy Commercialization.

Promoting Grid Integration with Neighboring Countries

Energy integration is emerging as a highly relevant strategy to improve energy security in neighboring countries, mostly because of the benefits related

to economic complementarity among different countries. Grid integration also has the potential to reduce energy costs and diversify the energy mix (Carta Capital, 2015). Countries with a high exportable surplus of energy resources (such as Venezuela, Bolivia, Paraguay, and Peru) share borders with others that need to import energy to meet domestic demand (such as Argentina, Brazil, Chile, and Uruguay).

Cross-border integration of the energy generation system can reduce the risk of failing to meet energy demands in a specific country, and a regional power grid offers the possibility of improved management of seasonality, intermittency, and complementarity of different renewable power sources, thus expanding their potential. In the case of Brazil, energy integration between the country and bordering countries is an option that can provide many joint benefits, in particular, increased reliability and security of supply of complementary national hydropower systems (EPE, 2014).

Brazil's larger borders with neighboring countries include: Argentina 1,263 km, Bolivia 3,403 km, Colombia 1,790 km, Guyana 1,308 km, Paraguay 1,371 km, Peru 2,659 km, Uruguay 1,050 km, and Venezuela 2,137 km. In addition to the Binational Itaipu Hydropower that encompasses Brazil and Paraguay, there are currently interconnections between Brazil and Argentina, Uruguay, and Venezuela (EPE, 2014). There are also some planning studies for the expansion of such joint investments, following the example of projects with Peru, Bolivia, and Guyana. These joint projects have been established predominantly to generate renewable and low-cost energy, for example, through construction of hydroelectric dams.

However, as of 2014, only 25 percent of the potential joint hydropower between Brazil and neighboring countries had been explored (EPE, 2014). The construction of hydropower plants in trans-boundary areas, such as the hydropower plant in the Madeira River, is very challenging and requires monitoring stations and mechanisms for sharing hydrological data (Soito and Freitas, 2011).

Building national hydropower plants is complicated enough and, while reaching an agreement between two countries might be even more challenging,

it could still be a reasonable way to increase the sustainable use of cross-border natural resources (IPS, 2012). Because the national grid is highly dependent on short- and medium-term water availability to generate energy, the need to guarantee that energy supply will meet demand is a critical issue, and it becomes imperative to take advantage of opportunities for regional integration (Soito and Freitas, 2011).

Besides hydropower plants, Brazil and Uruguay launched, in February 2015, a wind farm in Uruguay with generation capacity of 61.5 MW (the Artillero's Park). Development of the wind project was originated in the "Agreement for Evaluation and Joint Development of wind farms for Power Generation Installed in the Eastern Republic of Uruguay," signed in 2012 by Brazil and Uruguay. The project is part of a cooperation agreement between the Brazilian and Uruguayan Electric Utility Companies (Eletrobras and UTE) for the construction of up to 300 MW of wind power in Uruguayan territory (Brazil, 2015a). This is the first commercial investment by Eletrobras outside Brazil, and it constitutes part of the recognition that energy integration is needed to ensure a South American grid with better quality and cheaper electricity (Brazil, 2015b).

Additionally, the power grid of Brazil could benefit, and be of benefit, in a regional approach that seeks to lower the combined carbon footprint of power generation. The movement toward integration of regional economies, while usually argued in plain financial terms, could also result in substantial carbon benefits.

The federal government could recognize the relevance of regional energy integration, and the possibility of expanding such interconnections, or establishing new interconnection grids, could be the subject of new international agreements between the Brazilian government and other relevant countries.

The government could also incentivize energy integration with neighboring countries through bilateral treaties focused on the shared use of water resources, for example, where the energy generated would be divided equally among the corresponding countries. As a preliminary step, it could be relevant to create more incentives for the elaboration of joint



hydropower project inventories and assessments of trans-boundary areas, as well as to enhance understanding of the hydro potential in neighboring countries, and identify joint opportunities for the implementations of new hydropower plants.

To reproduce bilateral agreements like the Binational Itaipu with Paraguay, a supranational legal regime is required. A supranational legal framework—such as the one provided in the European Energy Charter on energy efficiency and related environmental aspects (EUR-LEX, 1997) that has been decisive for energy integration in Europe—would provide assurance to binational and multinational initiatives, as well as to institutional investors engaging in long-term return endeavors in South America.

Increasing Energy Efficiency Requirements for Electrification and Buildings

In view of the current national energy landscape, increasing energy efficiency requirements for electrification is an evident need (Pereira, Lambert, and Ghisi, 2013). Increasing energy efficiency could save consumers money, reduce the likelihood of future energy shortages, and reduce energy consumption and GHG emissions.

Energy efficiency actions can be turned into kilowatt hours saved on the energy bill and hence into bottom-line savings, but this cannot be realized without good measurement.

While mandatory efficiency standards have a role to play on the supply side, on the demand side, mechanisms such as rebates and feebates could create powerful incentives to drive the selection of more efficient equipment, including replacement of electric showers by solar systems. There are several opportunities for more vigorous action on energy efficiency on the demand side, including stronger product standards, and improved access to efficient equipment through financial and tax-favorable mechanisms.

Improved equipment could be introduced through the creation of electronic equipment with energy self-service capacity: this service could be achieved through the use of small-scale solar energy powering low-potential equipment and perhaps charging small batteries in communication devices, among other things. The PNE 2050 includes this alternative and estimates a consumption reduction of approximately 24 TWh compared to the reference scenario, which represents seven percent of total electricity consumption (EPE, 2015). However, this projection was done only for the Brazilian residential sector, but it could also be applied to the commercial sector.

Globally, in the not-too-distant future, renewable and decentralized systems attached directly to buildings will provide electricity to smart grids, bringing reductions in electricity consumption of 10 percent or more, as well as better stability of supply (fewer disruptions), and reduced baseload power generation from polluting sources (Lang and Mutschler, 2012).

Additionally, it would be important to increase the share of solar hot-water heating and decrease that of electric and natural-gas systems. The deployment of solar water heaters is already part of the current housing policy of the Federal Government; solar heating systems (SAS) must be included in the federal housing assistance program “Minha Casa, Minha Vida,” established by the state-owned Brazilian bank “Caixa Economica Federal” and implemented by the Ministry of Cities (MC). The replacement of old and inefficient equipment that consumes a lot of energy is an important government policy. However, this type of initiative could be expanded to include more households. This energy-efficiency program presents some contradictions. For example, the program implies that the families that consume less energy receive more resources, but low-income families already consume much less energy than wealthier households. Additionally, in terms of reducing energy consumption, it would be important to broaden this kind of tax-relief program to focus additionally on large factories and the replacement of old and inefficient machines that consume far more energy than low-income households.

Governmental procurement is a powerful tool to influence markets. In the case of popular housing, the “Minha Casa, Minha Vida” (and other state or city programs) should pay close attention to the building standards for thermal and lighting comfort. The building envelope should utilize low-transmittance materials, frames should provide natural ventilation and illumination, avoiding the use of air conditioners and artificial lighting as far as possible. Government buildings could be labeled under the Procel-Edifica Scheme. Recent developments by the Federal Government are intensifying these measures, and their importance should be highlighted in national energy and climate policies.

Commercial and public buildings offer significant possibilities for decentralized energy—both thermal and electric. Hybrid systems and cogeneration improve efficiency and resilience against power outages. Solar thermal heating reduces energy bills for heating water and, with improved technologies, even for cooling. Nevertheless, there are several misconceptions within the civil construction sector concerning these options, mostly because of the high initial capital costs and disregard for the life cycle cost of energy.

It is important to highlight the social disparities and regional heterogeneities in Brazil. Different climatic zones, urbanization patterns, and income levels require different perspectives for energy generation, consumption, efficiency, and GHG emission profiles. Improving socioeconomic indicators entails reducing inequalities, providing widespread and sufficient energy services, and ensuring environmental quality. Among existing frameworks, one that could be adopted is the Sustainable Development Goals (SDGs) indicators that measure citizens’ access to affordable, reliable, sustainable, and modern energy (UNSDSN, 2015). Sustainable Development Goal 7 refers to energy and includes, among other indicators, access to modern cooking solutions and to reliable electricity generated by sustainable sources. It also includes incentives for low-carbon energy in the electricity sector and the rate of improvement in primary energy intensity.

