Impacts of Climate Change

Itaú Asset Management

Itaú

Presentation

This White Paper aims to assess the impacts of climate change in economic activities, identify the most impacted agents and sectors, their exposure and necessary actions to mitigate risks and seize business opportunities.

Besides presenting the challenge for Brazilian society and economy, this paper summarizes internal studies from Itaú Asset Management (IAM) regarding potential climate change impacts on fixed income and equity portfolios, from a sectoral perspective.

Since 2010, IAM applies a proprietary method to integrate environmental, social and governance (ESG) issues into equity and fixed income research. Climate change is one of the eight dimensions that can affect equity value and credit risk, together with "Water, energy and materials", "Biodiversity and land use", "Waste management", "Labor relations", "Community relations", "Client relations" and "Supplier relations".

The first chapter presents an overview of climate change, its causes and consequences, national and international agreements and related trends. In the following chapter, we discuss how such impacts may affect the performance of several economic sectors, as well as social well being.

In chapter 3, we discuss the key instruments that the public and private sector have been developing to mitigate climate change effects, such as carbon pricing, changes in the energy mix and mobility systems.

Chapter 4 presents the impacts of climate change in the assessment of about 100 Brazilian listed companies, according to the abovementioned method, highlighting risks and opportunities for the private sector in Brazil.

Being aware of the challenges, assessing risks and identifying opportunities may represent an advantage for our businesses and enable new investment opportunities in the Brazilian context. Conclusions of this study are presented in chapter 5.

Summary

1. What is climate change?

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a significant change in average climate conditions for a long period (decades or more). The IPCC concluded that the Earth's internal processes, external forces or impacts of human activities on the atmosphere (such as increasing concentration of greenhouse gases) and land use can affect the climate [2].

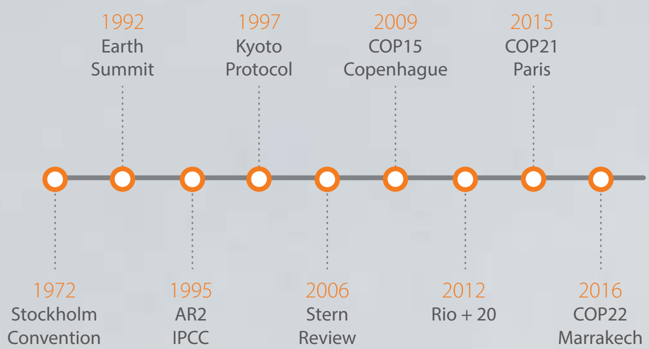
The main consequences of the phenomenon are the intensification of extreme weather events, change in rainfall patterns, average temperature, concentration of greenhouse gases in the atmosphere, agricultural yields, among others.

Human activities started to affect climate patterns after the Industrial Revolution, when sizeable emissions of greenhouse gases (GHG) started. The most relevant gas is carbon dioxide (CO2), which comes mostly from fossil fuel burning. Carbon dioxide or carbon dioxide equivalent is also the unity of measure for potential global warming of other greenhouse gases, such as methane and nitrous dioxide[1].

After realizing anthropogenic causes can drive climate change, concerns regarding human impacts on climate increased and the issue was broadly discussed in 1970's global forums.

The United Nations Framework Convention on Climate Change (UNFCCC) was opened for signature at the 1992 Earth Summit, in Rio de Janeiro. The UNFCCC objective is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Several heads of state attended to the conference and 175 countries ratified [4]. Such movements culminated in the IPCC Second Assessment Report (1995), which recognized the human influence on climate.

After the 1992 Earth Summit, several important events contributed to the discussions:



Every year, the UNFCCC Conference of Parties (CoP) debates the agreements for climate change mitigation and adaptation. The Kyoto Protocol, settled in 1996, was the first international agreement to determine goals to reduce greenhouse gases in developed countries. The protocol came into force in 2005, as an international legal instrument to reduce greenhouse gases emissions.

COP21, in Paris, 2015, was the last one making significant progress. The Paris Agreement determined strategies to keep the average global temperature from increasing more than 1.5ºC up to 2100, compared to pre-industrial levels. It also determined annual contributions to climate change mitigation and adaptation from developed countries to developing countries, to start from 2020 [5].

[1] Carbon dioxide equivalency determines the amount of CO2 that would have the same global warming potential in comparison to other greenhouse gases emissions, when measured over a specified timescale. The unity measure is metric tons of carbon dioxide equivalent per year (TonCO2eq/year).

2. Why should we be concerned?

2.1 Increased frequency of extreme weather events

One of the most relevant consequences of climate change is the increase in the frequency of extreme weather events, such as droughts, floods and severe winds, which could harm the economy, infrastructure and human health.

Globally, estimated economic losses caused by extreme weather events amounted to approximately US$ 3.08 trillion between 1996 and 2015, which represents about 0.3% of global GDP, and lead to about 528,000 direct deaths [6]. It is important to point out that developing countries, such as Brazil, are more exposed to extreme weather events, given their less resilient infrastructure and lower capacity on evacuation procedures and disaster relief.

In Brazil, extreme weather events amounted to R$ 355.6 billion in losses between 2002 and 2012. Those events also affected 33.9 million Brazilians and left 2.2 million homeless [8].

2.2 Losses in coastal areas

Approximately 60% of the world population lives in coastal areas or relies on it daily. In Brazil, that number is around 20%[2]. Coastal areas are more exposed to climate change due to sea level rise and the increased frequency of extreme weather events. Some of the major impacts are the following:

- Structural impact on ports and terminals
- Damage to coastal cities
- Damage to water and sanitation infrastructure
- Direct impact on aquifers and marine biodiversity

The Brazilian coastal area is defined as up to 50 kilometers from shore plus 12 nautical miles of sea. The geographical distribution of potential losses by micro region is presented in Table 1.

Table 1

Potential losses in coastal areas caused by climate change

Microregion	Total losses between 2010 and 2100 (R$ 000)	Annual losses / annual municipal GDP	Annual losses / annual municipal revenue
Rio de Janeiro	84,313,230	0.33%	10%
Salvador	21,204,710	0.45%	12%
Porto Alegre	16,891,740	0.31%	11%
Vitória	14,721,420	0.75%	27%
Santos	14,428,250	0.85%	17%
Recife	13,140,960	0.31%	11%
Fortaleza	12,134,450	0.25%	10%
Other microregions	30,655,240	-	-
Total	**207,490,240**	**-**	**-**

Source: Marcovitch (2011) and IBGE (2014). For calculations, municipal GDP and municipal revenue data from 2014 were used in current values. Annual municipal revenue comprehends the sum of all municipal taxes.

[2] The population that lives up to 50 kilometers from shore. Coastal area also includes 12 nautical miles of sea.

Climate change is defined as a significant change in average climate conditions for a long period.

It is clear that the cities of Rio de Janeiro and Salvador are more exposed to financial losses, in absolute terms, not only due to geographical conditions, but also because of the quality and development stage of infrastructure.

2.3 Increase on insurance premium

In 2011, the World Bank published Economics of Adaptation, a report that estimated the annual global economic loss in between US$ 77.6 billion and US$ 89.6 billion until 2050 due to climate change [11].

Table 2

Global extreme events: losses caused by sector

Sector	Dry scenario (US$ billion)	Wet scenario (US$ billion) [3]
Infrastructure	13.5	29.5
Coastal zones	29.6	30.1
Water supply and flood protection	19.2	13.7
Agriculture, forestry, fisheries	7.3	7.6
Human Health	1.6	2
Extreme weather events	6.5	6.7
Total	**77.7**	**89.6**

Source: Economics of Adaptation – World Bank (2011).

In many cases, insurers and reinsurers will bear climate change costs through reimbursement of insured losses, notably property, health and personal insurance. The cause of these physical damages are mainly natural disasters and spread of infectious diseases. In the automotive segment, claims rate caused by extreme weather events has reached 6%, as reported by a Brazilian lead insurer [12].

According to Verisk Analytics (2016), natural catastrophes caused US$ 50 billion in insured losses associated to property and personal insurances in 2016, 11% more than the average for the past 10 years [13]. Given the trend of increased frequency of extreme weather events caused by climate change, these costs are expected to rise over the next decades. Consequently, insurance companies may experience increased losses before adapting their premium to higher claims rates.

Initiatives such as Climate Wise and Principles for Sustainable Insurance seek to engage the insurance sector in adapting to climate change impacts.

3 The dry and wet scenarios were developed by CSIRO (Commonwealth Scientific and Industrial Research Organization) e NCAR (National Center for Atmospheric Research), respectively. They consist of models for global temperature and precipitation increase until 2050. The CSIRO (dry) scenario expects a 2% average increase in precipitations by 2050, while the NCAR (wet) scenario predicts an average increase of 10% per year.

2.4 Impacts on human health

In 2014, the World Health Organization (WHO) published a report estimating that climate change is already responsible for about 60,000 deaths annually due to natural disasters and 100,000 due to infectious diseases. Between 2030 and 2050, the death toll can rise up to 250,000 [14].

