REPORT . 2021

OPPORTUNITIES FOR BRAZIL IN CARBON MARKETS

ICC BRASIL
INTERNATIONAL CHAMBER OF COMMERCE
The world business organization

WAY CARBON

OPENING LETTER

Gabriella Dorlhiac
Executive Director
of ICC Brazil

One of the main challenges of our time, climate change endangers the lives and livelihoods of billions of people. Extreme weather events, loss of biodiversity, changing water regimes, and increasingly frequent natural disasters also directly impact the economy, making prosperity in the 21st century unthinkable without acting on the risks of a global temperature 1.5° C above pre-industrial levels.

A recent report by the Intergovernmental Panel on Climate Change, linked to the United Nations Organization, made it clear that the climate emergency is the result of human action. And it is through human action that, in a coordinated way between the private sector, governments, and civil society, we will need to overcome this challenge.

Global cooperative efforts will be more essential than ever and must translate into policies that are aligned with the economy and that raise our ambition for strategies that result in positive and concrete climate impacts. COP26 in Glasgow will be a turning point in the global climate agenda: the success of the negotiations will dictate the pace at which regulatory frameworks - such as a regulated carbon market - financial incentives and structural changes in the way production and consumption will allow effective decarbonization by 2050.

The private sector has a key role to play in this journey of transition to a low-carbon economy. It is inspiring to see that more and more companies are committing to targets to reduce their emissions in a fundamental exercise of rethinking how to do business.

More than that, the need to mitigate the risks and consequences of the climate crisis offers us an opportunity to reflect on the country we want and can be. We have the necessary elements and the conviction that it is possible to combine economic and social development with environmental conservation, creating opportunities and boosting a new economy for the country.

It is in this sense that the ICC Brazil developed, in partnership with WayCarbon consultancy, the present study that highlights the economic opportunities for Brazil in carbon markets from a multi-sectoral perspective. With a potential that reaches tens of billions of dollars, although this should not be the focus of the solution to the climate crisis, it is evident a giant economic opportunity to reap the fruits of the immense environmental vocation that Brazil holds.

We hope that the main conclusions of this publication can provide input for negotiators, policymakers, the business community, and society at large in preparation for COP26 and other forums that will be critical to the success of the arduous mission of ensuring a future with production, balance, and quality of life.

ICC Brazil, one of the national chapters of the International Chamber of Commerce (ICC), was created in 2014 with the mission of bringing the private sector to the center of the international trade agenda and expanding the voice of the Brazilian business community with governments and international organizations, in the elaboration of projects focused on economic development, improvement of the business environment.

From a multi-sectoral approach, we produce knowledge through projects and advocacy initiatives, seeking to bring the private sector closer to government agencies and global debates in multilateral organizations, such as the UN, WTO, and G20, providing subsidies for the development of public policies that are beneficial to business and society.

We also disseminate locally the content developed by the global ICC in its 12 areas of operation, organize events on issues of relevance to the country's economy, give a voice to companies installed in Brazil globally, and transmit to the relevant government authorities the ICC's positions on key issues for a healthy, fair and sustainable business environment.

ICC globally was founded in 1919 with the mission to promote more open, fair, and transparent international trade. Currently, the ICC represents the voice of companies at the highest levels of intergovernmental decision-making, whether in the World Trade Organization, the G20, or the United Nations, being the first private sector organization with observer status at the UN General Assembly. It is this ability to connect the public and private sectors that sets ICC apart as a unique institution, responding to the needs of all stakeholders involved in international trade and its surrounding issues, such as innovation and sustainability.

To learn more, visit **iccbrasil.org**

Established in Brazil since 2006, WayCarbon is a technology-based company and the largest strategic consultancy exclusively focused on sustainability and climate change in Latin America. The company offers the market solutions that combine professional experience, innovation and technological development, aiming to transform sustainability into a competitive element for business.

WayCarbon is a reference in advising on global climate change, managing environmental assets and developing strategies and businesses aimed at eco-efficiency and a low-carbon economy. WayCarbon is a Certified B Corporation and is part of the main innovation hubs in the country.

WayCarbon understands that the carbon market agenda is strategic for the country and through its experience and market intelligence develops technical basis and financial innovation for the success of the implementation of opportunities in the country, clear motivation for partnership with ICC Brazil, and delivery of this work.

To learn more, visit **waycarbon.com**

Authors

Laura Albuquerque
Letícia Gavioli
Sergio Margulis
Caio Barreto
Fabiana Clemente
Julia Goulart
Sandro Esposito

Technical Review

Henrique Pereira
Rodrigo Wanderley
Ana Pinheiro

SPONSORED BY:

SUMMARY

On any page of this report, click this button and return here to summary.

INTRODUCTION

This report explores Brazil's opportunities to enter carbon markets with its productive sectors, specifically regarding Article 6 of the Paris Agreement and voluntary carbon markets. The study provides a brief conceptual contextualization of these markets, followed by the identification of potential opportunities for carbon credit generation by the productive sectors and in its chains associating with socioeconomic benefits. Next, opportunities are prioritized in cost-effectiveness and are discussed on the access of these opportunities to the market and the barriers identified for priority sectors. Subsequently, the prioritized sectoral opportunities are presented and supported by current carbon markets. Finally, arguments and strategic recommendations are presented for Brazilian action in different types of carbon markets.

CONTEXTUALIZATION

The COVID-19 pandemic was economically devastating and a similar experience to systemic financial crises in the recent past and magnified its impact on public health and our way of life. This combination justifies the stimulus packages that support more integrated recovery processes and, so governments responded by providing stimulus or aid packages to support recovery processes. However, the pandemic is not the only challenge of this decade, as record annual temperatures, rising natural disasters, and the decline of biodiversity show urgent warning signs for human longevity on Earth. Global warming, which unequivocally has human influence, will exceed 1.5°C before the middle of the century but can be minimized with immediate ambitious action to reduce emissions (IPCC, 2021).

Economic recovery packages, especially in advanced economies, have focused heavily on sustainable development and carbon neutrality. To ensure this achievement in a cost-effective manner governmental authorities, have been using regulatory mechanisms and carbon pricing instruments to unlock financial opportunities for countries' post-pandemic recovery plans and to accelerate sustainable economic growth (LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE; UNIVERSITY OF LEEDS, 2020).

The French authorities, for example, recognized the importance of introducing an economic recovery plan that brings sustainable progress to Europe, addressing climate and ecological crises, especially in the energy transition, considering direct taxation of fossil fuels; or as part of a strengthening of the European Union Emissions Trading Scheme (EU-ETS); and even a combination of both policies (EUROACTIV, 2020). The UK government also considered in a statement that actions to zero the emissions and limit the harm of climate change will help rebuild the country with a stronger economy after the Covid-19 pandemic. In this sense, the government affirms that reducing greenhouse gas emissions and adapting to climate change should be an integral part of any recovery package. Measures include support for qualifications and research for the development of an adapted economy; facilitation for people to walk, cycle or work remotely; tree planting, restoration of pet fairs, green spaces, and other green infrastructure (COMMITTEE ON CLIMATE CHANGE, 2020).

CARBON MARKETS

The term carbon market has been used to express two different types of environmental asset trading related to greenhouse gas (GHG) emissions:

1. GHG emission allowances - referring to an Emission Trading System (ETS)

2. Certified or Verified Emission Reduction Certificates (CER/VER) - referring to an offset mechanism. Both types of trading are called carbon markets in which the term "GHG emission" has been simplified to "carbon".

Carbon Markets have two approaches: as a regulated carbon market or as a voluntary carbon market. These markets have participants, scopes, regulations, and specific rules to follow. The regulated market is linked to a regulatory framework, while the voluntary market is a compensation mechanism without regulatory ties.

REGULATED MARKETS - ETSs

Are regulated systems at the international, national, or regional level where through a regulatory framework a maximum GHG emission limit (cap) is established. The agents that emit below this limit may trade their allowances with those that emit above the predetermined limit. In some cases, sectors of intense emission exposed to international trade may benefit from additional emission rights (CEBDS, 2020). On the international level, the regulatory framework of the Kyoto Protocol was in force with targets for developed countries (Annex 1) and today the Paris Agreement has agreed upon with targets called NDC (Nationally Determined Contributions). At the national and regional level, context-specific regulatory frameworks exist for about 30 ETSs, of which the largest and most important ETS, among others, is the European Union Emissions Trading Scheme (EU ETS) (CPLC, 2021a).

VOLUNTARY MARKETS

Offset mechanisms: are systems in which there are no maximum limits of emissions defined by regulation to agents. GHG reduction targets are not regulated but meet methodologies of certain standards led, in general, by non-governmental organizations that generate GHG emission reduction results in the implementation of projects (CPLC, 2021b). Emission reductions are traded between companies and individuals and meet a voluntary corporate or individual target with credits generated by other companies and individuals that have been certified by processes certified by a third party aligned with the respective principles and methodologies that vary between existing standards. These credits can also be used to partially meet the goals of a regulated market under an international agreement or domestic policies related to GHG mitigation provided that they are explicitly permitted in international regulation or agreement (CPLC, 2021b). The main regulated market standards are Verra, Gold Standard, Social Carbon, among others (CEBDS, 2020; CPLC, 2021b).

Both carbon markets trade in a ton of carbon dioxide equivalent (tCO_2e), in which an allowance is said to be a carbon credit, and likewise - a certified emission reduction equivalent to a carbon credit. There are three different trading environments of carbon credit: the regulated carbon markets under the United Nations Framework Convention on Climate Change (UNFCCC); regional, national, and subnational regulated carbon markets; and the voluntary carbon markets.

The UNFCCC trading environment was regulated by the Kyoto protocol until 2020 and is now transitioning to the Paris Agreement. The Kyoto Protocol established an ETS between Annex I countries and established two offset mechanisms - the Clean Development Mechanism (CDM) and Joint Implementation (JI). In the case of the CDM, developing countries could trade carbon credits so that Annex I countries could achieve their goals more cost-effectively, and thus promote their sustainable development. According to the UNFCCC (2018), 40% of CDM projects engage with local communities, leading to job creation, education promotion and, improved living conditions. In addition, 27% of these projects generate financial benefits for the local and regional economies. In this sense, the CDM in Brazil enabled US$ 32 billion in investments with about 340 projects, in which the set of renewable energy generation projects corresponded to 97% of the total of this invested capital. The great mobilization of capital in projects in this sector was due to the CDM's ability to promote investments in renewable energy generation contributing to a total installed capacity of approximately 20 GW (IPEA, 2018).

New market mechanisms are established in Article 6 of the Paris Agreement, and it is expected that their rules will be defined at COP 26 (26th Conference of the Parties to the UNFCCC) in November 2021. The implementation of Article 6 potentially provides a global policy basis for a comprehensive ETS that serves as an umbrella between all countries participating in the Paris Agreement under NDC targets. Article 6 has the potential to increase international cooperation on emissions mitigation by regulating emission exchange between countries through Internationally transferred mitigation outcomes (ITMOs[1]), which can pave the way for achieving the targets set in the NDC at a lower global cost through cooperation. This cost-effective cooperation was clearly highlighted by the Joint Institute for Global Change Research, indicating a cost reduction resulting from collaboration in relation to the individual achievements of NDC targets of US$ 249 billion (63%) in 2030, US$ 345 billion (41%) in 2050, and US$ 988 billion (30%) in 2100 (IETA; UNIVERSITY OF MARYLAND; CPLC, 2019)

1. ITMOs metrics are also dependent on trading, they may include other metrics such as renewable capacity or hectares of newly planted forest. In addition, countries could also link their ETS through this mechanism.

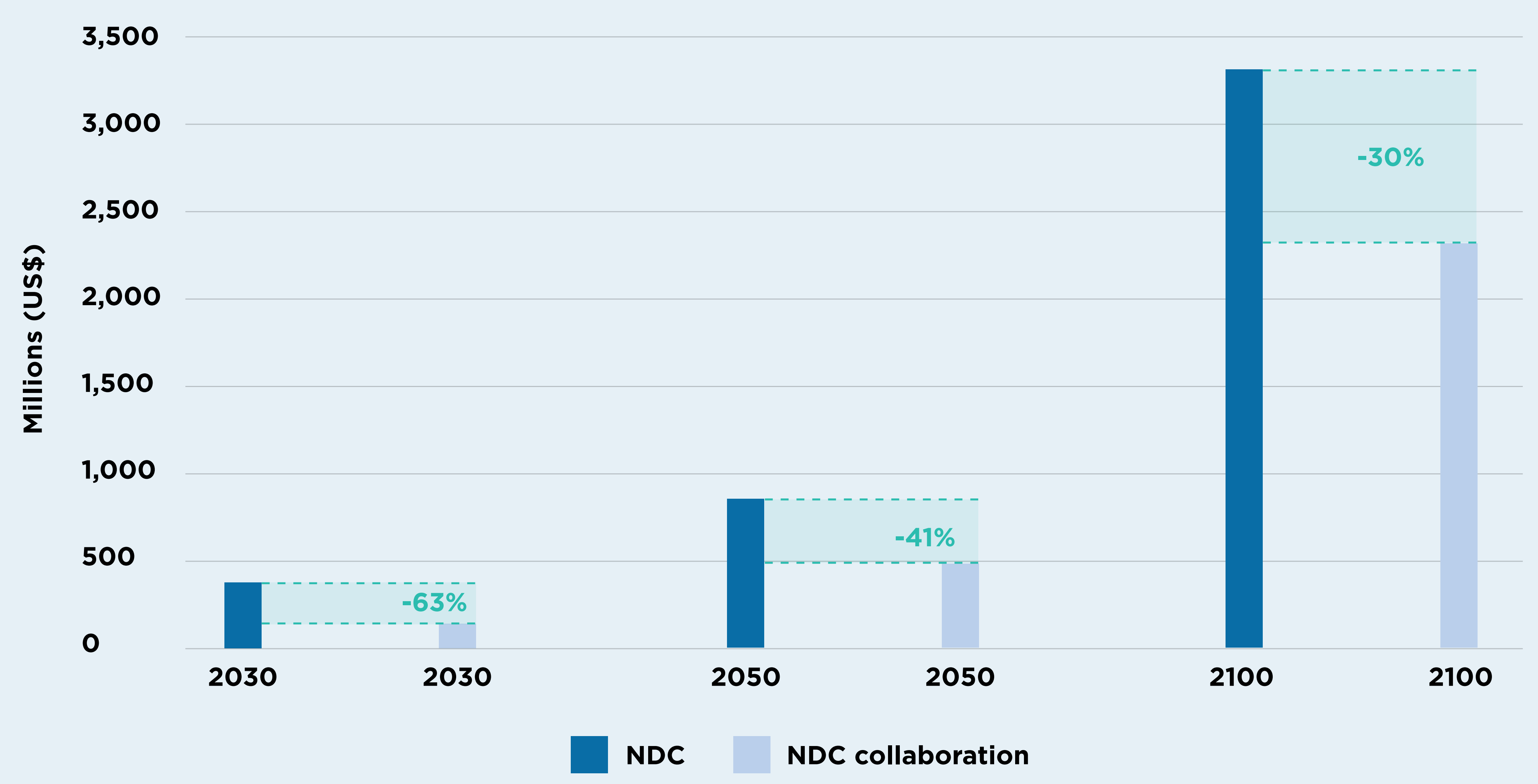


Figure 1: Emissions Mitigation Costs – Individual NDC vs. NDC Collaboration
Source: Authors' elaboration based on (IETA; UNIVERSITY OF MARYLAND; CPLC, 2019).

Article 6 highlights Article 6.2, which states that ITMOs can be negotiated between countries, and Article 6.4, which allows direct transfers between countries and the private sector through the so-called Sustainable Development Mechanism (SDM). Therefore, participating countries with a competitive advantage due to abundant natural resources, sustainable infrastructure, and their respective companies will be able to transfer their emissions mitigation to other non-favoured countries (IETA; UNIVERSITY OF MARYLAND; CPLC, 2019). As one of the countries with the most cost-effective mitigation potential, Brazil has a unique opportunity to utilize the mitigation potential from its key sectors in these new mechanisms and play a strategic geopolitical role in mitigating climate change. However, as mentioned, the Article 6 rules for the structure of the CDM and the ITMO, and their means of implementation are conditioned to the negotiations that will be held at COP 26 (UNFCCC, 2019).

Despite this diplomatic delay, there is climate urgency and latent economic opportunities. Therefore, interested countries are carrying out their Article 6 pilots through bilateral agreements or programs, such as those between Canada and Chile and Canada and Mexico, as well as the treaties signed between Switzerland and Peru and Switzerland and Ghana. Chile and Peru are in the process of implementing emission reduction projects that indicate that their ITMOs are marketed with Canada and Switzerland, respectively. Between 2015 and 2020, Canada announced $2.65 billion in international climate finance to help developing countries address the challenges of climate change and support their transition to low-carbon economies and climate change resilience (CANADA, 2017). The country technically and financially supports Chile through the Canada-Chile Agreement on Environmental Cooperation (CCAEC) to reduce methane emissions in the waste sector and will acquire mitigation units for this Chile project to meet commitments in the Canadian NDC. The CCAEC is part of the Free Trade Agreement between Chile and Canada and aims to provide high levels of environmental protection in both countries by environmental laws and regulations (CANADA, 2010). In addition, Mexico, Costa Rica, and several countries in Asia and west and east Africa[2] joined the pilots. These cooperation programs will present new perspectives for climate change and economic opportunities in this carbon market (GREINER *et al.*, 2020).

It is important to note that the possibilities of carbon leakage and double counting can be substantially reduced with a cooperative approach while resulting in cost-effective emission mitigation.

Box 1

Bilateral agreement between Switzerland and Peru

In October 2020, Switzerland and Peru signed a bilateral agreement aimed at increasing their climate ambition. In line with Article 6 of the Paris Agreement, this agreement provides for the reduction of GHG emissions and the promotion of funding for national projects implementing low-carbon technologies and practices. As presented, according to Article 6 of the Paris Agreement, a country can use the excess CO_2 reduction of another country to help achieve its goal through ITMOs.

The agreement between these two countries provides that Switzerland will finance Peruvian projects that implement low GHG technologies and practices. In this sense, Switzerland's €20 million investment is earmarked for the Tuku Wasi program. This program improves stoves for Peru's rural population, reducing not only GHG and particulate matter emissions. As a consequence, it reduces in lung diseases affecting the population. Throughout the implementation, Peru will define monitoring, reporting, and verification actions for GHG reductions. Thus, the agreement between Switzerland and Peru is an example of how cooperation between countries can facilitate their climate goals achievement. In addition, it can bring prosperity and well-being to the population (CONFEDERACIÓN SUIZA Y REPÚBLICA DEL PERÚ, 2020).

2. Among the Asian countries are: Jordan, Saudi Arabia, Bangladesh, Mongolia, Myanmar, Japan, Thailand, Laos, Cambodia, Vietnam, Philippines, Indonesia and Maldives. While, among the countries of Africa, are included: Tunisia, Morocco, Mali, Senegal, Burkina Faso, Ivory Coast, Ghana, Benin, Democratic Republic of the Congo, Zambia, Zimbabwe, Ethiopia, Uganda, Kenya, Rwanda, Mozambique and Egypt. / 3. *Carbon leakage*.