Reconciling the Role of Hydropower with Concern for Sustainability and Resilience

Large-scale deployment of hydropower has contributed to Brazil’s position as a world leader in low-carbon energy development, and has generated important economic benefits, including limiting the country’s reliance on imported fossil fuels, enabling the expansion of access to modern energy services, and serving as a low-cost domestic energy source. Hydropower reservoirs have both positive and negative socioeconomic impacts: while they provide energy storage, flood control, multiple water uses throughout the year, and tourism development, among other goods, they cause damage including biodiversity loss, submersion of sensitive sites, and local population displacement. Trade-offs are extremely context-specific (Goldemberg and Lucon, 2008; Sathaye et al, 2011).

Brazil still has 100GW in hydroelectric potential—and, in theory, such potential would easily be enough to meet the projected demand of six GW of additional installed capacity per year until 2023 (EPE, 2023), while offering stability and low emissions (except for methane in certain instances). Despite this potential, forecasts indicate a gradual reduction in the relative share of hydropower in Brazil's electricity-generation mix (EPE, 2014). The country has vast hydro resources still untapped: Of the 100GW in hydroelectric potential, 69.2 GW have been inventoried and only 16.7 GW of potential projects have had feasibility studies completed (Eletrobras, 2013). However, hydropower expansion is facing significant barriers. These include: (i) lack of adequate public engagement at all stages of developing new projects; (ii) increasing public protest driven by social and environmental concerns; (iii) lack of strong coordination between federal- and state-level governments; (iv) long and complicated licensing procedures; and (v) increasing unreliability of hydropower because of climate

Overall, the reliance on baseload hydropower generation in Brazil is diminishing. If the government intends to maintain the major role of hydropower in the electricity mix, it will be important to promote grid interconnection with non-hydro modern renewables.

change impacts. As a result of these factors, according to the 2014 Brazilian National Energy Balance (BEN) the estimated available hydro potential declined from 50.5 GW in 2005 to 26.5 GW in 2013 (BEN, 2014). Therefore, if hydropower is to play the increased role in the power sector that the government plans for it, the aforementioned challenges will need to be proactively addressed. Potential solutions are both technological and governance-focused, as discussed below.

Streamline environmental license processes

The current environmental regulatory framework in Brazil requires a range of licenses for hydropower, resulting in high fees for the use, consumption, and discharge of water. Considering the multi-level nature of Brazilian environmental licensing laws, many projects face overlapping environmental jurisdictions at the federal and state levels. The costs increase even more if environmental licensing is delayed, which in turn leads to higher costs for licensed plants as they seek to meet energy demand (Soito and Freitas, 2011). New hydropower projects have been affected by difficulties in obtaining environmental licenses (especially for larger projects), which often leads to a reduction in the size of planned reservoirs for storage capacity. Consequently, the costs increase, as the share of supply sources changes because of the reduction in the planned reservoirs, which may lead to higher energy prices. It will be important to reduce the uncertainties regarding the environmental licensing process in plants that appear likely to impact protected areas, and IBAMA could streamline its environmental license process and promote better coordination with state agencies and other federal environmental agencies. Providing more regular revisions to update and contextualize environmental licensing rules could reduce such conflicts and political disputes without compromising the integrity of environmental protection.

Increase reliability and resilience of hydropower

Global warming is likely to change the hydrological cycle, impacting the availability of water in Brazil's drainage reservoirs (Soito and Freitas, 2011). Severe droughts have reduced hydropower generation in recent years (2001, 2010, 2014,

2015). Hydropower—and especially run-of-the-river hydropower projects with no reservoirs—is at risk from drought-induced reductions in water levels. The extent to which hydropower can be expanded will depend significantly on the ability to store water in reservoirs, because such power plants will then be somewhat independent of the rainfall regime (ONS, 2013b). Hydropower in the flat Amazon region is not able easily to include energy storage, because reservoirs have deep environmental and social implications, leading to the option of run-of-the-river projects with lower capacity factors.

Overall, the reliance on baseload hydropower generation in Brazil is diminishing. If the government intends to maintain the major role of hydropower in the electricity mix, it will be important to promote grid interconnection with non-hydro modern renewables. Another option would be to increase national energy storage capacity in such a way that the additional generation possible during the wet season can be used during the dry season. Also, the Energy Research Company (EPE), the Electricity Regulatory Agency (ANEEL), and the major Electricity Utility Company (Eletrobras) could consider measures and policies to encourage investments in energy complementarity and storage capacity in regions other than the Amazon. Such measures could increase resilience during the dry seasons. There are also some other techniques that could support increased storage capacity in Brazilian watersheds (Hunt, Freitas, and Pereira Jr., 2014), such as enhanced-pumped-storage, pumped-storage in cascade, additional storage reservoir dams, or retrofit of run-of-the-river dams into storage reservoir dams. Such systems result in less water loss through evaporation and have high storage efficiency (roughly 90 percent). However, although they could be a reasonable option to store energy from hydropower—because such systems require a substantially smaller flooded area to store water than traditional hydropower plants—it is important to highlight that over-reliance on pumped storage might undercut the benefits, because more energy is used pumping the water uphill than is gained when it is released. Finally, it is important to highlight the importance of increasing energy efficiency for electrification to help decarbonize the energy-related GHG emissions sectors, and of deploying at large



scale demand-side management (DSM) measures, in response to climate change. These measures could save consumers money, reduce the probability of future energy shortages, and, ultimately, reduce energy consumption and GHG emissions.

Enhance public engagement at all stages of new projects

As of December 2014, there were 48 hydropower feasibility studies with installed capacity above 100 megawatts registered at the National Electricity Regulatory Agency (ANEEL). Of these 48 studies, 30 are located in tropical forests, with implied risks of delays or non-viability caused by lack of public acceptance. One major project represents 19 percent of the total 31.6 GW; the top three projects cover 48 percent and the top seven cover more than 73 percent, which means that if just one or two of these projects do not go through then much less of this potential will be delivered (ANEEL, 2014).

The fact that the remaining hydroelectric potential is located predominantly in the Amazon region, which also encompasses most of Brazil's protected areas and indigenous communities, has several consequences for the development planning of power plants. Located in the Amazon Region, Belo Monte is the largest infrastructure work in progress in Brazil, and because of socio-environmental con-

cerns and lack of public acceptance, it is expected to take more than three decades to move from its initial announcement to operations. The originally planned size of the reservoir was reduced by 58 percent and the current installed capacity is approximately 11 GW (ANEEL, 2015), and the plant's estimated costs doubled. Even so, opponents of the project believe that the case of Belo Monte will set a precedent for other large projects in the Amazon region that could be detrimental going forward (EPE, 2011; ANEEL, *nd*; ISA, *nd*; Pereira 2013).

Policy recommendations to overcome lack of public acceptance of new projects include that the federal government could encourage higher public engagement in all stages of such projects, and developers could create permanent and more effective channels of communication with local people who will be affected over the whole cycle of the project. Although the need to manage the process better to gain public acceptance is relevant, it is important to highlight that addressing the real socio-environmental concerns as part of the project is the key issue to gain public acceptance, because public rejection is often motivated by genuine concerns and real issues with hydropower projects. Therefore, dealing with this issue does not imply only overcoming public resistance but also making

decisions that incorporate the negative externalities based on understanding the specific local context and trade-offs.

Reconsidering an Emission Performance Standard (EPS) for Fossil-Fuel Power Plants

In order to reduce GHG emissions from fossil-fuel power plants and encourage the growth of modern renewables in the electricity mix, the federal government could also reconsider establishing an emission performance standard (CO₂ EPS) for fossil-fuel power plants that was adopted in 2009 but subsequently revoked (discussed further below). An EPS could play a key role in the development and implementation of climate policies in different countries, and it could accelerate the process of generating energy efficiently, while enabling the development and dissemination of advanced technologies to reduce GHG emissions (Romeiro, 2014). A CO₂ EPS could also be relevant to foster the deployment of certain clean technologies that otherwise are unlikely to be viable at the commercial scale, such as carbon capture and storage.

Over the past few years, many countries and states have attempted to create EPS for fossil-fired power plants (Table 4).



Most of the countries and states have established restriction limits of 1,100 lbs of CO₂/MWh. The most stringent carbon emission restriction (EPS level) has been proposed by Canada (825 lbs of CO₂/MWh), followed by the rejected United Kingdom

EPS proposal (880 lbs. of CO₂/MWh). Only new plants were included in the standards, except Brazil (revoked) and Scotland (where the EPS states that all fossil-fired power plants, planned and existing, will have to comply with the EPS by 2025).

