Consumption Patterns and the Transition to a Low-Carbon Economy in 2050 – The Case for Brazil

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1. Introduction

Purely technological solutions cannot deliver a transition towards a low-carbon development by themselves, shifts in consumption patterns and lifestyles are also essential to achieve safe levels of greenhouse gases concentration.

A major challenge in doing so is to simultaneously decrease the carbon footprint of consumption patterns, support the middle class boom in emerging economies, and meet the basic needs of the poorest strata. Understanding how these variables should evolve is a key task for building future scenarios and assessing the expected outcomes of environmental policies and regulations.

The Paris Agreement goals determine countries should seek to stabilize their emissions at levels consistent with a temperature increase of well below 2o C compared to pre-industrial levels by the middle of the century, ideally at 1.5o C. According to the UNEP's Emissions Gap Report, such an aim means global per capita GHG emissions varying between 2.4 and 0.8 tCO2e in 2050, without taking into account burden-sharing aspects, say between developing and developed countries (UNEP 2016).

However, current ongoing efforts, established in the countries' Nationally Determined Contributions (NDCs) under the scope of the Paris Agreement are insufficient to reach such goals: if fully complied with, global emissions would still lead to a 3o C temperature increase.

This study analyses exploratory emissions scenarios for the whole Brazilian economy up to 2050, with a special focus on household income and consumption aspects. In the first scenario, the Brazilian NDC is put in place up to 2030, leading to an emissions reduction of 43% compared to 2005 levels. With no extra official mitigation efforts from 2030 on, emissions resume and grow up to 2050. This is the base case scenario, even though it cannot be considered a 'business-as-usual' scenario, since there are mitigation efforts.

The second scenario explores how changing consumption patterns and greater ecological awareness can help meet these goals, with a special focus on energy consumption. Households pursue a more environmentally friendly behavior: healthier diets, with reduced meat consumption; prioritizing public and non-motorized transportation, instead of private cars; a broadened lifespan of goods such as clothes and appliances, and a more sound consumption of energy within the household. In a general way, this leads to a less energy-intensive and dematerialized lifestyle, in which personal and cultural services are favored. Nonetheless, it is highly unlikely that demand-side only efforts manage to stabilize emissions at safe concentration levels, especially in Brazil, where the majority of emissions are related to land-use, for which export-oriented activities play a major role.

The methodological framework used in this study is a hybrid general computable equilibrium model, the IMACLIM-S BR. It is developed to assess the macroeconomic and social implications of climate policies in the medium and long term in a comparative statics fashion. It combines top-down and bottom-up approaches using a double accounting system in which both physical and economic flows are balanced.

The model comprises six energy sectors, seven industrial sectors, apart from the Agriculture and Livestock, Transport and Services sectors, and represents the Brazilian economy for a 45-year period, from 2005 to 2050. The household sector is divided in ten income deciles, with household consumption and income levels calibrated using national household surveys.

The model's input-output framework allows for a comprehensive understanding of the effects of changing consumption in sectors demand level, prices, job creation and their feedback effects on governmental budget and households income and consumption possibilities, GHG emissions, and so on.

This article is organized as follows: section 2 details the methodology used for assessing the prospective scenarios, which are described in section 3. Section 4 presents and discusses the main findings. Section 5 concludes and explores further mitigation possibilities in the supply side needed to reach the aimed emissions level.