The trading environment of national and regional carbon markets is extensive and used at all governmental levels[3]. Compared to 2020, the global coverage of GHG emissions has increased by more than 50% and currently covers 16.1% of all GHG emissions worldwide (Figure 2), corresponding to 29 implemented ETSs in 2021 (WORLD BANK, 2021a). This substantial increase is a consequence of the national ETS introduction in China[4], the world's largest ETS initiative in terms of emissions coverage, with more than 4,000 $MtCO_2e$. This initiative from one of Brazil's largest trading partners signals future expectations regarding the role of GHGs in sustainable foreign trade (KRAUSE *et al.*, 2021).

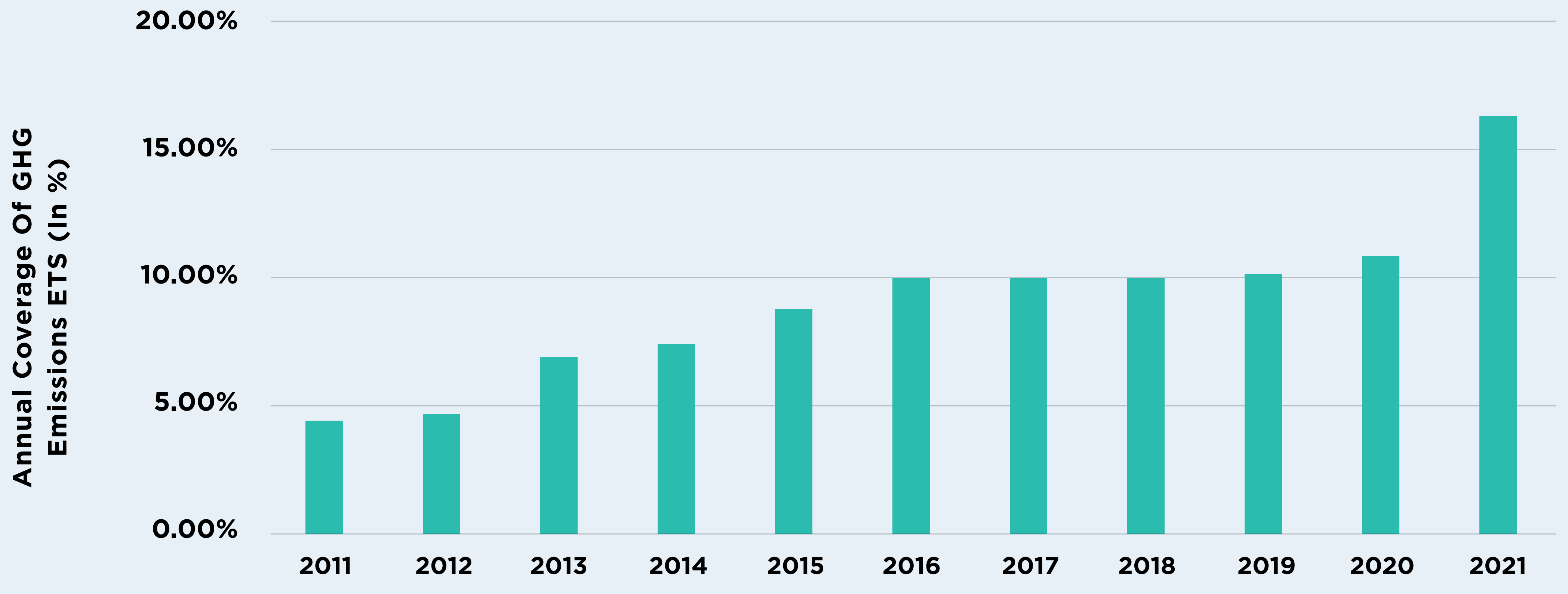


Figure 2: Annual GHG Emissions Coverage
Source: Authors' elaboration based on ICAP (KRAUSE *et al.*, 2021).

THE TRADING ENVIRONMENT IN THE VOLUNTARY CARBON CREDITS MARKET

Voluntary initiatives trade carbon credits between companies for voluntary offsets or limited compliance with existing ETS targets. Voluntary markets such as the Gold Standard and Verra have existed since 2003 and 2005, respectively, and have together reduced more than 681.25 $MtCO_2e$ by 2021 (GOLD STANDARD, 2021c; VERRA, 2021c). Historically the main credit generators of the voluntary carbon markets are located in India (23.1 $MtCO_2e$), in the USA (14.4 $MtCO_2e$), in China (10.2 $MtCO_2e$), and Brazil (4.6 $MtCO_2e$) (DONOFRIO *et al.*, 2020). The sectors that stand out in the crediting approach are the forestry and land use, renewable energy, and waste disposal sectors. In China and India, carbon crediting projects are mostly associated with the renewable energy sector. However, in the United States, the sectors of Waste Disposal, Chemical Processes/Industrial Plants, and Forest and Land Use reached the largest Project credit volume (DONOFRIO *et al.*, 2020). In Brazil, the agriculture, energy, and especially forest sectors stand out in the generation of credits in VCS projects (Verified Carbon Standard), although credits from the transport and waste sectors have also been issued, in a smaller amount, in some years of the last decade (VERRA, 2021a). In the Gold Standard, Brazil has carbon credits only in the energy sector (GOLD STANDARD, 2021a).

The voluntary market is still relatively small compared to the regulated ones, but in 2020, it gained momentum with the recent commitments of large business groups towards carbon neutrality and the Task Force for Voluntary Carbon Markets that aims to diagnose the challenges of this market to identify the growth opportunities that will be outlined. The Task Force is composed of more than 40 leaders from six continents with experiences in relation to the carbon market value chain from the financial sector, market infrastructure providers, as well as buyers and providers of carbon offsets (KERSCHNER *et al.*, 2021).

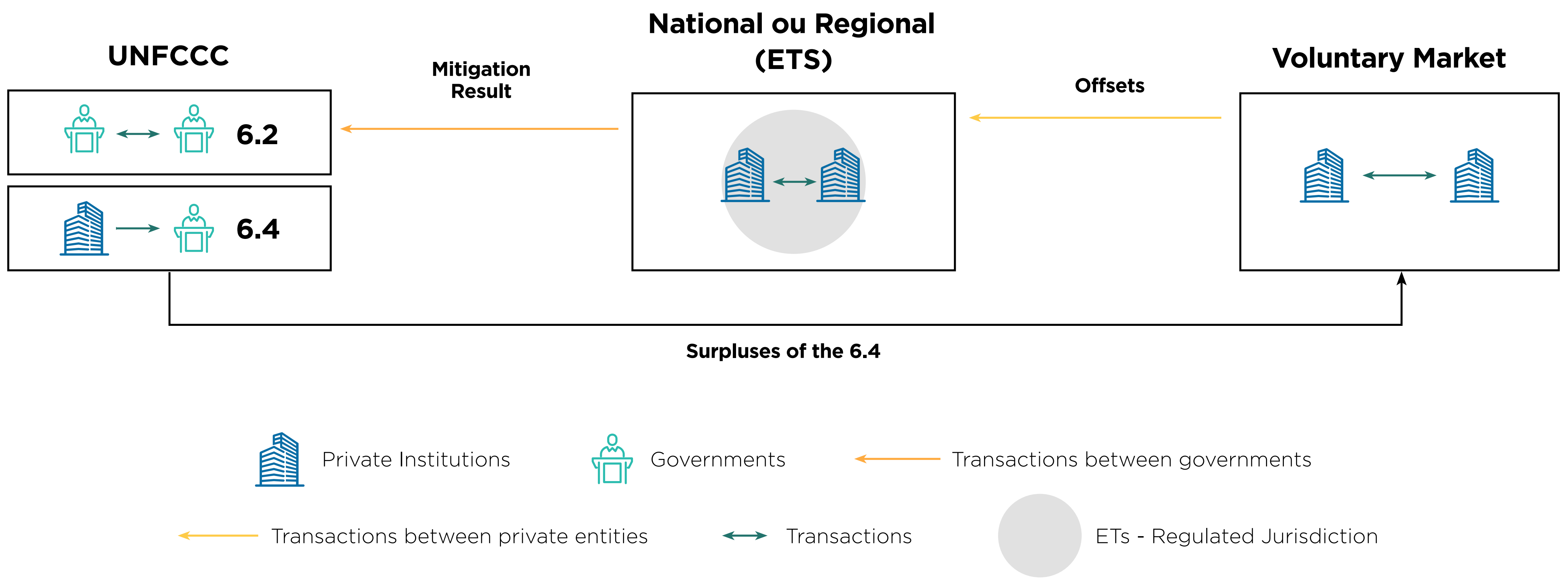


Figure 3: Carbon Markets Trading Environments
Source: Authors' elaboration.

3. National, regional (such as European Union) and subnational (such as states, provinces, metropolitan regions).
4. The marketing of permissions in this market is planned to start before the end of June 2021.

THE CONTEXT OF BRAZIL

In 2015, Brazil declared in accordance with the Paris Agreement its NDC with GHG emission reductions of 37% by 2025 and 43% by 2030 based on levels recorded in 2005 - a reduction to 1,300 $MtCO_2e$ in 2025 and 1,200 $MtCO_2e$ in 2030 in absolute terms, respectively (FEDERATIVE REPUBLIC OF BRAZIL, 2016). In contrast to this first NDC from Brazil, the updated submission for 2020 does not contain absolute numbers and, therefore, the business sector, referring to the 33 companies that subscribe to the manifesto letter "Climate Neutrality: A Great Opportunity", requested more ambitious targets to capitalize on the country's competitive advantages for emissions mitigation (CEBDS, 2021; UNFCCC, 2020). In contrast, in 2021, during the Climate Summit organized by the United States, President Jair Bolsonaro said that Brazil's climate neutrality should be achieved by 2050 (EPBR, 2021).

In parallel, there are national initiatives to reduce emissions using carbon markets as an instrument that deserve attention:

1. PMR BRAZIL PROJECT:

Under the coordination of the Ministry of Economy and the World Bank, the PMR Brazil Project aimed to discuss the convenience and opportunity of including carbon pricing in the package of instruments to implement National Policy on Climate Change (in Portuguese, *Política Nacional sobre Mudança do Clima - PNMC*) in the post-2020 period. After four years, the project ended in December 2020, with the recommendation of an Emissions Trading System - ETS – as the most suitable instrument for Brazil (WORLD BANK, 2020). After four years, the project ended in December 2020, with the recommendation of an Emissions Trading System (ETS – as the most suitable instrument for Brazil. Corroborating this indication, companies of the Climate Business Initiative (CBI) support a national ETS since 2016, and the Brazilian Business Council for Sustainable Development proposes that the Brazilian ETS be for the industry (CEBDS, 2018a; INSTITUTO ETHOS, 2016). After the PMR project, the Partnership for Market Implementation (PMI) is expected to operate. It aims to assist participating countries in designing, piloting and, implementing explicit carbon pricing instruments aligned with internal development priorities (WORLD BANK, 2019b). In April 2021, Brazil sent the World Bank a document of interest in joining the PMI. The adoption of this program could help the country generate public revenues, in addition to encouraging innovation and directing investments (MATSUI, 2021).

2. RENOVABIO:

In December 2019, the National Biofuels Policy (RenovaBio) was officially launched to expand the use of biofuels in the Brazilian national energy matrix. Through the Resolution nº 8, dated August 18, 2020, of the National Energy Policy Council (in Portuguese, *Conselho Nacional de Política Energética -* CNPE), the Decarbonization Credit (in Portuguese, *Crédito de Descarbonização* - CBIO) target of 24.86 million was established for 2021, representing 24.86 $MtCO_2$ of avoided emissions, as well as the agreement of targets for the period up to 2030 (BRASIL, 2021c). Moreover, Renovabio is an incentive policy and does not fit the regulated market definition conceptualized in this work.

3. NATIONAL POLICY ON PAYMENTS FOR ENVIRONMENTAL SERVICES:

After the launch by the Environment Ministry, in 2020, of the Forest+ and Forest+ Carbon Program, which provided for the generation of carbon credits through the conservation and recovery of native vegetation of Brazilian biomes as an alternative of additional income for forest protection practices, in January 2021, under law nº 14.119, the Brazilian Government established the National Policy on Payments for Environmental Services (PNPSA), the National Registry of Payment for Environmental Services (CNPSA), and the Federal Program of Payment for Environmental Services (PFPSA). These defined concepts, objectives, guidelines, actions, and criteria to encourage the conservation of environmental conditions of the ecosystems of Brazil (BRASIL, 2020, 2021b). After approval, the policy still needs to be regulated to ensure its proper implementation to existing practices in Brazil.

4. BRAZILIAN EMISSIONS REDUCTION MARKET:

Bill 528/21 establishes the Brazilian Emissions Reduction Market (MBRE) that regulates the transaction of carbon credits (BRASIL, 2021d). The initial proposal offers the development of a voluntary market for carbon credits to serve companies or governments to offset the environmental impact of their activities. This Bill is under analysis by the Chamber of Deputies and already presents proposals for a replacement text in the process that considers the inclusion of an ETS, in line with the recommendation of the PMR Brazil project to establish an ETS in the country.

Given this context, the focus of this work is on the regulated carbon market under the UNFCCC and the Paris Agreement and the voluntary carbon market.

SECTORIAL REVIEW

The objective of this chapter is to identify potential opportunities for carbon credits generation in the productive sectors, identify other opportunities in the production chain and their socioeconomic benefits. In this sense, two in-depth studies of Brazil regarding the country's mitigation potential and the opportunity for a new economy formed the basis of the sectorial review presented. These are: "Mitigation Options of Greenhouse Gas (GHG) Emissions in Key Sectors in Brazil" (Mitigation Options Project) of the Ministry of Science and Technology Innovations and Communications (MCTIC) and "A new economy for a new era: elements for building a more efficient and resilient economy for Brazil", led by the WRI Brasil and the New Climate Economy (NCE) initiative. In addition, specific references for each productive sector and internal studies from ICC member companies were utilized.

It is important to note that this study acknowledges the opportunities for carbon credits generated in the trading environment of the UNFCCC, under Article 6 of the Paris Agreement, and in the trading environment of the voluntary market. Consequently, the selected technologies and measures that represent the mitigation potential of each sector have an umbrella guideline consisting of measures listed in the first version of the Brazilian NDC as well as in the methodologies of the existing voluntary VCS and Gold Standard programs.

Click on the name of each of the productive sectors next to it and check out the potential opportunities for generating carbon credit that each of them offers in Brazil.

SECTORIAL REVIEW

On any page in this session, click this button and return to that home page.

AGRICULTURE SECTOR

FOREST SECTOR

ENERGY SECTOR

TRANSPORT SECTOR

INDUSTRIAL SECTOR

AGRICULTURE SECTOR

It was the productive sector responsible for 6.8% of the national GDP in 2020 and 27.52% of GHG emissions in 2019 (BRASIL, 2021e; SEEG, 2021). To mitigate GHG emissions, the Brazilian NDC presents objective targets for the agriculture sector associated with the expansion of the recovery areas of degraded pastures (+15 Mha) and areas of integrated crop, livestock, and forest systems (ICLF) of +5 Mha for 2030, in addition to strengthening the Low Carbon Agriculture Plan (ABC Plan) (UNFCCC, 2016). In this sense, the recovery of degraded pasture (RDP) and ICLF systems represent opportunities related to productivity gains in agriculture while contributing, in parallel, to the mitigation of GHG emissions (BRASIL, 2017a). Thus, the commitments adopted by the NDC reinforce and expand the ABC Plan goals[5], and the emission reduction estimates presented in this section take into account the technologies present in both documents.

TECHNOLOGIES FOR EMISSION REDUCTION

The Mitigation Options Project estimated potentials and abatement[6] costs related to measures for the Agriculture and Livestock sector during 2012 and 2050 while considering a low-carbon scenario (LC) in relation to the reference scenario (BRASIL, 2017a). The measures analyzed in the project scenario present an accumulated abatement potential of 2,419.3 $MtCO_2e$ by 2050, with costs varying from -1,978.00 to 1.99 US$/$tCO_2e$[7]. More than 98% of the sector's abatement potential is concentrated in the beef cattle ranching intensification strategy, including the recovery of degraded pastures (RDP), the fertilization of extensive pastures and feedlots. Despite having a low marginal abatement cost ($1.99), this measure would require a total investment of $4.7 billion[8]. On the other hand, the strategies of integrated systems - with crops and livestock (ICL) and crops, livestock, and forests (ICLF) - and low carbon agriculture - which involves mainly biological nitrogen fixation (BNF) and no-till farming – have a cost of, respectively, -1,978.00 US$/$tCO_2e$ and -311.7 US$/$tCO_2e$, thus presenting the potential for net revenue generation (BRASIL, 2017a).

Nature-based solutions (NBS) are actions for protection, sustainable management, and restoration of natural or modified ecosystems that relate effectively and adaptively to societal challenges while simultaneously generating human well-being and biodiversity benefits. Technologies for regenerative approaches in the agriculture sector are characterized as NBSs actions (WRI BRASIL, 2020).

In this sense, despite the necessity of urgent advancements regarding technical assistance and finance opportunities for the potential reduction of emissions, the technologies presented are already known and, in fact, part of the ABC Plan (WRI BRASIL; NEW CLIMATE ECONOMY, 2020)

5. The ABC Plan goals included, in addition to others, the recovery of 15 Mha of degraded pastures and the expansion of these recovered areas.
6. When the cost is negative, mitigation incurs net benefits. In addition to enabling a reduction in CO_2e emissions, it provides financial return over the life of the technology and/or the implementation horizon of low carbon activity. On the other hand, if the cost is positive emission mitigation will require financial effort for the agent, except through carbon pricing in the market.
7. The potential and abatement costs of all study measures directly related to the Agriculture sector are presented in the Appendix (Table A - 1).
8. This value considers these additional actions to the model's reference scenario measures: 1) Reduction of the herd by 57 million heads (with the maintenance of meat production); 2) Increase in 50% in the percentage of confined animals, recovery of additional degraded pasture of 6.7 Mha.

Box 2

Sustainable Production Systems, Practices, Products, and Processes of the ABC Plan (SPS_{ABC}):

Sustainable Production Systems, Practices, Products, and Processes of the ABC Plan (SPS_{ABC}):

I. Systems in integration (in the modalities ICLF, ICL, IPF and AFS), and no-till farming (SPD);
II. Biological nitrogen fixation (BNF);
III. Planted forests;
IV. Recovery of degraded pastures; and
V. Treatment of animal waste

In April 2021, the Ministry of Agriculture, Livestock and Supply (MAPA) launched the ABC Plan+ with a time horizon from 2020 to 2030. The document with the strategic vision of the Plan points out that the SPS_{ABC} adopted in the previous cycle will continue to be promoted, besides other initiatives that demonstrate effectiveness in facing climate change and that are in accordance with the 2020-2030 guiding axes. However, the actions and targets of the new cycle of the Plan only will be presented in the ABC+ Operative Plan, which will be published in the second half of 2021. In any case, the ABC+ strategies presented already point to foremost developments in terms of monitoring, reporting, and verification (MRV), as well as the consideration of cross-cutting instruments for the commercialization of GHG emission reduction credits to stimulate the use of SPS_{ABC} (BRASIL, 2021g).

According to MANZATTO *et al*. (2020), the adoption of SPS_{ABC} is one of the main commitments of the ABC Plan. The estimates on the reduction and mitigation of GHG emissions resulting from the expansion of the adoption of SPS_{ABC} were based on the year 2010, the year of launching the ABC Plan, and the completion of the III Communication of the National Greenhouse Gas Inventory. These were in the order of 133.9 to 162.9 $MtCO_2e$ until the final deadline of the commitment in 2020.