Table 4 | CO₂ EPS for Fossil-Fuel Power Plants Worldwide

COUNTRY OR STATE	EPS LEVEL		TYPE OF PLANT
Canada	825 lbs. of CO ₂ /MWh	375 kg CO ₂ /MWh	New/existing
United Kingdom	880 lbs. of CO ₂ /MWh	400 kg CO ₂ /MWh	New (rejected)
U.S. New York	925 lbs. CO ₂ /MWh	420 kg CO ₂ /MWh	New
U.S. Federal	~1,000 lbs. of CO ₂ /MWh	454 kg CO ₂ /MWh	New
Australia	1,100 lbs. of CO ₂ /MWh	500 kg CO ₂ /MWh	New
European Union	1,100 lbs. of CO ₂ /MWh	500 kg CO ₂ /MWh	New
U.S. California	1,100 lbs. of CO ₂ /MWh	500 kg CO ₂ /MWh	New
U.S. Maine	1,100 lbs. of CO ₂ /MWh	500 kg CO ₂ /MWh	New
U.S. Oregon	1,100 lbs. of CO ₂ /MWh	500 kg CO ₂ /MWh	New
U.S. New Mexico	1,100 lbs. of CO ₂ /MWh	500 kg CO ₂ /MWh	New
U.S. Washington	1,100 lbs. of CO ₂ /MWh	500 kg CO ₂ /MWh	New
AU South Austr.	1,540 lbs. of CO ₂ /MWh	700 kg CO ₂ /MWh	New
Germany	1,694 lbs. of CO ₂ /MWh	700 kg CO ₂ /MWh	New
AU Victoria	1,760 lbs. of CO ₂ /MWh	800 kg CO ₂ /MWh	New (abandoned)
Scotland	CCS		New/existing
AU Queensland	Clean coal (with CCS)		New
AU Western Austr.	Clean coal (with CCS)		New
U.S. Montana	CCS — at least 50 percent of CO ₂		New
U.S. Illinois	CCS — 50, 70 or 90 percent of CO ₂		New
Brazil	Reforestation, en. Efficiency ^a		New/existing (revoked)

Source: Romeiro, 2014.

^a Compliance with carbon sequestration/reforestation and investments in energy efficiency

In 2009, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) published the Normative Instruction No. 07/2009. The Normative Instruction referred to the UNFCCC and to the 2008 Brazilian National Plan on Climate Change, and stated that the environmental license for new fossil-fuel power plants would need to include a Mitigation Program to reduce CO₂ emissions. The instruction established the following criteria to achieve such emissions reductions: (i) at least one third of the CO₂ emissions would need to be mitigated by reforestation; (ii) up to two thirds of the CO₂ emissions would need to be mitigated through investments in renewable energy or measures to promote energy efficiency (IBAMA, 2009). However, the Normative Instruction was revoked in 2010 (see below).

The IBAMA Normative Instruction no 07/2009 was clearly intended to reduce CO₂ emissions while promoting the increased use of renewable energy. Nevertheless, it created an obligation on the part of a UNFCCC Non-Annex I country to reduce its CO₂ emissions. The Normative Instruction therefore provoked contentious discussion because of its impact on Brazilian projects under the clean development mechanism (CDM). As a result, it was revoked one year after its creation, through the IBAMA Normative Instruction No. 12/2010

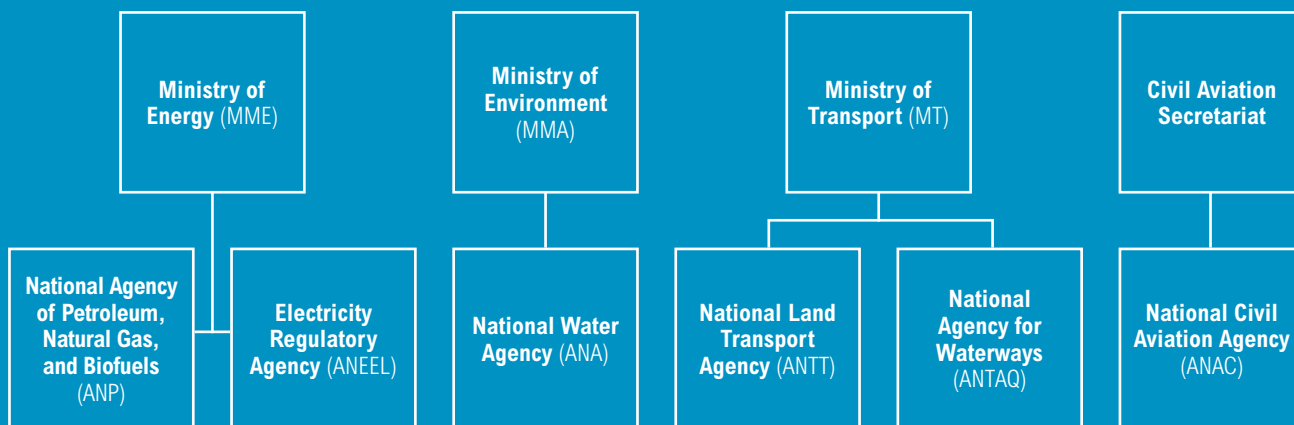
(IBAMA, 2010). The government could reconsider establishing such an EPS for fossil-fuel power plants in Brazil as an attempt to discourage the continued increase of fossil-sourced power.

Opportunities to Improve Integration between Climate and Energy Policies in Brazil

In terms of energy governance in Brazil, six agencies under three ministries (and one presidential secretariat) have supervision over energy regulation at the federal level, as shown in Box 2. These ministries also participate with 13 others in the Inter-ministerial Committee on Climate Change (CIMC).

Nevertheless, under the Ministry of the Environment (MMA), environmental bodies, such as the Institute of Environment and Renewable Natural Resources (IBAMA) do not regulate energy policies, and because IBAMA is the environmental regulatory body that approves the operation of new energy projects at the federal level, energy planners cannot foresee whether environmental licensing for new developments will be approved, even if the necessary requirements are reached. Moreover, conflicting directives among different areas of government and pressures from the private sector to

BOX 2 | ENERGY GOVERNANCE AND COORDINATION CHALLENGES FOR ENERGY AND CLIMATE IN BRAZIL



Source: Authors' elaboration.

Table 5 | **Brazilian Nationally Appropriate Mitigation Actions (NAMAs): Changes in the Business-as-Usual GHG Emission Projections for 2020**

SECTOR	2020 BASELINE EMISSIONS (MT CO ₂ E)		PERCENT CHANGE
	GHG EMISSIONS PROJECTED BY 2020 UNDER THE COPENHAGEN ACCORD	GHG EMISSIONS PROJECTED BY 2020 UNDER THE DECREE OF THE NATIONAL POLICY ON CLIMATE CHANGE	
Agriculture	627	730	+ 16.4
Industry and Waste	92	234	+ 254.3
Energy	901	868	- 3.6
Land-Use Change	1.084	1.404	+ 29.5
Total	2.703	3.236	+ 19.71

Source: Brazil, 2009 and Brazil, 2010.

speed development in the energy sector frequently result in environmental authorities being accused of delaying Brazil's economic development with complex licensing procedures and rules.

In December 2009, the Brazilian Government launched the National Policy on Climate Change (PNMC) through Federal Law No. 12.187/2009. In line with its submission to the UNFCCC, the PNMC pledged Brazil to a 36.1–38.9 percent reduction in GHG emissions by 2020, relative to a trend line scenario. A year later, Decree 7.390 was established to regulate the PNMC, and stated that the 2020 commitments should be achieved through mitigation and adaptation sectoral plans. It has also decreed that the Ten-Year Energy Expansion Plan (PDE), revised and updated on an annual basis, should constitute the Energy Sectoral Plan for mitigation and adaptation to climate change, which means that energy-related climate policies in Brazil are defined by the Ministry of Mines and Energy.

The Ten-Year Energy Plan is supposed to represent Brazil's official sectoral plan to address climate change. However, because it prioritizes economic development over climate-change concerns, the scientific recommendations to deeply reduce GHG emissions are not fully heeded and the necessary

shifts in priorities to efficiently tackle climate change in Brazil are not sufficiently considered.