According to Hoberg and Brooks (2015), scientists from Nebraska-Lincoln University, climate change favours the spread of infectious diseases. In addition, hotter weather can increase the concentration of air pollutants, negatively affecting water quality and increasing the reproduction of disease vectors [15]. Climate change can also influence non-communicable conditions, such as respiratory and cardiovascular diseases.

Some policy options that aim to reduce population vulnerability and avoid a sharp increase in public health expenditure are: (i) supporting research and qualification on climate change impacts on human health; (ii) strengthening environmental sanitation initiatives; (iii) promotion of environmental education and communication; (iv) implementation of prevention and emergency plans, including warning systems; and (v) monitoring climate events and their impact on health.

2.5 Change in water cycle

Water cycle are directly associated with temperature variation and incidence of solar radiation. Therefore, climate change is able to make critical hydrological events such as droughts and flooding more frequent, along with influencing river flow.

The IPCC report suggests that the main changes expected to take place in the Brazilian water cycle are (i) increased aridness in central Northeast and Southern Amazon regions and (ii) rise in rainfall levels in the South region.

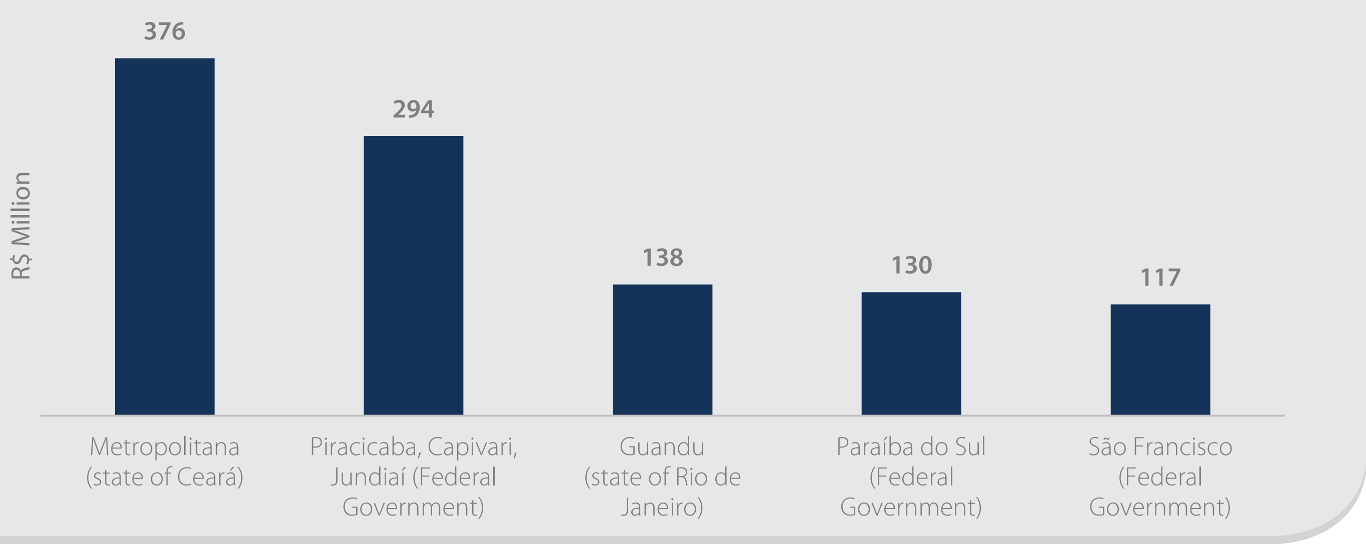
According to Brazilian National Water Agency (ANA), most studies [17, 18] regarding water flow projections in Brazilian river basins reached diverging results. However, all studies indicate the occurrence of changes in the fluid flow, although it is hard to pinpoint the rate and the magnitude of such impact.

Additionally, ANA clarifies that not only superficial water will be affected, but also groundwater and aquifer recharge. A 70% decrease in groundwater recharge is expected in the Northeast region until 2050, in comparison to the early 2000s [19].

Given the critical state of some river basins, it is possible to predict changes in water right grants for production activities: decline in water availability for multiple uses, creation of criteria to reduce water withdrawals and cancellation rules. Figure 1 presents the main Brazilian river basins that already implemented water-pricing schemes.

Figure 1

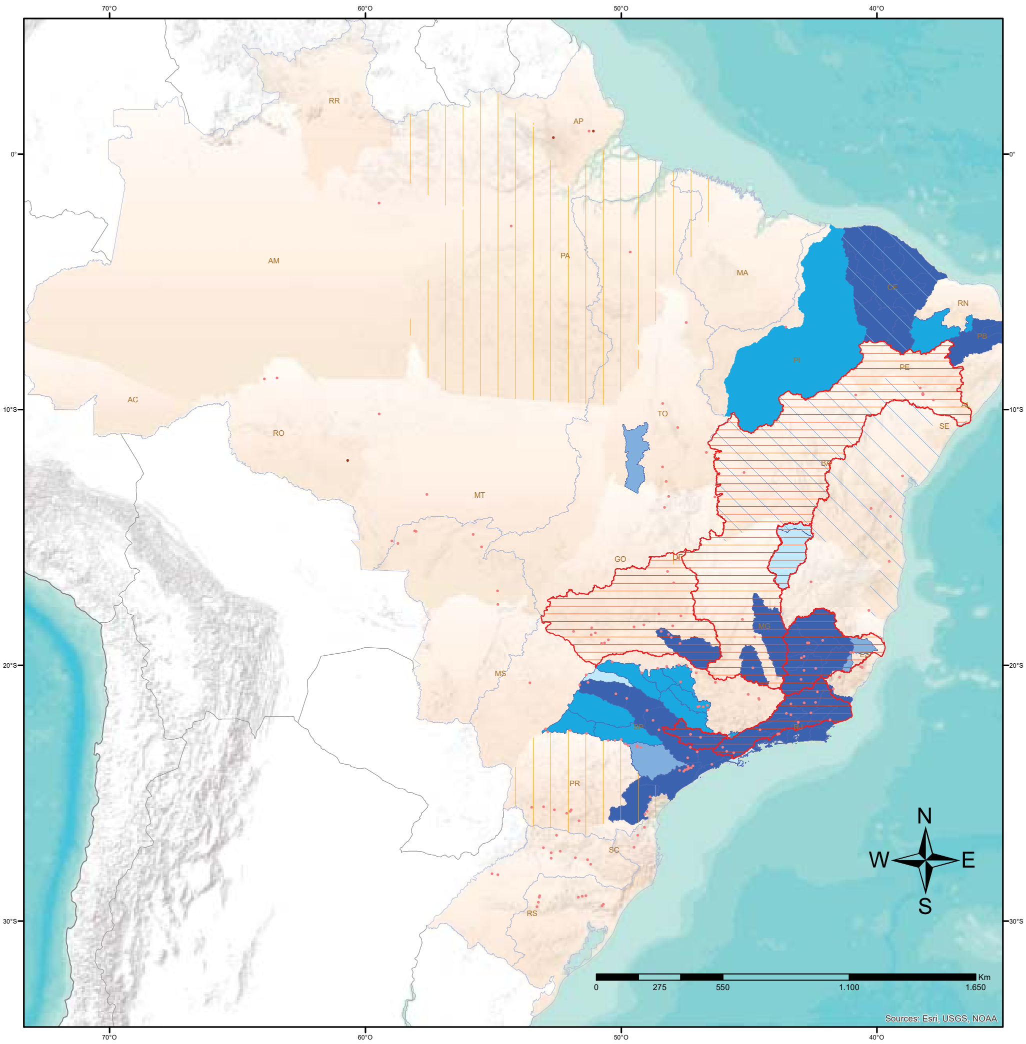
Water pricing in river basins – collection history



Source: National Water Agency - ANA (2016) [20].

Figure 2

Status of water pricing



Water pricing implemented

- Hydropower plants (Pricing implemented in law number 9,984/00)
- Interstate basin with implemented water pricing scheme
- State basin with implemented water pricing scheme

Water pricing in implementation

- Scheme approved by Governor
- Scheme approved by the State Council of Water Resources (CERH)
- Scheme proposed by the state River Basin Committee (CBH) for approval

Tariff for raw water supply

- Implemented in Bahia and Ceará states

Tariff for monitoring water resources use

- Implemented in the Federal District (DF), Pará and Paraná states

Territory

- River basin limits
- States

Updated on: 05/10/2017

Source: ANA (2017) [20].

Changes in rainfall patterns can affect the Brazilian power sector severely, especially hydro plants, which are responsible for almost 65% of annual power generation. Lucena (2010) projected a 75-year analysis for each Brazilian hydro plant's water flow between 2025-2100, based on IPCC scenarios (A2 and B2[4]). Predicted changes in average generation of the 20 main hydro plants below (Table 3) was based on said report [21].

[4] IPCC developed multiple climate change scenarios, which are grouped within families based on similarities of their assumptions. Scenario family A2 consists of a world with independent nations, solid demographic growth and robust economic development with a regional focus. B2 scenarios are based on a more environmentally sustainable world; with continuous demographic increase (at a lower rate than in A2); regional initiatives focused on economic, social and environmental stability; intermediary economic development and less accelerated technological changes [41].