The study "Model for acting in the carbon credit market for agriculture"[9], prepared by Markestrat Agribusiness and contracted by Bayer, presents several actions that promote the reduction of GHG emissions in the sector, as well as actions that promote CO_2e capture. In addition to the measures already mentioned, it can be highlighted for the reduction of emissions:

I. the fertilizer usage management, with correct formulation, rate, time, and place of application;

II. rice management systems, with limiting the time of flood irrigation and ensuring that the appropriate level of crop residue remains in the field; and to capture the building soil carbon, through practices such as composting and biochar.

Box 3

Regenerative Agriculture

In 2021, Nespresso started planting avocado seedlings as part of the "regenerative coffee growing" project to counter the damaging effects of rising temperatures and droughts in the Cerrado region of Minas Gerais. A benefit of the strategy over time, there is a decrease in the need for pesticides, fertilizers, irrigation, and an increase in the level of nutrients in the soil, besides the increase of carbon sequestration and its fixation in the soil and the reduction of heat on the coffee plantations due to the shade generated by the avocado trees. As a consequence, one can mention the saving of inputs, the diversification, and increase of income sources, with the sale of avocados to the food and cosmetics industry, next to the potential trade of carbon credits (SCHERER, 2021).

SOCIO-ECONOMIC BENEFITS

The adoption of low-carbon agriculture strategies unlocks the potential for revenue generation. Regarding no-till systems, the expansion of 1.2 Mha has the potential to increase net revenue by US$ 9.8 billion until 2050 due to increase of agriculture productivity. Concerning the use of BNF, an increase of 8.8 Mha would generate an increase in net revenue of US$ 1.7 billion, mainly due to the savings from the purchase of traditional fertilizers (BRASIL, 2017a).

In association with integrated systems strategies, the paper presents the potential for generating additional net revenue of $8.9 billion as a result of adopting ICL and ICLF strategies. In addition, it provides co-benefits related to the implementation of the measures presented above and to the intensification of cattle ranching:

I. increased income for the producer;

II. improved quality of working conditions in the field;

III. diversification of economic activities; and

IV. promotion of sustainable development (BRASIL, 2017a).

Other benefits from the strategies, beyond GHG emissions reduction, such as the opportunity for increased production efficiency emerge as a result of RDP and ICLF systems, or concerning the adoption of RDP and ICLF strategies:

I. availability of ABC Plan credit lines;

II. recovery of the productive potential in degraded areas;

III. contribution to the environmental adequacy of properties (Permanent Preservation Area and Legal Reserves) (CEBDS, 2017a).

In addition, low-carbon agriculture strategies and intensified cattle ranching practices reinforce the hypothesis that increasing productivity per hectare of agricultural activities would reduce the demand for new areas to increase production, thus reducing pressure on deforestation. Moreover, the adoption of such strategies would represent a win-win situation. However, the paper underlines the need for knowledge dissemination and financing to capitalize on the gains in productivity and pasture recovery - with an investment value of around R$ 25 billion to recover 12 million hectares of degraded pastures, which has a certain return, with a timeframe of 6.58 years (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

Crop and pasture management and the implementation of ICLF can guarantee competitiveness among the main international agricultural suppliers, especially in the current scenario in which commercial partners, such as the European Union, have applied restrictions to products originating from unsustainable production chains. Another opportunity would be to obtain capital at a lower cost directed to sustainable enterprises, which is an international financial trend (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

The implementation of agroforestry systems (AFS) can fortify small producers, generating social, economic, and environmental benefits and services such as income generation and contribution to the food se-

9. Unpublished study.

Box 4

Circular Carbon Project

Natura's compensation activities advance in line with the Sustainable Development Goals, allowing the generation of jobs, technology transfer, strengthening local economies, training women, and protecting biodiversity and water resources. In 2007, the Carbon Neutral Program was launched to account for, reduce and neutralize the company's GHG emissions. On average, for every R$ 1 invested in Natura's compensation projects, the equivalent of R$ 31 in social and environmental benefits is generated. The union of the Carbon Neutral and Amazon programs allowed the development of its first carbon offset payment project within Natura's production chain, a practice also known as carbon insetting. Initially, the project was carried out in partnership with the Cooperative of Economic Reforestation Consorciado and Adensado (in Portuguese, *Cooperativa de Reflorestamento Econômico Consorciado e Adensado* - RECA) and aims to contain deforestation in the Amazon and stimulate the role of the family farmer in the conservation of local vegetation. Thus, the Circular Carbon project remunerates smallholder families not only for the purchase of income and benefit-sharing but also for the environmental conservation service (NATURA, 2018).

curity of families through agroecological production (IPÊ, 2021).

Finally, the model projections presented in the study show that the low-carbon New Economy in Brazil (NEB) and NEB+ scenarios would generate fewer jobs compared to Business as Usual (BAU), although this differential does not reach 2% for any of the years analyzed. However, that is due to the scenario limiting land conversion and decreasing the expansion of agricultural land observed in the BAU scenario. In contrast, the farmers' income would increase by more than 40% in 2030 in the NEB and NEB+ scenarios due to increased productivity (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

OPPORTUNITIES FOR THE PRODUCTION CHAIN

There are other technologies related to the agriculture and forest sectors that can provide opportunities for the production chain. The production of ethanol from second-crop corn is a relevant example. While biofuel reduces emissions by 71% and 100% compared to gasoline, the rotation between soy and corn generates attractive income streams for producers. The rotation system uses the inputs from the first planting, protects the soil, and does not affect food production. Furthermore, the process of making ethanol from second-crop corn generates by-products for highly nutritious animal feed called distillers dried grains, decreasing the demand for corn and soybeans for animal feed (MOREIRA *et al*., 2020). It also has the potential to generate bioelectricity with the possibility of inserting the surplus into the electricity grid. The construction of a plant that produces 500 million liters per year of ethanol from corn can generate around 8.5 thousand direct and indirect jobs during the construction phase and an added economic value of US$ 206 million. Moreover, in the operation phase, the same plant generates 4.5 thousand jobs per year and added value of about US$ 283 million per year (MOREIRA *et al*., 2020).

Thus, a great difficulty for the agriculture and forest sectors are the actions of Monitoring, Reporting, and Verification, hampered by the heterogeneity of soils and climates found in Brazil, as well as the accuracy and reliability of the reported information (PEROSA *et al*., 2019). For these reasons, the new cycle of the ABC+ Plan (2020-2030) seeks to enable MRV mechanisms aligned with internationally accepted criteria, which will allow the establishment of economic incentives and market instruments to remunerate sustainable production systems (BRASIL, 2021g).

Box 5

PPP and allied technologies for low carbon agriculture

The application of measures related to the agriculture sector can also stimulate technological sectors, following the example of the strategy used by Bayer in a public-private partnership (PPP) with Embrapa. In this partnership, 500 corn and soybean farmers who are in compliance with the Brazilian Forest Code and are customers Climate FieldView digital platform were selected. The platform is an important pillar to ensure the collection and transparency of data, storing analyses on soil, temperature, the volume of fertilizer and pesticide sprays, and the performance of machines in crops, from planting to harvesting processes. From the PPP mentioned, producers are instructed to adopt good agricultural practices, such as crop rotation and no-till farming. Thus, the platform ensures the best decision-making by the producer and consultants over time. After the data from the platform is released, it will be possible to verify the entire history of implementation of more sustainable management, productivity data, and carbon accumulation in the soil in the areas. It is aimed, in a later stage of the project, the remuneration of producers who reduce GHG emissions. (SCHERER, 2021). This will be possible by building a network of alliances with partner companies, connecting participating producers to exclusive benefits such as access to differentiated financial credit and more attractive agricultural insurance.

10. Values indicated by WRI BRASIL and NEW CLIMATE ECONOMY (2020) through BACEN (2019) data.

FOREST SECTOR

Land-use change and forestry are responsible for 44.5% of national GHG emissions and are also the most cost-effective GHG reduction sectors (SEEG, 2021). Reforestation is generally evaluated as the best mitigation option in the forest sector for the short term due to the ease of implementation provided that they are based on an economic logic that justifies it. Similarly, forest management and forest restoration also present themselves as great opportunities. (CEBDS, 2017b).

TECHNOLOGIES FOR EMISSION REDUCTION

The Mitigation Options Project estimated the potentials and abatement costs related to sector-specific measures that are considered nature-based solutions as they relate to forest protection, its management, and restoration. Considering the low-carbon scenario, the measures related to the sector analyzed in the study have a joint abatement potential of 2,565 $MtCO_2e$ and costs ranging from -0.38 to 9.22 US$/$tCO_2e$[11] for the period 2012-2050. Although the planted forest strategy has a negative total cost and therefore has the potential to generate net revenue - due to the commercial purpose of the wood for energy use from the additional plantations - the strategy of reducing deforestation has the greatest capacity for GHG emissions abatement. However, besides representing the lowest potential abatement among the strategies studied for the forest sector, forest restoration also presents the highest cost among them (BRASIL, 2017a).

A study developed under the PMR Brazil Project estimated a high potential for generating forest carbon credits. Three approaches were analyzed. First, asset generation in the form of removal units (RMUs) from forest restoration would allow the reduction of 500 $MtCO_2e$ with a reduced value of around R$ 20 per tCO_2e. The potential of this approach could reach up to 2,400 $MtCO_2e$, although the abatement values grow exponentially for total removals from 2,000 $MtCO_2e$. As for the planted forest approach, there is an estimative that, if it were possible to generate temporary carbon credits (tCERs[12]) in CDM standard projects, there would be a potential emission of 416 MtCERs, with more than half at a marginal abatement cost of less than R$2.50 per tCER. Finally, taking into account the risk of deforestation, the potential abatement from avoided deforestation emission was estimated to be around 11,000 $MtCO_2e$, and, of this total, approximately 1,000 $MtCO_2e$ would have a marginal cost of less than R$ 5.00 per tCO_2e in the studied scenario of strong environmental governance (WORLD BANK, 2021b).

Other potentials were mapped by the Brazilian Tree Industry (in Portuguese, *Indústria Brasileira de Árvores* - IBÁ). According to the work 7.8 million hectares of forest plantation areas of private entities, in 2015, were responsible for the stock of 1.7 billion tons of CO_2e, while the 5.6 million hectares of native vegetation conservation areas have the potential to stock 2.48 billion tons of CO_2e (IBÁ, 2017). Additionally, it is important to consider the potential for carbon sequestration in mangroves, tidelands, salt marshes and seagrass beds present in Brazil, given that the country has the second largest mangrove area in the world (approximately 1.4 million hectares), hundreds of hectares of carpets of seagrass and extensive areas of marshes and salt marshes (MINISTÉRIO DA FAZENDA, 2018).

It is highlighted that, in Brazil, there are several indigenous and traditional populations in the regions of interest to carbon projects in the Forest sector. Historically they act in environmental preservation and

11. The potential and abatement costs of all study measures directly related to the Forest sector are presented in the Annex (Table A - 2).
12. Represents permission to emit a metric ton of CO_2e. The temporary CER is a CER (certified emission reductions) issued for a forestry or reforestation project activity in the CDM that expires at the end of the commitment period after it was issued (KRUG, 2004). Thus, the tCER was used in the logic of CDM projects that are measured forest activities that continuously promote carbon removal in specific categories of land use, being possible to involve different time arrangements for the issuance of credits due to the risk of non-permanence of carbon stocks (WORLD BANK, 2021b). In contrast, in the context of VERRA, the issue of the risk of permanence is addressed through the application of a buffer and a Long Term Average Benefit (LTBA) approach.

can contribute to the development of these projects. Thus, it is relevant the participation of these populations is directly affected in the decision-making process and discussions about these projects (CEBRI, 2021).

SOCIO-ECONOMIC BENEFITS

In Brazil, the forest sector is responsible for generating approximately 7 million jobs (CNI, 2021a). In addition to the numerous benefits for physical and mental health provided by forests, ecotourism is a segment capable of stimulating the generation of jobs and income in the country. Parks have the potential to contribute R$ 44 billion to the Brazilian economy in which, for every R$ 1 billion, 22,000 jobs can be created (CNN, 2021).

Reducing deforestation and burning activities generate almost incalculable ecological benefits, especially in the Amazon and Cerrado biomes. Besides the biodiversity, all the services of the standing forest are preserved, such as the maintenance of hydrological cycles, absorption of carbon from the atmosphere, the microclimate and regional climate, and the maintenance of soil nutrients. Additionally, there is greater land regularization in the region and a greater diversity of products exploited in Forest Management Units. The reduction in fires is associated with a reduction in the incidence of respiratory diseases and the loss of forest carbon. The Adoption of associated strategies, such as payment for environmental services and incentives for sustainable forest management and non-timber forest products, increases the diversification of the economic activities (BRASIL, 2017a).

In addition, there are business opportunities through environmental services and credit markets, as well as the generation of employment, income, and the development of a local bioeconomy. The large-scale planting of native species and their sustainable exploitation can position Brazil as a leader in exports in the international market for tropical wood. This strategy provides, in addition to carbon capture from increased forest biomass, a reduction in illegal deforestation for timber production, a decrease in erosion, a loss of soil fertility, improving water quality and its availability. Forest restoration, when occupying pastures with maximum levels of degradation, can achieve rates of return on investment between 13% and 28%, compatible with the rates verified in investments in basic sanitation infrastructure. Among the benefits of ICLF, there is also an emphasis on the increase in local biodiversity. (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

Among the socio-economic benefits related to measures to reduce deforestation and restore forests are: (i) the high cost-effectiveness of mitigation options for the sector, compared to other sectors covered by the NDC, which favors investment flows; (ii) the encouragement and strengthening of a forest-based economy, including new business opportunities in biomaterials, biochemicals and bioenergy; (iii) the development of local productive arrangements (APL) or the integration of forestry activities into existing value chains, fostering business and adding value to forest-based products; (iv) the valuation of Natural Capital and Environmental Services, through the implementation of the Environmental Reserve Quota (in Portuguese, *Cota de Reserva Ambiental* - CRA) and Payment for Environmental Services (PSA), for example; (v) the economic use of the Legal Reserve; (vi) the benefits for the private sector when positioning itself in a clear manner, aligning the objectives of forest preservation and the restoration and the generation of new business (CEBDS, 2017b).

Box 6

Zero deforestation + investments in Amazonia

A recent study by NEMEA/Cedeplar-UFMG elaborated a zero-deforestation scenario with investments for agricultural land in the Amazon Biome. Such investments, conditioned to zero deforestation, would result in increased land productivity, reducing the area destined for agricultural production in the sector and, consequently, generating environmental gains. The total investment estimated by the model as necessary to neutralize the negative impacts of the zero-deforestation policy corresponded to R$ 1.45 billion over 20 years. In return, in this same 20-year period, would be avoided emissions of 40,000 Gg CO_2e and the deforestation of 10 million hectares would be prevented, in addition to an increase in the Biome's GDP of 0.68% (R$ 2.7 billion) and 0.48% in employment (DOMINGUES; CARDOSO; MAGALHÃES, 2021).

Box 7

Forest restoration in the Atlantic Forest

Suzano, Procter & Gamble, and WWF-Brazil became partners for the joint planning of the Atlantic Forest restoration in Espírito Santo. The initiative, aligned with other native forest recovery projects implemented by Suzano, is part of P&G's commitment to having all carbon-neutral operations through this decade. The project aims to ensure the protection and recovery of the Atlantic Forest from a movement that encompasses social, environmental, and sustainable development aspects. The actions in Espírito Santo are led by WWF-Brazil and have Suzano's support and expertise in generating income for local communities. The recovery of the forest landscape in the Atlantic Forest produces benefits for biodiversity and the population of the region, besides contributing to water security and carbon capture from the preserved and recovered areas.

OPPORTUNITIES FOR THE PRODUCTION CHAIN

There are several opportunities for the production chain arising low carbon strategies application in the forest sector. For example, when dealing with the restoration of permanent preservation areas (PPA) of family farmers, the possibility of increasing the supply of fruits and non-wood products will arise. For medium and large landowners, the recovery of degraded pastures through reforestation makes it possible to recover soil quality; to improve animal welfare, increasing the quality of livestock; in addition to the supply of non-timber products and wood with high added value, utilized for the production of furniture and buildings. Additional possibilities of generating products related to other sectors are bioproducts, -such as bioplastics, biochemicals, and biolubricants - and biofuels, through the use of wood waste in thermoelectric plants and the production of energy from forest biomass, for example. The restoration and reforestation activities themselves generate jobs and income due to the planting, seed collection, and maintenance of the areas (CEBDS, 2017b).

Box 8

Private technology in forest monitoring

Just as in the agriculture and cattle-raising sector, the application of measures related to the forest sector can also stimulate technological sectors, for instance, through monitoring mechanisms. Microsoft, for example, is developing a tool with sensors and satellite images that monitors the growth of trees and estimates the amount of carbon captured from the atmosphere based on improved soil cover (SCHERER, 2021).

Box 9

Sociobiodiversity and modern technologies for the sustainable development of the Amazon

The Amazônia 4.0 project, coordinated by climatologist Carlos Nobre, seeks to encourage the local economy sustainably to increase the added value of local products, such as açaí, and thus increases the income of local communities. The project aims to create biofactories for the production of the final product, as in the case of cocoa. In addition, the project also originated the Amazon Creative Laboratories, aiming to create solutions and added products for what is extracted from the forest. By seeing the possibility of increased income through forest products, local producers will have a greater interest in protecting the Amazon forest and take a stand against deforestation (JORNAL DA USP NO AR, 2021).

ENERGY SECTOR

With its unique electric matrix, Brazil stands out with 83.2% renewable generation comparing to other countries. The country has shown strong growth in its wind and solar power generation in recent years, increasing from 2,177 GWh in 2010 to 55,986 GWh in 2019 (growth of 2,571%) and from 2 GWh to 6,655 GWh (growth of 332,650%), respectively (MINISTÉRIO DE MINAS E ENERGIA; EPE, 2020). Currently, wind energy corresponds to 10.4% of the Brazilian generation, while solar energy represents 1.87% (ANEEL, 2021).