Changes in the business-as-usual (BAU) GHG emission projections between the 2009 Brazilian commitments under the Copenhagen Accord and the 2010 Decree of the National Policy on Climate Change: implications for energy-related GHG emissions

The first problem is the unexplained revision (increase) of projected GHG emissions under the Brazilian business-as-usual (BAU) scenario. The original BAU projection for 2020, announced in November 2009 as part of the Copenhagen Accord, was 2.7 GtCO₂e. However, the National Decree 7.390 of 2010, which regulates the PNMC, revised and increased the BAU GHG emissions for 2020 to 3.2 GtCO₂e—which represents an increase of more than 18 percent, as shown in Table 5.

In addition, because Brazil's pledge is framed as a percentage reduction relative to the baseline level, the total 2020 emissions associated with achieving the pledge depend entirely on the definition of the baseline. The higher the BAU, the lower will be Brazil's ambition, because the country will be able to meet its pledge with a smaller reduction in emissions.

BOX 3 | EXAMPLES OF CHANGES THAT WOULD REQUIRE REVISIONS TO BASELINES

- Structural changes in the jurisdiction that have a significant impact on its baseline scenario emissions, including:
- Changes in calculation methodologies, including:
 - updated inventory calculation method
 - improvements in the accuracy of emission factors or activity data
 - changes in GWP values
- Changes in goal boundary, including sectors, gases, or geographic area
- Discovery of significant error(s) in original calculations
- Any other significant changes that would otherwise compromise the consistency and relevance of the reported GHG emissions information.

Source: WRI GHG Protocol Mitigation Goals Standard

The same decree states that the 2020 targets will be achieved through sectoral mitigation and adaptation plans, which means that such sectoral plans are based on the aforementioned higher baseline projection (3.2 GtCO₂ instead of the first announcement of 2.7 Gt CO₂), which make the commitments under the 2010 Decree of the National Policy on Climate Change less ambitious than the voluntary pledge submitted to the UNFCCC in 2009.

Regarding the energy sector, the 2010 Decree establishes that the Ten-Year Energy Plan and its updates constitute the energy sector plan for mitigation and adaptation to climate change. Because the plan includes efforts to increase renewables, nuclear, and energy efficiency, the Brazilian NAMAs were then translated into targets for the energy sector under PDE 2022, as represented in Table 6.

Table 6 | **Energy Sector 2020 Targets (Decree 7.390/2010)**

2020 OUTLOOK	MTCO ₂ E
Projected emissions (trendline)	868
Trendline—target abatement	188 to 234
Emission target	634 to 680

Source: Brazil, 2010.

The pledge itself, however, established a weaker target than originally expected because of Brazil's adjustment of the business-as-usual scenario against which reductions are to be measured. Three factors play an important role:

1. Lack of revisions to the baseline of the National Policy on Climate Change and the expectation of high economic growth with virtually no decoupling

Another problem is the lack of revisions to the baseline to take account of the global economic crisis and other macroeconomic trends. As the economic and political circumstances of a country change over time, the original data used to create a target (emissions drivers, assumptions, or included policies and measures) might become less pertinent or might be revealed to be inaccurate. The baseline scenario and associated emissions estimates then need to be reconsidered. The WRI GHG Protocol Mitigation Goals Standard (WRI, 2012) provides some examples of changes that would require revisions to the baseline (Box 3).

As part of the revision and recalculation process, the country should establish and disclose its significance threshold in a consistent manner. In the case of Brazil, the current energy plans forecast expansion in the total (end-use) fuel consumption. Such expansion, however, was scaled back from PDE 2019 to PDE 2022, as a result of the 2008 global economic crisis. This retreat did not, however, lead to a revision of the underlying assumptions of Brazil's climate pledges. Brazilian climate policies have not changed since 2010, while the Ten-Year Energy Plans are adjusted each year (the latest, PDE 2023, was released by EPE at the end of 2014). The changes in the baseline for the

energy sector, allied with the lack of ambition of the PDEs to reduce GHG emissions, cast doubt on whether these plans can be considered as medium- to long-term instruments of climate policy in Brazil, as determined by Decree 7.390/2010.

2. The EPE forecast for growth in the energy sector is based on two non-practical assumptions:

The first is that average GDP growth assumed in the Ten-Year Energy Plan is five percent per year, while, in practice, GDP growth has averaged approximately 3.4 percent per year since 2010, falling to 0.4 percent in 2014.

3. Non-LUC sectors had their BAU trend lines based on expectations of a high GDP growth rate.

For industry, waste, and agriculture it was estimated to be five percent per year over the period 2006 to 2020—a total increase of 97 percent. The energy sector was expected to grow at 4.8 percent per year (EPE, 2013). From 2006 to 2012, Brazilian GDP grew 4.2 percent per year. According to the IMF (2015) growth was 2.7 percent in 2013, 0.1 percent in 2014 and forecasts indicate growths of negative 1.5 percent in 2015 and positive 0.7 percent in 2016. The official estimate of GDP growth for the present year, as of June 2015, is -1.3 percent (Central Bank of Brazil, 2015).

The EPE forecast for growth in the energy sector is much higher than the reality, and GDP and energy demand is not decoupled, which means that the efficiency of the economy is assumed not to improve. EPE's outlooks of six GW of additional installed capacity per year may be an overestimate, based on GDP assumptions alone. The second assumption is that GDP and energy demand will not be decoupled—in other words, the efficiency of the economy will not improve. It is important to decouple expectations of growth in energy demand from expectations of economic growth (Lucon, Romeiro, and Pacca, 2013).

In light of these issues, there is ample opportunity to strengthen energy and climate policies in Brazil. The first necessary action is to acknowledge the considerable lock-in risks posed by current energy and climate policies. Despite remarkable improvements in deforestation control, changing patterns of emissions pose considerable threats for Brazil

after 2020, and the present narrative of mitigation strategies undertaken by the government may not endure for long. More specifically, the federal government should update the baseline announced by the Decree 7.390 of 2010, because the inflated baselines represent steep increases in emissions that are not consistent with historical trends and forecasts.

Another necessary action is to consider revisions to the baseline based on the global economic crisis/other macroeconomic trends, for example, under the provisions established by the WRI GHG Protocol Mitigation Goals Standard (mentioned above). It will be important to decouple the emissions reduction pledges from the expectations on economic growth, given that current trends present relatively small improvements in efficiency and decarbonization. The 36.1 percent–38.9 percent reduction pledges under the National Policy on Climate Change (Brazil, 2009) actually translate to a reduction of only 15–18 percent when 2005 is the baseline year, and the contribution from the energy sector is even lower.

It would be important to create comprehensive metrics to decouple expectations of growth in energy demand from expectations of economic growth (Lucon, Romeiro, and Pacca, 2013). Some indicators to be monitored at the national and subnational levels could be considered, such as efficiency improvements in final energy use, reduction in energy consumption, and mitigation of GHG emissions. A monitoring process, accessible to the public at large and based on quantifiable dimensions, would be relevant to move from public policy rhetoric to results-driven climate and energy policies. Metrics regarding generation, consumption, efficiency, and GHG emissions could help civil society to follow up on sound policy implementation and bring about meaningful results.

Given that the Ten-Year Energy Expansion Plan (PDE) constitutes the energy sector's climate plan, climate change concerns are subordinate to economic growth in Brazil. On the eve of the Paris Climate Change Conference, the federal government could consider effectively integrating climate policies more fully into the sectoral energy plan.



CONCLUSIONS AND RECOMMENDATIONS

Until the early years of the 21st century, climate change mitigation in Brazil was almost exclusively, and rightly, associated with forests and land-use change. The absolute volume of GHG emissions produced by unsustainable deforestation and agricultural practices was overwhelming, while the carbon intensity of Brazil's energy mix was relatively low. That is changing.

While Brazil's energy sector is relatively efficient, with moderately low carbon intensity (because of the significant use of biofuels for transport, the relative efficiency of iron and steel production, and the major role of hydropower), current policy approaches leave a lot of opportunities "on the table." A combination of efforts to increase efficiency and the share of all forms of renewable energy in the national energy mix could reinforce Brazil's position as a low-carbon economy—which is currently in jeopardy—and deliver many other benefits to its citizens, including better air quality, enhanced and cleaner mobility, and overall improvements in quality of life. Reflecting these opportunities in its approach to international climate policy, likewise, would reinforce Brazil's position as a leader in the international community and enhance pressure on other major economies to implement international best practices. This, in turn, would create a further competitive advantage for Brazilian industry, which is already more efficient than the global average.