Table 3

Change in average generation in major hydropower plants

#	Power Plant	River Basin	Average annual generation in GWh (historic figures)	Change in average annual generation in A2 scenario (GWh)	Change in average annual generation in A2 scenario (%)	Change in average annual generation in B2 scenario (GWh)	Change in average annual generation in B2 scenario (%)
1	Belo Monte	Amazônica	39,500	-5,369	▼ 13.6%	-3,416	▼ 8.6%
2	Itaipu	Paraná	36,603	11,760	▲ 32.1%	10,119	▲ 27.6%
3	Tucuruí	Tocantins Araguaia	14,665	-4,980	▼ 34.0%	-3,873	▼ 26.4%
4	Tucuruí II	Tocantins Araguaia	14,665	-4,839	▼ 33.0%	-3,764	▼ 25.7%
5	Ilha Solteira	Paraná	15,004	5,786	▲ 38.6%	4,979	▲ 33.2%
6	Xingó	São Francisco	14,689	-6,182	▼ 42.1%	-7,144	▼ 48.6%
7	Jirau	Amazônica	7,081	-1,506	▼ 21.3%	-958	▼ 13.5%
8	Santo Antônio	Amazônica	7,283	-1,367	▼ 18.8%	-870	▼ 11.9%
9	P. Afonso	São Francisco	9,812	-4,815	▼ 49.1%	-5,563	▼ 56.7%
10	Itumbiara	Paraná	6,864	3,498	▲ 51.0%	3,010	▲ 43.9%
11	Teles Pires	Amazônica	4,357	-870	▼ 20.0%	-554	▼ 12.7%
12	São Simão	Paraná	10,626	2,873	▲ 27.0%	2,472	▲ 23.3%
13	Foz do Areia	Paraná	5,903	2,816	▲ 47.7%	2,423	▲ 41.0%
14	Jupiã	Paraná	8,698	2,606	▲ 30.0%	2,242	▲ 25.8%
15	Porto Primavera	Paraná	8,436	2,587	▲ 30.7%	2,226	▲ 26.4%
16	Maribondo	Paraná	6,274	2,500	▲ 39.8%	2,151	▲ 34.3%
17	Itaparica	São Francisco	6,660	-2,893	▼ 43.4%	-3,343	▼ 50.2%
18	Itá	Uruguai	6,747	227	▲ 3.4%	510	▲ 7.6%
19	S. Santiago	Paraná	7,194	2,386	▲ 33.2%	2,053	▲ 28.5%
20	P. Afonso 1, 2 e 3	São Francisco	3,632	-2,775	▼ 76.4%	-3,207	▼ 88.3%
	Total		**234,693**	**1,442**	▲ **0.61%**	**-508**	▼ **0.21%**

Source: Elaborated based on Lucena, 2010 and ONS, 2016.

Changes in average power generation was calculated applying the estimated changes in average generation in each river basin to its respective hydro plants.

Given increasing public pressure against hydro plants with large dams, declines in average energy generation could be worse than predicted (Lucena, 2010). With reduced capacity to store energy in hydropower reservoirs, the increase in power generation of plants located at Paraná and Uruguay basin is less likely to compensate for the decrease of power generation of plants in São Francisco, Amazonian and Tocantins Araguaia basins.

The decline in average power generation in the Northeast region, even though partially compensated by the increase at Atlântico Sul and Paraná basins, will demand greater use of transmission lines, which could increase power losses and require further investments.

Changes in rainfall patterns and river flows should also affect energy policy, increasing the need for alternative energy sources.

[5] The energy amount that a hydroelectric plant is able to store is proportional to its reservoir area. There has been a growing public pressure for smaller reservoirs due to environmental impacts. However, with less stored energy, hydro plants are more exposed in drought periods, which could affect energy security.

2.6 Change in agroforestry yields and distribution

Extreme weather events are likely to have significant impact on agriculture. Studies estimate around R$ 7.4 billion in annual losses in grain production due to climate change from 2020, and up to R$ 14 billion from 2070 (Pinto and Assad, 2008).

Table 4

Potential agricultural production in Brazil per crop until 2050

Crop	Potential area in 2016 (km^2)	Potential area in 2020 (km^2)	Potential area in 2050 (km^2)	Variation in potential area 2016-2050 (%)
Cotton	4,029,507	3,583,461	3,449,349	▼ 14.4%
Rice	4,168,806	3,764,488	3,655,029	▼ 12.3%
Coffee	395,976	358,446	328,071	▼ 17.1%
Sugar cane	619,422	1,608,994	1,477,816	▲ 139%
Bean	4,137,837	3,957,481	3,715,178	▼ 10.2%
Sunflower	4,440,650	3,811,838	3,709,223	▼ 16.5%
Cassava	5,169,601	5,006,777	5,866,398	▲ 13.5%
Corn	4,381,791	3,856,839	3,716,684	▼ 15.2%
Soy	2,790,265	2,132,001	1,837,447	▼ 34.1%

Source: Pinto and Assad, 2008. Potential area in 2016 estimation was based on Pinto e Assad [22] projections.

Sugarcane is the most benefited crop under future conditions, with an expected increase of 139% in production area until 2050. Simultaneously, the greatest negative impact will be on soy and cotton crops, with a potential loss of 34.1% and 14.4% in production area, respectively [22].

Crop distribution will also be affected, as farming migrates in search of better weather conditions, including:

- Decline in coffee production in the Southeast region
- Better conditions in the South region for coffee and sugarcane production, given the decrease in frost incidence
- Decline in soy potential production in the South region
- Potential production area for sugarcane may double in the next decades

Some studies indicate that climate change and the carbon dioxide concentration increase in the atmosphere may favour productivity in the forestry sector and, consequently, pulp and paper production.

However, the Brazilian Agricultural Research Corporation (Embrapa) understands that, after a certain saturation point, the concentration of carbon dioxide in the atmosphere would have negative effects in the forestry sector [35].

In order to mitigate such risks, companies in the pulp and paper sector have been investing in genetic improvement, monitoring climate patterns and changes in land use [36].

3. Tackling Climate Change

Given the scientific consensus regarding the anthropogenic causes of climate change, as well as its negative impacts on the economy and society, the international community, including National States, Supranational organizations, companies and civil society, has been acting to mitigate the phenomenon and become more resilient to its effects. The following subsections describe the main initiatives in this direction.

3.1 Putting a Price on Carbon

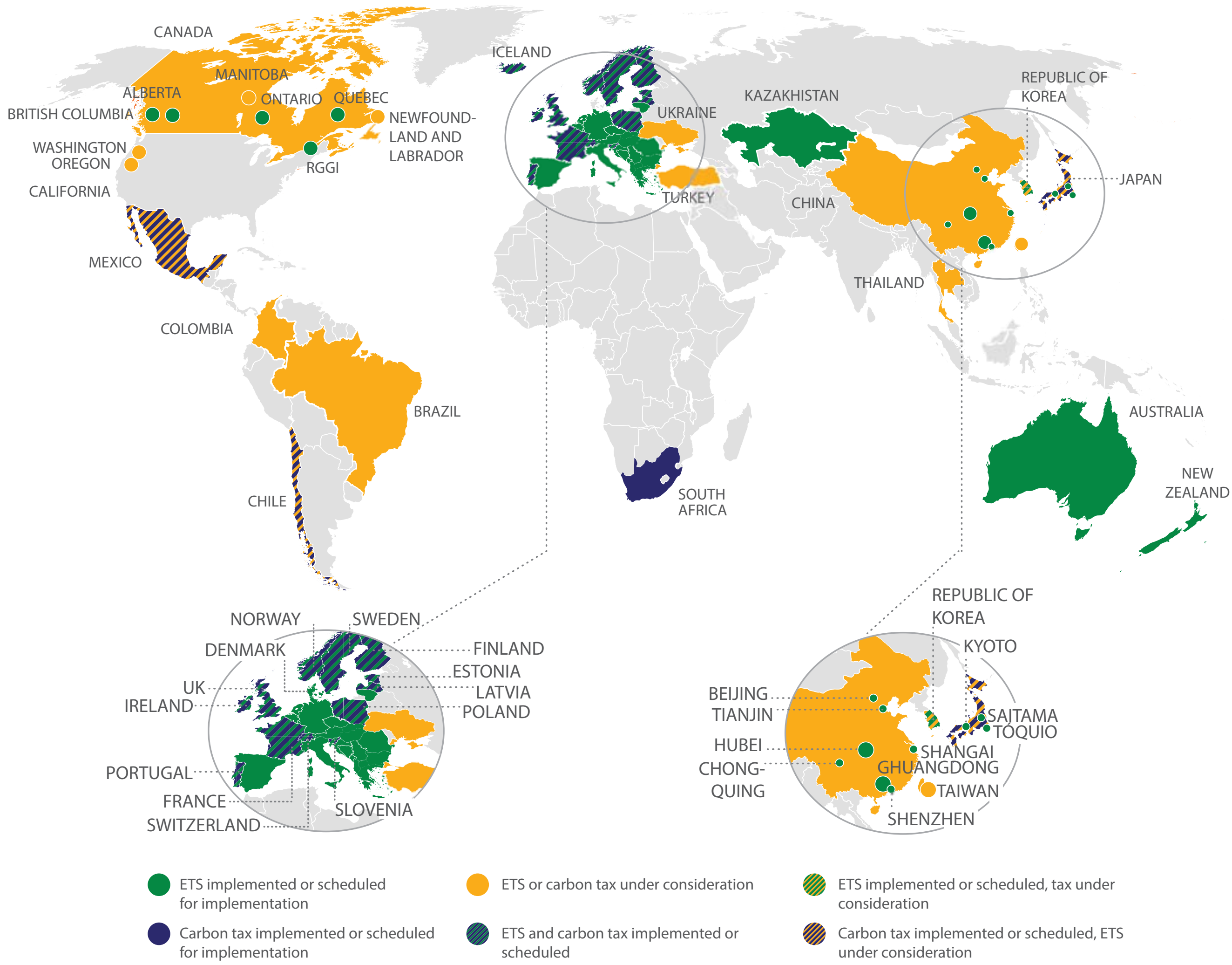
Carbon dioxide (CO2) is among the most important greenhouse gases and is used as unit of measurement in all discussions related to climate change.