2. Modeling tool: the IMACLIM-S BR model

2.1 The IMACLIM-S model

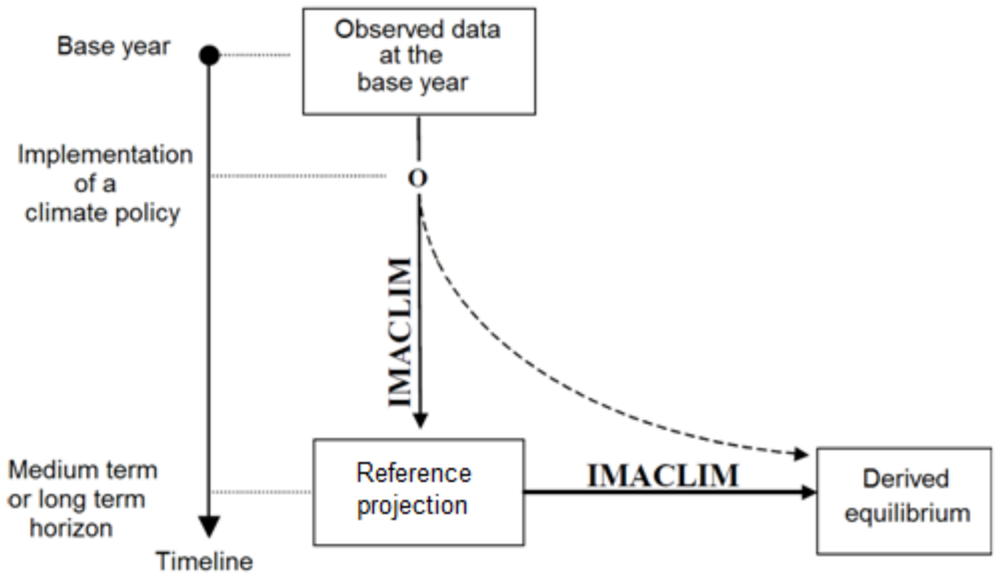
IMACLIM-S is a CGE model designed to assess medium- to long-term macroeconomic impacts of aggregate price - or quantity-based carbon policies, in an accounting framework where economic and physical flows (with a special focus on energy balances) are equilibrated (Ghersi, F., Thubin, C., Combet, E., Hourcade 2009), (Combet, E., Ghersi, F., Hourcade, J-C, Thubin 2010), (Wills and Lefevre 2012) and (Wills 2013).

IMACLIM-S calculations rely on the comparative-static analysis method: they provide insights that are valid under the assumption that the policy-induced transition from the reference equilibrium to its policy-constrained counterpart is completed, after a series of technical adjustments whose duration and scope are embedded in the elasticities of production and consumption retained. The transition process in itself is however not described, but implicitly supposed to be smooth enough to prevent e.g. multiple equilibriums, hysteresis effects, etc. (Ghersi, F., Thubin, C., Combet, E., Hourcade 2009).

IMACLIM-S is a 'hybrid' model in the sense that it pictures energy volumes that are not deduced from national accounts statistics and a single energy price hypothesis, but rather result from an effort to harmonize these macroeconomic data with energy balances and energy prices statistics in the reference year.

IMACLIM-S operates by projecting the comparative static equilibrium of an economy (reference scenario), and then the deformation of this equilibrium where a climate policy is implemented, as depicted in Figure 1.

Figure 1 – IMACLIM-S layout



Source: Adapted from (Ghersi 2003)

2.2 The IMACLIM-S BR model

The Brazilian version of IMACLIM-S, called IMACLIM-S BR, was first developed by (Wills and Lefevre 2012) and (Wills 2013), which subsidize this section. Recent applications of the model seeking to assess climate policy impacts can be found in (E. L. La Rovere et al. 2015), (E. L. et al La Rovere 2016) and (Lefèvre 2016).

The current version of the model includes the following features:

(a) up to 19 productive sectors, aggregated into 12 for this study:

- Biomass
- Coal
- Oil
- Natural gas
- Oil products
- Electricity
- Transport (load and passenger transportation);
- Cattle
- Agriculture and food industry
- Energy-intensive industry (Paper and Pulp, Steel, Cement, Non-ferrous metals, Chemicals, Mining)
- Rest of industry
- Composite (Services and Construction)

(b) Extensions of benchmark hybrid I-O table: emissions-intensive sectors are represented in physical units - tons of oil equivalent units for energy goods, tons for industrial goods, data in m^2 of land for agriculture and husbandry, ton.km for freight transportation and pass.km for passenger transportation;

(c) Four institutional sectors: households, government, firms and the rest of the world.

The household sector specifically is split into six income classes, using deciles of representative households in base year. Income and consumption profiles are outlined through the reconciliation of National Accounts components and household budget surveys[1].
In general, the poorer the household, the bigger its size. Hence, lower income deciles account for a higher share of total population than top ones. Households are organized as follows:

- HH1 - Decile 1 (10% poorest households; 12% of total population)
- HH2 - Deciles 2 and 3 (20% next; 22% of total population)
- HH3 - Deciles 4 and 5 (20% next; 20% of total population)
- HH4 - Deciles 6 and 7 (20% next; 19% of total population)
- HH5 - Deciles 8 and 9 (20% next; 18% of total population)
- HH6 - Decile 10 (10% richest households; 9% of total population)

3. Overview of prospective scenarios

The analysis considers two scenarios up to 2050. The first scenario is the base case, followed by an alternative pathway that seeks to stabilize GHG emissions at safe levels, described below.