Due in part to the lack of historical association between the energy sector and climate-change mitigation in Brazil, climate change has not been considered thoroughly in national energy policy. The existing annual Ten-Year Energy Plan, with its conservative assumptions and modest efficiency improvements, was simply adopted as the mitigation and adaptation sectoral plan for the energy sector to represent climate policy. Sectoral climate plans that have an impact on the energy sector, likewise, do little to enhance ambition relative to the annual Ten-Year Energy Plan. They have been slow to be developed and implemented, lack specificity and priority, and ignore significant, cost-effective potential abatement options.

In contrast to many other major emerging economies, Brazil's energy mix is becoming *more* carbon intensive, not less, because of increased reliance on fossil fuels, heavy investments in the Pre-Salt oil fields, subsidies to keep gasoline prices artificially low, and tax subsidies that encourage the purchase of new cars, among other reasons.

A variety of scenarios have identified key technologies and cost-effective abatement opportunities that offer emissions reductions of approximately 40

percent relative to the baseline. (Some very recent studies are in the process of publication, or were published too late for inclusion in this report, and have not been included in this analysis.) Public policy recommendations evaluated in this report indicate that a different future is possible for GHG emissions from Brazil's energy sector if significant efforts are made to overcome existing barriers. It is important to highlight that this report did not attempt to discuss other key related questions such as equity, fairness, and financing, despite their significance in international climate negotiations. Although these issues will play an important role both domestically and internationally, the aim of this report was to focus on national circumstances and initiatives that could improve the integration between existing climate and energy policies in Brazil.

Keeping in mind that Brazil has many disparities and regional differences, we propose a comprehensive set of public policy priorities, stemming from the recognition that high-carbon lock-in is a risk, both to Brazil's economy and to the global climate. It is very unlikely that decarbonization and energy efficiency improvements will proceed at the necessary pace without a strong policy signal to guide public and private investment. The policy priorities proposed below address the key energy subsector emitters (transport, industry, and power generation), as well as opportunities for more integration between the energy sector and climate policies:

Transport

- Accelerate the implementation of fuel-economy standards and bring them into line with best international practice
- Diversify and integrate modal transportation systems for freight and public transport by conducting scoping studies on rail for freight transportation and high-speed rail for public transport; developing high-capacity bus and rail systems in high-demand areas; and increasing investment in low-emission transportation modes
- Offer municipalities incentives to create local mass-transport plans
- Streamline licensing for key rail and waterway projects
- Establish carbon pricing for transport

- Promote the use of biofuels while ensuring that they do not cause negative land-use changes
- Provide incentives to encourage the inclusion of hybrids and electrical vehicles in the energy transportation mix over the next 20 years
- Establish public procurement of cleaner fuel and vehicles as a strategy to promote a more sustainable transport system

Industry

- Accelerate implementation of an MRV system as a basis for creation of a carbon market
- Implement Brazilian Market for Emission Reductions
- Develop LCA-based benchmarks and labels to differentiate products
- Leverage environmental licensing to improve efficiency
- Accelerate plans to replace coal with renewable biomass

Power generation

- Invest in the development of wind and solar technologies aimed at competitiveness
- Hold dedicated auctions for modern renewables, incorporating fair pricing practices
- Provide more long-term loans for grid infrastructure
- Incentivize energy integration through bilateral treaties focused on the shared use of water resources
- Increase the share of wind and solar PV sources in the electricity mix
- Consider a commitment to increase the share of solar and wind in the energy mix to 30 percent by 2030 as part of Brazil's intended nationally determined contribution (INDC)
- Explore the options for new storage technologies to reduce the social and environmental impacts of large hydropower projects, while increasing their resilience to climate change
- Reconsider establishing an EPS for fossil-fuel power plants
- Develop a regulatory framework for carbon capture and storage

Integration between climate and energy policies in Brazil

- Adopt rigorous metrics, at national and subnational level, to track the decoupling of economic growth from natural resource use. Possible indicators include: (a) efficiency improvements in final energy use, (b) reduction in energy consumption, and (c) mitigation of GHG emissions
- Revise the baseline of the National Policy on Climate Change and its decree, based on international standards and best practices
- Establish a monitoring process, accessible to the public at large and based on quantifiable dimensions. This would help with moving from public policy rhetoric to results-driven climate and energy policies, and address barriers
- Review the sectoral plans regularly (every other year) with a view to enhancing ambition over time, as implementation improves and technology and financing options advance
- Establish a robust, periodic review process for national climate policies and plans that is transparent about assumptions and that is participatory, with an ample public comment period and a mandate to respond to public comments
- Consider the implications of integrating global carbon budget constraints into Brazil's climate plan for the energy sector, with due regard for equity, fairness, technology support, finance, and other issues of particular concern to non-Annex I Parties
- Integrate ambitious energy targets into Brazil's INDC—first in Paris, and then with a view to ratcheting up targets every five years, or some other time frame that is determined to be appropriate

This ambitious agenda will require political leadership at the highest levels, strong coordination across line ministries and up and down jurisdictional levels, as well as participation of the private sector and civil society. The rewards, however, are significant—cost savings, health benefits, enhanced competitiveness, and an improved quality of life for the citizens of Brazil—and enhanced Brazilian leadership in climate policy at the global level.

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ENDNOTES

1. CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆.
2. Such values are applicable for the “GHG worst case scenario,” that is, when the flex vehicle is running on Brazilian gasohol (a test-driving gasoline blended with 22 percent of anhydrous ethanol, also called E22).
3. It is estimated that the subsidy policies practiced by the government led to a tax waiver of approximately USD 350 million per month in 2013. The value corresponds to the exemption of the Intervention Contribution in the Economic Domain (CIDE) on gasoline and diesel, according to calculations of the Brazilian Infrastructure Centre (Brasil Econômico, 2013). As of 2015, ending all subsidies for gasoline and diesel could imply savings of approximately USD 4.5 billion per year, and these savings could be used to support the broad dissemination of modern renewable energy-based systems (EBC, 2015).
4. From 8,173 PJ (peta-joules) in 2010 to a reference 17,040 PJ in 2050 or alternative 12,600 PJ in this same year.
5. These assumptions are subject to uncertainties related to future economic development in the country, which are not captured by this analysis or, to any great extent, by the official plans.
6. This is only applicable to basic oxygen furnaces.
7. The potential for increasing nuclear and hydropower was not considered, because of the need for long-term planning for nuclear plants and challenges related to environmental licenses and climate impacts on the water regimes underpinning hydropower.
8. Building-integrated photovoltaics (BIPV), though still a novelty in Brazil, gained more momentum after the recent changes in regulations for net metering (ANEEL Resolution 482 of 2012, National Council of Fiscal Policy (CONFAZ) decision to exempt electricity bidirectional flows from taxes as a way to ease the connection of small power generation plants to the grid by using renewable sources). This resolution proposed the establishment of an energy compensation system to enable the additional electricity generated in a small power plant to be released into the grid. The regulation also established that the remaining credits of electricity at the close of a contract between consumers and distributors may not be subject to any form of compensation to the consumers.