Currently, two different mechanisms are used for carbon pricing. A carbon tax is a tax levied on carbon equivalent emissions. Such mechanism can be segregated by sector (e.g.: tax on CO2 emissions from thermal power plants) or volume (e.g.: tax on CO2 emissions from power plants above 200MW).

On the other hand, carbon markets or emissions trading schemes (ETS) assume that market-based mechanisms can overcome transaction costs and other flaws in carbon tax regulation. Carbon markets demand a regulatory authority to determine GHG emission limits for each agent. If an agent emits below its limit, it can trade the surplus with other agents.

Besides carbon taxes and carbon markets, a hybrid mechanism can also be established. Several initiatives for carbon pricing have been created over the last decades and are likely to expand in the future, according to Figure 3.

Figure 3 - **Current carbon pricing initiatives (tax and ETS)**



Source: World Bank (2016). ETS = Emissions Trading Scheme

According to the IPCC, carbon pricing is the most effective strategy to mitigate climate change. The International Monetary Fund (IMF) also supports the initiative, as it aims to stimulate a low-carbon economy, based on renewable energy and clean technologies [24].

Carbon pricing will also have an increasing importance to keep the global temperature rise below 2 degrees Celsius this century. More than 100 Parties, which correspond to about 58% of global GHG emissions, have already implemented or are considering the implementation of carbon-pricing mechanisms in the following years [25].

Carbon pricing mechanisms already affect several companies. The leading companies in mandatory carbon offset contributions are Exxon Mobil (USA), Origin Energy (Australia), Eni SpA (Italy), Iberdrola (Spain) and Endesa (Chile) [37]. Other companies offset their emissions voluntarily in order to improve their reputation and to be ready for future obligations. For example, Disney invested about US$ 48 million in carbon compensation between 2009 and 2014 and General Motors invested approximately US$ 40 million in the same period.

Carbon tax and emission trade schemes are usually implemented in specific sectors, especially the most carbon intensive ones such as energy, transport and heavy industry, as portrayed in table 5 [25].

Table 5

Carbon pricing initiatives implemented or scheduled for implementation, with sectoral coverage and percentage of GHG emissions covered

Country/Jurisdiction	Pricing mechanism	Covered sectors	% of GHG emissions covered
Alberta (CAN)	ETS + Tax	Industry, Energy, All fossil fuels (tax only)	90%
British Columbia (CAN)	Tax	All fossil fuels (tax only)	70%
Ontario (CAN)	ETS	Industry, Energy, Transport, Buildings	82%
Quebec (CAN)	ETS	Industry, Energy, Transport, Buildings	85%
RGGI[6] (USA)	ETS	Energy	21%
California (USA)	ETS	Industry, Energy, Transport	85%
Mexico	Tax	Solid fossil fuels, Liquid fossil fuels	46%
Chile	Tax	All fossil fuels (tax only)	42%
European Union	ETS + Tax	Industry, Energy, Aviation, All fossil fuels (tax only)	52%
Switzerland	ETS + Tax	Industry, Energy, Buildings	34%
Kazakhstan	ETS	Industry, Energy, Transport, Agriculture	50%
Beijing	ETS	Industry, Energy, Transport, Buildings	40%
Shanghai (CHI)	ETS	Industry, Transport, Aviation, Buildings, Shipping	57%
Tianjin (CHI)	ETS	Industry, Energy, Buildings	60%
Chongquing (CHI)	ETS	Industry, Energy	40%
Hubei (CHI)	ETS	Industry, Energy	35%
Guangdong (CHI)	ETS	Industry, Energy, Aviation	55%
Shenzhen (CHI)	ETS	Industry, Energy, Buildings	40%
South Korea	ETS	Industry, Energy, Aviation, Buildings, Waste	68%
Japan	Tax	All fossil fuels (tax only)	66%
Australia	ETS	Industry, Energy	50%
New Zealand	ETS	Industry, Transport, Waste, Forestry	52%
South Africa	Tax	All fossil fuels (tax only)	80%

- Industry
- Energy
- Transport
- Aviation
- Buildings
- Waste
- Forestry
- Agriculture
- All fossil fuels (tax only)
- Solid fossil fuels
- Liquid fossil fuels
- Shipping

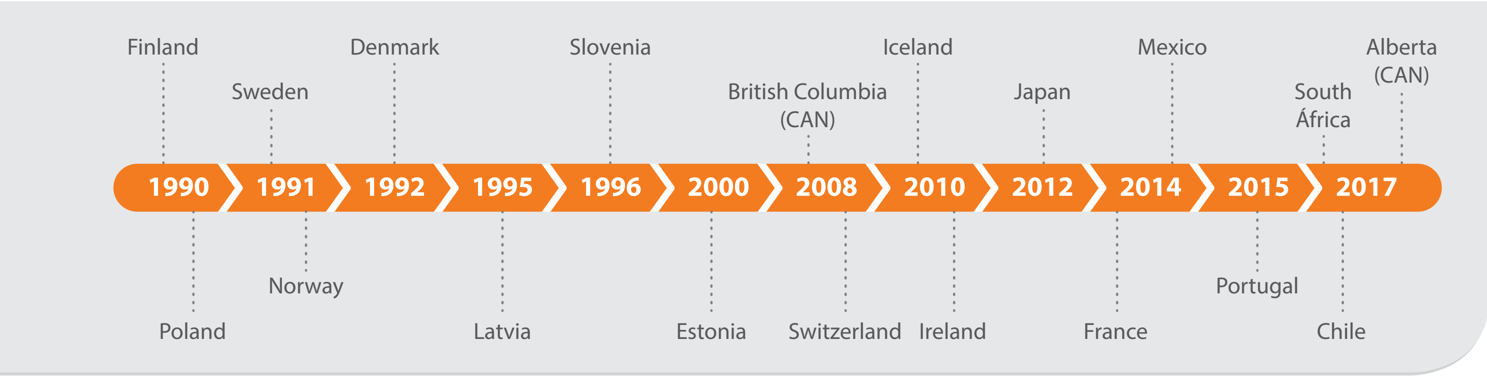
Source: World Bank (2016). ETS = Emission Trade System [25].

The following sections discuss the main mechanisms for carbon pricing, as well as its pros and cons.

[6] Note: RGGI or Regional Greenhouse Gas Initiative is a mandatory market based program in the United States to reduce greenhouse gas emissions. RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New York, Rhode Island and Vermont.

3.1.1 Carbon tax

Carbon tax is a fee imposed by the government in order to limit greenhouse gas emissions to a maximum level. If set high enough, carbon tax is able to create economic incentives to investment and production. Carbon tax can also represent a new competition factor, given that emissions will cost more. The timeline of carbon tax initiatives is presented below:



Source: World Bank (2016). ETS = Emission Trade Scheme [25]

A fiscal authority is usually responsible for setting a carbon tax, defined in tons of carbon equivalent (tCO2q). The tax level can present considerable variation among countries. In August 2016, the carbon tax in Sweden, Switzerland and Finland was, respectively, US$131, US$86 and US$65 per tCO2eq[7]. On the other hand, carbon tax in Mexico and Poland was below US$1/tCO2eq [25].

Brazil has not yet defined a start date for the implementation of a national carbon tax. However, according to the Nationally Determined Contribution (NDC) that was signed by the Brazilian Government in 2015 and ratified by the Brazilian Parliament in 2016, the country will reduce its GHG emissions in 37% and 43% up to 2025 and 2030, respectively, compared to 2005 levels.

