Brazil Chapter

pathways to deep decarbonization

2014 report

IDDRI
SciencesPo.
SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

Published by Sustainable Development Solutions Network (SDSN)
and Institute for Sustainable Development and International Relations (IDDRI),
september 2014

The full report is available at deepdecarbonization.org.

IDDRI

The Institute for Sustainable Development and International Relations (IDDRI) is a non-profit policy research institute based in Paris. Its objective is to determine and share the keys for analyzing and understanding strategic issues linked to sustainable development from a global perspective. IDDRI helps stakeholders in deliberating on global governance of the major issues of common interest: action to attenuate climate change, to protect biodiversity, to enhance food security and to manage urbanization, and also takes part in efforts to reframe development pathways.

SDSN

Sustainable Development Solutions Network (SDSN) mobilizes scientific and technical expertise from academia, civil society, and the private sector in support of sustainable development problem solving at local, national, and global scales. SDSN aims to accelerate joint learning and help to overcome the compartmentalization of technical and policy work by promoting integrated approaches to the interconnected economic, social, and environmental challenges confronting the world.

Disclaimer

The 2014 DDPP report was written by a group of independent experts acting in their personal capacities and who have not been nominated by their respective governments. Any views expressed in this report do not necessarily reflect the views of any government or organization, agency or programme of the United Nations.

Publishers : Jeffrey Sachs, Laurence Tubiana
Managing editors : Emmanuel Guérin, Carl Mas, Henri Waisman
Editing & copy editing : Claire Bulger, Elana Sulakshana, Kathy Zhang
Editorial support : Pierre Barthélemy, Léna Spinazzé
Layout and figures : Ivan Pharabod

Preface

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative, convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2 degrees Celsius (°C). Achieving the 2°C limit will require that global net emissions of greenhouse gases (GHG) approach zero by the second half of the century. This will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, a transition we call "deep decarbonization."

Currently, the DDPP comprises 15 Country Research Partners composed of leading researchers and research institutions from countries representing 70% of global GHG emissions and different stages of development. Each Country Research Partner has developed pathway analysis for deep decarbonization, taking into account national socio-economic conditions, development aspirations, infrastructure stocks, resource endowments, and other relevant factors. The pathways developed by Country Research Partners formed the basis of the DDPP 2014 report: Pathways to Deep Decarbonization, which was developed for the UN Secretary-General Ban Ki-moon in support of the Climate Leaders' Summit at the United Nations on September 23, 2014. The report can be viewed at deepdecarbonization.org along with all of the country-specific chapters.

This chapter provides a detailed look at a single Country Research Partner's pathway analysis. The focus of this analysis has been to identify technically feasible pathways that are consistent with the objective of limiting the rise in global temperatures below 2°C. In a second—later—stage the Country Research Partner will refine the analysis of the technical potential, and also take a broader perspective by quantifying costs and benefits, estimating national and international finance requirements, mapping out domestic and global policy frameworks, and considering in more detail how the twin objectives of development and deep decarbonization can be met. This comprehensive analysis will form the basis of a report that will be completed in the first half of 2015 and submitted to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC).

We hope that the analysis outlined in this report chapter, and the ongoing analytical work conducted by the Country Research Team, will support national discussions on how to achieve deep decarbonization. Above all, we hope that the findings will be helpful to the Parties of the UNFCCC as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015.

Contents

Preface 1

1. Country Profile 3

1.1. The National Context for Deep Decarbonization and Sustainable Development 3

1.2. GHG Emissions: Current Levels, Drivers and Past Trends 4

2. National Pathways to Deep Decarbonization 6

2.1. Illustrative Deep Decarbonization Pathway 6

2.1.1. High-level characterization 6

2.1.2. Sectorial characterization 8

2.2. Assumptions 12

2.3. Alternative pathways and pathway robustness 12

2.4. Additional Measures and Deeper Pathways 13

2.5. Challenges and Enabling Conditions 13

2.6. Near-Term Priorities 14

Brazil

Emilio Lèbre La Rovere,
COPPE, Federal University of Rio de Janeiro (UFRJ)

Claudio Gesteira,
COPPE, Federal University of Rio de Janeiro (UFRJ)

1 Country Profile

1.1 The National Context for Deep Decarbonization and Sustainable Development

Brazil has a unique position among major greenhouse gas (GHG) emitting countries due to relatively low per capita energy-related GHG emissions, which is attributable to the use of abundant clean energy sources. Major emissions have been historically concentrated in agriculture, forestry, and other land use (AFOLU), related mostly to deforestation, crop growing and livestock. In Brazil, deforestation has recently slowed down considerably, to the point where forestry has ceased to be the major source of emissions. The agriculture and livestock emissions have been driven by the expansion of the agricultural frontier in the "cerrado" (savannah) and Amazon biomes for crop and cattle raising activities, as Brazil is an important world supplier of soybeans and meat. In parallel, as the economy grows, emissions related to the combustion of fossil fuels for energy production and consumption have been increasing significantly and are expected to become the dominant source of GHG emissions over the next decade.[1] Brazil faces the challenge of building upon the low historical GHG emission levels through new decarbonization strategies while pursuing a rise in the living standards of the population.

In the past, Brazil had been strongly dependent on oil imports, mostly for the industrial and transportation sectors (oil products are neither used significantly in electricity generation nor in the residential sector,

1 La Rovere, E.L., C.B.S. Dubeux, A.O. Pereira Jr; W.Wills, 2013; Brazil beyond 2020: from deforestation to the energy challenge, Climate Policy, volume 13, supplement 01, p.71-86.

as ambient heating is needed only sparingly in the south of Brazil). Oil imports have in particular fueled on-road modes of transportation that dominate the sector both for urban and long distance travel, whether freight or passenger-related. Over the last decade, large offshore oil reserves were found, raising the expectation that Brazil can become a major oil exporter, since these reserves exceed the country's own consumption needs and current governmental plans do not envision using these reserves for internal needs. The country is not endowed with large coal reserves, having only a low-grade variety, and the coal use is limited to a few industries that need it for their specific processes (e.g. coke for steel mills, cement) and to some complementary electricity generation. Natural gas produced in the country has not matched the rapid growth in demand, creating a need to import gas either through the pipeline from Bolivia or as liquefied natural gas (LNG). The need to import natural gas will be eliminated in the future as new discoveries are fully exploited.