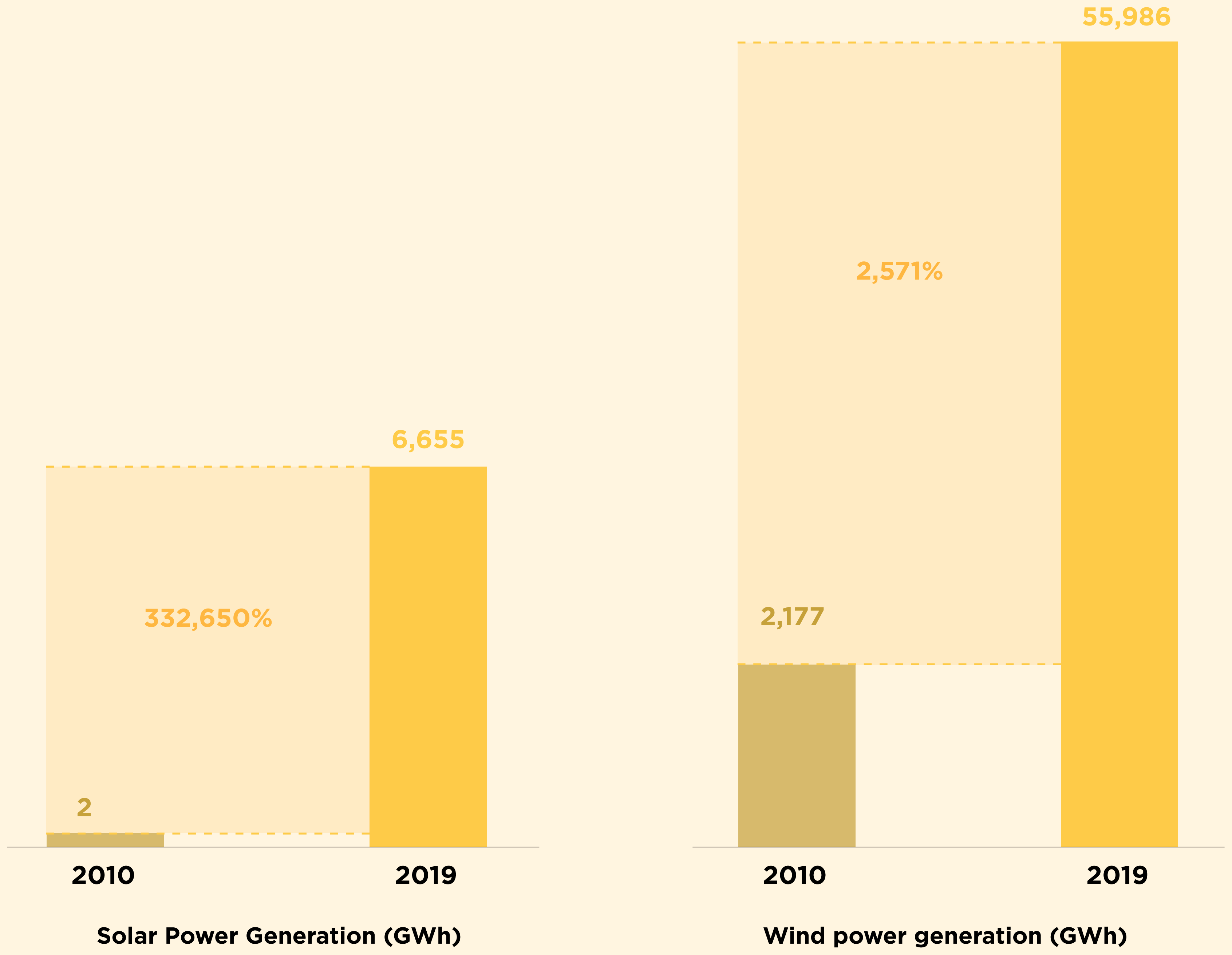


Figure 4: Solar and wind power generation in Brazil, 2010 e 2019
Source: Adapted from Ministério De Minas e Energia; EPE (2020).

The energy sector as a whole accounted for 19% of GHG emissions in 2019 and is historically one of the sectors with the higher increase in emissions in the country between 1990 and 2019, primarily due to the transport sector, which accounts for 47% of energy sector emissions (SEEG, 2020).

To reduce GHG emissions effects in transportation, Brazil has several public policies to encourage the generation and consumption of biofuels, such as the mandatory addition of ethanol to gasoline, the National Program for Biodiesel Production and Use (in Portuguese, *Programa Nacional de Produção e Uso do Biodiesel* - PNPB), and RenovaBio. Thus, the consumption of biofuels has been increasing in the country, with a projected growth of 3.7% per year for domestic consumption of fuel ethanol and 4.7% for biodiesel consumption between 2021 and 2030, according to the Ten Year Expansion Plan for Energy (MINISTÉRIO DE MINAS E ENERGIA, 2020).

TECHNOLOGIES FOR EMISSION REDUCTION

The Mitigation Options Project estimated potentials and abatement costs related to energy sector considering a low-carbon scenario for the period up to 2050 (BRASIL, 2017b). Among the main mitigation measures presented, which are related to NDC measures and those accepted by the voluntary VCS and Gold Standard, the total abatement potential could reach 1,273.4 MtCO_2e by 2050 if the measures were applied in combination[13]. The abatement cost varies from -5.5 to 24.185,0 US$/t$CO_2$ between the measures. In the hydroelectric subsector are highlighted the installation of hydrokinetic turbines and the repowering of existing plants, the latter being close to cost-effectiveness.

13. The potential and abatement costs of the main measures in the sector can be found in the Annex (Table A - 3).

Box 10

Floating solar photovoltaic (PV) installations open up new opportunities to increase solar generation capacity.

Photovoltaic solar use of hydroelectric plant surfaces can be a great alternative to large, flexibly operated installations and can be used to increase the energy production of these assets and help manage periods of low water availability. That allows the operation of the hydroelectric plant in "peak" mode instead of "baseload" with mutual benefits. Hydroelectric power can soften variable solar production by operating in a "load tracking" mode. Other possible improvements are: reducing evaporation and improving water quality due to reduced algae growth. However, there are still challenges for its implementation, among them, the lack of a robust history of this type of investment; uncertainty around costs and about the forecast of the environmental impact; and the technical complexity of the design, construction, and operation in the water (especially electrical safety, anchoring and mooring issues and operation, and maintenance) (WORLD BANK, 2018).

Another main area would be wind power, taking into account the Brazilian potential in extracting energy from higher altitude winds and in coastal areas, via offshore wind power plants[14] (FERREIRA, 2020). The least-cost abatement measures include increased power generation at distilleries from the intensive use in boiler and straw co-processing in the biofuels sector and efficiency increases at oil and natural gas thermoelectric plants due to the potential for net revenue generation, thus demonstrating the cost-effectiveness of these measures, which are therefore called no-regret (BRASIL, 2017b).

Brazil is the world's second-largest producer of biofuels, with 25% of global production, second to the United States, responsible for 42% of production (IEA, 2020). Although the main sources of Brazilian biofuel production are sugarcane and soybeans, other inputs can be used such as castor beans, oil palm, sunflower seeds, and palm oil, present in the semi-arid North and Northeast regions. These regions count on family farming tax incentives for producers who buy raw materials from family farmers included in the Programa Nacional de Fortalecimento da Agricultura Familiar (PRONAF) (IPEA, 2005). The potential for use in bioenergy technology with carbon capture and storage (BECCS) is also considered in Brazil (KÖBERLE, 2018).

By the use of biomass, given the edaphoclimatic characteristics of the country, it is possible to obtain several sources of these materials as an alternative for energy use, such as sugar cane residues (bagasse, straw, vinasse); wood industry residues; soy, and corn crop straw, etc. (EPE, 2018). This availability allows the use of by-products for energy generation which, especially the by-products of sugarcane processing, are responsible for generating 16.7% of the energy consumed in the Brazilian industry in 2019 (MINISTÉRIO DE MINAS E ENERGIA; EPE, 2020). In this scenario, the production of second-generation ethanol (E2G) emerges as an opportunity to expand the use of by-products for energy generation, with a production potential of up to 10 billion liters by 2025, with the advantage that waste destined for E2G production can be used in off-season periods when the plants are idle (BNDES, 2016).

In addition to the technologies considered in the Mitigation Options Project, green hydrogen - generated from electrolysis, which uses electricity to separate hydrogen from water - is worth mentioning. For hydrogen to be considered green, the energy for hydrolysis is required to be from renewable energy. In December, an alliance was created - the Green Hydrogen Catapult - with seven of the world's largest companies producing hydrogen from renewable energy

Box 11

Cogeneration of residual gas processes

Siemens Energy has designed a cogeneration plant powered by a process residual gas with high hydrogen content to reduce water use and CO_2 emissions for Braskem, the largest producer of thermoplastic resins in the Americas and a world leader in the production of biopolymers, at the Mauá (SP) plant. Due to network quality problems and low efficiency in gas consumption, Brazil has a history of production losses and high maintenance costs. As Braskem serves, among other regions, the extensive city of São Paulo with more than 12 million inhabitants, the company also needed to reduce its environmental impact, minimizing water use and CO_2 emissions. In partnership with Siemens Energy, Braskem has found a solution: the ABC Petrochemical Pole project in Mauá will modernize the region's power generation system, resulting in greater production efficiency, while improving the company's sustainability indicators.

14. According to the Energy Research Company, Brazil has a technical potential of 700 GW for offshore wind power generation in deep locations up to 50 meters.

Box 12

Use of Second Generation Ethanol in Brazil

With disruptive technology, the new plant of the Raízen joint venture integrates a new strategy of the Shell Group. The second E2G plant will be integrated into the Bonfim bioenergy plant, which in addition to the production of sugar, first-generation ethanol, and electricity from sugarcane biomass, also houses the first Biogas plant of Raízen, inaugurated in October 2020. The new plant is expected to go into operation in 2023. With the start of operation of this second unit, Raízen's total production capacity will be approximately 120 million liters of E2G ethanol per year. E2G is obtained from sugarcane biomass instead of broth used in the traditional production. The announcement of the new unit in Guariba meets the growing demand for the product in the international market, with most of its volume already sold in long-term contracts with a global player. With the mastery of technology, Raízen consolidates itself as the only producer in the world to operate two cellulosic ethanol plants on an industrial scale.

to increase the feasibility to build 25 gigawatts of green hydrogen capacity by 2026 (MACHADO, 2021). In this way, fuel costs could be reduced to US$2/kg over the period. Currently, the cost of green hydrogen is between US$3 and US$6.55/kg (DICHRISTOPHER, 2021).

SOCIO-ECONOMIC BENEFITS

An increase in the use of renewable energy sources in the industry can have positive impacts on employment and income generation since jobs in renewable energy chains are generally more labor-intensive than jobs in fossil energy chains. Brazil, for instance, shows itself to be a powerhouse when it comes to the labor force employed in the renewable energy sector, especially in the bioenergy chain with almost 839,000 jobs in biofuel generation, corresponding to almost 70% of all jobs generated related to renewable energy (IRENA, 2019). It is estimated that through the purchase of GHG emission reduction certificates (CER) from CDM projects throughout its portfolio, 8.74 million people have gained access to renewable energy, 14,500 new job opportunities have been created, and 1.31 million people, mainly women, and children are benefiting from better air quality, among other co-benefits (UNFCCC, 2018).

Regarding the co-benefits of measures in the biofuels sector, biodiesel production allows the reduction in variable energy costs due to the production efficiency resulting from purification technologies. While the implementation of technologies associated with the production of advanced biofuels such as ethanol and cogeneration generates higher added value through the productive use of biomass, it also allows the creation of new jobs in rural regions (BRASIL, 2017c). In addition, there are logistical advantages when it comes to the use of biomass fuels in locations far from main consumption centers and which lack infrastructure. Local production increases the generation of social benefits and gains in energy efficiency (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

Among the co-benefits associated with the adoption of low carbon activities applicable in the renewable electricity generation sectors are also those related to energy security and the creation of local photovoltaic (PV) and Concentrating Solar Power (CSP) panel components (BRASIL, 2017d). In Brazil, the Northeast and Midwest regions have irradiation conditions considered very good when compared to regions where solar energy has already reached more significant participation in the electricity matrix, such as in countries like Germany and Italy (BRASIL, 2017d). The benefits of self-generation solar energy outweigh any costs to Brazilian consumers and are capable of generating R$ 139 billion in new investments for the country by 2050 (ABSOLAR, 2021a). Concerning job generation, solar power generation has reached 166,000 cumulative jobs in the country since 2012 (ABSOLAR, 2021b). As for the wind power generation sector, ABEEólica estimates that the investments of R$66.95 billion made between the years 2011 and 2019 were able to create, on average, more than 498,000 jobs per year in the Northeast and South regions of Brazil - regions that concentrate most of the wind power plants (OLIVEIRA *et al.*, 2020).

In relation to the co-benefits associated with energy efficiency in natural gas and oil thermoelectric plants, it is highlighted the reduction of operational costs with competitiveness gain in the long term (BRASIL, 2017e). Opportunities related to low-carbon electricity systems are associated with increased energy efficiency, linked to reduced demand for new power plants, new power grids, and reduced costs related to fuel consumption. Such an increase in efficiency contributes to greater sectoral sustainability, with a potential impact on electricity tariffs. In addition, the rational use of energy promotes greater energy security for the country and less exposure to external dependence (CEBDS, 2017c). Additionally, the response to energy demand should be improved with the use of smart grid technologies and smart meters, improving consumers' ability to make decisions regarding energy consumption. With this, it is expected that there will be a reduction in the activation of thermal power plants so that the maximum demand is met, as well as a reduction in generation costs (REGO *et al.*, 2019).

Waste-to-Energy technology (WtE), referring to the power generation process in the form of electricity and heat, is also an opportunity for the energy sector because it is an energy source, besides allowing waste management with an efficient final disposal method (SUN *et al.*, 2020). The possibility of making the process carbon neutral to restrict incineration to waste derived from non-fossil fuels makes the WtE even more attractive. The WtE process, in addition to avoiding CO_2 emissions generated by the use of fossil fuels, eliminates potential methane emissions from landfills, thus avoiding any possible release of this gas in the future (HETTIARACHCHI; KSHOURAD, 2019).

OPPORTUNITIES FOR THE PRODUCTION CHAIN

For opportunities related to the use of new technologies and low carbon fuels, such as biofuels and biogas, although still little used, it has great potential for distributed energy generation, adding value to industries that produce large amounts of organic waste, such as the food, environmental sanitation, and sugar-energy sectors. Regarding the expansion of biodiesel production, as well as ethanol, there are relevant economic and social gains in its production chain and co-benefits for the biofuel expansion measure (CEBDS, 2017c).

Box 13

Technology strengthening the biofuels chain

Looking forward to ensuring the reliability and security of information about the origin of raw materials and supplies, Embrapa is conducting a project supported by blockchain technology for the storage, registration, organization, and tracking of products from the sugar and ethanol sector. Although the initial idea was to trace the sugarcane chain to add value to the product, the project showed the potential of the technology being used also by biofuel producers. They showed interest in using it for Renovabio's energy and environmental efficiency calculator (RenovaCalc) to enable the emission of decarbonization credits (CBios) from the program (MACHADO, 2021b).

Regarding the solar segment, the solar photovoltaic value chain comprises manufacturers and suppliers of goods and all services related to the segment. Besides the fact that the energy chain hires the most in the world in manufacturing, installation, operation, and maintenance, distributed energy generation generates opportunities for small businesses in the photovoltaic segment, such as reaching a larger and more comprehensive potential market (SEBRAE, 2018). The value chain associated with the wind power segment also generates opportunities for the insertion of small businesses, such as consulting services (SEBRAE, 2017).

TRANSPORT SECTOR

The transport sector is responsible for 47% of the energy sector's emissions, contributing to 13.8% of national emissions. It is predicted that the transport sector will be responsible for 55% of the increase in national emissions by 2025. In the sector, there is a large set of easily accessible opportunities associated, mainly, with technological leadership and energy policies such as PROALCOOL and Renovabio in the country, which favors the production of renewable energy sources, such as biofuels. The projected share in the energy matrix of transport is about 30% in 2030 (BRASIL, 2021f).

TECHNOLOGIES FOR EMISSION REDUCTION

When considering a low-carbon scenario, the Mitigation Options Project estimated the abatement potentials and costs related to measures for the transport sector throughout 2012 - 2050. If applied together, the measure would have the cumulative abatement potential of 1,575 $MtCO_2e$ by 2050, with costs ranging from -36.68 to 441.98 US$/$tCO_2e$. The measures with the highest potential for abatement are concentrated in the road mode and include hybrid vehicles, more efficient heavy trucks, and more efficient flex-fuel. The modal shift from cars to urban buses and subways is the measure that presents the highest abatement potential[15] . Regarding abatement costs, the implementation of hybrid vehicles had the highest cost, while the implementation of more efficient urban buses had a negative abatement cost, thus presenting a net revenue generation potential. Focussing on incremental improvements in buses and making them 30% more efficient demands less effort in comparison to other implementation options. Finally, after the implementation of more efficient urban buses, the modal shift from cars to urban buses and subways is again highlighted, as it presents the lowest abatement cost among the measures studied (BRASIL, 2021f).

SOCIO-ECONOMIC BENEFITS

The key socio-economic benefits include job creation, local development, access opportunities, and support for poorer communities (WRI BRASIL; NEW CLIMATE ECONOMY, 2020). It is estimated that the investments required for freight transport infrastructure improvement would represent about 2% of the GDP, bringing a return in just three years (ANTONACCIO *et al.*, 2018).

Among the benefits associated with energy efficiency, modal shifts and the use of biofuels resulted from transformations in the transportation matrix in the sense of the efficiency of the modals. That goes beyond fuel savings, including improvements in national energy security, related to the reduction of oil dependence, as well as the operating costs reduction in the sector and greater technological dissemination (BRASIL, 2017f).

Increased energy efficiency in the transport sector generates benefits associated with public health due to air pollutants reduction and increased safety on the streets due to accidents reduction. In metropolitan areas, most accidents and traffic jams involve trucks older than 20 years since older vehicles need more parts, becoming more conducive to accidents. In this sense, the renewal of the truck fleet to ensure better energy efficiency and greater economic efficiency is also responsible for providing more safety on streets and roads (BRASIL, 2017f). Regarding health costs, these can be significantly reduced through investments in clean and efficient public transport infrastructure, which can reduce congestion, accidents, and improve air quality, especially in large urban centers (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

Investments in the expansion of public transport and improving vehicle efficiency can lead to the creation of more than 3 million net jobs annually in cities of the Organization for Economic Cooperation and Development (OECD), and between 3 million and 23 million net jobs annually in non-OECD cities in the period up to 2050 (GOULDSON *et al.*, 2018). The modal shift from light vehicles to public transport also allows the reduction in the level of congestion in cities (BRASIL, 2017f).

15. The potential and abatement costs of all measures can be found in the Annex (Table A - 4).

Congestion costs, through lost time and wasted fuel, add up to more than 1% of GDP in most developed cities and up to 10% of GDP in developing cities (GOULDSON *et al.*, 2018). In addition, the modal change allows achieving improvements in the quality of life of the population associated with greater accessibility and incentives to cultural programs and historical centers, with initiatives of sharing bicycles, use of electric vehicles (BRASIL, 2017f)The value of health benefits of investments in cycle infrastructure can reach more than five times the necessary investment (GOULDSON *et al.*, 2018).

The use of alternative fuels with low carbon emissions, such as biofuels, also contributes to improvements in energy security by allowing the diversification of fuel consumption in the sector, as well as helping to generate jobs and income in the industry and rural areas (BRASIL, 2017f).

OPPORTUNITIES FOR THE PRODUCTION CHAIN

The opportunities in the transport sector are related to low carbon technologies that provide efficiency gains and opportunities for the insertion of new technologies in the sector towards emission mitigation, mainly for the integration, the modal shift, and for urban mobility and low carbon fuels.

Opportunities associated with efficiency measures may include incremental improvements, hybridization and electrification technologies, and actions related to demand management. For the automotive industry, incremental efficiency opportunities may occur through engine downsizing, which is gaining ground in the industry, with the potential to reduce GHG emissions by up to 15% in light-duty vehicles and up to 30% in hybrid configurations. Another opportunity associated with incremental efficiency is vehicle weight reduction. Weight reduction measures involve the value chain more broadly, allowing the generation of opportunities for different industry segments, mainly encompassing the steel, petrochemical, and auto parts sectors. Furthermore, hybridization and plug-in electrification technologies are associated with disruptive efficiency gains (CEBDS, 2017d).

Expanding the share of low-carbon fuels reduces the dependence of the transport sector on fossil fuels. Encouraging the production of biofuels is also related to the generation of new markets, which can benefit from the trend toward regulation in favour of the transition to cleaner fuels. Furthermore, the increased use of biofuels allows the development of ethanol fuel cells for trucks over long distances, providing, in addition to efficiency gains, also a reduction of the vulnerability of Brazilian logistics to variations in international diesel prices and, helping to mitigate the negative impact on the trade balance due to the need to import diesel, since the Brazilian refineries currently do not have the capacity to produce enough fuel to meet the country's demand (WRI BRASIL e NEW CLIMATE ECONOMY 2020).