Based on these efforts, Instituto Escolhas (2016) evaluated two scenarios for carbon pricing in Brazil: 1) The application of a tax on emissions arising from the burning of fossil fuels with two different tax rates, US$ 10/tCO2eq and US$50/tCO2eq. 2) The application of a tax on emissions arising from the burning of fossil fuels in which the increase in tax revenue would neutralize the drop due to the simplification of the PIS/COFINS tax [26]. The results of this study are presented below.

	without simplifications of the PIS/COFINS		**with** simplifications of thePIS/COFINS
Impact	Carbon tax of **US$ 10**/tCO2eq	Carbon tax of **US$ 50**/tCO2eq	Carbon tax of **US$ 36**/tCO2eq
GDP	▼ 0.19%	▼ 0.94%	▲ 0.47%
Wages level	▼ 0.16%	▼ 0.79%	▲ 0.41%
Employment rate	▼ 0.21%	▼ 1.03%	▲ 0.53%

Source: Instituto Escolhas, 2015 [26].

The aforementioned study aimed to demonstrate the possibility of implementing a carbon tax without harming the economy. That said, it is important to highlight that the positive impacts on the GDP is a consequence of the correction of tax distortions.

One of the main arguments against carbon pricing is the expected loss of competitiveness of countries that adopt such initiatives. In 2015, the World Bank developed a study confirming that the adverse impacts really occur, especially the carbon leakage, in which companies move their productive unities to countries that have not implemented carbon pricing mechanisms yet [27]. This impact is more relevant for commodities, since price competition is more frequent. Still, empirical evidence point out that carbon pricing initiatives stimulates technological innovation.

The concept of "climate sanctions" is growing stronger among political authorities and policy analysts. These sanctions are import tariffs against countries that do not have initiatives to reduce greenhouse gas emissions, such as carbon pricing. The initiative aims to avoid loss of competitiveness in countries that already have carbon pricing in place, avoiding the carbon leakage effect [38].

[7] Metric tons of carbon dioxide is the unity measure for greenhouse gases in the atmosphere.

3.1.2 Market-based mechanisms

The most widespread market based mechanism for carbon pricing is Cap-and-Trade. In contrast to command-and-control mechanisms, Cap-and-Trade needs a central authority to allocate or sell a limited number of permits to emit specific quantities of GHG per time. Agents are allowed to trade their permits according to their GHG emissions, so companies can choose between purchasing carbon credits (permits) and making investments to reduce its GHG emissions.

Cap-and-Trade is considered one of the most efficient mechanisms to reduce carbon emissions, since it can stimulate new business opportunities, trigger technological innovation and reduce emissions where they are cheaper.

According to the World Bank (2015), 39 countries have already implemented emissions trading schemes or taxes. From 188 national strategies to reduce GHG emissions, 90 mentioned the establishment of market based mechanisms. The International Emissions Trading Association (IETA) estimated that by 2020 Canada will have its own emissions market, while Australia, Brazil, Chile, Japan, Mexico and South Africa should start after 2025.

Prices in carbon trading systems tend to be lower than carbon taxes, usually between US$5/tCO2eq (European Union) and US$15/TCO2eq (South Korea). These prices are expected to rise in the future in order to meet carbon reduction goals committed in COP-21.

The Paris Agreement (2015) recommends that different countries must cooperate to implement a common carbon market, where agents can trade emission allowances, such as the European Union Emission Trade System (EU ETS). This initiative would ensure that emissions are reduced where they are cheaper. According to the World Bank, an international carbon market would reduce sharply the costs for countries to meet their carbon goals: US$ 115 billion (32%) per year by 2030 and US$ 3.9 trillion (54%) by 2050 [25].

The main barriers to create a global carbon market are the following:

- Uncertainty about the future: Net providers of emission reductions may be unwilling to do so if they remain unconvinced of their capacity to meet domestic targets. Buyers will also need assurance that there will be adequate supply of emission allowances.
- Lack of environmental integrity: In a cooperative system, it is difficult to guarantee that one jurisdiction will effectively meet its agreed reduction. That usually depends on the level of environmental compliance and monitoring capacity.
- Local impacts: In an international market, carbon abatement takes place where it is cheaper. Therefore, some jurisdictions can avoid reducing its emissions by purchasing carbon credits. This dynamic can increase local pollution levels, lack of low-carbon innovation and negatively affect energy security.
- Floating price: Carbon price can vary among countries due to market fluctuation. Such oscillations make it difficult to predict costs and to meet emission targets.

The Ministry of Finance of Brazil, supported by the World Bank Group's Partnership for Market Readiness, developed a study aiming to implement a carbon-trading scheme in Brazil. The project has been in extensive consultation with civil society. Several agents in Brazil support carbon markets, since Brazil's tax load is already high.

In the said study, the authors simulated the impact of distributing trading allowances (carbon credits) for selected sectors in Brazil, representing 15% of reductions of emissions until 2030, compared to business as usual. The carbon price, calculated endogenously, was US$71.29/TonCO2eq. In this scenario, the impact on the GDP was -1.37%, caused by consumption reduction due to inflationary impacts of carbon pricing. As mentioned earlier, the correction of tax distortions (PIS/COFINS) can mitigate this negative impact [28].

3.2 Changes in the energy mix

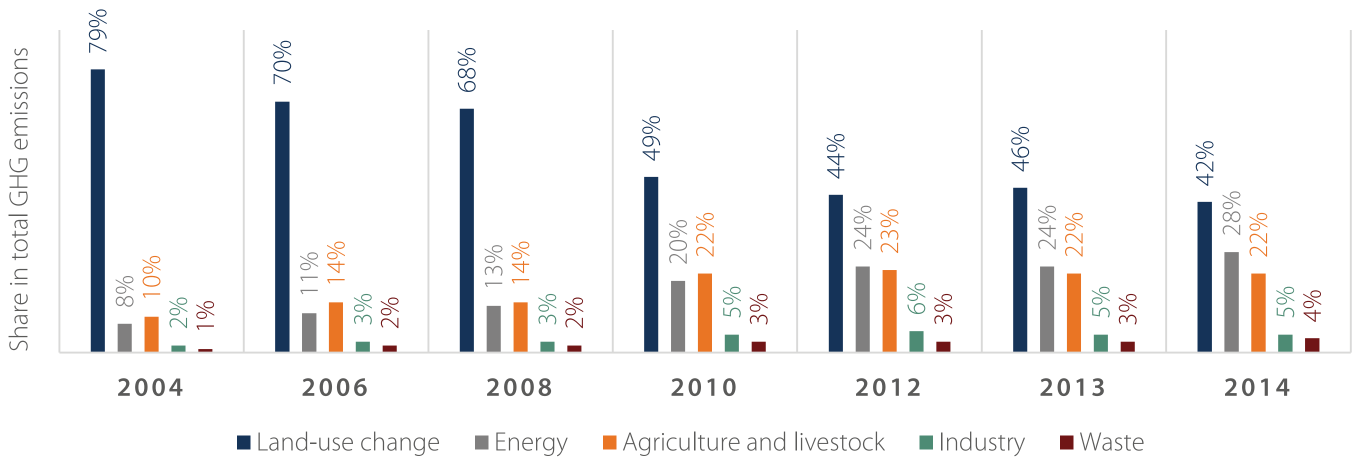
The energy sector is responsible for more than two thirds of global anthropogenic GHG emissions. The sector emits both directly, through fossil fuel burning for power generation or fuel extraction, refining and processing, and indirectly, mainly through fossil fuel burning for transport and industrial activities.

The energy sector (including electric energy) is the second main cause of Brazilian GHG emissions, just behind land-use change, representing 28% of total emissions in 2014 [29]. That percentage has been growing recently, which indicates that Brazil is in the opposite direction of decarbonisation of the power sector than the rest of the world.

Simultaneously, the decline in deforestation in the last decade has been contributing to the decrease in land-use change emissions. That decline is a result of various initiatives, such as the Action Plan for Prevention and Control of the Legal Amazon Deforestation (PPCDAm), implementation of satellite monitoring systems (SAD, DETER), establishment of protected areas, identification of municipalities with critical deforestation rates, adoption of a voluntary moratoria by soy and beef industries, among others [39].

Figure 4

Main sources of GHG emission in Brazil (2004 – 2014)

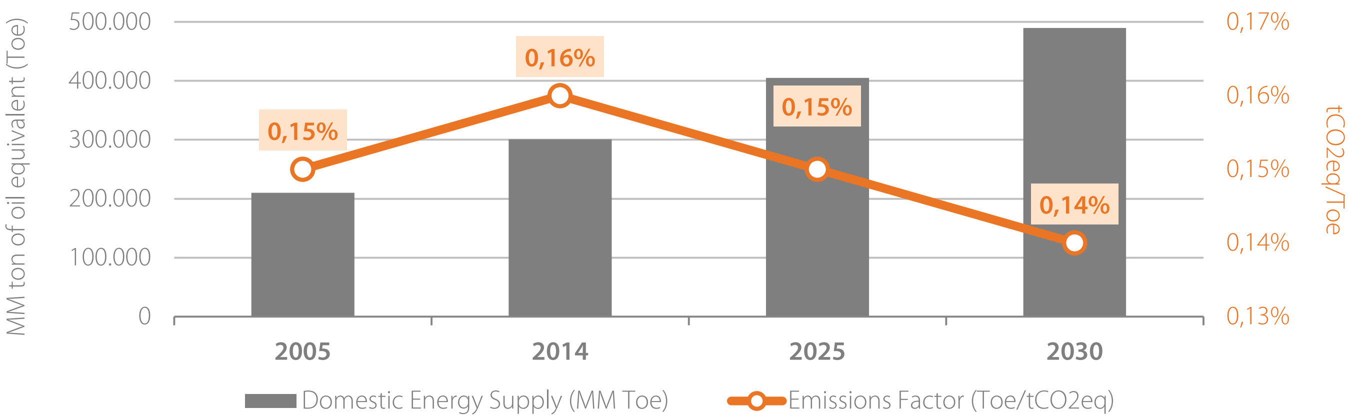


Source: EPE, 2016 [30].