Brazil is also endowed with a large renewable energy potential. Hydropower provides more than 70% of the country's electricity and has great untapped potential, although not all of it will be used due to concerns over environmental impacts. Brazil also has an abundance of land that can be sustainably used to produce biofuel feedstocks, especially sugarcane for ethanol, which is already widely used as a fuel for light-duty vehicles. The country also has a great wind and solar potential, and the last five years have witnessed an increase in the use of wind for electricity generation.[2] Therefore, keeping a low energy emissions growth trajectory appears feasible, and, if carefully planned and prioritized, economic growth can be achieved with a declining consumption of most fossil fuels, with the possible exception of natural gas.

Income inequality is another major concern, and, although the level remains high, there has been visible progress in recent years, with the lower income strata of the population witnessing a greater increase in income than the national average. Regional inequality is also high and is the subject of some regional incentive programs. On this point, the need to provide enough energy to fulfill the needs of the whole population while decarbonizing the economic activity remains a key challenge, although not an insurmountable one.

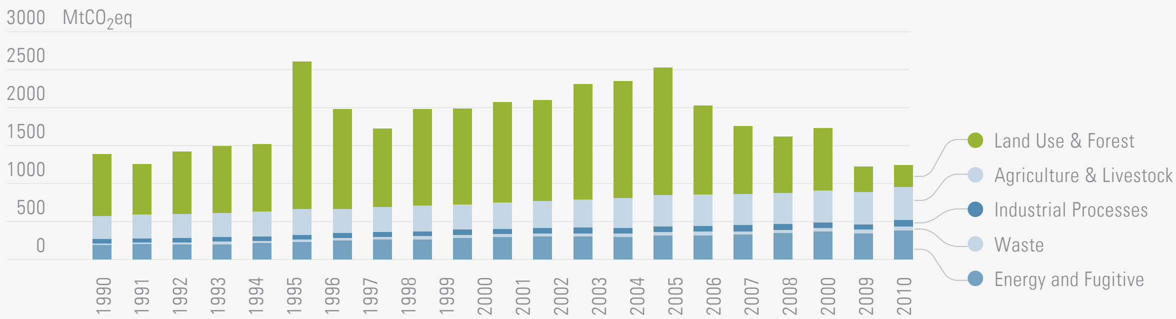
1.2 GHG Emissions: Current Levels, Drivers and Past Trends

The Brazilian population has increased from 145 to 191 million people between 1990 and 2010. Population growth rates have declined to 0.9 percent per year. GHG emissions increased from 1.4 in 1990 to 2.5 billion metric tons CO_2 equivalent ($GtCO_2e$) in 2004, followed by a substantial reduction (by half), reaching 1.25 $GtCO_2e$ in 2010, thanks to the sharp fall of deforestation (see Figure 1 below).

Due to the lower rate of deforestation, the share of CO_2 in the GHG emissions mix has declined sharply, from 73% to 57% between 2005 and 2010. The recent growth in GHG emissions has been driven by methane emissions from the enteric fermentation of the large Brazilian cattle herd (numbering 213 million heads in 2012), and the share of fossil fuel combustion in total GHG emissions has been steadily increasing in recent years, from 16% to 32% over the period 2005-2010, ranking second after agriculture and livestock in 2010 (see Figure 2a). Among fossil fuels, oil is by far the dominant source of emissions, followed by natural gas and coal (see Figure 2b). Population and economic growth have been consistent drivers of increased energy-related CO_2 emissions, whereas the energy-related CO_2 intensity per unit of GDP increased from 1990 to 2000 but decreased from 2000 to 2010 (see Figure 3a). Transportation is the largest energy-related emissions source, followed by industry, electricity generation, and buildings (see Figure 3b).

2 EPE (2013), 'Balanço Energético Nacional' ; Available at: http://www.mme.gov.br/mme/galerias/arquivos/publicacoes/BEN/2_-_BEN_-_Ano_Base/1_-_BEN_Portugues_-_Ingles_-_Completo.pdf

Figure 1. Brazilian GHG Emissions by Source 1990-2010



Source: MCTI,2013: Estimativas Anuais de Emissões de Gases de Efeito Estufa no Brasil.