Concerning modal shift in passenger and freight transport, there are promising possibilities for reducing the energy intensity of trips in which the transition of demand from individual transport to public transport allows for lower energy consumption per passenger kilometer travelled (CEBDS, 2017d).

There are also opportunities associated with the technological branch arising from the transport sector, such as the implementation of Intelligent Transportation Systems (ITS), which contribute to the integration of different modes capable of reducing displacement in urban centers by 15% to 20%, besides allowing the reduction of pollutant emissions by 10%. In financial terms, the market for SITs worldwide is expected to reach US$2.5 trillion per year by 2025 (CEBDS, 2017d). Additionally, IoT, Cloud, and Artificial Intelligence (AI) solutions can help to provide the data intelligence for traffic and transit optimization through automated sensors, which also results in lower operating costs due to decreased downtime and optimized maintenance using smart sensors and devices.

INDUSTRIAL SECTOR

The domestic industry represents 20.4% of Brazilian GDP and accounts for 5% of gross national emissions, with a 2% decline from the total emissions in the previous year (2018) (CNI, 2021b; SEEG, 2020). However, indicated by the business sector (CEBDS, 2018b), Santos (2018), and the PMR Brazil Project (2021a), the industry is a key for a national ETS in Brazil. Therefore, for the identification of opportunities, this work will consider the same sectors as mentioned in the reports: cement, pig iron and steel (steelmaking), aluminum, lime and glass, paper and cellulose, and chemicals, all part of the transformation industry and will focus on mitigation opportunities in their processes.

Based on the abatement potentials identified in the selected sub-sectors, an accumulated emissions mitigation potential of 261 $MtCO_2$ is estimated regarding the measures described in the first Brazilian NDC. It is worth mentioning that the NDC for the industrial sector has a very generic character, not in specifying technologies, but in general their measures.

TECHNOLOGIES FOR EMISSION REDUCTION

Each of these subsectors has its specific sphere of mitigation opportunities with new clean technology standards, scaling up energy efficiency measures, and expanding low-carbon infrastructure.

In the cement sector, the Mitigation Options Project estimated potentials and abatement costs related to measures for the sector with an accumulated potential by 2050, in the Low Carbon scenario, of approximately 90 $MtCO_2e$, with abatement costs ranging from -7 to -161 US$/$tCO_2$ (OLIVEIRA, 2019)[16]. The cement sector has in the furnace efficiency increase and, mainly, in the reduction of the clinker/cement ratio the main opportunity to reduce emissions additionally to the gradual petroleum coke reduction with the substitution, principally, for the greater use of biomass and natural gas - fuels with lower emission factors - and the co-processing of residues (CEBDS, 2017e).

Box 14

Co-processing of açaí seeds in cement production

Since 2017, Votorantim Cimentos has been using açaí seeds to replace fossil fuels used in cement kilns. In 2017, about 550,000 tons of Acai seeds were produced in the state of Pará, and part of these seeds, previously discarded, now undergo a drying process and replace part of the petroleum coke used in the kilns. With this, it is possible to reduce the emission of greenhouse gases in the plant and the transport of the coke, now imported in smaller quantities (VOTORANTIM, 2018).

In the pig iron and steel sector, the Mitigation Options Project provides mitigation opportunities for the sector with an accumulated potential by 2050, also in the Low Carbon scenario, of approximately 54 $MtCO_2$ with abatement costs between -330.35 and 150.07 US$/tCO[17]. The most representative measure is the new furnace technologies implementation in the integrated mills (especially SCOPE - Super Coke Oven for Productivity and Environmental Enhancement) and sensible heat recovery in the furnaces (BRASIL, 2017g). The existing options involve energy efficiency of production processes, opportunities for the reuse of process gases and heat for energy purposes, and even the use of sustainable charcoal as a renewable energy source. The latter may be a competitive differential of the sector in Brazil since, currently, only the country uses this input in a scalable and efficient way. The future Brazilian steel industry will still rely on coke, but there will be greater penetration of renewable energy sources, especially sustainable charcoal, which may have a share of up to 50% in the steel industry by 2050 (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

16. The potentials and abatement costs of all measures analyzed in the study for the cement sector can be seen in the Annex (Table A - 5).
17. The potentials and abatement costs of all measures analyzed in the study for the pig iron and steel sector can be seen in the Annex (Tabel A - 6).

Box 15

Charcoal as an energy source in the thermal treatment of pellets

Vallourec steel mill uses 100% charcoal as an energy source in the thermal treatment of the pellets. To do this, the company built a plant suitable for the use of charcoal, adapting equipment built for coal use, related to the burning process, production process control, operation, and maintenance procedures. The new installation for this energy source use demonstrated not only good economic viability but also a large reduction in the emission of greenhouse gases (IBRAM, 2021).

In the chemical sector, the accumulated abatement potential by 2050, in the Low Carbon scenario, is approximately 46.7 $MtCO_2e$, with abatement costs between -70 and 81 US$/$tCO_2$. The main measures are related to the efficiency of motor systems and the adoption of natural gas in boilers and furnaces to replace more carbon-intensive fuels, such as coke, coal, diesel oil, and fuel oil (BRASIL, 2017h)[18] . Among the process measures and emerging measures, green chemistry through the renewable ethylene production route stands out because, although still emerging in the world, this technology is already dominating and adopted in Brazil. Excluding the analysis of feedstock production (which can increase the costs of the measure), the green ethylene route would be able to mitigate more than 30 $MtCO_2e$ in the analysis horizon until 2050 at negative costs, between -19 and -1 US$/$tCO_2$ (CEBDS, 2017e).

Box 16

Green Polyethylene

Braskem began producing green polyethylene on an industrial and commercial scale in 2010, a plastic produced from sugarcane instead of oil or natural gas. From the planting of the sugarcane to the production of ethanol, suppliers must comply with Braskem's "Responsible Ethanol Purchasing" principles, which cover aspects of sustainable development such as respect for biodiversity and good environmental practices. As the material produced has the same properties as polyethylenes of fossil origin, it can also be recycled within the same recycling chain as traditional polyethylene (BRASKEM, 2021).

In the lime and glass production sectors there is an accumulated potential to reduce emissions by 14.2 $MtCO_2e$ by 2050 with abatement costs between -53.90 and 292.20 US$/$tCO_2$. The measure with the greatest potential is the replacement of coke by natural gas in the lime sector (BRASIL, 2017i). For the glass industry, the increased recycling of glass used as a raw material mix constituent is an excellent opportunity as it mitigates 1 tCO_2 for every 6t of glass recycled and used in production, and strengthens the links in the glass recycling chain (ABIVIDRO, 2019).

In primary aluminum production, the accumulated emission reduction potential was estimated at around 39.4 $MtCO_2$ by 2050 with abatement costs between 0.16 and 326.08 US$/$tCO_2$ where heat recovery measures in the furnaces are highlighted (BRASIL, 2017i)[19] . There are also measures related to anode effect reduction that reduce perfluorocarbons (PFC) emissions.

In the Pulp and Paper sector, the potential in the BC scenarios in 2050 is 16.7 $MtCO_2$, with abatement costs between -330.70 and 929.50 US$/$tCO_2$, with the most representative measures being the application of specific dryers and the use of more efficient presses. In a scenario with innovation, the mitigation potential increases by 26% (BRASIL, 2017j)[20]. One should remember that this sector has a high potential for carbon capture through direct soil storage, accumulated through the growth of planted and/or native forests described in the section on the forest sector (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

Box 17

Reduction of anodic effects

Albras (2008) implemented a new computational program aimed at controlling and reducing the anodic effects of aluminum metal production. The activity involved two stages: the first was the installation of an "Anodic Effect Early Detection Algorithm", based on the resistance behavior of the cell to reduce the frequency of the anodic effect; the second stage was the installation of another algorithm, integrated with the first, which allows a further reduction in the frequency of the anodic effect. Between the years 2006 and 2015, the project reduced 802,860 equivalent tons of CO_2 (MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES (MCTIC); MINISTÉRIO DAS RELAÇÕES EXTERIORES, 2017).

18. The abatement potentials and costs of all measures analyzed in the study for the chemical sector can be found in the Annex (Tabel A - 7).
19. The abatement potentials and costs of all measures analyzed in the study for the aluminum sector can be seen in the Annex (Tabel A - 9).
20. The potentials and abatement costs of all measures analyzed in the study for the lime and glass sector can be seen in the Annex (Tabel A - 10).

Box 18

Carbon capture and storage technology

Carbon Capture and Storage (CCS) is a method to prevent carbon dioxide emissions from its source and allows for large-scale reduction of CO_2 already present in the atmosphere through its removal technologies (GLOBAL CCS INSTITUTE, 2020). In this sense, CCS includes three technologies: capture, transport, and storage. The capture process includes the separation of CO_2 from the gases generated from various procedures. Once separated, captured CO_2 is transported to a suitable location for storage through pipelines. Finally, there is the injection of CO_2 into deep underground rock formations (VERIFIED MARKET RESEARCH, 2020). CCS technology can play a key role in reducing CO_2 emissions from the industrial sector. The cement, iron and steel, and chemical subsectors emit carbon due to the nature of their industrial processes, configuring themselves as the harder subsectors to decarbonize. Thus, CCS technology is one of the most economically viable available solutions for achieving zero net emissions in industries of these subsectors. To achieve a climate result consistent with the Paris agreement, the CCS is expected to slaughter 29 billion tons of CO_2 between 2017 and 2060 in these subsectors. This technology is especially applicable in the chemical industry, delivering 14 billion tons of CO_2 slaughtered by 2060 (GLOBAL CCS INSTITUTE, 2020).

Finally, it is important to note that rising energy costs stimulate energy efficiency measures that are adopted in the cement and chemicals sector and, to a lesser extent, in the steel industry and other sectors (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

SOCIO-ECONOMIC BENEFITS

The sector presents economic benefits linked to cost reductions related to fuel and energy consumption due to the optimization of combustion processes and the installation of more efficient equipment. Moreover, cost reductions are possible regarding raw material consumption due to the use of more economically viable and cost-effective options or recycled material. Additionally, it has additional financial returns and cost reductions due to the economic valuation of waste and the lower volume destined for disposal, characteristics of the circular economy as well as the reduction of logistics costs from the modal integration, which allows the reduction of the participation of road mode in the sector, responsible for the highest cost per kilometer traveled (CEBDS, 2017f).

Energy and process efficiency measures and the reuse of by-products as raw materials in different production lines will play an even more critical role in the medium and long-term economy. Mitigation measures in the industry, such as energy efficiency, have a positive impact on service chains, generating business opportunities and consequently new revenues for small and medium-sized companies such as ESCOS (Engineering Companies, specialized in Energy Conservation Services). The partial substitution of raw materials, especially for pig iron, cement, and steel, strengthens the links in the recycling chains of these materials and can facilitate a structure collection and distribution of these recyclables, generating more jobs with auxiliary services and local income, as well as enhancing the local supply of alternative biomass and recyclable materials.

There is also the generation of employment and income by increasing the competitiveness of the production poles associated with the implementation phase of the low carbon technologies (BRASIL, 2017k). Job creation in a WRI-defined new economy scenario is estimated to be about 11% higher than the Business as Usual (BAU) scenario, with 19.7 million jobs in this sector by 2040 (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

Furthermore, the sector presents benefits from the adoption of technologies such as cloud computing and big data, which aggregate data such as location, the slope of the terrain, and the composition of the soil to support the work of the companies that monitor the planted areas.

Box 19

Revenue generation by the industry in the agricultural waste chain

In the state of Ceará, an environmental-renewable energy project, certified by the Gold Standard, replaced in five ceramic factories the use of fuel from illegal firewood for agricultural and industrial waste. This replacement generated $4.5 million in revenues for local communities, improved working conditions, increased water availability, and avoided deforestation of 1,750 hectares in ten years, and reduced greenhouse gases (GHG) emissions by 36,173 tons of carbon dioxide equivalent (CO_2e) per year (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

OPPORTUNITIES FOR THE PRODUCTION CHAIN

There is an interaction of the industry with other sectors of the economy as there are interdependencies between the energy, transport, and forest sectors providing the ability for the industry to achieve, on a broad basis, GHG emission reductions. The energy sector can provide low carbon intensity fuels through biofuel and biomass production and increases the renewable content of electricity generation. The transport sector can contribute to the reduction of emissions from the industry through new infrastructure that allows modal integration and the electrification of freight modes, especially rail. Greater infrastructure integration will provide, in addition to emissions mitigation, opportunities for efficiency gains and reduced logistics costs. Moreover, the forest sector will increase the supply of biomass that can be used for energy production, both electricity and thermal, or consumed as a renewable raw material (CEBDS, 2018b).

Finally, digitalization enables improved monitoring of the entire production process, resulting in:

I. the allocation of equipment with greater efficiency, optimizing processes;

II. speed in identifying problems and reducing bottlenecks;

III. increased efficiency in the use of resources, such as electric power; and

IV. the reduction of costs (CEBDS, 2017f).

In this sense, the transition to Industry 4.0 is a positive trend for the sector. The integration of the industry with the increase of information provided by the technologies characteristic of Industry 4.0 is responsible for the opportunity to increase productivity in this sector through the optimization of processes, efficiency gains in the expenditure and use of inputs, expansion of increasing returns of scale and reduction of the cost of production and the marginal cost of production (CEBDS, 2017f).

VISION SIMPLIFIED OF RELATIONSHIPS INTERSECTORAL MITIGATION OF GHG

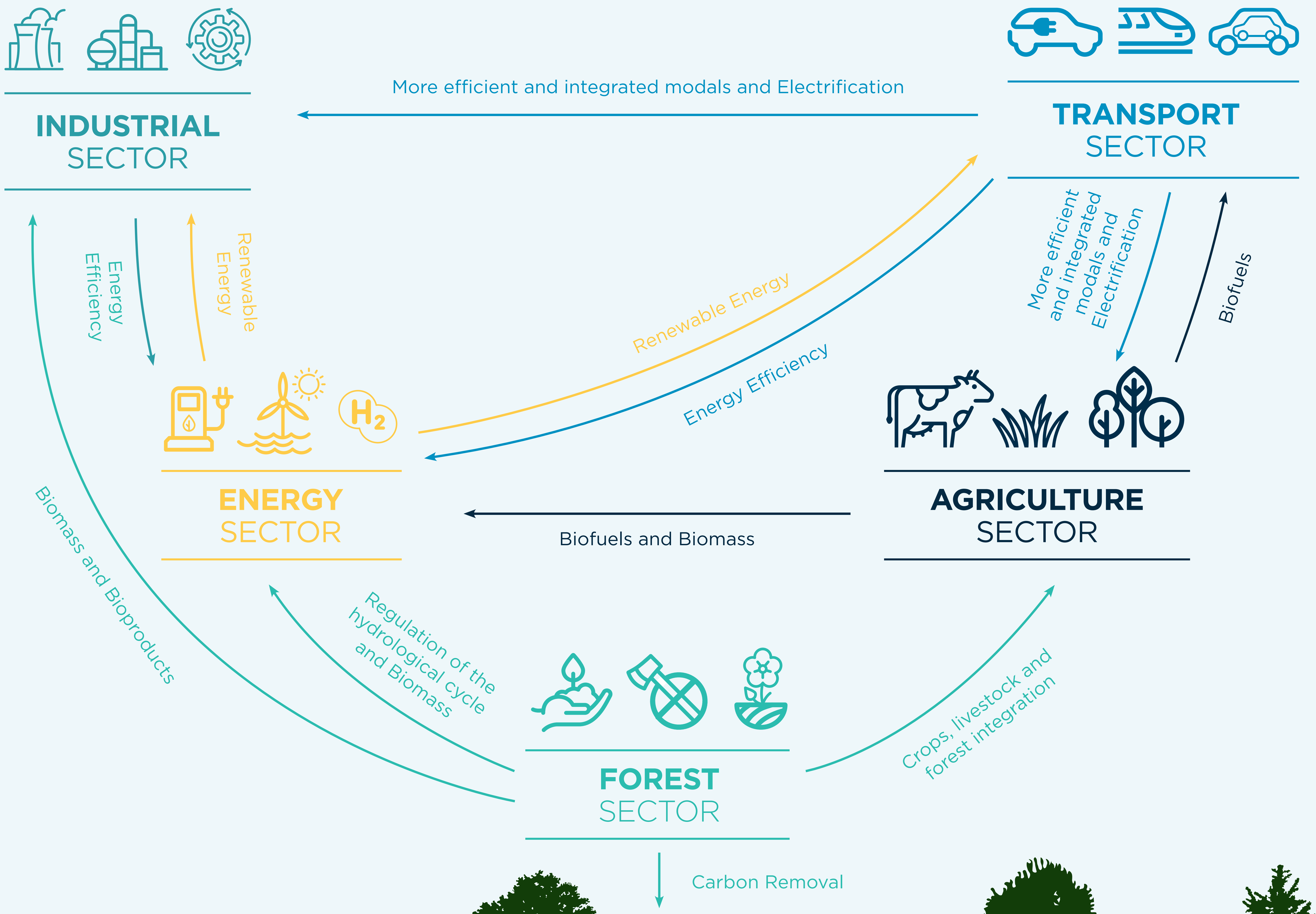


Figure 5: Intersectoral GHG Mitigation Relations
Source: Authors' elaboration.

MARKET ACCESS IDENTIFICATION

The potential opportunities for carbon credit generation listed in the Sector Review point to extremely relevant GHG reductions, numerous socioeconomic benefits, and leverage opportunities in the production chain. Though, the path between characterizing the potential generation of credit and issuing credit is long and complex and connects intrinsically with the conceptualization made in the Contextualization of this work in which carbon credit will be I. the right to issue GHG or II. certificate of reduction of GHG emissions.

Therefore, before identifying the potential access of credits to carbon markets, concerning supply and demand, it is necessary to define in more detail what would be each type of market addressed in this work that is the markets to be regulated under Articles 6.2 and 6.4 of the Paris Agreement and voluntary markets that, in the thesis, would transpose in Article 6.2 a right of emission and in 6.4 and on the voluntary market, a certificate of reduction of GHG emission.

ARTICLE 6

PREDECESSORS

Until 2020, the Kyoto protocol was in force, which established an ETS between Annex I and non – Annex I countries, of which Brazil was a part, and two compensation mechanisms – the Joint Implementation and the Clean Development Mechanism (CDM). Until 2017, Brazil ranked third in the number of CDM projects, behind China and India, with a reduction potential of up to 379.8 million tonnes of CO_2 (tCO_2e). In numbers of Certified Emission Reductions (CERs) effectively issued by the CDM Executive Board, Brazil ranked fourth, which corresponds to approximately 124 million tCO_2e avoided (IPEA, 2018).

Table 1: Participation of each country in aspects of the CDM (Nov/2004 to Apr/2017)

	CDM project activities recorded by country	Annual GHG Reduction Potential by country in CDM projects	CERs Issued by host country
China	48.4%	59.4%	57.1%
India	21.1%	11.5%	12.6%
Brazil	4.4%	4.9%	6.8%
South Korea	ND*	2.0%	8.9%

*Not provided in the reference document.
Source: (IPEA, 2018).