Scenario 1 - Governmental Plan Scenario: this scenario incorporates policies that are foreseen in the Brazilian long-term governmental strategy, ranging from deforestation goals, biofuel development, efficiency gains in energy and agriculture, among others. It contemplates the full implementation of the Brazilian Nationally Determined Contribution (NDC) under the scope of the Paris Agreement up to 2030, and its continuity from 2030 to 2050 with no further increase in ambition.

Scenario 2 - Environmentally friendly behavior scenario: this scenario assumes a more environmentally sound household behavior regarding energy, transport, food and appliances consumption, as well as waste generation. We seek to identify to what extent the increased awareness can contribute to mitigation.

3.1 Governmental Plan Scenario drivers

[1] Consumer Expenditure Survey (POF in Portuguese) and National Household Sample Survey (PNAD in Portuguese) (IBGE 2003; IBGE 2009; IBGE 2006).

3.1.1 Macroeconomic drivers

The macroeconomic reference scenario was based on PNE 2050 (Empresa de Pesquisa Energética (EPE) 2014), the most relevant long-term strategy report available for the Brazilian economy, with a special focus on energy planning. The PNE 2050 scenario assumes relatively high GDP growth rates for Brazil and for the rest of the world, which were reviewed due to the political-economic crisis in Brazil, apart from other reevaluated projections, such as global economic growth and energy prices.

The domestic macroeconomic environment is characterized by improved infrastructure, aiming at reducing transportation costs and enhancing competitiveness of productive sectors. Greater investments in education, including revenues from the exploitation of the pre-salt layer, decreasing labor informality, better income distribution and a social security reform in order to stabilize deficit to GDP in 2005 standards are also presumed. These policies contribute to greater overall productivity of the Brazilian economy. In the 2005-2050 period, Brazil grows at an average annual rate of 2.8% p.y..

Brazilian population growth is expected to slow down at intensified rates, due to lower fertility rates. Population peaks between 2040 and 2045 and reaches 226 million people in 2050.

Efforts to curb deforestation rates and improve agriculture and cattle practices contribute to lower emissions related to AFOLU[2]. However, the improved socioeconomic scenario leads to income gains that raise demand for goods and services. Households have better access to appliances, private vehicles, industrialized food products and consumer goods in general. This is expected to boost energy-related emissions over the assessed period.

3.1.2 Household trends and converging consumption patterns

PNE2050 provides the main drivers with regard to the expected evolution of Brazilian households' socio-demographic and cultural characteristics, related to higher urbanization, smaller household size (due to decreasing fecundity rates) and technological progress.

With the aid of some extensive literature, (Weiss and Pereira Jr. 2016) complement the PNE2050 and outline the household energy consumption for Brazilian households in the GPS scenario. Ownership rates, usage levels and efficiency gains are discussed for:

(a) Lighting (incandescent, fluorescent and LED bulbs)
(b) Food conservation (fridges and freezers)
(c) Air conditioning (fans and air conditioners)
(d) Water heating (electric, LPG, natural gas and thermosolar shower)
(e) Cooking (LGP, natural gas, firewood, charcoal and electric stoves)
(f) Other uses (miscellaneous appliances, mainly related to information, communication and leisure)

[2] Acronym for ' Agriculture, Forestry and Other Land Use'

Table 1 – Brazilian households´ characteristics projections

	2005	2010	2020	2030	2040	2050
Population (millions)	185	195	212	223	228	226
Households (millions)	52.9	60.0	72.8	82.0	92.0	99.0
Urban households (%)	85%	86%	86%	88%	88%	89%
Average household size (members)	3.5	3.3	2.9	2.7	2.5	2.3

Source: Adapted from (Weiss and Pereira Jr. 2016)

PNE2050 also contemplates trends in passenger transportation, namely motorization rates, electric car penetration and the choice between ethanol and gasoline in flex-fuel vehicles. These variables are also incorporated in GPS and are detailed in (D´Agosto, Schmitz, and Di Beo 2016).