Figure 2. Decomposition of GHG and Energy CO_2 Emissions in 2010

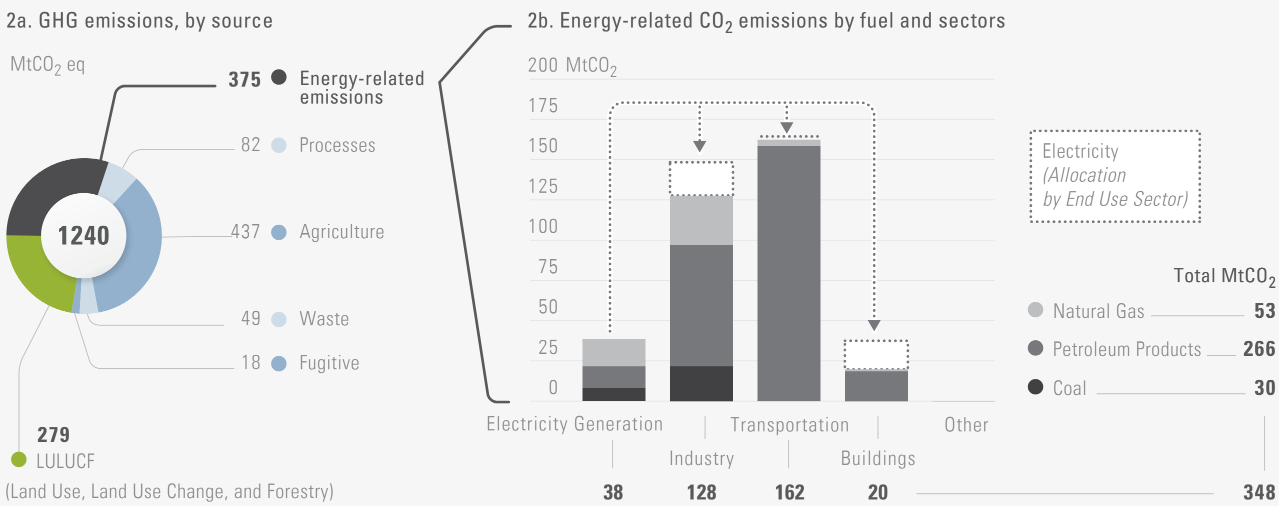
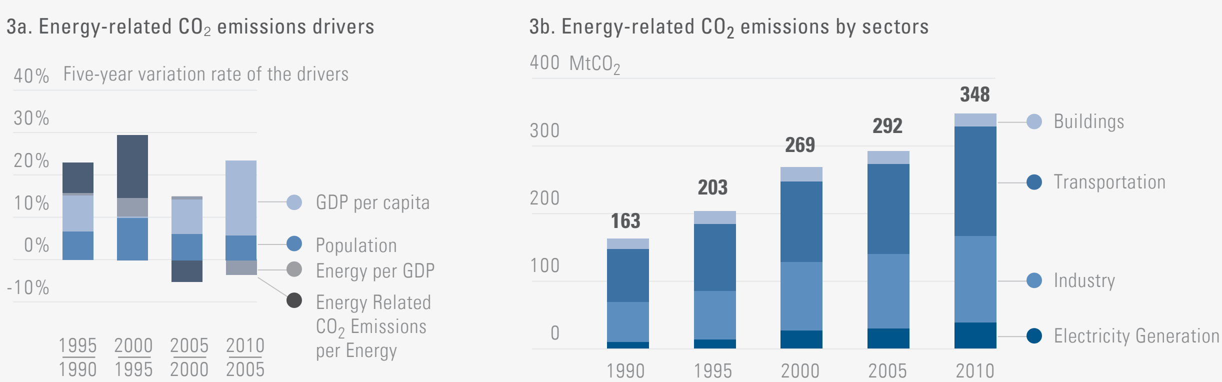


Figure 3. Decomposition of historical energy-related CO_2 Emissions, 1990 to 2010



2 National Pathways to Deep Decarbonization

2.1 Illustrative Deep Decarbonization Pathway

2.1.1 High-level characterization

Through 2030 the illustrative Brazilian deep decarbonization pathway assumes that a majority of the economy-wide emission reductions will be realized through actions outside of the energy sector. However, actions will need to be taken in the near-term to set in motion the major infrastructure changes that would allow for the significant reduction of energy-related emissions after 2030. Thus, Brazil`s energy-related emissions are expected to grow in the immediate future, to peak around 2030, and then decline through 2050. Since Brazil has sizable biological CO_2 sinks, which are assumed to increase until 2050, the Illustrative Pathway will be strongly complemented with initiatives promoting decarbonization outside the energy sector.

The large share of renewable resources in the Brazilian energy mix will form a strong starting point for the process of deep decarbonization, which will focus on the expansion of existing systems. Deep decarbonization will be further supported by efficiency measures and structural changes that can reinforce the mitigation gains while at the same time improving living conditions and fueling economic growth. In fact, economic growth is assumed to be very strong through 2050, with a tripling of GDP per capita, and total population will stabilize at around 220 million people between 2040 and 2050, as shown in Table 1.

Non-energy related GHG emissions

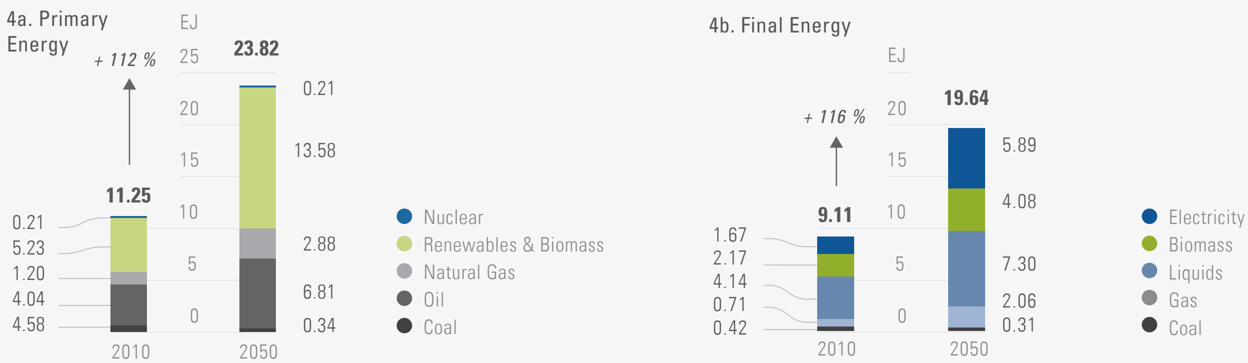
Insofar as agriculture and livestock is currently the most important source of GHG emissions in the country, the decarbonization pathway assumes the extension of the policies and measures of the Plan for Consolidation of a Low Carbon Emission Economy in Agriculture,[3] launched to meet the voluntary goals set for 2020. It thus assumes mitigation actions such as the recovery of degraded pasture land. Moreover, there will be an increase in land covered by agroforestry schemes, and more intensive cattle raising activities (integrated agriculture/ husbandry/forestry activities), while the planted area under low tillage techniques will also be expanded. In addition, areas cultivated with biologic nitrogen fixation techniques will be increased, replacing the use of nitrogenous fertilizers, and there would be greater use of technologies for proper treatment of animal wastes. In forestry and land use, the decarbonization pathway assumes the extension of the policies and measures of the Action Plan for Prevention and Control of Deforestation in the Amazon[4] and of the Action Plan for Prevention and Control of Deforestation and Fires in the Savannahs,[5] launched to meet the voluntary goals set for 2020. These action plans include a number of initiatives that combine both economic and command-and-control policy tools that succeeded in bringing down the rate of deforestation in recent years (see Figure 1).