Between November 2004 and April 2017, 342 project activities were registered in the CDM Executive Board by Brazil, with a peak of activities in 2006, when the CDM began to establish itself in the carbon market, and another peak in 2012, at the end of the first compliance period of the Kyoto Protocol commitments. In relation to CERs issued to participants in CDM project activities in Brazil, we highlight the years 2007 and 2008, which together concentrated almost 20% of total CERs issued. This concentration is due to the reflection of global competition to encourage emission reduction projects, and the biennium of 2011 and 2012, with 26% of total CERs issued, possibly as a result of the uncertainty about the continuity of the CDM after the end of the first period of the Kyoto Protocol (IPEA, 2018).

Historically, the predominant CDM project activities in Brazil were related to the energy and waste sector, corresponding to hydropower projects, with 27.5% of registered projects; followed by biogas projects (18.4%); wind (16.7%); landfill gas (15.2%); and energy biomass (12%). These five activity types accounted for 83% of the total 379.8 $MtCO_2e$ of estimated GHG emission reductions from Brazil's CDM project activities by April 2017. These five activity types accounted for 83% of the total 379.8 $MtCO_2e$ of estimated GHG emission reductions from CDM project activities project activities by April 2017 (IPEA, 2018).

ARTICLE 6.2 AND 6.4

With the regulation of Article 6 of the Paris Agreement which is scheduled for COP 26 in November 2021, there are two new mechanisms that differ from the previous ones by considering that, with the Paris Agreement, all signatory countries now have emissions reduction targets, even if these goals have different metrics or different periods for compliance.

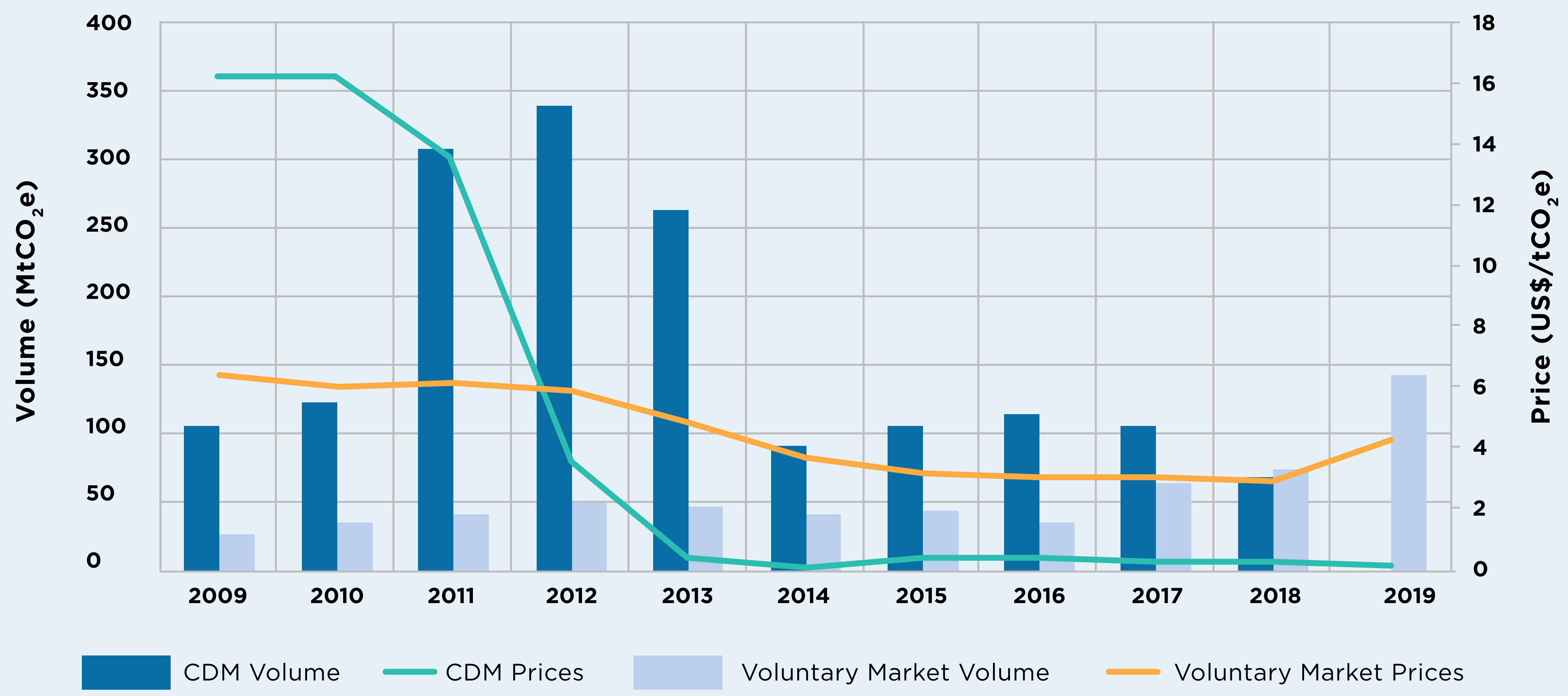
Article 6.2 aims to establish a mechanism for the commercialization of internationally transferred mitigation outcomes traded directly between countries that follow the Agreement, similar to the GHG emission reduction certificate (EVANS; GABBATISS, 2018). This mechanism would be based on a credit generation system above a baseline that indicates how emissions would evolve without the market instrument incentive (SEROA DA MOTTA, 2021a).

The regulation of Article 6, both 6.2 and 6.4, has been facing some bottlenecks to its establishment, such as issues related to the corresponding adjustment. For instance, the adjustment of GHG emission targets provided for in the NDCs equivalent to the number of carbon credits or mitigation results sold to other countries, issues related to the rules for the transfer of credits, methodologies, and types of project validity in the transition of Kyoto Protocol to the Paris Agreement.[21]

CARBON MARKETS TODAY

Both the regulated and voluntary markets have seen an increase in carbon credit transactions in recent years. The total value of the global carbon markets grew by 34% to €194 billion, with over 14,500 carbon credit projects registered in the past. Nearly 4 billion tCO_2 of carbon credits have been generated up to 2020, with the forest sector issuing more credits than other sectors (42% in total over the last 5 years) with an increase in forest offset transactions and an apparent preference for projects that generate co-benefits. More than half of all credits were issued by CDM projects (MARKESTRAT *et al.*, 2020), which changed as of 2018, when almost two-thirds of credits were issued by independent mechanisms in the voluntary market, according to Graphic 1.

The volume of global carbon credit emissions in the voluntary market was 142 $MtCO_2e$ in 2019, with 66.2% of the volume transacted globally in that year corresponding to the VCS standard. In Brazil, 5.08 $MtCO_2e$ credits were issued by the VCS program, representing 3.6% of the voluntary credits issued globally that year (DONOFRIO *et al.*, 2020a; VERRA, 2021a). In the country, this is the only voluntary standard that includes in its scope the sectors of agriculture, livestock, and REDD projects (Reduction of emissions from fo-

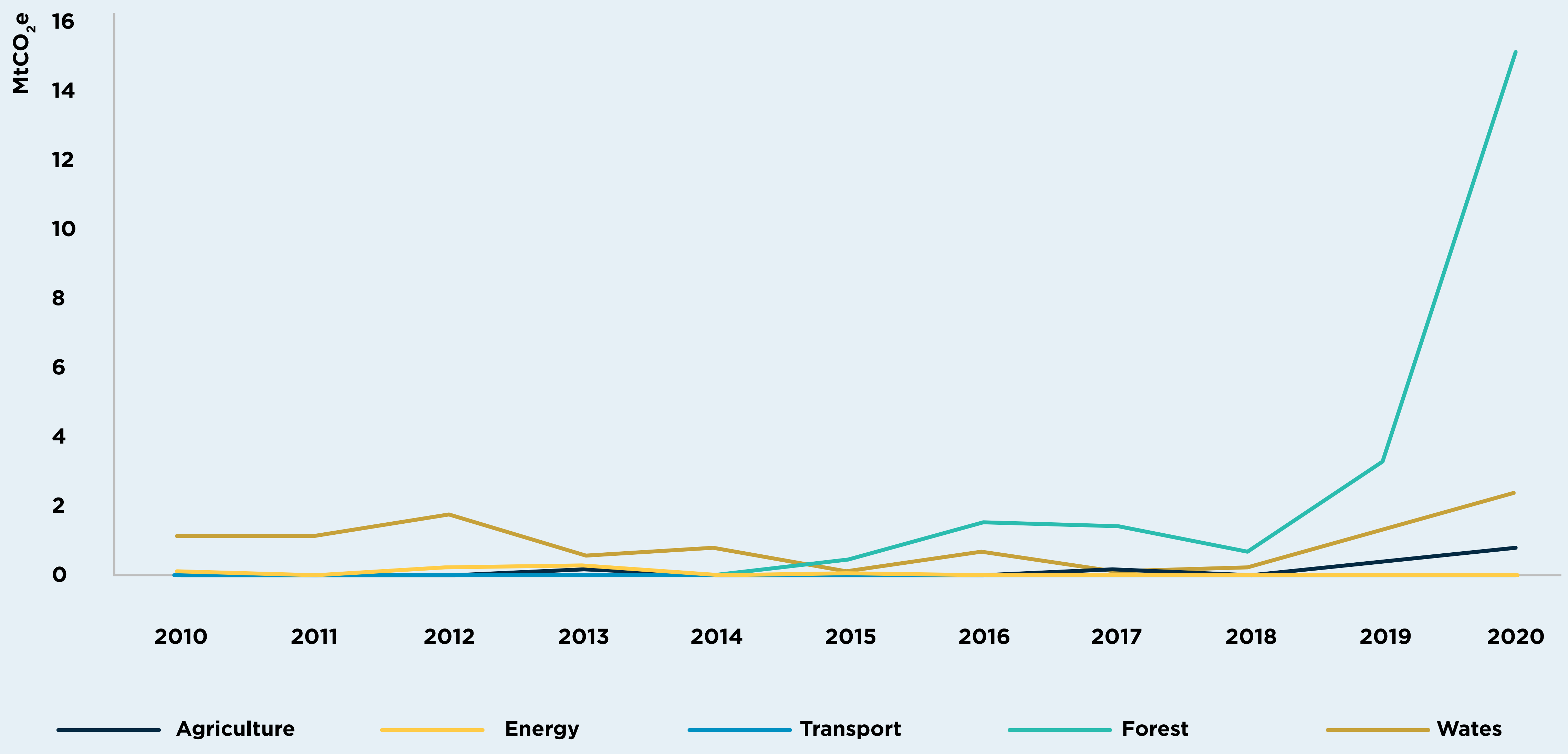


Graphic 1: Average CDM volumes and prices and voluntary market in the world, 2009 to 2019[22]
Source: Authors' elaboration based on data taken from Donofrio *et al.* (2020) e World Bank (2019a).

21. For more details on the specifics of the mechanisms created by Articles 6.2 and 6.4, see Frame A - 1 of the Annex.
22. Data on the average volume of CDM are only available until 2018.

rest degradation and deforestation), and even energy projects that also have Gold Standard registrations the VCS is more representative, with 58 registered projects, while the Gold Standard platform has only 14. In India and China, most projects are renewable energy, while in the United States, waste disposal, chemical processes, forests, and land use are the projects that trade most credits by volume (DONOFRIO *et al.*, 2020b).

Brazil also had significant growth in credit generation in 2019 and 2020, especially in the generation of credits for forest assets, according to Graphic 2. That is possibly due to the high prices of reductions arising from Nature-Based Solutions, which grew 30% in 2020, together with the strong preference of buyers for offsets from projects in developing countries (DONOFRIO *et al.*, 2020a; S&P GLOBAL, 2020).



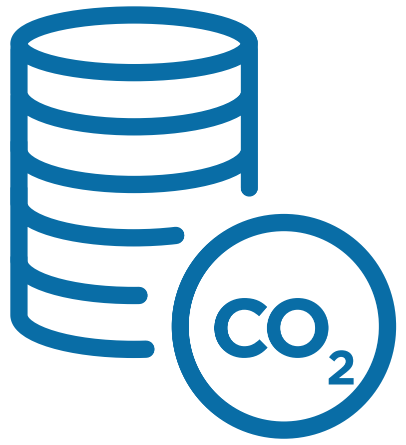
Graphic 2: Credits being monitored in VCS projects in Brazil, by issue date
Source: Authors' elaboration based on data from Verra (2021a).

Box 20

The financial sector is scaling the carbon market

In this context of intense transactions in this market, financial institutions are acting on opportunities. Itaú, for example, in partnership with banks from other parts of the world, created a project in which it aims to support the voluntary carbon offset market by removing existing barriers to purchase, with pricing and well-established standards to enable neutrality commitments. This project, whose pilot is due to be launched in August, aims to facilitate a greater delivery of high-quality carbon offset projects, a marketplace for negotiating carbon credits with price transparency and greater market liquidity, the creation of a strong ecosystem in support of the compensation market and the development of tools to help customers manage climate risk (ITAÚ UNIBANCO, 2021). The results of this cooperation will support a document with the proposition of instruments for the compensation of emissions considering the incorporation of collective benefits related to water, biodiversity, soil, and microclimate (BNDES; EPE, 2021).

POTENTIAL SUPPLY OF CREDITS



Brazil's current supply share in the voluntary market VCS is at 3.6%. In the coming years, a corresponding share of about 10% is envisaged since countries that traded higher percentages than Brazil in 2019, especially India, had projects linked to the renewable energy sector that are no longer allowed in new project registrations in the VCS standard since January 2020. For 2030, the Taskforce on Scaling Voluntary Carbon Markets estimates an annual potential, on average, of 10,000 $MtCO_2$ for credit generation, although it points out that a supply of, on average, 3,000 $MtCO_2$ would be more likely, due to barriers of complexity and rate needed to scale up projects, geographical complexity, risks and lack of financial attractiveness (IIF, 2021).

Based on these data, it was estimated the potential for offering credits. The Agriculture and Forest sectors were prioritized for their emission mitigation measures to present higher reduction potentials and better cost-effectiveness ratios, as presented in the previous chapter, and the Energy sector that has a mitigation potential mapped to Brazil that contains technological innovation to be explored and stands out for the great experience that the country has with CDM projects. Thus, it is possible to consider two following scenarios for these Brazilian productive sectors, taking into account that the trend of sectoral participation remains due to the sectoral experience already acquired in the processes of obtaining carbon credit, as indicated in Frame 1, below:

Frame 1: Credits issued in 2019 and potential emission scenarios ($MtCO_2$) in 2030, by sector, in Brazil[23]

Supplier sectors of carbon credits	Credits issued in Brazil – 2019 ($MtCO_2$)	Global supply scenarios - 10,000 ($MtCO_2$) - 2030		Global supply scenarios - 3,000 ($MtCO_2$) - 2030	
		3.6%	10%	3.6%	10%
Total	5.08	357	1,000	107	300
Agriculture	0.46	32	90	10	27
Energy	1.27	89	250	27	75
Forest	3.35	236	660	71	198

Source: Authors' elaboration.

Regarding the economic opportunity arising from these scenarios, the most conservative possibility - Brazil representing 3.6% of a 3,000 $MtCO_2$ market in 2030 and with the average price from 2009 to 2018 (4.6 US\$/tCO_2)[24] - would have the potential to generate \$493 million from total carbon credit sales in the country. In an optimistic scenario - Brazil representing 10% of a 10,000 $MtCO_2$ market in 2030 and with a price level necessary for a rapid and prolonged drop in carbon emissions of 100 US\$/tCO_2[25]– the carbon credits sold could generate up to \$100 billion in 2030.

For the voluntary market, it is considered that the non--eligibility of the energy sector since 2020 results in a potential generation of only residual credits, referring to projects before this change, and that can present credit generation until 2030. This value should not vary and significantly affect the potential generation of voluntary market credits. Therefore, only the potentials related to the agriculture and forest sectors are considered. Thus, the total potential for credit generation in 2030 is 80 $MtCO_2e$ for the conservative scenario and 750 $MtCO_2e$ for the optimistic scenario. With this, Brazil can supply 5% to 37.5% of global demand, tied to business commitments, in 2030.

23. To provide a notion of magnitude order of these projections it is considered that, in 2019, the total emissions of the sectors of the Brazilian economy and the agriculture, energy, and forest sectors correspond to 2,175.63 $MtCO_2e$, 598.67 $MtCO_2e$, 413.67 $MtCO_2e$, and 968.06 $MtCO_2e$, respectively (SEEG, 2021)
24. Average price based on data from Forest Trends' Ecosystem Marketplace *et al.* (2019).
25. For more details, see Houlder and Livsey (2021).

On the other hand, despite the conceptual indefinitions related to types of projects eligible for Article 6.4, it is understood that the carbon market under Article 6.4 could contemplate the totality of credit emissions potential estimated above for Brazil in 2030, 107 $MtCO_2e$ in the conservative scenario and 1,000 $MtCO_2e$ in the optimistic scenario. With this, Brazil can supply 2% to 22% of global demand by the mechanism established by Article 6.4 of the Paris Agreement in 2030.

Unlike the voluntary market, the mechanism established by Article 6.4, includes energy sector projects because for this sector it is possible to establish two premises:

I. that both in Article 6.4 and the voluntary market the credit generating institution will be a private one choosing the market where the project will operate the project in and,

II. given the mitigation potential in the energy sector mapped for Brazil to contain technological innovation to be exploited (see Chapter of Sectorial Review and Table A - 3), there are potential projects in this sector. This premise is aligned with the current discussions regarding the types of projects accepted under the UNFCCC. (SEROA DA MOTTA, 2021b).

Still on the energy sector, for Brazil, the expectation is that the productive sectors that use electric power as an input, especially the energy sector and the industrial sector will benefit, since the electric matrix is mostly renewable. The differential of carbon intensity in the matrix in relation to other countries may function as a competitive advantage attracting investments according to what will be defined for the carbon markets from the implementation of Article 6 of the Paris Agreement (SEROA DA MOTTA, 2021a) given the maintenance of the growth of the renewable portion and reduction of the fossil portion in the electric matrix.

Alternatively, the carbon market under Article 6.2 could also serve as a mean for trading the emission reduction results of projects related to the sectors presented in the Frame 1, since it is possible to include private projects in the packages that will make up the ITMO. However, under this mechanism, one can also include results from the implementation of robust public policies that cover producers of different sizes that allow them to scale their results collectively. In this aspect, there is already a trend in government plans and programs related to the agriculture and forest sectors of instruments that stimulate the generation of carbon credits, such as the ABC+ Plan and Forest+ Carbon Plan, as well as jurisdictional studies mentioned in the previous chapter. In a scenario where the country accounts for the benefits of the mitigation results of its public policies in a structured and transparent way with frequent and regular monitoring, it becomes possible to establish bilateral contracts with other governments to sell these results achieved, given successful compliance with the national NDC. In this context, the potential supply for global demand by Brazil would be even higher than the estimated 22% for Article 6.4 in 2030. Therefore, the forest and agriculture sectors that have low abatement costs present great opportunities.

Especially when analyzing the importance of the Amazon biome in the context of opportunities to generate carbon assets through forestry activities, it can be displayed that of the potential generation of 2,400 $MtCO_2e$ of credits from the restoration of legal reserve liabilities in the national territory by 2030, about two thirds (1,600 $MtCO_2e$) would correspond to the Amazon. Of the total potential, about 2,000 $MtCO_2e$ would correspond to areas that can be restored at a low cost, less than R$ 35 per ton. As for avoided deforestation, when considering the areas that present a significant risk of deforestation until 2030 and, therefore, would have the potential for carbon credit emission, two-thirds are located in the Amazon biome, which represents a potential of 5,300 $MtCO_2e$ out of a total of 8,000 $MtCO_2e$ for the national territory. For less valued areas, a theoretical potential of around 5,000 $MtCO_2e$ by 2030 is estimated, with a marginal cost of up to R$ 5.00 a ton. With this, we highlight the potential of the Brazilian forest sector in participating in carbon markets, with special emphasis on the Amazon biome (WORLD BANK, 2021b).