Unlike other countries, the main challenge for Brazil is to sustain the share of renewable sources in the energy mix amid a growing demand for power in the following years. In order to achieve that, on-site generation should have a key role, notably biomass and distributed solar energy generation. Figure 5 shows a projection for total energy production until 2030, along with its associated GHG emissions [30].

Figure 5

Projections for energy supply and CO2 emission factors (2005 – 2030)



Source: EPE, 2016 [30].

3.3 Smart mobility

The transport sector is the main responsible agent for burning fossil fuel in Brazil [26]. In 2014, the sector represented around 14% of total GHG emissions in the country, with half emitted by cargo transport and the other half by passenger transport.

Even though many countries are already moving from individual to mass transport, Brazil and other emerging countries still face some challenges to achieve that, such as: 1) need for significant improvement of public transportation systems; 2) promote road paving and other road improvements; 3) increase investments in rail transport; 4) reduction of traffic congestion and improvement of quality and safety conditions for users [31].

On the other hand, there is an eminent opportunity to reduce emissions in cargo transportation through the expansion of rail and waterways. Railways are responsible for 20.7% of total transported cargo in Brazil and represent 3% (3.3 MtCO2eq) of emissions in the cargo transportation sector. In addition, 61.1% of total cargo was transported by heavy vehicles, which are responsible for around 80.4% of emissions in the cargo transport sector [10].

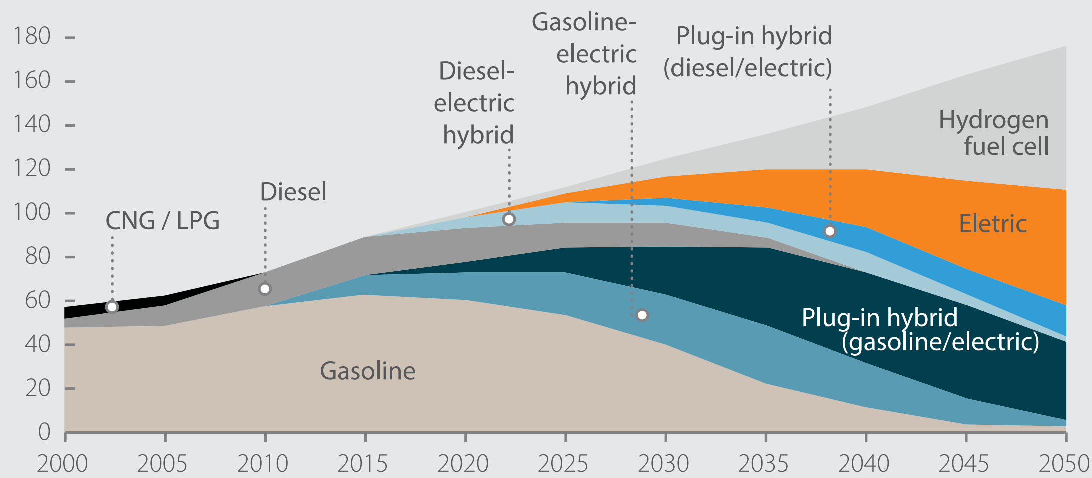
A transition to a greater use of public transport is necessary to increase the efficiency of urban mobility and decrease the total carbon emissions in the transport sector. Even though heavy vehicles only make for a small part of the national fleet (around 4%), they represent half of the sector's GHG emissions. Initiatives such as training drivers on efficient driving, energy efficiency improvement and fleet renewal could result in a significant decline of total emissions from heavy vehicles.

The decarbonisation of the transport sector is also highly dependent on the increasing of the electric fleet. Hybrid and electric vehicles still represent a small share of the fleet in emerging markets, but are expected to grow as battery prices lower and fossil fuel prices increase. An inflexion of hybrid and electric fleet is expected between 2025 and 2030, as portrayed in Figure 6.

Brazil has an **eminent opportunity to decrease emissions** in the cargo transport sector through the expansion of rail and waterways.

Figure 6

Evolution of light vehicle sales per fuel type between 2000 and 2050 (in millions of vehicles)



Source: United Nations, 2016 [31].

According to the UN (2016), a shift towards more efficient mobility does not require an increase in investments, but rather a redistribution within the sector. Estimated annual cost for financing a transition to sustainable mobility is around US$ 2 trillion per year, against US$ 1.4 – 2.1 trillion of current annual investments in the transport sector.

As stated in Baran (2012), electric and hybrid vehicles should represent a third of the Brazilian light fleet by 2031, resulting in a 28% decline in energy consumption in this segment [32]. In addition, a transition to a fully electric fleet could promote a better management of electric power demand, due to the use of batteries to store energy [32].

The introduction of electric vehicles still depends on greater coordination among the government, industry and electric utilities. The government should employ tax incentives and stricter environmental requirements for vehicles, in order to decrease the relative cost of less pollutant vehicles. The industry should strengthen research aimed at lowering production costs and take advantage of new business models such as car sharing, funding programs, among others. Electric utilities have an important role in developing supply infrastructure and planning for electric vehicle charging.

The Brazilian NDC indicates urban planning as an important tool to reduce emissions from transport. Despite the importance given to urban mobility, the document recognizes that Brazil still lacks integrated public policies and further research in the sector [33].

4. Risks and Opportunities for the Brazilian productive sector

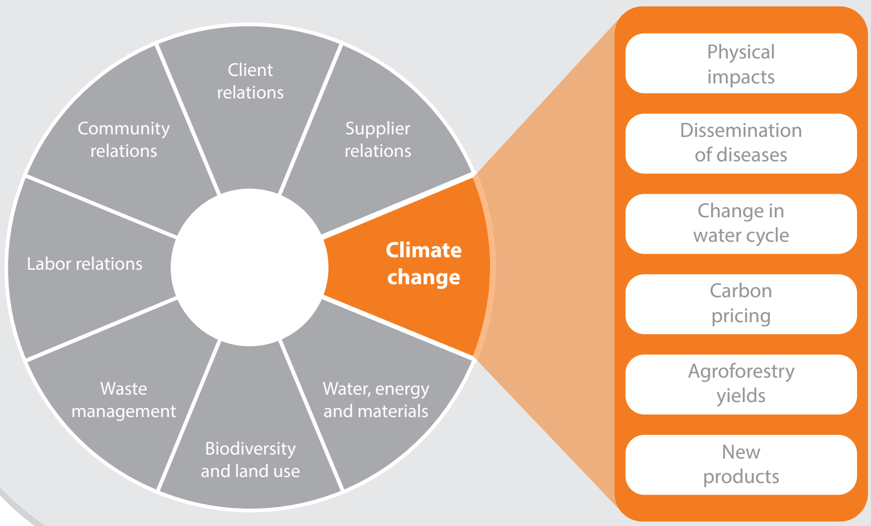
The previous chapters demonstrated how climate change may affect society and social wellbeing. This chapter will focus on the assessment of risks and opportunities of climate change in the productive sector, through an aggregate and sectoral perspective, highlighting impacts on Brazilian listed companies.

Since 2010, IAM applies a proprietary method to integrate Environmental, Social and Governance (ESG) issues into equity valuation, including eight dimensions: "Labor relations", "Community relations", "Client relations", "Supplier relations", "Water, energy and materials", "Biodiversity and land use", "Waste management" and "Climate Change". The results presented below focus on the theme Climate Change.

Our method incorporates social and environmental variables into the fundamental equity valuation model, by analyzing these impacts on cash flow over the time. This process is divided in two main stages: (i) research and sectoral scenario building followed by (2) impact valuation, in which we evaluate how these scenarios will produce impacts that will affect companies' value, considering their specificities and the quality of management. These impacts can take place in different ways, according to the figure 7.

Figure 7

Socio-environmental themes and types of climate change impacts



Source: Itaú Asset Management, 2017.