Moreover, the proposed decarbonization pathway assumes the successful implementation of afforestation and reforestation activities, which

Table 1. Development Indicators and Energy Service Demand Drivers

	2010	2020	2030	2040	2050
Population [Millions]	190,756	206,933	217,715	222,619	220,857
GDP per capita [$/capita]	11.236,54	14.928,24	20.014,95	26.305,84	35.634,84

Figure 4. Energy Pathways, by source



would lead to a dramatic increase of forest plantations using eucalyptus and pine trees, not only for the pulp and paper industry, but also for timber and charcoal use in the production of pig iron and steel. In fact, there is a huge availability of degraded land in the country where these afforestation programs would be developed with both environmental and economic benefits. It is assumed that such initiatives will continue and expand in the coming decades, so that as early as the mid 2020's, land-use change and forestry will become a substantial net carbon sink, and, by 2050, it would be capable of offsetting a substantial share of the emissions from the energy sector.

The robustness of such a pathway was demonstrated by a recent study using various models and climatic datasets: an estimate of the carrying capacity of Brazil's 115 million hectares of cultivated pasturelands has shown that its improved use would free enough land for expansion of meat, crops, wood, and biofuel, respecting biophysical constraints, and including climate change impacts.[6]

The waste management system will require large investments in sewage pipelines, waste disposal facilities, and industrial effluents treatment units with methane capture and burning facilities that may curtail emissions. With the capture of methane, a renewable fuel source is created, and biogas would be used to replace some fossil natural gas.

Energy-related GHG emissions

In 2050, renewables and biomass become the dominant source of primary energy and are used to meet a majority of final energy needs, notably through direct use of biomass and low-carbon electricity generation. Energy efficiency has a strong potential in Brazil, and several energy saving initiatives have been set in motion in recent times and will be extended across the board (see Figure 4).

Energy-related CO_2 emissions stabilize by 2030 and decline thereafter as a result of opposing drivers that result in a 2050 emission level that is only slightly higher than in 2010 (see Figure 5).

3 Available at: http://www.mma.gov.br/images/arquivo/80076/Plano_ABC_VERSAO_FINAL_13jan2012.pdf

4 Available at: http://www.mma.gov.br/florestas/controle-e-preven%C3%A7%C3%A3o-do-desmatamento/plano-de-a%C3%A7%C3%A3o-para-amaz%C3%B4nia-ppcdam

5 Available at: http://www.mma.gov.br/florestas/controle-e-preven%C3%A7%C3%A3o-do-desmatamento/plano-de-a%C3%A7%C3%A3o-para-cerrado-%E2%80%93-ppcerrado

6 B.B.N. Strassburg, B.B.N.; Latawiec, A.E.; Barioni, L.G.; Nobre, C.A.; da Silva, V.P.; Valentim, J.F.; Vianna, M. Assad, E.D.; "When enough should be enough: Improving the use of current agricultural lands could meet production demands and spare natural habitats in Brazil", Global Environmental Change 28 (2014) 84-97

Figure 5. Energy-related CO_2 Emissions Drivers, 2010 to 2050

5a. Energy-related CO_2 emissions drivers

5b. The pillars of decarbonization

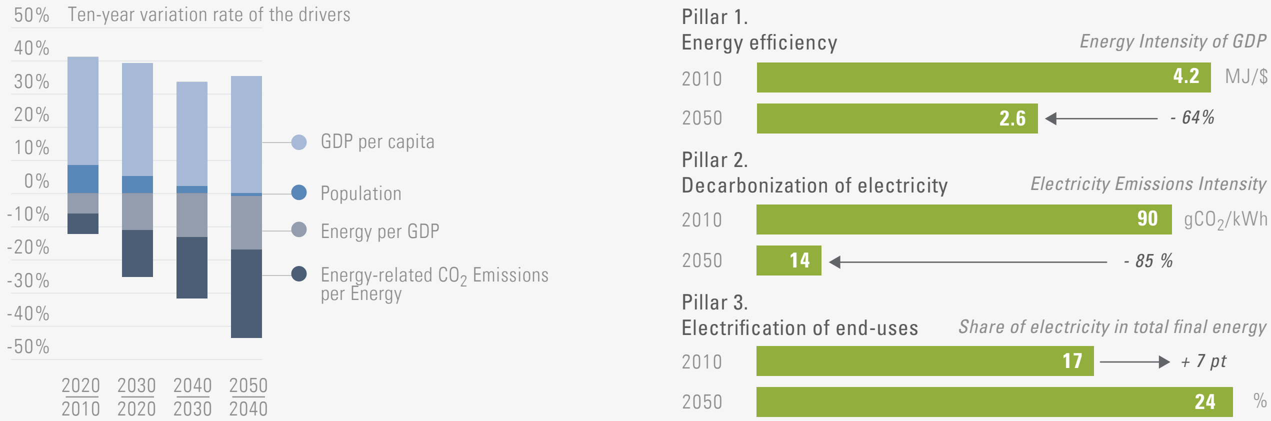
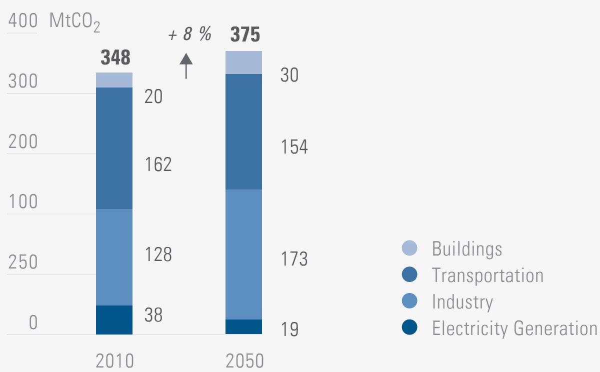


Figure 6. Energy-related CO_2 Emissions Pathway, by Sector, 2010 to 2050



2.1.2 Sectorial characterization

Emissions will be pushed upwards by the strong growth of GDP per capita, but this effect is offset by a decreasing demographic pressure (where population stabilizes by 2040) and, even more importantly, by a substantial fuel shift towards renewable energy supply and a decrease in final energy intensity per unit of GDP. The transportation and industrial sectors will be responsible for the bulk of emissions, with transportation emissions dominating across most of the period, but surpassed by emissions from industry in 2050 (see Figure 6).