Furthermore, concerning the potential of ITMOs, it would be possible to think of policies and programs that result in emission reductions such as the aforementioned ABC+ Plan, the Sustainable Steel Program, the Plans to Combat Deforestation and Energy Efficiency Programs that could make up an extensive portfolio of mitigation results, with their respective monitoring architectures, compliance with the NDC. Finally, it is also possible to suggest that a successful national ETS, which meets its reduction targets, can become an opportunity to offer credit from this system globally.

WHAT IS THE DEMAND FOR GLOBAL AND NATIONAL CREDITS?

GLOBAL

The Global and domestic demand for carbon credits has two simplified origins: regulated commitments, such as countries' NDC targets and regulated carbon markets, and voluntary commitments, such as net-zero offset[26] targets.

For the global demand, based on the NDC targets ratified in the Paris Agreement, it is estimated that by 2030 countries such as the United States, Japan, Australia, South Korea, and European Union countries will demand approximately 4,500 $MtCO_2$ per year (IETA, 2019). This value could be understood as the demand for Article 6.

26. When the "anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period." (IPCC, 2018).

Already from voluntary commitments, a growing number of multinational companies have pledged to neutralize their carbon emissions. More than tripling the number from 2019, 1,565 companies had publicly announced their commitments by October 2020 (NEWCLIMATE INSTITUTE; DATA-DRIVEN ENVIROLAB, 2020). Furthermore, more than 20% of the world's 2,000 largest companies declare that they are committed to neutralizing their emissions (IETA, 2021). It is forecasted that annual voluntary demand for carbon credits could reach 1,500 to 2,000 $MtCO_2$ in 2030 and 7,000 to 13,000 $MtCO_2$ in 2050, depending on the pricing scenario. Compared to the market in 2020, these figures indicate a 15-fold growth by 2030 and up to 100-fold growth by 2050 in global demand for voluntary carbon credits (BLAUFELDER; LEVY; PINNER, 2021).

According to TROVE RESEARCH, the demand from Voluntary Carbon Markets (VCM) was about 95$MtCO_2e$/year in 2020, which represents 0.2% of global emissions. By 2050, this demand is expected to grow between 10 and 30 times compared to 2020, given the growth in the number of companies making commitments to neutralize their emissions. As the demand for credits grows, project costs are also expected to increase as lower-cost projects dry up. Currently, the average price of a ton of carbon is between $3 and $5 and could be between $20 and $50 by 2030, rising to $100 if governments take on the lowest cost projects first. With the expected increase in demand by 2030, the voluntary market would account for about 5% of the emission reductions required by countries' NDCs in 2030 and 2% of the reductions needed to meet the Paris 1.5°C target in 2030 (UCL; TROVE RESEARCH; LIEBREICH ASSOCIATES, 2021).

NATIONAL

In the context of a valid NDC for all sectors of the economy and the absence of a national database of emission reduction targets, WayCarbon suggests estimating the potential demand for carbon credits in Brazil from a hypothetical scenario in which most Brazilian companies set science-based net zero emissions targets in which residual emissions would be offset with carbon credits. For this estimate, it was conceptualized that a large portion of Brazilian companies could be represented by the most relevant productive sector in terms of Scope 1 and Scope 2 GHG emissions. As the Public Emissions Registry (2019) states, the manufacturing industry represents 46.7% of the reported emissions, so this group was selected. We then applied the science-based targeting tool, developed by the Science Based Targets initiative (SBTi) (CARILLO PINEDA *et al.*, 2020). For this, the base year 2019 and the target year 2034 (limited by the tool) were determined, and the absolute approach was used, whereby the percentage reduction in absolute emissions required by a given scenario is applied to all companies equally. It was considered only a scenario with a restriction for the heating of 1.5°C since, from 2022, goals with less ambition will no longer be accepted by SBTi. According to the tool, for the iron and steel, cement, aluminum, pulp and paper, and service buildings subsectors, a 63% reduction in scope 1 and 2 emissions is needed to be well below the 1.5°C scenario. As a result of this approach, in this hypothetical scenario there will be potential demand for carbon credits in Brazil corresponding to residual emissions of 26.8 $MtCO_2e$.

Table 2: Sectorial decarbonization approach for the Brazilian manufacturing industry.

Scenario	Scope 1 and 2 Emissions ($MtCO_2e$)	
	2019	2034
1.5°C	72.5	26.8

Source: Authors' elaboration.

Box 21

Potential demand for the voluntary market in a national ETS

As pointed out in the contextualization chapter, there are prospects for a possible national ETS implementation. These perspectives take into account the developments of the PMR Brazil project, the expression of interest of the Brazilian government in the participation of the implementation phase of the project, the PMI, in addition to possible referrals that are outlined with changes in the wording of the bill 528/21. This perspective of establishing an ETS in Brazil also stands as an opportunity for the national voluntary market, especially to the forest sector, since the Synthesis Report of the PMR Brasil project pointed out as one of the results of the study the fundamental and surprising role that offsets had in the simulations. Even in the more restrictive scenarios modeled in the study, the large supply of forest offsets allowed the containment of compliance costs since it would expand the scope of the regulated sectors - not being the forest among them - giving greater flexibility in meeting the emission reduction targets. In addition, the study pointed to the potential to generate more than R$ 2 billion in revenue for offset providers, highlighting opportunities to encourage and unlock investments in the country, expanding the reach of the carbon price signal and, thus, the efficiency of national mitigation as a whole (WORLD BANK, 2020).

27. Science-based targets are used by companies to reduce their greenhouse gas emissions aiming to reduce heating to 1.5°C above pre-industrial levels (CARILLO PINEDA *et al.*, 2020).

ECONOMIC OPPORTUNITIES

Despite the recent economic slowdown, project registrations for carbon credit markets increased by 11% in 2020 compared to 2019. This trend is driven by independent carbon credit certification standards which are administered by private third-party organizations, contributing 50% of credits in 2020, of which 96% were voluntarily transacted by companies (WORLD BANK, 2021a).

The growth in voluntary corporate commitments is the main driving force behind the steady increase in demand for carbon credits. As mentioned earlier, by October 2020, 1,565 companies have adopted emissions neutrality commitments, half of them indicating that carbon offsets will be an integral part of their transition strategy. According to the World Bank, 75% of the stand-alone credits yet to be issued have buyers lined up. Although less than voluntary demand, demand for credits for carbon taxation or ETS compliance obligations is also growing, as the recent start of Chinese carbon market operation in July 2021, a national ETS covering 40% of the country's emissions (WORLD BANK, 2021a). However, deep questions remain about the limited scale and effectiveness of the initial emissions trading scheme, including the low price[28] attributed to pollution. Initially, the market will cover 2,225 energy producers responsible for releasing approximately 13.92 billion CO_2e into the atmosphere in 2019 (EURACTIV, 2021).

A study examined emission trends and reduction opportunities from 2020 to 2035 in 28 EU member countries and 34 other countries. Its model includes the energy, transport, industry, and forest, and land-use sectors. In addition, the countries were classified according to their importance in terms of emissions, in which Brazil's importance is clearly stated (PIRIS-CABEZAS; LUBOWSKI; LESLIE, 2019).

This study further indicates that global Emissions Trading Systems (ETS) can improve the achievement of emission targets in addition to being more cost-effective than expected. To date, each ETS has driven up mitigation costs in their localities, while global systems would provide stability to mitigation costs and nearly double the value of mitigation outcomes compared to non-international market values.

Preventing deforestation was identified as the main driver for ambition gains. Including Reducing Emissions from Deforestation and forest Degradation (REDD+) for global trade yields the greatest potential cost savings. REDD+ has the capacity to supply the global market with low-cost reductions, totalling 55% of global cost-effective opportunities between 2020-2035. However, the potential benefits may remain underestimated, as the researchers did not include the emission of gases other than CO_2 in agricultural or reforestation activities and improved forest management. Finally, the overall cost savings are 96% related to international trade, while only 4% are based on domestic trade. Therefore, Brazil can unlock a great opportunity in carbon credit trading by avoiding deforestation through REDD+ (PIRIS-CABEZAS; LUBOWSKI; LESLIE, 2019).

Another study pointed out that the implementation of Article 6.2 of the Paris Agreement would open up the possibility of a reduction of up to US$ 320 billion for the cooperative achievement of the NDCs of the signatory countries of the Agreement in 2030. This would come from emission reductions in the most cost-effective way so that countries in more unfavourable conditions in this regard would buy emission reduction results from countries in more favourable mitigation conditions (IETA, 2019). As the partnership between Peru and Switzerland, described in the Contextualization chapter, it is noteworthy that the partnership between countries through an ITMO can facilitate the achievement of the climate goals of each one. Also, it brings economic gains and social well-being once their projects have actions to monitor, report and verify the GHG reductions agreed between the parties (COZIJNSEN, 2020). Figure 4 explains that Brazil has a great potential to become a seller of emission reductions, especially in a scenario that includes the land-use change and forest sector, which has almost all of this potential and could sell ITMOs corresponding to the reduction of about 1 $GtCO_2$ in 2030.

28. According to Reuters, on the first day of trading, the ton of carbon (tCO_2e) closed the day at $7.92, up 6.7 percent from the opening price. The Chinese government is still negotiating the inclusion of other sectors in ETS, such as metallurgy, non-ferrous metals, and chemicals (REUTERS, 2021).

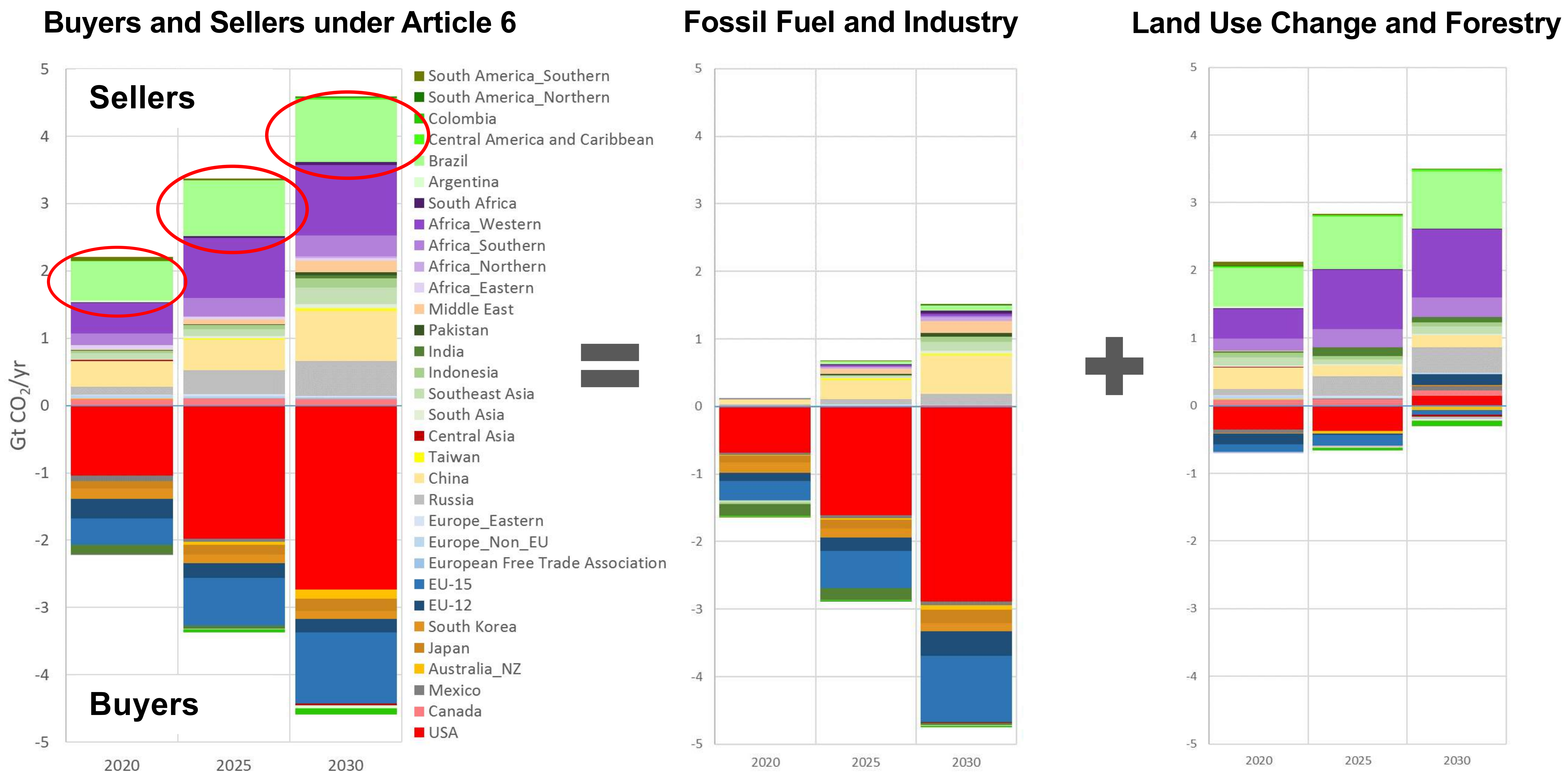


Figure 6: Potential buyers and sellers of emission reduction results under Article 6
Source: De Clara (2021).

Note: 1GtCO_2 equals 1,000 MtCO_2

In another study, Brazil has the opportunity to mitigate emissions to meet its NDC at a total reduction cost of $26 billion. This forecast is based on the opportunity costs of reducing deforestation and cost-benefit reductions in other sectors. With the implementation of the Paris Agreement, Brazil could further reduce its emissions and benefit from revenue generation from the reduction surplus. To capitalize on this revenue opportunity, Brazil must reduce emissions in the near term to capture higher future carbon prices in its new contracts. Therefore, possible delays in policy implementation would translate into lost monetary opportunities. Conservative projections of future carbon prices show that Brazil could exceed its existing targets and generate substantial revenues by trading the surplus reductions. The country could generate a net positive value of US$ 19 billions[29] in present value from 2016 to 2030. If Brazil invests more in achieving more short-term reductions, it could capture higher future carbon prices and generate additional net revenues of $27 billion between 2020 and 2030 and $40 billion between 2030 and 2035 (ENVIRONMENTAL DEFENSE FUND, 2016). Thus, as this negotiation of emission reduction surpluses concerning the NDC target is within the scope of the Article 6.2 mechanism, these figures highlight the opportunities that Brazil has in achieving the goal of its NDC in the short term and with the formation of a Brazilian ITMO.

29. Disregarding the restoration cost for 12 million hectares, because according to the study the net cost of reforesting this area is uncertain and would range from scenarios with negative costs to scenarios with net costs of up to $9 billion, depending on the discount rate and underlying assumptions.

BARRIERS FOR CARBON MARKET

1 MARKET: MARKET STRUCTURE AND CARBON CREDIT CERTIFICATION

The voluntary market has gained strength and is currently the utilized option for projects carried out in Brazil. However, with the negotiations around Article 6 of Paris, CORSIA, and the expectation of regulation of the Brazilian market, the movement may change (MARKESTRAT *et al.*, 2020). However, the costs linked to the carbon credit certification process are high and require a large volume of carbon credit that compensates for this additional investment to the project implementation costs, often viable only for large companies with capital available for such investment. Frame 2 below summarizes estimates of fixed certification costs involved in a carbon credit project in the voluntary market. The minimum annual reduction value to enable a project would be 15,000 tCO_2e considering the average price of 5 US$/$tCO_2e$.

Frame 2: Approximate costs of a registered carbon credit project

Information	Value
Cost of Drafting Project Documentation	Specific by project
Minimum annual reduction potential for financial viability (tCO_2e)	15,000
Validation Cost (US$)	30,000 to 40,000
Account Opening Cost (US$)	700
Registration Cost (US$)(1)	10,000 + annual fee
Verification Cost (US$)(2)	30,000
Maintenance Cost (3)	Specific by project
Monitoring Costs	Specific by project
Credit issuance cost (US$/credit)(4)	US$ 0.025 to 0.30 depending on program, credit period and amount of credits

Source: Market intelligence WayCarbon.

Notes:
(1) Ceiling value for registration;
(2) For forest projects, it is suggested that verification be carried out every 5 years;
(3) Value per project to maintain what is needed for monitoring;
(4) One credit corresponds to 1 tCO_2e.

Certification brings greater reliability but also some barriers to the credit generation process. The option of not certifying carbon credits although it has less investment compared and lower cost of the credit generated, promotes the reduction of the cost of opportunity, and requires monitoring and auditing to confer credibility and methodologies and methods that prove additionality resulting in the same rigidity, but without the seal. On the other hand, the generation with a standard, despite giving more credibility to the operation and providing more market opportunities and experience thinking about serving the regulated market, results in a slower, more costly process – according to Chart 2- and bureaucratic, depending on its complexity.

Moreover, each pattern has its characteristics that can influence the complexity of the processes. Comparing the VCS and Gold Standard standards, much recognized in the global carbon market, it can be considered: VCS, which operates only in the voluntary market, has less complexity and more flexibility, has no directly linked co-benefits[30], is faster, and has a lower cost; while the Gold Standard is more complete, with co-benefits and enables the performance in the regulated and voluntary markets, which provides a more complex and bureaucratic process and greater cost. The choice between standard types depends on the degree of the requirement of potential buyers. Generally, in Brazil there is no condition for certification for buyers as long as it is by a recognized standard the American market accepts well the VCS and the European Gold Standard (MARKESTRAT *et al.*, 2020).

In addition to that barrier, challenges remain for the voluntary market. Carbon credits are not alike, and high-quality credits are generally hardly available. If these high-quality credits are scarce, companies may lose confidence in the mitigation solutions offered, resulting in the reduction of demand. This condition is similar to the demand of Article 6 of the Paris Agreement, where the demand is highly dependent on the security of the accounting implemented framework. This is made explicit by the 21 Article 6 pilot initiatives that are in place to build capacity, establish the necessary infrastructure, and facilitate transfers between countries party to the Paris Agreement (WORLD BANK, 2021a).

The scarcity of these high-quality credits is due to the variation in methodologies for accounting and verification of credit type and the rare definition of their co-benefits, which can also provide an increase in project completion time. Some seals can be added to credits and give greater credibility by valuing projects (VERRA, 2021b).

The complexity of carbon projects is a barrier, as there are assessment criteria that determine the eligibility of projects that need to be considered. They are (CAREPA, 2021):

I. adherence to the registered methodologies, determining the calculation of the volume of credits;

II. proof of additionality, to ensure that the benefit provided by this activity really has a significant differential in environmental, economic-financial, and implementation aspects;

III. temporality, which brings several locks with emphasis on the alignment between the effective intention of generating credits and implementing projects;

IV. reliability, meticulously proven by verifications of both the registration bodies themselves and the 3rd authorized party;

V. and the stakeholder conference, proving the direct impacts to stakeholders and the very applicability of their registration for credit generation.