A complementary hypothesis – especially relevant while assessing household behavior - is that as income per capita converges across income classes, consumption patterns will converge as well, leading to a potentially higher demand for goods and services and consequentially higher emissions.

3.2 Alternative pathway scenario

In this scenario, raised environmental awareness and solidarity with future generations lead households to pursue a strong dematerialization of consumption and waste reduction, focusing on well-being, culture and education over physical goods. Environmental attitudes which promote resource conservation from the demand side take place in various aspects of daily life (see Annex I for detailed effects of behavior shifts), such as:

- **Household appliances, furniture, personal belongings:** households adopt 'reduce, reuse and recycle' policies through extended lifespan, ´do it yourself´, second-hand purchase, sharing economy (renting, lending and borrowing instead of buying)

- **Household energy:** improved energy saving behavior (switching off stand-by, turn off appliances when not needed, washing clothes at full loads and with cold water, reducing duration of showers)

- **Transportation:** increased home office, online services and e-commerce decrease mobility demand. Carpooling, car sharing and higher preference for public transportation lead to lower car ownership rates. Favored non-motorized transportation (e.g. walk or bike for short distances) also contribute to decreasing energy requirements in passenger transportation. Flex-fuel vehicles in private transportation, both internal combustion and hybrid ones, are fueled with renewable energy, namely ethanol. Fewer business air trips are needed, and demand for trips with leisure purposes also decrease.

- **Food:** household shift to diets with reduced meat consumption, replacing animal protein for vegetables, fruits and cereals. Pursuit of more healthy diets also leads to a decreased consumption of beverages and industrialized products in general. In addition, increased awareness lead to a reduced waste generation.

Literature supporting lifestyle changes assumptions can be found in (Pernollet, Coelho, and van der Werf 2017), (ITDP 2014), (Kriström and Kiran 2014), (Millock 2014), (Ehreke, Jaeggi, and Axhausen 2014), (Palatnik et al. 2014), (Nauges 2014), (ADEME 2013), (ADEME 2014), (ADEME 2015), (Weiss and Pereira Jr. 2016), (Greenpeace 2016), among others.

The remaining budget is shifted to the 'Composite' sector, to which belong activities related to well-being services, culture, sports, recreation, health and education. This is valid even if the household group savings rate is negative[3]: it assures that households' total consumption/expenditure does not change (consequently total household welfare levels are kept, if we consider consumption as a proxy for it).

Additional assumptions consider that land productivity increases in the biomass, cattle and agriculture sectors. This results from reduced activity of cattle ranching, which alleviates resource competition among the above mentioned sectors. Moreover, reduced internal demand for emissions-intensive sectors are partially offset by higher exports, especially regarding commodities, sectors with international competitive advantages.

4. Preliminary results and discussion

[3] This does not mean that saving rates do not vary along the assessed period, on the contrary. In base year, lower income deciles' expenditures surpass enormously their total income, leading to negative saving rates (-146% for the lowest decile). This is mainly caused by the underreporting of income, related to informal activities, for example, and reveals that household income must be further explored. In the Governmental Plan Scenario, education and labor policies that contribute to a better income distribution help households to adjust their savings.

This section presents and discusses the main results regarding macroeonomic aggregates, household income and consumption and emissions.

4.1 Macroeconomic results

Table 2 below presents the main macroeconomic results for the scenarios 1 and 2 up to 2050. Reduced demand for resource-intensive products as in scenario 2 does not jeopardize GDP, leading to a minor reduction of growth rates. In contrast, it actually results in higher job generation and a slightly lower unemployment rate. This happens because of reduced activity in sectors such as cattle and non-renewable energy, which are not labour-intensive. Meanwhile, jobs are created in biomass, agriculture and services (Table 3). This is also sustained by the assumption that some sectors counterbalance decreases in domestic demand with higher exports. Effects on investment, trade and inequality are minor or inexistent.