All sectors experience growth in absolute terms, but the structure of the Brazilian economy features a partial evolution towards the commercial sector, see Table 2. The commercial sector increases the share in GDP by 1 percentage point per decade to reach 70.3% in 2050, whereas the share of heavy industry decreases (as a consequence of the uncertain growth prospects in a globalized and mobile industrial landscape), and the share of agriculture and livestock remains constant (capturing increasing global demand for food), see Table 3.

Electricity generation

The illustrative deep decarbonization pathway includes a further expansion of hydropower, tapping the potential for doubling the installed capacity with environmentally acceptable projects, along with an expansion of bioelectricity generation and a limited amount of wind and solar photovoltaic generation. Nuclear energy currently provides only 2.7% of total electricity in Brazil, and no further increase of this output level is considered in this pathway, due to high costs compared to other electricity generation options and uncertain social acceptance.

The full utilization of the country´s hydropower potential requires an improved design and construction of hydropower plants with reservoirs, while simultaneously meeting local environmental concerns. In recent years hydropower construction has included minimal reservoirs (i.e. mostly run-of-the river plants) with limited energy storage capacity and without dispatchable generation characteristics. Therefore improved designs are needed to decrease the reliability concerns associated with this potentially intermittent resource. In addition, the pathway includes use of the huge potential for renewable biomass, mainly from wood and from sugarcane byproducts of ethanol production (i.e. bagasse, tops and leaves, and stillage).

This renewable electricity mix can be designed to match the country's variable electricity demand by exploiting the complementarity between the renewable resources and by including a sizable standby capacity of dispatchable generation coming from natural gas- and biomass-fired power plants, which will progressively displace all coal-

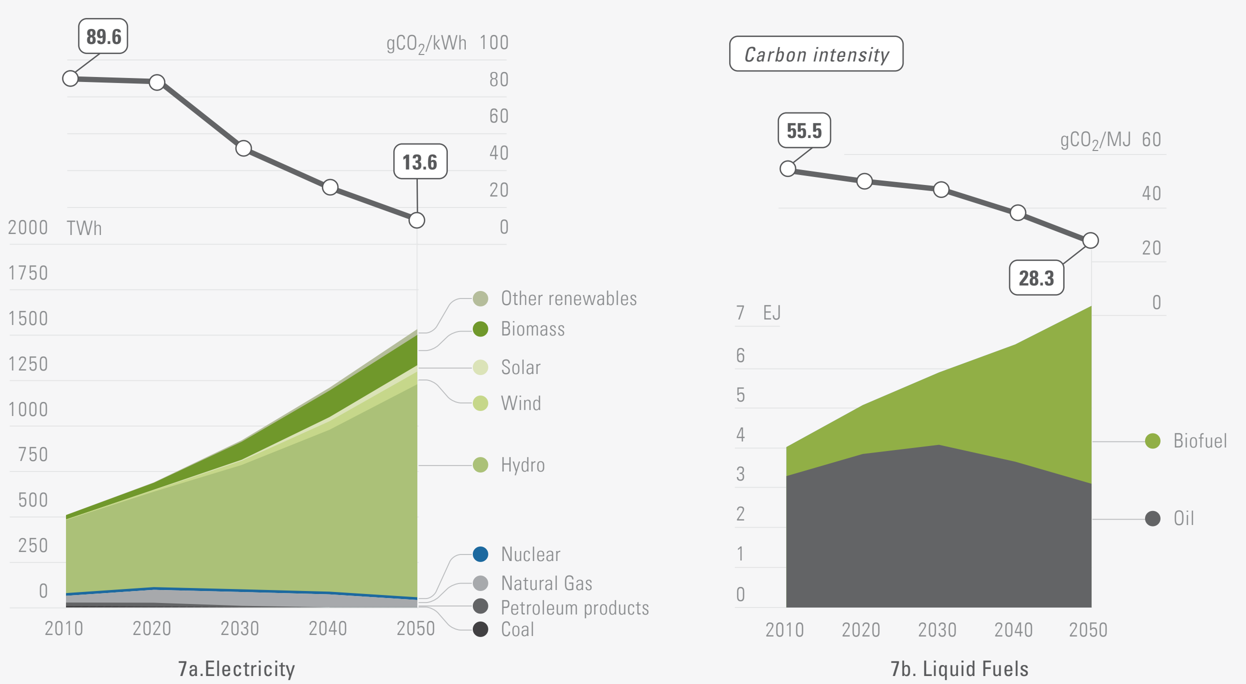
Table 2. Sectorial GDP (Billion 2010 US$)

	2010	2020	2030	2040	2050
Total GDP	2,143	3,089	4,358	5,856	7,870
Agriculture and Livestock	122	176	248	334	449
Heavy Industry	600	834	1,133	1,464	1,889
Commercial	1,421	2,079	2,976	4,058	5,533

Table 3. Sectorial GDP Shares (%)

	2010	2020	2030	2040	2050
Agriculture and Livestock	5.7	5.7	5.7	5.7	5.7
Heavy Industry	28.0	27.0	26.0	25.0	24.0
Commercial	66.3	67.3	68.3	69.3	70.3