4.1 Research and construction of sectoral scenarios

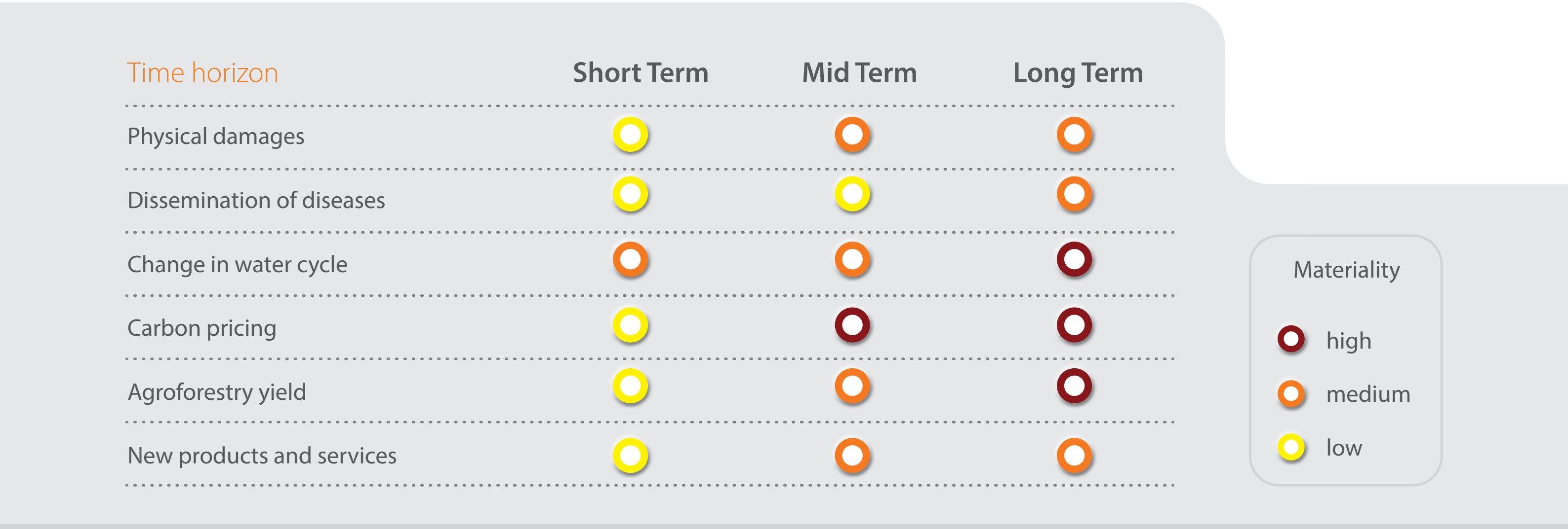
Our method develops rationales and scenarios for different issues related to climate change.

a.	**Physical damages**	Damages caused by extreme weather events on companies' assets, including interruptions in activities. The most vulnerable sectors are those intensive in fixed assets, such as the industrial sector, energy sector, toll roads and sanitation. Physical damages derived from extreme weather events are already observable, but still not relevant to companies' cash flows. Most climate models estimate the deepening of these phenomena over the next decade (a mid-term to long term risk).
b.	**Dissemination of diseases**	An increasing number of cardiovascular and respiratory diseases will impact the health sector. A higher health insurance claim ratio and demand for health services shall take place in the mid-term and long term.
c.	**Change in water cycle**	Changes in rainfall patterns will affect water availability for several sectors, which may increase costs or even interrupt activities. Water-intensive sectors, as well as power and sanitation utilities have already been impacted by this trend, which makes this risk already material in the short term.
d.	**Carbon pricing**	Carbon pricing initiatives are more likely to impact carbon-intensive sectors, such as oil and gas, heavy industry or thermal power utilities. On the other hand, sectors that reduce the amount of GHG in the atmosphere, such as forestry and renewable energy may generate revenue by selling carbon credit or allowances. Brazil still does not have a starting date to establish carbon pricing mechanisms. However, given the evolution of the theme in other countries and emissions reduction targets committed by Brazil, carbon pricing is expected to become a material risk in the mid-term.
e.	**Agroforestry yield and cost of inputs**	The increasing number of extreme weather events, change in rainfall patterns and loss of ecosystem services shall affect agricultural yield in the next decades. Geographical distribution of crops may also change, as mentioned in previous chapters. This trend will demand adaptation investments and may increase cost of inputs for several sectors. The forestry sector, on the other hand may benefit from genetic improvements and land use changes [23]. According to our analysis, climate change impacts on agroforestry sector tends to be more material in the mid-term and long term.
f.	**New products and changes in consumption pattern**	Climate change will also affect consumption pattern and demand new kinds of products and services. The potential beneficiaries are equipment suppliers for energy efficiency and renewable energy industry, as well as some retailers. The financial sector can also increase its revenue by creating products that support the transition to a low carbon economy, since it is a crucial player for this transition. An increasing demand for new products and services aligned to a transition to a low carbon economy is already occurring. This trend is expected to grow stronger in the mid-term, generating new business opportunities to the abovementioned agents.

The time horizon of these issues is shown in figure 8 below.

Figure 8

Climate Change Value Drivers, by time horizon and materiality



Source: Itaú Asset Management, 2017.

We defined these value drivers based on recurrence and impacts on several sectors in the economy. Clearly, the impact may vary according to the sector, time horizon, region and quality of management of each company.

4.2 Company valuation

In this stage, we identify types of risks and opportunities that may affect the company, derive quantitative metrics for each relevant impact and understand time horizons where these events could materialize, increasing or decreasing a company's cash flow. This step is important to make sure that our scenarios do not disproportionately penalize companies that have been adapting to climate change effects[8].

We estimate cash flows over time and adjust to present value according to the Weighted Average Cost of Capital (WACC) of the company. Finally, we attribute a probability to each estimated event based on technical reports, recurrence of events, specialists' opinion and consultation with companies.

The aforementioned method was applied to about 100 Brazilian listed companies across 10 sectors according to the Global Industry Classification Standard (GICS). The companies covered in this analysis composed, in December 2016, the Corporate Sustainability Index (ISE), Brazil 100 Index (IBX-100) or Ibovespa Index, from B3[9].

[8] For example, we can assume that a future legislation that put a price on carbon will affect adversely thermal power utilities. However, if some utility have a carbon capture and storage initiative, the impact tend to be less relevant.

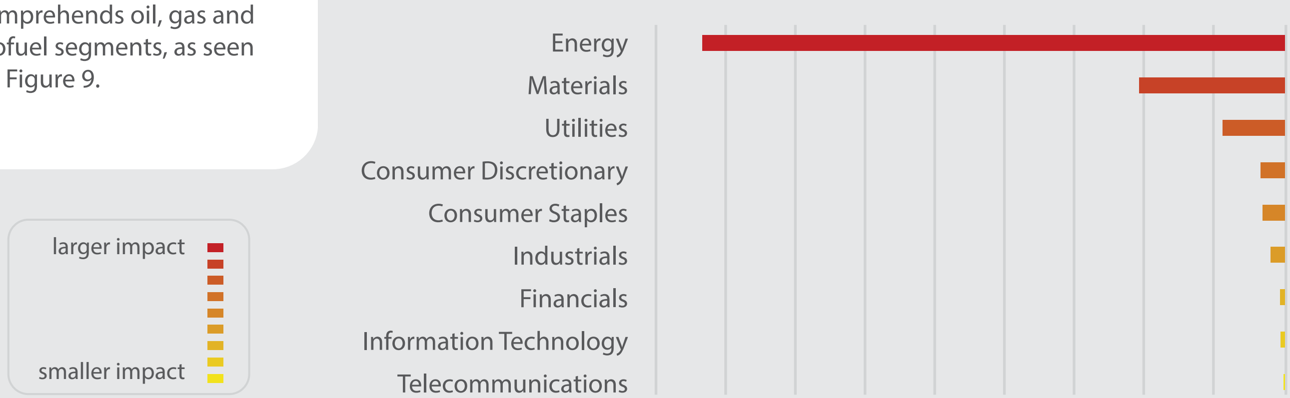
[9] The IBX-100 and Ibovespa are indices composed by a theoretical portfolio with the most actively traded and best representative stocks of the Brazilian stock market. The ISE is an index composed by a portfolio of companies committed to corporate sustainability and social responsibility.

4.3 Key Findings

4.3.1 Climate change risks

The most impacted sector shall be Energy, which comprehends oil, gas and biofuel segments, as seen on Figure 9.

Figure 9 - **Climate change relative impact on the market value of companies per sector**



Source: Itaú Asset Management. This analysis does not take into consideration the positive impacts of climate change.

In the oil and gas industry, part of the energy sector, the main negative impacts should be an increase in production costs and a decrease in revenues, as future demand is expected to decrease due to carbon pricing schemes.