Table 2 - Macroeconomic results[4]

	2005	**2050**	
	Base year	**Scenario 1**	**Scenario 2**
Population (Millions)	185	226	226
GDP (Trillion 2005 USD)	0.88	3.02	2.99
Average GDP Annual Growth (%)	-	2.77	2.75
GDP per capita (thousand 2005 USD)	4.76	13.33	13.21
Number of jobs (thousands)	91,212	114,465	114,527
Unemployment rate (%)	8.6%	5.9%	5.8%
Price index variation	-	6.5%	8.6%
Gini coefficient	0.58	0.48	0.48
Investment rate (% of GDP)	13.6%	13.2%	13.1%
Trade balance (% of GDP)	3.7%	1.2%	1.2%

Source: The authors

Table 3 - Sectorial results

[4] Using 2005 exchange rate: 2.43 BRL / USD

	Jobs			Activity growth		
	2005	2050		2005	2050	
	Base year	Scenario 1	Scenario 2	Base year	Scenario 1	Scenario 2
Biomass	2,329	3,046	3,178	-	149%	160%
Coal	8	12	12	-	216%	200%
Oil	38	57	55	-	186%	176%
Natural Gas	5	9	8	-	270%	242%
Oil products	143	181	151	-	143%	102%
Electricity	233	421	399	-	246%	229%
Transport	3,858	6,601	6,534	-	228%	225%
Cattle	1,000	1,144	964	-	248%	193%
Agriculture	18,000	20,729	21,440	-	250%	262%
Energy intensive industry	1,619	2,266	2,171	-	186%	174%
Rest of Industry	14,007	20,160	17,215	-	194%	151%
Composite	49,973	59,839	62,401	-	233%	247%
Total	**91,212**	**114,465**	**114,527**	**-**	**-**	**-**

Source: The authors

4.2 Households results

Tables 4 and 5 below show that both gross and disposable income grows at higher rates for lower income deciles. However, disposable income grows less than proportionally because these classes also manage to improve their savings account status (Table 6).

Table 4 - Real Per Capita Gross Income (R$2005) and Variation (%)

	2005	2050	
	Base year	Scenario 1	Scenario 2
HH1	970	6,680	6,706
HH2	2,364	9,771	9,788
HH3	3,937	13,097	13,105
HH4	5,477	18,182	18,178
HH5	12,314	34,789	34,729
HH6	50,452	118,020	117,409
HH1	-	588%	591%
HH2	-	313%	314%
HH3	-	233%	233%
HH4	-	232%	232%
HH5	-	183%	182%
HH6	-	134%	133%

Source: The authors

Table 5 – Real Per Capita Disposable Income (R$2005) and Variation (%)

	2005	2050	
	Base year	Scenario 1	Scenario 2
HH1	2,216	9,432	9,466
HH2	3,227	12,772	12,791
HH3	4,824	14,838	14,842
HH4	7,099	21,061	21,043
HH5	11,672	30,118	30,044
HH6	26,423	68,350	67,942
HH1	-	326%	327%
HH2	-	296%	296%
HH3	-	208%	208%
HH4	-	197%	196%
HH5	-	158%	157%
HH6	-	159%	157%

Source: The authors

Table 6 - Saving Rate (%)

	2005	2050	
	Base year	Scenario 1	Scenario 2
HH1	-146%	-56%	-56%
HH2	-43%	-39%	-39%
HH3	-30%	-21%	-21%
HH4	-42%	-29%	-29%
HH5	-5%	4%	4%
HH6	41%	37%	37%

Source: The authors

Biomass consumption increases significantly in both scenarios, due to the expansion of biofuels in private transportation, namely sugar cane ethanol. In the environmentally friendly scenario, households prioritize biomass fuels over fossil ones, so per capita consumption is even higher.

In Scenario 2, apart from the shift to renewable fuels, reduced private mobility demand also reduces gasoline and diesel consumption (also valid for electricity, but to a much lesser extent, since in 2050 a small share of private vehicles fleet is electric). Within the household, energy saving behaviour decreases demand for liquid fuels (namely LPG for cooking), natural gas and electricity.

Table 7 - Direct Energy per Capita Physical Consumption (kTEP) and Variation (%)