Figure 7. Energy Supply Pathways, by Resource



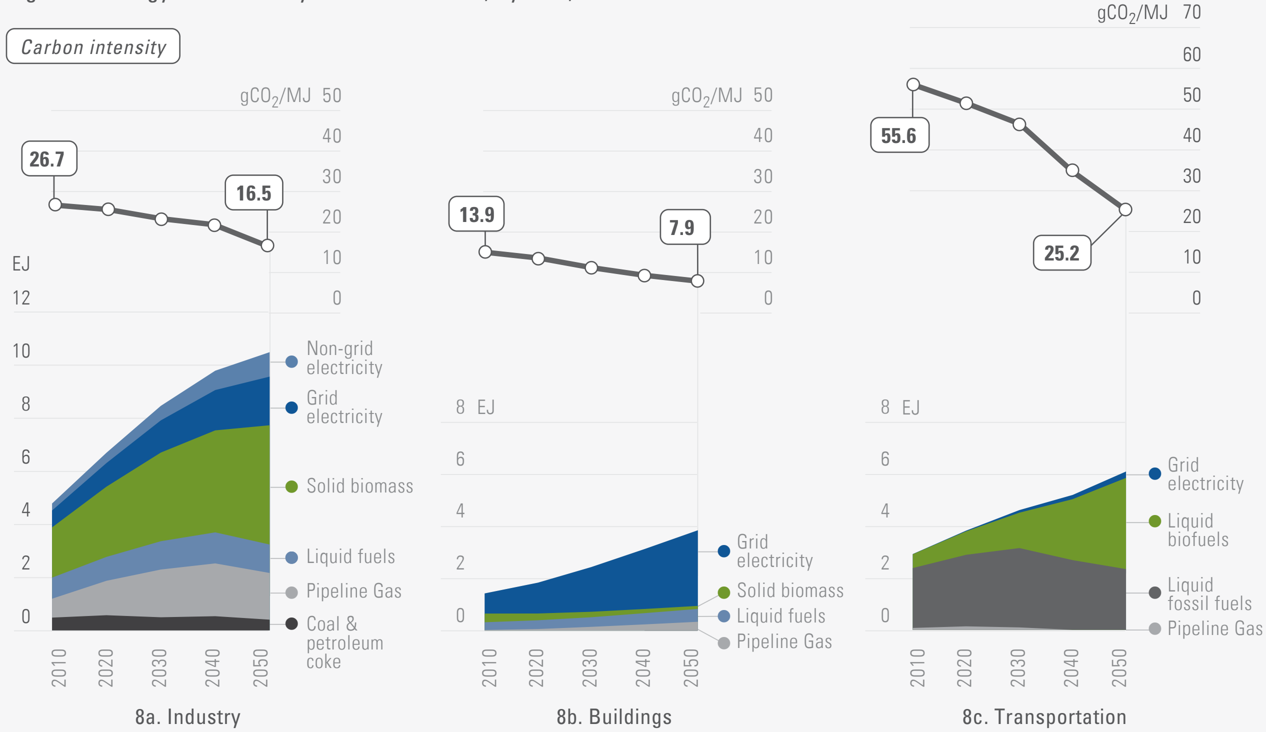
and petroleum product-fired power plants. The resulting carbon intensity of electricity generation in 2050 is therefore much lower than the (already low) 2010 level (see Figure 7a).

Transportation

In the transportation sector, the reliance on renewables, especially ethanol, will increase. Regular gasoline sold in the country will continue to contain a 25% mandatory ethanol content, and most new cars manufactured for the internal market will continue to be 'flex-fuel,' capable of running on 100% ethanol. An ambitious biofuel program will increase the production of ethanol from sugarcane and biodiesel and biokerosene from a combination of sugarcane and palm oil. This would allow for a significant substitution of gasoline by renewable ethanol to fuel most of the light-duty vehicle fleet (with some natural gas used by taxicabs in major cities) and blending aviation jet fuel with biokerosene for long distance transportation. The biodiesel blend to diesel, used by trucks and buses, would be further increased to 25% (the government has just announced an increase from 5 to 7%). Therefore, more than half of total energy used in transportation would be renewable and the carbon intensity of fuels per unit of energy would be cut by more than half in 2050 (see Figure 8c).

Energy efficiency standards would be used to increase fuel economy of cars, buses, and trucks, and a shift in freight towards trains and waterways would be promoted (when possible) for a deep decarbonization of the transportation sector. Also, the pathway includes a significant extension of ur-

Figure 8. Energy Use Pathways for Each Sector, by Fuel, 2010 – 2050



Note: Carbon intensity for each sector includes only direct end-use emissions and excludes indirect emissions related to electricity generation.

ban mass transportation infrastructure (subways and trains, bus rapid transport systems, etc.). As a result, the energy intensity per passenger-kilometer of travel would be reduced by 40% in 2050 compared to 2010.

Buildings

Demand for energy in buildings is likely to rise strongly, reflecting economic growth and social-inclusiveness. Energy efficiency is to be pursued, although the efforts are not likely to produce as significant a reduction as in countries with colder climates, where insulation and other efficiency measures can considerably reduce the relative weight of sizable heating needs. Fuel shifts in households would be focused on solar thermal for hot water, with some replacement of LPG by natural gas, ethanol, and grid electricity. The adoption of solar photovoltaic panels in residences through a proper regulatory framework and smart grid infrastructure would be stimulated, allowing for the introduction of photovoltaic power.

For household electricity consumption, the share of lighting will be reduced due to the emergence of compact fluorescent light bulbs (CFLs) and light emitting diodes (LEDs), while consumption from electronic equipment and appliances would increase. Air conditioners will become more widely adopted in the future, and despite the use of more efficient technologies (such as split units, central air conditioning, and heat pumps), their total consumption of electricity will increase.

In the commercial sector (including both private businesses and public institutions), the expansion of energy consumption and the associated emissions follow economic growth. Decarbonization measures to be adopted in this sector are similar to those in the residential sector, with more weight given to energy efficiency in air conditioning installations.

In both the residential and commercial sectors, the decarbonization pathway includes increasing energy efficiency for all LPG uses (cooking and water heating) and greater energy efficiency in all electricity uses to reduce some of the growth in demand. In the end, building energy use would to more than double and most energy needs of this sector would be met by low-carbon electricity (see Figure 8b).

Industry

Most of the industrial (productive sector including energy-related emissions from agriculture and livestock) GHG emissions are composed of CO_2. More than half of the emissions are energy-related, but non-energy emissions resulting from industrial processes are also significant, corresponding in 2010 to roughly 40% of the industrial GHG emissions.

It is assumed that the share of industry in energy demand would remain relatively stable over time, with almost a doubling in absolute terms despite the assumed widespread adoption of energy efficiency measures. As a consequence, its share of energy emissions would grow (Figure 6) since fuel switching is not always feasible in industrial processes. The non-energy emissions of industrial processes are also likely to increase, given the inflexibility of some of those processes.