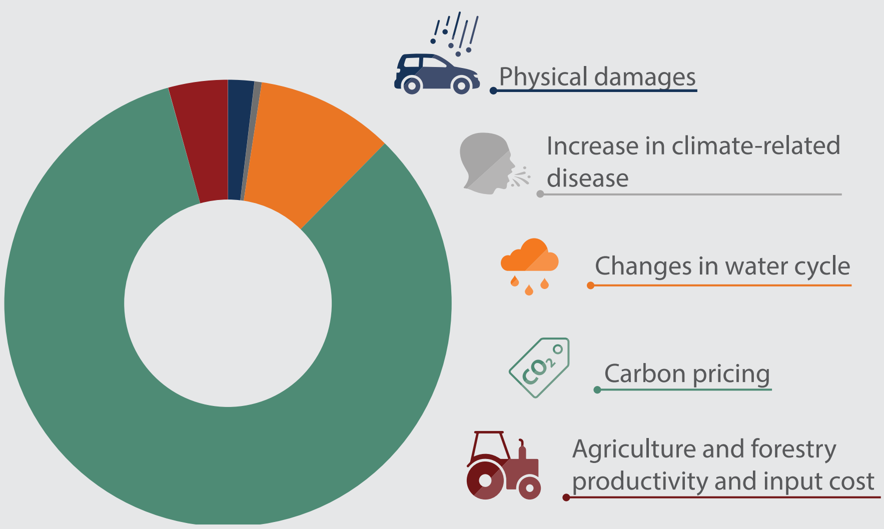
The second most impacted sector is materials, especially due to an increase in costs caused by water stress in mining and iron and steel industries. Another important risk in this sector is the increased costs due to carbon pricing for direct emissions and energy indirect emissions. The total climate change impact in the materials sector is partially mitigated by the pulp and paper industry.

The main impact in the consumer staples sector is the production cost increase in the food industry due to changes in agricultural productivity. In the industrial sector, losses are mainly due to physical damages caused by extreme weather events, especially for logistics and toll road industries.

Considering all sectors, carbon pricing is the main impact in company's market value, as shown in Figure 10.

Figure 10

Types of climate change impact on the market value of companies



Source: Itaú Asset Management, 2017.

Carbon pricing shall affect all analyzed companies to a certain extent. If not directly, then through the supply chain and mainly through energy consumption. The capacity to pass on additional costs to clients and to decrease emissions will be key factors for business competitiveness.

Companies that are energy-intensive emissions-intensive tend to be the most affected by carbon pricing. Notably oil and gas, iron and steel, petrochemicals and the power industries.

Most Brazilian companies are still not prepared to deal with the possible implementation of a carbon pricing system, either tax or market-based. The development of a national carbon price is still not widely accepted and few companies recognize carbon pricing as a potential risk [34].

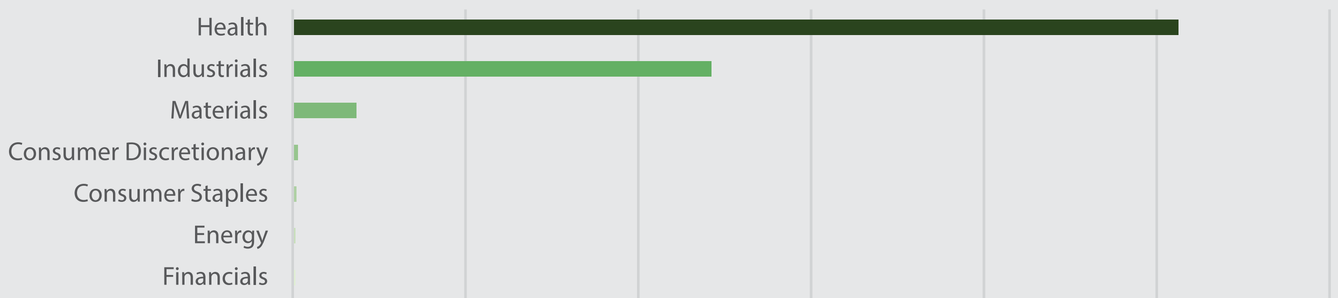
The second main impact is a consequence of shifts in water cycle. Such changes could result in an increase in water utility prices and in public water withdrawal prices, which could impose difficulties in the acquisition of water permits or even temporarily interrupt water intensive activities. This is expected to affect mainly the food, power, iron and steel and mining industries.

4.3.2 Climate change opportunities and initiatives

Looking at opportunities, the sectors expected to be most positively affected by climate change are Health, Industrials and Materials, respectively:

Figure 11

Climate change positive relative impact on the market value of companies



Source: Itaú Asset Management. This analysis does not take into consideration the negative impact of climate change on companies.

The increased occurrence of climate change-related diseases could increase the number of hospitalizations and the demand for medical service and laboratory exams, which could increase the health sector's revenue.

Opportunities in the industrial sector derive mainly from increased demand for equipment and services directed to build a low carbon economy, such as energy efficiency and renewable power generation, which would benefit the capital goods industry.

In the materials sector, opportunities are concentrated in pulp and paper production, which could generate extra revenues by selling carbon credits. The increase in forestry productivity could have positive impacts also.

Finally, the increase in temperatures and the rise in energy and water costs could boost retail sales, especially for cooling equipment and energy efficient household appliances.

4.3.3 Results

The matrix shown in Figure 12 below consolidates the total value of climate change impacts across 10 sectors, shown as the percentage, corresponding to impacts of climate change, of the market value of analyzed companies in each sector.

Figure 12

Climate change impacts on sector's market value, per sector and per type of impact (%)

Source: Itaú Asset Management, 2017.

The quality of management related to climate change impacts vary significantly by company. The total impact values presented above are aggregated by sectors, thus hiding considerable intra-sector and even intra-industry differences. In the Financial sector, for example, banks with greater exposure to agricultural sectors are more sensitive to weather variations.

It is key that the energy and materials sectors develop strategies to overcome challenges imposed by the imminent implementation of carbon pricing in Brazil. According to the Carbon Disclosure Project (CDP), out of 571 companies that use a carbon shadow price worldwide, only 15 are Brazilian [34].

The transition to a low carbon economy requires great efforts from the Industrial sector in terms of energy efficiency gains. Energy and power sector will need to adapt to a new technological paradigm based on alternative renewable sources. These changes represent growth opportunities for the sectors' supply chain, especially for equipment suppliers.

Changes in water cycle and water stress can potentially affect all economic sectors. Sectors more exposed to water risks need to develop alternative solutions, such as adopting rational water use practices, investing in wastewater reuse technologies, exploring new water sources and incorporating water risks to operational risk management system.

All climate change impacts affect the financial sector both direct and indirectly, as it is an intermediate for the productive sector. On the other hand, new or adapted financial products focused on financing low carbon solutions represent a new source of income, in addition to helping develop new technologies. In this context, international financial institutions practices stand out, namely the International Finance Corporation (IFC), Inter-American Development Bank (IADB), German Development Bank (KfW), among others. These institutions play an important role in financing projects aligned with a low carbon economy in Brazil and in Latin America.

It is key that Energy and Materials sectors **develop strategies to overcome challenges** imposed by the imminent implementation of carbon pricing in Brazil.

Conclusion

The Paris Agreement signed during COP-21, the 21st UNFCCC Conference of Parties, aims to reduce greenhouse gas emissions in order to avoid an increase above two degrees Celsius in the average global temperature and to redirect global finance flows to a low carbon economy.

According to estimates made by international organizations, US$ 93 trillion is the amount of total investments needed by 2030 to finance projects aimed at lowering GHG emissions. Still according to these estimates, the Energy sector shall be the most affected, demanding about half of the investments.

Apart from the Energy sector, climate change has been causing physical damages, through the increase in extreme weather events, especially to infrastructure assets. Coastal areas, home to around 20% of the Brazilian population, should be the most affected in the following years.

Extreme weather events should negatively affect human health, change water access and quality, in addition to secondary impacts. These impacts translate into potential economic losses and casualties. Changes in water cycle can affect water intensive sectors, such as Food and Beverages, Mining and Power Generation.

Another point of concern is Agriculture, whose productivity tends to be harmed by the increase in drought and heavy rain. The increasing physical risk could produce indirect impacts throughout its productive chain and in the financial sector, especially on banks with higher exposure to agricultural credit portfolios. Areas of suitable cropland could register a decrease in productivity due to water cycle changes.

Various mitigation and adaptation initiatives are being studied nationally and internationally. In this context, the implementation of a carbon pricing mechanism is expected in the medium term.

The key question around carbon pricing is which system to implement – a market-based cap-and-trade or a carbon tax scheme. Variations of both approaches were implemented by various countries and the biggest challenge will be to unify mechanisms while protecting markets and trade agreements.

In a carbon pricing scenario, the main industries affected are the carbon intensive ones, such as Oil and Gas, Iron and Steel and Power Generation.

On the other hand, sectors that are more aligned with a low carbon economy should benefit from regulatory and consumption pattern changes. A few examples of such sectors are energy efficient equipment and systems providers, renewable energy generators and clean mobility providers. The possibility of carbon trade may also favor the Forestry industry, as well as Pulp and Paper, given that both would qualify as sellers. The main challenge for these industries is to prove their carbon sequestration level.

The Financial sector has a fundamental role in the transition to a low carbon economy, as it is an intermediate for the productive sector. It has the potential to finance new business models and low carbon activities, as well as restricting finance to polluting activities. The process should begin with development banks and multilateral institutions taking the lead and secondly expand to private sector institutions. In addition, financial sector regulation shall increasingly demand adequate management of environmental and social risks in order to speed up capital deployment towards a low carbon economy.

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Disclosure

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