	Biomass			Natural Gas			Liquid Fuels			Electricity		
	2005	2050		2005	2050		2005	2050		2005	2050	
	BY	S1	S2	BY	S1	S2	BY	S1	S2	BY	S1	S2
HH1	0.05	0.21	0.25	0.00	0.00	0.00	0.01	0.10	0.06	0.01	0.05	0.04
HH2	0.05	0.19	0.23	0.00	0.01	0.00	0.01	0.21	0.13	0.02	0.07	0.06
HH3	0.06	0.20	0.23	0.00	0.01	0.01	0.03	0.25	0.13	0.03	0.08	0.07
HH4	0.07	0.23	0.28	0.00	0.01	0.01	0.07	0.35	0.16	0.04	0.11	0.09
HH5	0.08	0.23	0.27	0.00	0.01	0.01	0.17	0.55	0.24	0.06	0.15	0.12
HH6	0.11	0.32	0.40	0.00	0.01	0.01	0.44	1.26	0.52	0.10	0.24	0.20
HH1	-	343%	420%	-	336%	296%	-	1675%	1026%	-	359%	293%
HH2	-	249%	316%	-	276%	243%	-	1712%	994%	-	285%	236%
HH3	-	227%	283%	-	259%	228%	-	892%	416%	-	166%	146%
HH4	-	218%	278%	-	250%	217%	-	438%	153%	-	162%	127%
HH5	-	193%	244%	-	216%	189%	-	229%	43%	-	144%	105%
HH6	-	193%	263%	-	199%	176%	-	186%	18%	-	145%	109%

Source: The authors

Transport activity grows significantly from 2005 to 2050, in accordance with economic performance and income gains. In the environmentally friendly scenario non-motorized transportation and reduced mobility demand decrease passenger activity but this is offset by the shift from private to public transportation. Nonetheless, this is insufficient to avoid sectorial activity losses (see Table 3), most likely because it also comprises load transportation, for which reduced activity is expected.

Table 8 - Per Capita Physical Consumption with Transportation (millions pass.km) and Variation (%)

	Transport		
	2005	2050	
	Base Year	Scenario 1	Scenario 2
HH1	0.9	4.9	5.0
HH2	1.4	6.4	6.5
HH3	2.0	6.5	6.7
HH4	2.9	8.5	8.6
HH5	4.2	11.1	11.2
HH6	8.6	22.5	21.8
HH1	-	426%	439%
HH2	-	356%	366%
HH3	-	218%	226%
HH4	-	195%	198%
HH5	-	163%	164%
HH6	-	161%	153%

Source: The authors

Food consumption increases from scenario 1 to 2 because a healthier diet, with less animal protein content, requires higher daily intake quantities (see (Pernollet, Coelho, and van der Werf 2017)). As households adopt a more sound behavior regarding durable goods in general, consumption levels decrease remarkably. With a smaller budget share devoted to energy, transportation and consumer goods, households allocate higher amounts in services, which include leisure, sports, entertainment, health, education, among others. Altogether, they shift to a dematerialized consumption pattern. Annex II displays the budget share allocation for different categories per class, for the base year and the exploratory scenarios.

Table 9 - Per Capita Consumption (R$ 2005) and Variation (%)

	Food			Other Goods			Services		
	2005	2050		2005	2050		2005	2050	
	BY	S1	S2	BY	S1	S2	BY	S1	S2
HH1	611	3,000	3,204	308	1,555	1,153	726	3,626	3,957
HH2	767	3,192	3,379	473	2,408	1,691	1,150	5,364	6,154
HH3	927	3,229	3,362	735	2,836	1,991	1,905	6,779	7,836
HH4	1,171	3,422	3,492	1,181	4,062	2,723	2,868	10,916	12,728
HH5	1,365	3,674	3,703	2,091	5,783	3,764	5,105	16,939	19,841
HH6	2,119	5,447	5,612	4,696	12,700	7,876	12,701	42,636	49,228
HH1	-	391%	424%	-	404%	274%	-	399%	445%
HH2	-	316%	341%	-	410%	258%	-	366%	435%
HH3	-	248%	263%	-	286%	171%	-	256%	311%
HH4	-	192%	198%	-	244%	131%	-	281%	344%
HH5	-	169%	171%	-	177%	80%	-	232%	289%
HH6	-	157%	165%	-	170%	68%	-	236%	288%

Source: The authors

5.3 GHG emissions results

Despite significant GDP and GDP per capita growth, emissions per capita decrease significantly from 2005 to 2050, in both scenarios. Behavior shifts contribute to reducing total GHG emissions at some additional 11% compared to the base case scenario. As expected, even though total per capita emissions decrease in both scenarios, the opposite occurs to energy-related ones. In the green behavior scenario, households´ energy-related emissions grow significantly less. Even though this is way below 2005 standards, they are still far away from the required-by-science levels to keep temperature variation at safe levels.