In the illustrative pathway, the growth in industrial energy emissions will be tempered by a reduction in both the energy intensity of industrial products and in the emission factors. This will come about by substantially increasing energy efficiency in all uses of petroleum products, natural gas, and electricity, which will result in the industrial energy intensity per unit of value added decreasing by 30% in 2050 compared to 2010. This reduction in energy intensity is complemented by a transition to greater use of renewable energy sources (biomass residues, biogas, wood and charcoal, solar energy, and small hydropower) and by increased levels of recycling in selected industries (plastics, aluminum, scrap steel, paper, etc.) (Figure 8a).

A substantial effort will be required to reduce CH_4 and CO_2 fugitive emissions from the oil and gas production system (platforms and transport facilities), as the huge resources of the pre-salt layer are exploited. With the deployment of new infrastructure and some technical progress, it is assumed that the rate of natural gas venting and flaring can be reduced.

In Brazil, the bulk of GHG emissions associated with agriculture and livestock are not related to energy use. The decarbonization measures that will be adopted to curb sectorial energy-related emissions are the progressive replacement of diesel-based electricity generators by grid electricity or locally produced biomass, small hydropower or solar energy coupled with increasing energy efficiency. The use of biofuels (ethanol and biodiesel) to replace diesel in tractors and agricultural equipment would also be important.

2.2 Assumptions

The Illustrative Pathway designed for a deep decarbonization of the energy system would be achieved through efficiency gains and fuel switching, mostly relying upon existing technologies, such as hydropower and bioenergy. The production of ethanol from sugarcane is acknowledged as an advanced first generation biofuel and production levels can be considerably extended without causing any competition with food production or deforestation, as demonstrated by recent trends since the doubling of sugarcane areas between 2004 to 2011 (from 5 to 10 million hectares) has occurred in parallel with a notable fall of deforestation rate (from nearly 3 to less than 1 million hectares per year). Actually, sugarcane production areas are far from forests, as most production occurs more than two thousand kilometers away from the Amazon.[7]

While some second generation biofuels from sugarcane, such as biokerosene and farnesene ("diesel oil"), have already demonstrated technical feasibility, they see limited growth in the transportation sector due to the current high costs. Biodiesel production from palm oil would increase given the potential to grow the feedstock on the huge surfaces of degraded land available in the country.[8]

Clean power generation would be provided by hydropower, complemented by bioelectricity (to ensure reliability) along with emerging onshore wind and solar photovoltaic energy. In the productive sector, increased use of green electricity and biomass coupled with an interim substitution of natural gas for coal and petroleum products would be required.

2.3 Alternative pathways and pathway robustness

Alternative deep decarbonization pathways in Brazil might be designed with a larger deployment of electric vehicles coupled with a substantial increase in clean power generation. Electric cars are not an immediate priority in Brazil for GHG reductions purposes because "flex fuel" light duty vehicles can run on ethanol with a near-zero net emissions and lower transition costs. However, electric cars have other benefits (less urban air pollution and noise, etc.) and may be an alternative option. Electrified buses could also reduce GHG emissions and local pollution. Other pathways would be made possible by technological breakthroughs and cost reductions in technologies such as second generation biofuels, carbon

7 Sources: INPE; IBGE; UNICA; NIPE-UNICAMP; CTC; in ICONE, 2012; Nassar et al, 2008 in Sugarcane Ethanol: Contributions to Climate Change Mitigationand the Environment. Zuurbier,P.; Vooren, J.(eds). Wageningen: Wageningen Academic Publ.

8 Estimates vary from 20 to 60 million hectares, according to the level of degradation (high, medium and low), see PPCDAm, PPCerrado and Strassburg et al, 2014.

capture and sequestration (CCS), offshore wind, and concentrated solar power.

Brazil has a huge renewable energy potential from a number of different sources (hydropower, biomass, wind, and solar energy) and the relative shares of these technologies in the future energy mix will depend mostly on the outcome of the technological race towards economic feasibility.

2.4 Additional Measures and Deeper Pathways

The availability of new technologies could eventually help Brazil follow a deeper decarbonization pathway than the illustrative pathway discussed hereinabove. Among the promising technologies, the diffusion of second-generation biofuel technologies, when proven economical, may contribute to further expand the already large Brazilian biofuel production. In the case of substantial cost reductions brought about by technological breakthroughs, ethanol production from lignocellulosic materials (wood, bagasse, and other biomass wastes) would allow for a much higher ethanol use in Brazil. A deeper pathway would be made feasible by the combination of high-efficiency biomass production and use, electric vehicles, and green electricity generation, and more substantial modal shifts towards railways and waterways in the transportation sector.

The infrastructure of urban mass transportation, relying mostly on a large privately owned bus fleet, could be further decarbonized with the expansion of urban and suburban trains. Long-distance freight transportation, currently carried out almost entirely on roads, could become more efficient if financial resources are made available for substantial investment in railways and waterways. In order to make possible a substantial shift to low-carbon electric vehicles, a number of additional sources of clean power generation may become increasingly available in Brazil. Offshore wind farms may become a relevant option, given the abundance of offshore sites, thanks to the potential synergy with the huge effort on offshore oil and gas drilling that would help reduce its costs. In addition, other clean power generation facilities may be built, such as concentrated solar power units with thermal storage, producing dispatchable energy.

Advanced batteries could overcome the non-dispatchability of intermittent renewable power sources, such as solar and wind, making it possible to replace natural gas as the base load supply, further reducing GHG emissions from power generation.

CCS in Brazil is not important for the purpose of reducing GHG emissions from coal, since the use of coal is very limited; however, CCS coupled with the use of natural gas could support deeper decarbonization. CCS could also be helpful to lower fugitive emissions from oil and gas production, due to its continuous deployment and expansion, given its high future availability from the pre-salt country's resources. CCS is already being developed by Petrobras through the injection of CO_2 for offshore enhanced oil recovery, but the feasibility of large-scale deployment of CCS remains unclear.