LIST OF ACRONYMS

ANA	National Water Agency	MBRE	Brazilian Market for Emission Reduction
ANAC	National Civil Aviation Agency	MCTi	Ministry of Science and Technology
ANEEL	Electricity Regulatory Agency	MDIC	Ministry of Development, Industry, and Foreign Commerce
ANP	National Agency of Petroleum, Natural Gas, and Biofuels	MF	Ministry of Finance
ANTAQ	National Agency for Waterways	MMA	Ministry of Environment
BECCS	Bio Energy with Carbon Capture and Storage	MME	Ministry of Mines and Energy
BOE	Barrels of Oil Equivalent	MRV	Measurement, Reporting, and Verification
BRT	Bus Rapid Transit	MT	Ministry of Transport
CCS	Carbon Capture and Storage	MW	Megawatts
CIDE	Economic Domain Intervention Contribution	NAMAs	Nationally Appropriate Mitigation Actions
CIMGC	Inter-Ministerial Commission on Global Climate Change	NEDC	New European Driving Cycle
CO ₂	Carbon Dioxide	PDE	Ten-Year Energy Expansion Plan
COFINS	Contribution to Social Security Financing	PIS/PASEP	Contribution to the Social Integration Program and Civil Service Asset Formation Program
CONAMA	National Environmental Council	Plan-Mob	National Mobility Plan
CONTRAN	National Traffic Council	PNE	National Energy Plan
COP	Conference of the Parties	PNLT	National Plan of Logistics and Transport
CTPIn	Technical Commission on the Industry Plan	PNMC	National Policy on Climate Change
CVM	Brazilian Securities and Exchange Commission	PPCDAM	Action Plan for Prevention and Control of Deforestation in the Legal Amazon
DENATRAN	National Department of Traffic	PPCerrado	Action Plan for the Prevention and Control of Deforestation and Forest Fires in the Cerrado
EOR	Enhanced Oil Recovery	PROCONVE	Vehicle Air Pollution Control Program
EPE	Energy Research Company	PRODES	Satellite Monitoring System of the Brazilian Amazon Forest
EPS	Emission Performance Standard	PSTM	Sectoral Plan for Transport and Urban Mobility for the Mitigation of Climate Change
ETP	Energy Technology Perspectives	SDG	Sustainable Development Goal
FA	Logistics Adjustment Factor	SEEG	Brazilian Greenhouse Gas Emissions System
GDP	Gross Domestic Product	SeMob	National Secretariat of Transport and Urban Mobility
GHG	Greenhouse Gas	tCO ₂ e	Tonnes of CO ₂ equivalent
GW	Gigawatts	TOR	Terms of Reference
IBAMA	Institute of Environment and Renewable Natural Resources	UNFCCC	United Nations Framework Convention on Climate Change
IEA	International Energy Agency	UNSDSN	United Nations Sustainable Development Solutions Network
IPCC	Intergovernmental Panel on Climate Change	WB	World Bank
IPI	Industrialized Products Tax	WEO	World Energy Outlook
IPPU	Industrial Processes and Product Use	WG Inventories	Working Group on Inventories
LCA	Life Cycle Analysis		
LNG	Liquefied Natural Gas		
LULUCF	Land Use, Land-Use Change and Forestry		

ANNEX 1. DETAILS FROM THE SCENARIO ANALYSIS

Summary of Scenarios

This section presents an analysis of the assumptions and results of the following energy scenarios, in order of year of publication, as set out Table A1-1.

The National Energy Plan—PNE 2030 (2007) is the official government scenario. It shows emissions in 2030 being reduced to 815 MtCO₂e or 16 percent below the projected trend line of 975 Mt CO₂e in 2030 (using a baseline of 329 MtCO₂e in 2005, 500 Mt CO₂e in 2010, and 437 MtCO₂e in 2012) (last historical figure). The main reductions were projected to result from replacing charcoal from deforestation with charcoal produced from renewable plantations (representing 31 percent of the total potential of the energy sector estimated by the PNE) and phasing out the use of nonrenewable energy sources in industry by 2030. PNE 2030 shows basically four scenarios, in a quite broad range of possibilities. In the intermediate reference, emissions in 2030 are reduced to 815

MtCO₂e or 16 percent below the projected trend line of 975 Mt CO₂e for that same year.

McKinsey (2009) utilized marginal abatement cost curves (MACC) to produce low-carbon pathways for all domestic sectors until 2030. The key opportunities for further emissions reduction potential in Brazil are identified as road transport (69 MtCO₂e) through modal shift, steel (50 MtCO₂e), chemicals (33MtCO₂e), oil and gas (20 MtCO₂e), and cement (16 MtCO₂e). It is not a pathway study, but can be assumed using linear growths from the base year.

World Bank—De Gouvello et al. (2010) analysis is another MACC study, based on the intermediate reference scenario from the National Energy Plan (PNE) 2030, which assumes an average economic growth rate for Brazil. GHG emissions in 2030 could be reduced to 815 million tons of CO₂e or 16 percent below the projected trend line of 975 Mt CO₂e in 2030 (using a baseline of 500 Mt CO₂e in 2010). The mitigation potential refers to reductions

Table A1-1 | **Summary of Scenarios**

AUTHOR OR ORGANIZATION	YEAR OF PUBLICATION	SCENARIO	MODELING APPROACH	TIME HORIZON
Energy Research Company	2007	National Energy Plan 2030	Current policy scenario	2030
McKinsey	2009	Low-carbon economy	Most cost-effective abatement technology	2030
World Bank	2010	Reference	Current policy scenario	2030
World Bank	2010	Low-Carbon Scenario	Most cost-effective abatement technology	2030
La Rovere et al.	2013	Scenario A	Hypothetical and counterfactual	2030
La Rovere et al.	2013	Scenario B	Current policy scenario	2030
La Rovere et al.	2013	Scenario C	New policy scenario	2030
International Energy Agency	2012	ETP 6°C Scenario	Global temperature	2050
International Energy Agency	2012	ETP 4°C Scenario	Global temperature	2050
International Energy Agency	2012	ETP 2°C Scenario	Global temperature	2050
Energy Research Company	2013	10-year Energy Plan 2022	Current policy scenario	2022
Greenpeace	2013	Energy revolution	Global temperature	2050
International Energy Agency	2014	WEO CPS	Current policy scenario	2040
International Energy Agency	2014	WEO NPS	New policy scenario	2040
International Energy Agency	2014	WEO 450ppm	Global temperature	2040
Lucena et al.	2015	Core baseline scenario	Current policy scenario	2050
Lucena et al.	2015	Carbon tax	New policy scenario	2050
Lucena et al.	2015	Abatement	New policy scenario	2050

Source: adapted by the authors based on various scenarios.

of carbon emissions arising from the change from the Reference Scenario to a Low-Carbon Scenario (by analyzing the mitigation options not deeply considered in the PNE 2030, such as hybrid cars, carbon capture and storage, among others).

The **Brazil BAU (2010)** considers only implemented and adopted policies in Brazil, and adopts the annual Ten-Year Energy Plan as the sectoral plan for mitigation and adaptation in the energy sector. Projected 2020 emissions (643 MtCO₂e) fall within the range pledged by the NAMA (634–680 MtCO₂e); however, projected GHG intensity per unit GDP and per unit of energy consumed both slightly exceed 2005 levels. (Brazil's climate policy dictates that these figures should not exceed 2005 levels.)

The Energy Technology Perspectives – ETP (2012) taskforce from the International Energy Agency (IEA) defined three scenarios for the Brazilian Energy sector, consistent with pathways leading to increased average temperatures of 2°C, 4°C, and 6°C respectively by 2100. The business-as-usual representative pathway leads to an increase in global average temperature of +6°C, while the 2°C scenario presents an emissions trajectory consistent with the IEA WEO 450 scenario, and details the new developments in energy technology necessary to achieve the objectives of limiting the global temperature rise to 2°C and enhancing energy security. The study projects that, even after compliance with the Brazilian Nationally Appropriate Mitigation Actions (NAMAs)—the voluntary pledges that Brazil announced in 2009 during COP15—the proposed emissions reductions would not be enough to keep within the 2°C trajectory, and would even stay above the 6°C trajectory (Figure 1).

La Rovere et al. (2013) show the energy sector as the biggest growing source of emissions for Brazil post-2020 and present projections based on existing policies and more ambitious policies. Scenario A is counterfactual and based on no further renewable energy growth, that is, it excluded any expansion of generation capacities based on renewable sources (including large hydropower plants) as of 2010. For Scenario B, the energy sources mix was taken from the 2019 Ten-Year Energy Plan (PDE 2019). The energy mix for the period 2020–2030 was determined through the evolution outlined in PNE 2030. Scenario C was constructed by including additional mitigation options not included in Scenario B, such as hybrid cars, and carbon capture and storage, among others. Advanced strategies are similar to those from the World Bank's study.

Greenpeace (2013) considers that GHG emissions from the energy sector are 358 MtCO₂e in 2010, reach 512 MtCO₂e in 2020, then reduce to 312 mtCO₂e by 2050. The scenario is based on five premises: decentralized and integrated renewable solutions; respect for environmental impacts when building new projects; gradual phase-out of fossil fuels and nuclear power; better distribution of the use of energy and natural resources; and decoupling economic growth from consumption of fossil fuels. Such goals require many policy changes, including (i) elimination of all subsidies to fossil fuels and nuclear; (ii) internalizing socio-environmental impact costs by means of carbon taxes or social indicators; (iii) rigorous efficiency standards for appliances, vehicles, and buildings, plus

labeling schemes and awareness-raising campaigns; (iv) regulatory frameworks for new renewable-energy sources, including access to the grid; (v) feed-in tariffs and fair minimum energy-auction prices for renewables; (vi) financing R&D for renewables and efficiency.