Table 10 – GHG emissions results

	2005	2050	
	Base year	Scenario 1	Scenario 2
Total GHG Emissions (Gt CO2e)	2.08	1.71	1.48
Total GHG Emissions Variation (2005-2050)	-	-18%	-29%
Emissions per capita (tCO2e/capita)	11.2	7.5	6.5
Energy-related emissions per capita (tCO2e/capita)	1.7	3.4	2.8
Emissions per GDP (tCO2e/thousand 2005 USD)	2.36	0.57	0.49

Source: The authors

Table 11 - Households Energy Emissions Variation (%)

	2050	
	Scenario 1	**Scenario 2**
HH1	1862%	1163%
HH2	1950%	1151%
HH3	1066%	517%
HH4	550%	211%
HH5	302%	77%
HH6	249%	45%

Source: The authors

5. Conclusion

Brazil´s carbon intensity is expected to decrease in the coming decades due to greater endeavors to curb deforestation, improve agricultural practices, increase biofuel penetration in transportation as well as renewable energy in electricity generation and industry. However, even the full implementation of the Brazilian NDC is not enough to stabilize emissions at levels consistent with the 1.5oC degree target. This is what is indicated by the base case scenario used in this study, which assesses the evolution of the Brazilian economy under the assumption that current pledges are put in place.

This paper sought to analyze to what extent changing consumption patterns can contribute to reducing domestic emissions, through an environmentally friendly behavior scenario. It evidences that lifestyles changes alone cannot deliver the required reduction in emissions-intensity. Households represent a major share of final demand in the Brazilian economy (62.5% of GDP in 2014), but Brazil´s emissions are closely related to deforestation, cattle-raising and agricultural practices, which are partially driven by exports (see (McAlpine et al. 2009) for evidence). For this reason, energy-related emissions drop more than overall or non-energy emissions in Scenario 2 compared to the base case scenario.

In addition, most consumption patterns changes require political will. An emblematic example concerns public transportation: without infrastructure investments and public policy efforts, individuals cannot shift from private vehicles to subways, buses or bicycle lanes.

5.1 Supply-side actions needed to complement demand efforts

Sound household consumption must be complemented with significant technological, institutional, governance and economic efforts in the supply side. The main available mitigation options are described below:

In the agriculture and husbandry sectors, is it possible to increase crop and herd outputs with no extra land clearing than that currently available (Strassburg et al. 2014), by expanding low-tillage, nitrogen biological fixation and integrated pasture-crop techniques, as well as increasing cattle productivity (through better fodder grass selection and use of forage legumes, tillage reduction, electric fencing, breed selection, reproductive management and earlier slaughtering).

In the forestry sector, the expansion of eucalyptus and pine forests would lead to net negative emissions through carbon sequestration, apart from providing renewable biomass that can be used to replace fossil fuels both in the steel sector and in thermo power generation.

In the transport sector, a huge mitigation potential can be explored through the increased penetration of LTV, subways and hybrid and electric vehicles. Expanding waterways and railways for freight transportation is also underlying, since road still accounts for the major share of load in Brazil. Biofuel blend shares can be increased both in diesel and gasoline.

The expansion of ethanol for passenger transportation would provide large amounts of sugar cane bagasse and straw that can be used for power generation. Residual forest products can be made available for power and heat generation, as already mentioned. A carbon-free emissions sector can be achieved, if the hydro, solar and wind potentials are properly explored.

In the industrial sector, energy efficiency gains and higher electrification rates, apart from increased biomass use can also contribute to reducing emissions. In the waste sector, methane capture must increase, and a significant share can be used for electricity generation.

Annex I – Effects of behavior shifts on consumption categories[5]