2.5 Challenges and Enabling Conditions

Given that such a formidable society-wide transformation as that implied in decarbonizing the country's economy will certainly have its winners and its losers, the political resolve that is necessary to muster the forces for change cannot be obtained without some preconditions. The first is a strong public awareness of the potential dangers of climate change and the pitfalls of inaction. Brazil would clearly benefit from a decarbonized world, given the abundance of non-fossil natural resources in the country.

The main risk here is the temptation to channel the recently discovered huge offshore oil and gas resources to expand its domestic use through a low pricing policy that would help to curb inflation down. So far, the announced governmental policy, confirmed by Congress, goes in the opposite direction, aiming to export the bulk of the oil resources and channel the oil revenue to finance government investments in education and health. It is imperative for the feasibility of a low-carbon future in Brazil to stick to this policy, avoiding the use of the newfound oil resources in such a way as to weaken the efforts to foster energy efficiency and renewable energy use.

The main technological challenges here are the design and building of a new generation of hydropower plants in the Amazon that would avoid the disruption of ecosystems, and using dispatchable bioelectricity to replace fossil fuel generation.

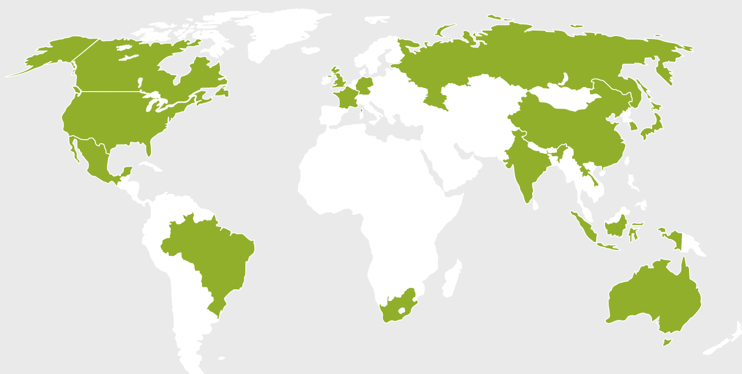
Many of the strategies would require structural changes and higher upfront costs. The barriers to their implementation are related to pricing, funding, and vested interests, especially in two fields: power generation and transportation (long-distance transportation and urban mobility). The huge upfront costs and long construction times involved in tapping the hydropower potential and building low carbon transportation infrastructure will require substantial financial flows and upgraded institutional arrangements (e.g. public/private partnerships) to provide funding in appropriate terms. The financial flow will need to largely come from outside of Brazil given the low savings capacity of the Brazilian economy.

Internationally, a set of technical and policy actions, with a realistic chance of delivering on the promise of a climate-stable planet, together with a convincing case for the perils of inaction, would be required to mobilize the resources needed for initiatives such as: accelerated research on the development of safe and energy-dense renewable fuels; research on industrial processes and materials useful to bring down the investment costs of renewable power sources; and the establishment of technology transfer mechanisms. The worldwide adoption of carbon valuation schemes and cutting back of fossil fuel subsidies would also be crucial.

2.6 Near-Term Priorities

For Brazil to get engaged in a deep decarbonization process, there are a number of immediate policy and planning measures that can be recommended. Reinforcing the initiatives aimed at curbing deforestation is one such measure to ensure that there would be no major deviations from a trajectory that leads to no illegal deforestation within a decade, at most. A similar priority should be granted to substantially expand the forest plantations in degraded land, providing the appropriate financial schemes to meet the upfront costs. Another required effort is to pass legislation so that the net effect of the system of taxes and subsidies on energy markets favor the widespread adoption of renewable energy and energy efficiency options. To this end, in the near-term it is essential to cut subsidies to gasoline and diesel, and redress the financial health of the electricity generation sector.

Extending the already existing incentives for investments in renewable energy resources to other types of equipment such as PV and solar heaters, and prompting electricity providers to adopt smart grid technologies would also produce short-term returns. Drafting a detailed and feasible plan for restructuring long-distance transport in Brazil, prioritizing an infrastructure that allows for the most energy and emissions-efficient modes of transportation such as railways and waterways, is another initiative that would both cut down emissions and respond to the concerns of the business community. A similar initiative should also be undertaken, in collaboration with local authorities, concerning urban mobility, an aspect of Brazilian infrastructure that needs improvement and is currently high in the political agenda.



COUNTRY RESEARCH PARTNERS. Australia. Climate Works Australia; Crawford School of Public Policy, Australian National University (ANU); Commonwealth Scientific and Industrial Research Organization (CSIRO); Centre of Policy Studies, Victoria University. Brazil. COPPE, Federal University, Rio de Janeiro. Canada. Carbon Management Canada; Navius Research; Simon Fraser University; Sharp. China. Institute of Energy, Environment, Economy, Tsinghua University; National Center for Climate Change Strategy and International Cooperation (NCSC). France. Université Grenoble Alpes, CNRS, EDDEN, PACTE; Centre International de Recherche sur l'Environnement et le Développement (CIRED), CNRS. Germany. Dialogik. India. The Energy and Resource Institute (TERI). Indonesia. Center for Research on Energy Policy-Bandung Institute of Technology, CRE-ITB; Centre for Climate Risk and Opportunity Management-Bogor Agriculture University (CCROM-IPB). Japan. National Institute for Environmental Studies (NIES); Mizuho Information and Research Institute (MIRI). Mexico. Instituto Nacional de Ecología y Cambio Climático (INECC). Russia. Russian Presidential Academy of National Economy and Public Administration (RANEPA); High School of Economics, Moscow. South Africa. The Energy Research Centre (ERC) University of Cape Town (UCT). South Korea. School of Public Policy and Management, Korea Development Institute (KDI); Korea Energy Economics Institute (KEEI); Korea Institute of Energy Research (KIER); Korea Environment Institute (KEI). United Kingdom. University College London (UCL) Energy Institute. United States of America. Energy + Environmental Economics (E3).

DDPP PARTNERS ORGANIZATIONS. German Development Institute (GDI); International Energy Agency (IEA); International Institute for Applied Systems Analysis (IIASA); World Business Council on Sustainable Development (WBCSD).