The **IEA's World Energy Outlook WEO (2014)** includes the Current Policies Scenario (CPS), which takes into account only policies and measures affecting energy markets that were formally enacted as of mid-2014. It both illustrates the consequences of inaction and makes it possible to evaluate the potential effectiveness of recent developments in energy and climate policy (IEA, 2014).

Lucena et al. (2015) is a more recent reference. Without showing pathways, it models the effects of market-based mechanisms and carbon-emission restrictions on the energy sector and compares six models under different scenarios for carbon taxes and abatement targets up to 2050. The results show an increase in GHG emissions in the baseline scenarios because of the increasing penetration of coal and natural gas. Nevertheless, climate policy scenarios indicate that high carbon taxes (roughly 50 USD/tCO₂e in 2020 rising to 162 USD/tCO₂e in 2050) can lead to GHG emissions reductions of around 60 percent. In a 2050 horizon, core baselines range from 0.9 to 1.6 Gt CO₂e. Most of the emissions after mitigation efforts range around 0.8 Gt CO₂e (Low C price); and 0.3–0.4 GtCO₂e (20% and 50% fossil fuel abatement scenarios). Despite the many models and pathways displayed, a 40-year span cumulative emissions can be easily estimated: 14 to 24 GtCO₂e (from the 0.4 GtCO₂e in 2010 to the final values ranging 0.3–0.8 Gt CO₂e in 2050). These results corroborate the recommendations made hereafter.

According to the baseline scenarios, emissions intensities (that is, emissions per unit of GDP and per unit of energy consumed) are projected to be higher at the end of the time horizon, because of increased energy consumption as a result of population growth and increased affluence, relatively lower penetration of renewables in the energy mix (low decarbonization), and no projected increase in energy efficiency. The non-reference scenarios assume more conservative population and GDP growth rates than those assumed in the PNE 2030, as do the scenarios of the IEA WEO 2014 (CPS, NPS, and 450ppm), Greenpeace (2013), and IEA ETP (2°C, 4°C, and 6°C).

According to Greenpeace (2013), projections of energy demand are normally subject to three main factors: population growth, which determines the number of consumers; economic growth, for which the Gross Domestic Product (GDP) is the most common indicator; and the amount of energy required to produce one unit of GDP (measured by energy intensity indicators and price elasticity of electricity demand (Greenpeace, 2013).

Greenpeace does not support low-carbon technologies such as carbon capture and storage (CCS), and indicates that the necessary GHG emissions reductions will be made possible by replacing thermal-power plants with non-fossil-fuel power plants to expand energy supply. It also assumes the widespread use of biofuels and electricity for light vehicles, the reduction of fossil sources in industry, strong measures on energy efficiency in all sectors, and the diffusion of technologies to store energy (Greenpeace, 2013).

Table A1-2 | **Macroeconomic Assumptions Underlying the Scenarios**

	SCENARIO	GDP GROWTH	POPULATION
EXCLUDING SOME EXISTING POLICIES IN PLACE	La Rovere et al. (2013) Scenario A	5 percent until 2020 4 percent (2021–2030)	Based on official projections (EPE, 2009) 220.1 mm in 2020 238.5 mm in 2030
CURRENT POLICIES	National Energy Plan 2030 Ten-year Energy Plan 2022	5 percent until 2020 4 percent (2021–2030)	220.1 mm in 2020 238.5 mm in 2030
	La Rovere <i>et al.</i> (2013) Scenario B	5 percent until 2020 4 percent (2021–2030)	Based on official projections (EPE, 2009)
	World Bank (2010) Reference Scenario	\$USD 1.38 trillion in 2020 \$USD 2.13 trillion in 2030	
	IEA WEO 2014 (CPS)	2.9 percent (2012–2020) 4.0 percent (2020–2030) 3.3 percent (2030–2040) 3.4 percent (2012–2040)	0.5 percent annual growth rate (2012–2040) 229 million in 2040 90 percent urbanization in 2040
MOST COST-EFFECTIVE ABATEMENT TECHNOLOGY	McKinsey - Base Case		Not mentioned
	World Bank (2010) Low-Carbon Scenario		
NEW POLICIES	La Rovere et al. (2013) Scenario C	5 percent until 2020 4 percent (2021–2030)	Based on official projections (EPE, 2009)
	IEA WEO (2014) NPS	2.9 percent (2012–2020) 4.0 percent (2020–2030) 3.3 percent (2030–2040) 3.4 percent (2012–2040)	0.5 percent annual growth rate (2012–2040) 229 million in 2040 90 percent urbanization in 2040
GLOBAL TEMPERATURE	IEA ETP 4°C IEA ETP 6°C IEA ETP 2°C	3.4 percent (2009–2050) 3.4 percent (2009–2050) 3.4 percent (2009–2050)	Not mentioned
	Greenpeace (2013)	3.7 percent (2011–2015) 3.5 percent (2016–2020) 2.5 percent (2021–2050)	0.64 percent annual growth rate (2011–2035) 223 mm (million of people) in 2050

Table A1-3 | **Key Assumptions Underlying the Scenarios and Implications for the Carbon Budget**

	SCENARIOS NOT CONSISTENT WITH CARBON BUDGET	SCENARIOS CONSISTENT WITH CARBON BUDGET
Energy consumption	705-792 TWh in 2020 933-1144 TWh in 2030 1156-1267 in 2040	679 TWh in 2020 872 TWh in 2030 1058 TWh 2040
Share of renewables in electricity consumption	Share of renewables capacity: 48 percent~73 percent 165 GW or 65 percent hydro capacity in 2030 81 percent hydro in power generation	Higher share of renewables capacity: 85 percent 187~197 GW in 2030 140 GW hydro capacity in 2030 (64 percent) 22 GW wind capacity in 2030
Industry sector	Steel and chemicals as most intensive sector Replacing charcoal from deforestation with renewable plantations	Enhanced energy efficiency standards Higher rate of recycling
Transportation sector	Ethanol and biodiesel blending mandate	Fuel efficiency improvements Enhanced support for alternative fuels Half of energy needs met with biofuels

ANNEX 2. CARBON BUDGETS AND COUNTRY ALLOCATIONS

To limit the average global temperature increase to 2°C by the end of the century, cumulative global CO₂ emissions should stay within a “budget” of approximately 990 (510–1505) GtCO₂ over the period 2012–2100 (IPCC, 2013). Scientists estimate that, ideally, global CO₂ emissions will need to reach net zero between 2050 and 2070 (UNEP, 2014) and should become negative over the remainder of the century to offset previous emissions and ongoing emissions from non-CO₂ gases. Global GHG emissions will need to reach net zero between 2080 and 2100 (IPCC, 2013).

Under current trends, this budget will be exhausted within the next 30 years, so immediate reductions in global emissions are necessary. The question of how much Brazil should contribute to the necessary global reduction was not addressed by the IPCC, and is fundamentally a political question. This Annex presents some of the literature that could be used to determine Brazil’s economy-wide “fair share.” The literature covers approaches including historical responsibility, ethical allocation including rights of future generations, economic capability, and least possible cost.

Kanitkar et al. (2010) and Höhne and Moltmann (2009) present a range of possible allocations of the carbon budget per country, including: (i) a budget for the 2010–2050 period with allocation based on the entitlements; (ii) a budget for the 2010–2050 period based on per capita allocation by 2000 population (known as the “German Budget Proposal”), and (iii) a gap (overdrawn entitlements) defining financial and technology transfers.

In particular, Höhne and Moltmann (2009) present allocations based on the following approaches:

- Greenhouse Development Rights (GDRs): All countries reduce emissions below their business-as-usual path based on their responsibility (cumulative emissions) and capacity (GDP); only emissions and GDP of the population above a development threshold counts toward responsibility and capability.
- Contraction and Convergence (C&C): Targets for individual countries are set in such a way that per capita emission allowances converge from the countries’ current levels to a level equal for all countries within a given period, from the present until 2050.
- Common but Differentiated Convergence (CDC): Targets are set so per capita emissions for all countries converge to an equal level over the period 2010 to 2050. For developed (Kyoto Protocol Annex I) countries’ per capita emission allowances convergence starts immediately. For individual non-Annex I countries’ per capita emissions convergence starts from the date when their per capita emissions reach a certain percentage threshold of the (gradually declining) global average.