	Shift to public transportation	Ethanol in flex fuel vehicles	Non-motorized transportation	Reduced mobility demand	Residential energy savings	Reduced animal protein demand and waste	Lower car ownership rates	Broadened lifespan of goods
Biomass								
Fuelwood								
Charcoal								
Ethanol	-20.0%	68.2%	-2.9%	-10.0%				
Natural Gas								
Natural gas					-10.0%			
Oil products								
Gasoline and diesel (transportation)	-20.0%	-45.2%	-2.9%	-10.0%				
LPG and other fuels (residential)					-10.0%			
Electricity								
Electricity	-0.8%		-0.1%		-14.3%			
Transport								
Road	18.0%		-4.4%	-10.0%				
Rail	2.0%			-10.0%				
Water				-10.0%				
Air				-10.0%				
Cattle								
Livestock (negligible)								
Agriculture								
Bread & cereals						55.5%		-5.0%
Fruits & Vegetables						51.2%		-5.0%
Poultry						-75.2%		-5.0%
Other meats						-64.6%		-5.0%
Beef						-57.6%		-5.0%
Fish & Seafood						-1.1%		-5.0%
Animal products						0.0%		-5.0%
Oils and fats						37.1%		-5.0%
Beverages						-19.0%		-5.0%
Other foods						-31.1%		-5.0%
Energy intensive industry								
Major maintenance and repair of the dwelling								
Goods for household maintenance								
Hygiene items								30.0%
Drugs, appliances, equipments								-30.0%
Other education expenses								

[5] Reconciliation with POF categories (IBGE 2003; IBGE 2009)

Rest of Industry								
Household appliances								-30.0%
Furniture and furnishing								-30.0%
Clothing, footwear, personal effects								-30.0%
Purchase of individual vehicle							-50.0%	
Telephone, audiovisual, computer								-30.0%
Audiovisual and information processing equipment								-30.0%
Other recreational items and equipment								-30.0%
Composite (residual)								
Feeding out of home	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Actual rentals for housing	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Loan payments for dwelling	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Water supply and miscellaneous services relating to the dwelling	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Services for household maintenance	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Personal care services	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Individual vehicles maintenance and others services	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Health services	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Private health care	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
School fees for primary or secondary education	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Telephone and postal services	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sports and culture (services)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Other expenses	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Annex II – Budget shares per consumption categories, per class

Table A2.1 – Household budget share in base year (%)

2005	HH1	HH2	HH3	HH4	HH5	HH6
Biomass	2.0%	1.6%	1.2%	1.0%	0.6%	0.4%
Natural Gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oil products	0.7%	0.9%	1.3%	2.3%	3.7%	4.2%
Electricity	1.8%	1.9%	2.2%	2.1%	1.8%	1.3%
Transport	4.9%	5.1%	4.9%	4.8%	4.2%	3.8%
Cattle	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
Agriculture	33.6%	29.0%	23.4%	20.1%	14.3%	9.8%
Energy intensive industry	6.6%	6.6%	6.3%	6.4%	5.6%	4.7%
Rest of Industry	10.4%	11.3%	12.3%	13.9%	16.3%	17.0%
Composite	40.0%	43.5%	48.2%	49.4%	53.4%	58.7%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table A2.2 – Household budget share in 2050 – Scenario 1 (%)

2050	HH1	HH2	HH3	HH4	HH5	HH6
Biomass	1.8%	1.2%	1.1%	0.9%	0.6%	0.4%
Natural Gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oil products	3.1%	4.8%	4.9%	4.8%	5.3%	5.3%
Electricity	2.1%	2.1%	2.1%	2.0%	1.9%	1.4%
Transport	6.2%	6.0%	5.3%	4.9%	4.5%	4.0%
Cattle	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Agriculture	31.7%	24.9%	21.7%	16.2%	12.2%	8.0%
Energy intensive industry	5.3%	4.9%	5.1%	5.3%	4.9%	4.1%
Rest of Industry	11.2%	14.0%	14.0%	13.9%	14.3%	14.4%
Composite	38.4%	42.0%	45.7%	51.8%	56.2%	62.4%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table A2.3 – Household budget share in 2050 – Scenario 2 (%)

2050	HH1	HH2	HH3	HH4	HH5	HH6
Biomass	2.1%	1.5%	1.3%	1.1%	0.7%	0.5%
Natural Gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oil products	1.9%	2.8%	2.5%	2.2%	2.3%	2.2%
Electricity	1.7%	1.8%	1.9%	1.7%	1.6%	1.2%
Transport	6.3%	6.1%	5.4%	4.9%	4.5%	3.9%
Cattle	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Agriculture	33.8%	26.4%	22.6%	16.6%	12.3%	8.2%
Energy intensive industry	4.8%	4.4%	4.8%	5.0%	4.6%	4.0%
Rest of Industry	7.4%	8.8%	8.6%	8.0%	7.9%	7.6%
Composite	41.8%	48.1%	52.8%	60.5%	66.0%	72.5%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: The authors

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