Table A2-1 presents possible budgets for Brazil, based on a review of existing studies covering all countries. From these cases, the most generous budget for Brazil would be 41.4 Gt CO₂e and the most stringent, 19.8 Gt CO₂e. Most of the prognostics range between 20 and 30 Gt CO₂e, meaning that average emissions per year would be between 0.5 and 0.75 Gt CO₂e.

The International Energy Agency’s World Energy Outlook 2013 (IEA, 2014) identifies an upper limit for Brazil’s energy-related GHG emissions of approximately 23 GtCO₂e over a 40-year period from 2010 to 2050.

The Climate Equity Reference Calculator and the Climate Equity Pledge Scorecard are equity reference tools to elucidate national responsibility and capacity for climate action, and to determine each country’s fair share of the global climate effort, on both the mitigation and adaptation sides. The tools have been developed by EcoEquity and the Stockholm Environment Institute, and serve as an equity reference framework to enable analysis of a broader range of possible conceptions of responsibility, capacity, and fair shares. According to the tool, under a strong two degrees scenario (2DS), and considering historical emissions to 1850, Brazil’s target for annual emissions in 2030 should be below 1 GtCO₂e (EcoEquity and the Stockholm Environment Institute, 2015).

Based on different analysis of equity allocation for mitigation efforts, the Brazilian Climate Observatory (OC) also “indicated” what Brazil’s target should be from a top-down perspective consistent with two degrees and fair share, and proposed a target below 1 GtCO₂e total emissions for Brazil in 2030 (Observatorio do Clima, 2015).

Figure A2-1 translates the pathways presented in Figure 5 into cumulative emissions and compares them to the 2010 to 2050 carbon budget here discussed. This comparison suggests that, while there is significant scope for abatement based on current, cost-effective technologies, only the most aggressive scenarios, which envision new, cutting-edge CO₂ removal technologies, are compatible with a budget that would limit the global temperature increase to 2°C by the end of the century. Illustrative extrapolations show how few scenarios fall within a theoretical budget (for energy only) of 25 gigatonnes of CO₂ until 2050.

Table A2-1 | Possible Carbon Budgets for Brazil in Non-LUC Sectors

BRAZIL	GTCO ₂ E
Total entitlements ^a 1850-2050	65.2
Occupation ^b 1850-2009	10.6
Occupation 1970-2009	13.6
Occupation (BAU, all exc. LUC, Decree 7390/2010) 2010-2020	14.0
Occupation (max NAMA mitigation, all exc. LUC, Decree 7390/2010) 2010-2020	12.7
Future entitlements 2010-2050; base 1850	54.6
Future entitlements 2010-2050; base 1970	51.6
Allocation ^c (TISS-DSF ScenA) 2010-2050; base 1850 (Annex I 1990 levels cut 48 percent by 2020; 97 percent by 2050)	19.8
Allocation (TISS-DSF ScenA) 2010-2050; base 1850 (Annex I 1990 levels cut 63 percent by 2020; 99 percent by 2050)	21.1
Allocation (TISS-DSF ScenA) 2010-2050; base 1970 (Annex I 1990 levels cut 48 percent by 2020; 97 percent by 2050)	29.6
Allocation (TISS-DSF ScenA) 2010-2050; base 1970 (Annex I 1990 levels cut 63 percent by 2020; 99 percent by 2050)	41.4
Allocation (WWF-Ecofys CDC max) 2010-2050	22.0
Allocation (WWF-Ecofys GDR max) 2010-2050	25.0
Allocation (WWF-Ecofys C&C max) 2010-2050	26.0
IEA (World Energy Outlook 2013) 2010-2050	23
Climate Equity Reference Calculator (emissions by 2030)	Below 1.0 per year by 2030
Climate Observatory (emissions by 2030)	Below 1.0 per year by 2030

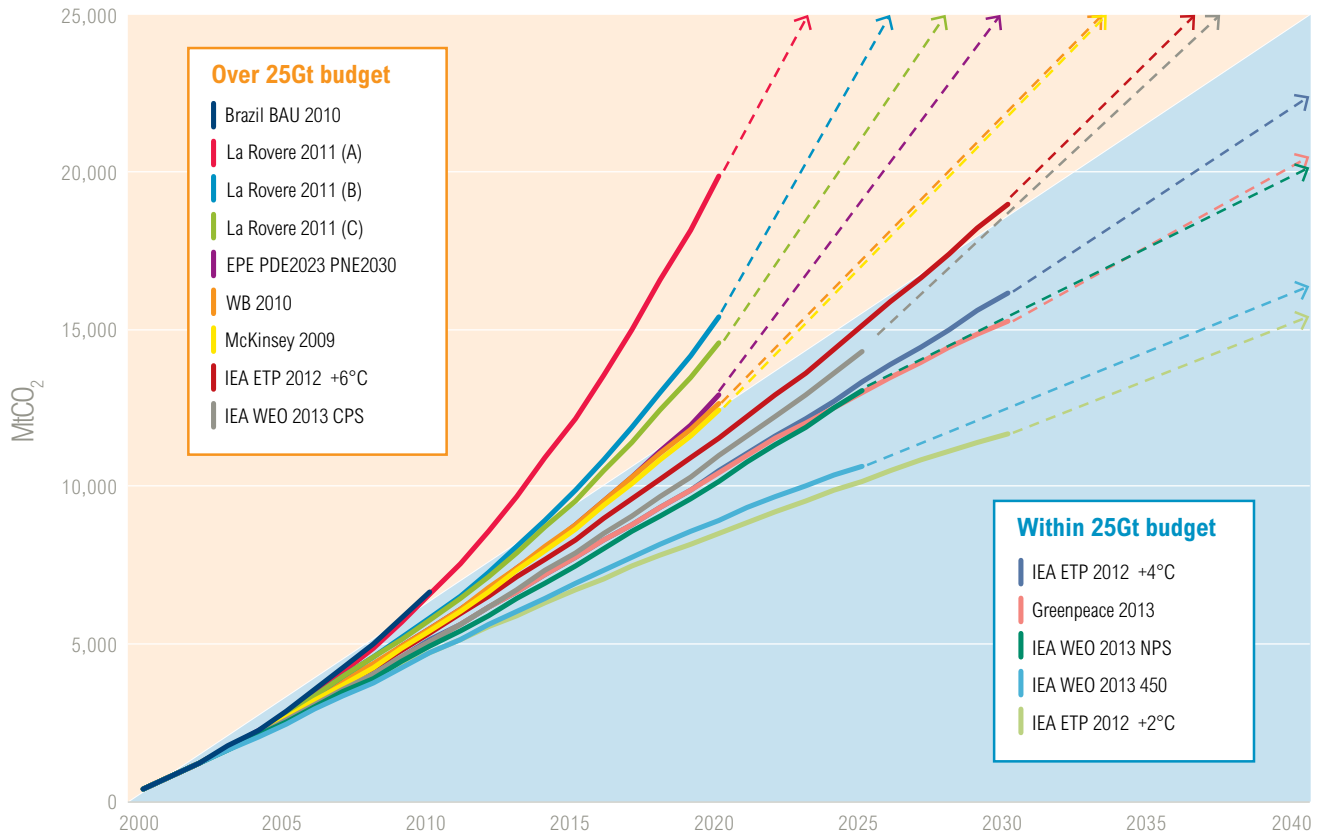
Sources: Kaniitkar et al, 2010; Höhne and Moltmann, 2009; Observatório do Clima, 2015; IEA, 2013; and EcoEquity and the Stockholm Environment Institute.

^a Kaniitkar et al. use the term 'entitlement' to refer to the fair share of emissions that a region/country will be allowed in a given time-period.

^b Occupation: Contribution to global carbon stock in a given time-period.

^c Allocation of the carbon budget for Brazil.

Figure A2-1 | **Screening of CO₂ Emission Outlooks Considering a 25 Billion Tonnes of CO₂ 40-year Carbon Budget for Brazil**



* Budget range for all sectors: 19.8-41.4 GtCO₂e in 40 years (models TISS-DSF, WWF-Ecofys, and GAMS). Energy budget 25 GtCO₂e based on 60 GtCO₂e (future entitlements) minus non-energy GHGs (~0.85 GtCO₂e in 2010 multiplied by 40 years).

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ABOUT OCN

The Open Climate Network (OCN) brings together independent research institutes and stakeholder groups to monitor countries' progress on climate change. We seek to accelerate the transition to a low-emission, climate-resilient future by providing consistent, credible information that enhances accountability both among and within countries. www.openclimatenetwork.org

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