There is also a tendency for projects to have more and more methodological complexity to ensure the quality of credits. In the case of nature-based solutions, concerns about environmental integrity around permanence, additionality, baselines, and the lack of an international credit accounting standard are considered as the main barriers to scale investment (IETA, 2021). It is noteworthy that the additionality depends on the set of revenues and costs of projects, as well as the context of the project in the territory that will be implemented. Therefore, the existence of revenue in the project does not prevent additionality. Each sector has particularities regarding the methodological complexities of the projects. The agriculture sector, for example, despite the great opportunities related to scale, faces challenges related to measurement and monitoring (PLUME, 2021). On the other hand, forest projects, as to their temporality, must be registered within 5 years of their start of implementation so that their credits are eligible with the VCS (CAREPA, 2021).

30. However, it allows for additional certifications in this regard.do.

2 POLITICAL: AGREEMENT ON CONCEPTS

CORRESPONDING ADJUSTMENT

Faced with the impasses of Article 6 regulations, a group of 32 countries, consisting of developing countries and most European Union nations, created their own market rules by adopting the "San Jose Principles for High Ambition and Integrity in International Carbon Markets (SJPs)" during COP25 in 2019. These principles aim to ensure the environmental integrity of the Paris Agreement by avoiding double-counting through corresponding adjustments in NDCs and prohibiting the use of Kyoto Protocol credits in the Paris Agreement (SEROA DA MOTTA, 2021a).

Box 22

San José Principles (SPJs)

• Ensures environmental integrity and enables the greatest possible mitigation ambition;
• Provides overall mitigation in global emissions, going beyond neutrality approaches to help accelerate the reduction of global greenhouse gas emissions;
• Prohibits the use of pre-2020 units, Kyoto units and permits, and any reductions underlying the Paris Agreement and other international targets;
• Ensures that double counting is avoided and that all use of markets for international climate objectives is subject to the corresponding adjustments;
• Avoids discussions on emission levels, technologies, or carbon-intensive practices incompatible with meeting the Paris Agreement's long-term temperature target;
• Applies allocation and baseline methodologies that support the implementation of the country's NDC and contribute to the Paris Agreement goal;
• Uses CO_2 equivalence to report and account for emissions and removals, fully applying the principles of transparency, accuracy, consistency, comparability and integrity;
• Uses centralized and publicly accessible infrastructure and systems to collect, track, and share the information needed for robust, transparent accounting;
• Ensures incentives for progression and supports all Parties towards emission targets for the entire economy;
• Contributes quantifiable and predictable financial resources to cover adaptation costs in developing countries that are particularly vulnerable to the adverse effects of climate change;
• Recognises the importance of capacity building to enable the parties to participate as broadly as possible under Article 6;
• Recognizes the importance of Article 6.8 in supporting the parties in the implementation of their PADs through non-market approaches;

Source: Authors' elaboration based on (DIRECCIÓN DE CAMBIO CLIMÁTICO, 2019).

SJP countries include the UK, Switzerland, Sweden, Germany, France, and Spain, which are historically the main buyers of Brazil's Kyoto Protocol carbon credits (CDM). Therefore, a Brazilian position contrary to the SJPs brings high risk for the commercialization of national credits in the new mechanism. Adhering to the San José Principles can guide and enable the inclusion of climate solutions based on nature in the regulation of Article 6 of the Paris Agreement. The non-acceptance of the corresponding adjustments in the mechanism of Article 6.4 is a risk to the environmental integrity of the Paris Agreement, which should seek the harmonization of visions and resolutions that do not harm the country's opportunities and avoid complex barriers of additionality (SEROA DA MOTTA, 2021a).

To avoid losses of competitiveness for Brazil with the accounting question regarding the corresponding adjustment and the rules for the transfer of credits, the country depends on the future price of sales of CERs is greater than US$ 39/tCO_2 and the full compliance of the Brazilian NDC, with its additional measures and focus on zero illegal deforestation (CNI, 2020).

There is also concern with the international transfer of results of the mitigation of emissions from REDD+ offsets under the Brazilian NDC. In the Paris Agreement, REDD+ is regulated by Article 5, which refers to actions to conserve greenhouse gas reservoirs, among which forests are, but there is no definition concerning the eligibility of REDD+ initiatives under Article 6. If REDD+ is included among the mechanisms of Article 6, it is expected as a consequence the reduction of domestic emission mitigation capacity due to the international transfer of REDD+ results. As reducing emissions from this Forest sector is generally considered a low implementation cost compared to other sectors, a host country needs to evaluate its willingness to trade REDD+ offsets internationally since it can be necessary not only REDD+ resources for forest preservation and conservation but also other actions with higher marginal abatement costs to achieve the goals of their own NDC (EPE, 2020). However, in the event of non-compliance with the NDC, additional care should be taken with impacts in other sectors, such as industry, in which eventual corresponding adjustments related to REDD+ offsets could increase costs and lose competitiveness, causing a greater unanticipated mitigation effort (CNI, 2020).

Specifically, concerning the competitiveness of sectors, it is essential to have a clear nationally established climate governance so that the national accounting of NDC compliance and the connections between the various carbon credit projects via Article 6.2, 6.4 and the voluntary market can offer security to buyers, transparency to the system and result in real GHG reductions while maintaining environmental integrity.

About Article 6, as all countries that sign the Paris Agreement have their GHG emission reduction targets, by agreeing to the sale of ITMOs, governments will need to look to not approve emission reduction transfers necessary for the fulfilment of NDC from their own countries. That is, it will be essential to deepen the knowledge of the mitigation efforts necessary to meet the NDC, the costs to achieve them, and how this equation translates into specific mitigation interventions, so as not to compromise their own goals due to the excessive sale of ITMOs (EPE, 2020).

THE TRANSITION FROM KYOTO TO PARIS

Brazil, which hosts CDM projects still in progress, demands that a transition of CDM project credits, its methodologies, and units to the Paris Agreement regime be allowed to provide security for investments made in these projects under the Kyoto Protocol. However, other countries fear that a complete transition could undermine the ambition of the international climate regime, allowing targets to be achieved without effective additional effort given the existence of a pre-2020 credit stockpile (EPE, 2020). The full transition would provide a larger potential supply of CDM credits relative to estimated demand, which would lead to lower credit prices and lower private sector interest, undermining the Article 6.4 mechanism since its inception (EVANS; GABBATISS, 2018). Thus, this transition will have to be adjusted and temporary, with the expiration of the carbon credits generated in the CDM for the Paris Agreement, in order not to become another commercial and reputational risk, since the main buyers of carbon credits are within the SJPs and do not accept the inclusion of this type of credit in the mechanism (SEROA DA MOTTA, 2021a).

Brazil has also defended principles that refer to the mechanism of Article 6.4 shall also be included in the ITMO, in order to guarantee the same objectives of ambition and financing for both instruments. These are the principle of general mitigation of global emissions (OMGE) to increase the ambition of the Agreement and the principle described in Article 6.6 that establishes that part of the revenues from the mechanism's transactions is used to finance Article 6 management activities; and adaptation in vulnerable countries, called Share of Proceeds (SOP). The price increase resulting from the adoption of these principles for transactions in the two instruments would be advantageous for countries where achieving reductions exceeding the NDC target would cost more than in countries with less ambitious NDCs (SEROA DA MOTTA, 2021a).

3 ECONOMICS: OTHER IMPACTS ON COMPETITIVENESS

THE TREND OF GREEN DEALS

Another barrier that Brazil may face is the pressure of the Green Deals on its trading partners. The green deals are plans for the transition to a sustainable economy announced by world economic powers of which the European and American Green Deals stand out. In particular, these plans provide the guidelines for the low-carbon transition, with targets for the years 2030 and 2050, through regulatory and market mechanisms.

The European Green Deal is, for the time being, the most advanced in terms of proposals for transition policies, foreseeing a reduction between 50 and 55% of the GHGs emitted in 1990 by the year 2030. Therefore, the European Committee analyzes the expansion of carbon pricing beyond the sectors covered by the current ETS, such as the inclusion of the construction and transport sectors; the general intensification of energy efficiency; greater use of renewable energy; intensification, flexibilities and a broader scope of legislation on Land Use, Land Use Change and Forest Sector. Depending on the success and interactions of these implemented policies, the Committee estimates that the price of a ton of carbon could be between 32 and 65 euros in 2030 (EUROPEAN COMISSION, 2020). For these goals to be achieved, the Paris Agreement and strong international diplomacy and leadership will be the main instruments used. In the international context, one mechanism proposed to reduce emissions in the European Union is the Border Carbon Adjustment Mechanism, or CBAM, an instrument that imposes a tax on products imported from jurisdictions with more lenient climate policies in an attempt to avoid carbon leakage[31] (EUROPEAN COMISSION, 2020a).

According to the released proposal, importers will have to provide emission data of the goods, as well as the calculation to estimate these emissions. The carbon tax should cover direct and indirect emissions through digital certificates that represent one ton of CO_2 embedded in the imported product.

Today, Brazil is not among the markets affected by CBAM, which will begin the transition phase in 2023 and last until 2026, covering the steel, iron, aluminum, cement, fertilizer, and electricity sectors. At the end of the transition period, the European Commission will assess whether to increase CBAM

31. A phenomenon in which companies migrate to countries with more lenient environmental rules in an attempt to reduce the costs associated with reducing greenhouse gas emissions.

sectoral coverage, including more products, and whether indirect emissions will be covered (EUROPEAN COMISSION, 2021). According to Moreira (2021), the greatest risk for Brazil would be in the pulp market since the country is the second-largest exporter of this commodity to Europe, with 44% of European imports in 2019.

In addition to the European Union, the United States also does not rule out the possibility of using CBAM: according to the 2021 Trade Policy Agenda released in March, the U.S. government says it intends to work with partners committed to combating climate change, including exploring and developing regulatory and market approaches to address greenhouse gas emissions in the global trading system, as appropriate to domestic approaches to reducing U.S. greenhouse gas emissions, including the use of carbon border adjustments (U.S. TRADE REPRESENTATIVE, 2021). Later, in July 2021, the idea was endorsed by Republican Senator Jeff Merkey, who said there is a lot of support for the idea for the tax funding the economic recovery package. The proposal, however, is not yet consensual in the government, given the statement by U.S. Climate Representative John Kerry, warning that this should be a last resort for climate policy (TAYLOR, 2021).

For Brazil, the risk is that these policies affect the country's competitiveness in the face of foreign competition, given that there would be an increase in the price of products exported (UNCTAD, 2021). Additionally, the possible creation of "Climate Clubs" as advocated by William D. Nordhaus, as a mechanism to reduce the "hitchhiking effect" can negatively impact trade in countries with more permissive climate regulation (NORDHAUS, 2015). In sectors not initially covered by the European CBAM, there are already moves pushing for Brazil to have stricter regulations, such as in the forest sector, in which the Forest Stewardship Council sent an open letter to the sector to encourage the certified sustainable timber market in Brazil and inform the current and expected needs of the European market (FSC, 2021).

A border adjustment mechanism for Brazil was considered by Appy, Watanabe Jr., and Kishinami (2016), highlighting the risk that this mechanism will be understood as protectionist measures in the World Trade Organization, but that the risk could be mitigated with a technically consistent demonstration that the amounts charged on imports (and/or reimbursed in exports) effectively correspond to the impact of carbon taxation. Ideally, the tax should also correct current distortions of the Brazilian tax system without causing fiscal impact and without further burdening the productive sector. In August 2020, economists Bernard Appy and Ana Paula Vescovi again advocated carbon taxation at an event promoted by the newspaper Valor Econômico (VALOR ECONÔMICO, 2020).

ANALYSIS AND PRIORITIZATION

To operate in carbon markets, all productive sectors have options with negative abatement costs, except the aluminum industrial subsector, and bring opportunities for production chains such as increased number of jobs, strengthening of links in production chains, and diversification of economic activities, in addition to associated co-benefits. Furthermore, analyzing the cost-effectiveness of mitigation measures, the Agriculture and Forest sectors stand out for their high potentials, 2,419 and 2,565 $MtCO_2e$, and low abatement costs, between -1978,00 and 1.99, and between -0.38 and 9.22 US$/$tCO_2e$, respectively (BRASIL, 2017a).

Thus, the best opportunities for credit generation are in the Agriculture and Forest sectors with mitigation estimates between 10 and 90 $MtCO_2e$ and between 75 and 660 $MtCO_2e$, respectively, demonstrating the relevance of nature-based solutions for Brazil. In the agriculture sector, there are estimates of investments of around R$ 25 billion to recover 12 million hectares of degraded pastures with a return in about 6.5 years (WRI BRASIL; NEW CLIMATE ECONOMY, 2020). Also, there is estimates of an increase in net revenue by 2050 of US$ 9.8 billion to no-till systems with the expansion of 1.2 Mha of area, US$ 1.7 billion with the use of biological nitrogen fixation (BNF) in an area of 8.8 Mha, and US$ 8.9 billion for integrated systems strategies (BRASIL, 2017a). The forest sector can achieve rates of return on investment between 13% and 28% when occupying only pastures with maximum levels of degradation (WRI BRASIL; NEW CLIMATE ECONOMY, 2020).

There are also several socioeconomic benefits associated with opportunities to generate carbon credits for these sectors. The Forest sector provides the reduction of erosions, maintenance in local biodiversity, and improvement of quality, water availability. This sector is also responsible for generating approximately 7 million jobs in Brazil (CNI, 2021a). The parks have the potential to contribute R$ 44 billion to the Brazilian economy, creating 88,000 jobs (CNN, 2021). This sector also produces positive effects on human health related to deforestation and fires reduction, and ecotourism. By the nature of this sector, it is important to highlight the relevance of the participation of indigenous and traditional populations directly affected in discussions about forest carbon projects being included in stakeholder consultations (CEBRI, 2021). The Agriculture sector also has as co-benefits the reduction of pressure on deforestation through the diversification of economic activities, which provides new sources of income to rural producers, in addition to improving the quality of working conditions in the field, increasing productive efficiency, recovery of productive potential in degraded areas, ensuring competitiveness among the main international agricultural suppliers, strengthening small producers and contributing to the food security of families.

There are also opportunities under Article 6 for the Energy sector depending on what is defined in the scope of the types of projects accepted in its mechanisms since 2020, this sector does not present eligibility for the voluntary market. Within this sector, the chains of biofuels and renewable sources of electricity generation stand out, for the logistical advantages and energy security, and the generation of new jobs with almost 839,000 new jobs with the generation of biofuels, 166,000 with solar power generation since 2012 and 498,000 per year for wind power generation between 2011 and 2019 (ABSOLAR, 2021a; IRENA, 2019; OLIVEIRA *et al.*, 2020). In this sense, biogas and energy recovery add value to waste from other sectors.

It is estimated that through the purchase of GHG Emission Reduction Certificates (CERs) from CDM projects throughout its portfolio, 8.74 million people have gained access to renewable energy, 14,500 new job opportunities have been created and 1.31 million people, mainly women, and children are benefiting from better air quality, among other co-benefits. About 40% of CDM projects engaged with local communities, leading to job creation, education promotion, and better living conditions. In addition, 27% of these projects generate financial benefits for the local and regional economies. As well as CDM projects, projects under Article 6 and the voluntary market also have the potential to generate a great positive impact on Brazilian society through its socioeconomic co-benefits (UNFCCC, 2018).

It was prioritized in this analysis these sectors mentioned above since the Agriculture and Forest sectors have higher abatement potentials and better cost-effectiveness ratios, and the Energy sector has a mitigation potential mapped to Brazil that contains technological innovation to be explored. Thus, an estimate of Brazil's credit generation potential for these sectors was made considering the current context of voluntary market growth and the regulation of Article 6 of the Paris Agreement. It was estimated, through a projection based on VCS data, that Brazil would have the potential to generate carbon credits between 107 and 1,000 $MtCO_2e$ by 2030, approximately between 30 and 300 times the emission of the city of Belo Horizonte in 2020 (PREFEITURA DE BELO HORIZONTE, 2021) for these sectors, generating revenues between US$ 493 million and US$ 100 billion.

Thus, it is understood that this potential could occur in three different carbon markets:

I. in the voluntary market, whose potential is estimated between 80 and 750 $MtCO_2e$ for 2030 since the values for the Energy sector are disregarded due to their non-eligibility from 2020 and the residual being derisory;

II. in the mechanism of Article 6.4, whose potential is estimated between 107 and 1,000 $MtCO_2e$ for 2030, taking into account that the share of credits for the energy sector would be similar to that of the VCS until 2019 with the caveat that the types of projects accepted would be related to innovation in this sector;

III. and the Article 6.2 mechanism, which could serve as a means for the transaction of the results of emission reduction (mitigation) of projects related to the same sectors mentioned in the 6.4 mechanism since in addition to including project results and implementation of public policies could encompass different sizes of projects (small, medium and large scale); being possible to consolidate projects of smaller private entrepreneurs into large packages that will make up the ITMO, so that this market mechanism would have a higher potential offer than in the other two mechanisms.

In the demand for credits, the NDC targets of the countries, regulated carbon markets, and are considered the demand from voluntary commitments, which tends to grow with the increase of zero net emission offset targets by private companies. For global demand, it is estimated 4,500 $MtCO_2$ per year, whose value can be understood as the demand of the mechanisms of Article 6 (IETA, 2019). For the annual voluntary demand for carbon credits, it is estimated from 1,500 to 2,000 $MtCO_2$ in 2030 and from 7,000 to 13,000 $MtCO_2$ in 2050, depending on the price scenario (BLAUFELDER; LEVY; PINNER, 2021).

In addition, there are clear opportunities for Brazil with the negotiation of emission reduction surpluses concerning the NDC target, which is within the scope of the Article 6.2 mechanism, with a potential sale of up to 1,000 $MtCO_2$ in 2030 (DE CLARA, 2021). It is estimated that the country could generate a positive net value of US$ 19 billion by 2030 with this sale of emission reductions surpluses, and if it invests in achieving more short-term reductions, it could capture higher future carbon prices and generate additional net revenue of $27 billion between 2020 and 2030 and $40 billion between 2030 and 2035. It is also considered that the estimated cost of mitigating emissions to meet the Brazilian NDC is US$ 26 billion, based on the opportunity costs of reducing deforestation and cost-benefit reductions in other sectors (ENVIRONMENTAL DEFENSE FUND, 2016). To take advantage of these opportunities in Brazil it is necessary to plan strategies to achieve the goals of your NDC in the short term and establish the set of actions and activities and/or projects that would form a robust and attractive Brazilian ITMO for potential partner countries.

However, there are market barriers to be faced with regard to the scarcity of high-quality credits, the certification of credits, and the increasing rigor regarding the complexity of carbon credit projects. To provide better management with greater reliability in the generation of credits in Brazil, we consider the importance of strengthening institutional governance, the presence of integrated MRV systems, and the definition of the roles of subnational governments.

In addition to market challenges, one should also consider the impasses of Article 6 regulations that may reflect Brazil's trade relations with its main trading partners in carbon credit projects and the tendency of green deals to use border adjustments that may impact Brazilian exports.

Thus, the agriculture and forest sectors are indicated to act in the mechanisms of Article 6 and the voluntary market, and the energy sector to act in Article 6 mechanisms. Frame 3 below provides an analysis of the potential of the sector supply of carbon credits and the summary of its associated co-benefits. It can be seen which potential mechanisms of Article 6 and the carbon market have, comparatively, within each sector indicated in this report.

Frame 3: Potential of the Sector Supply of Carbon Credits (non-exhaustive)

Potential for sector supply	Article 6.2 Mitigation Results (tCO_2e)	Article 6.4 Certified reductions in methodologies to be defined (tCO_2e)	Voluntary Market Certified Reductions of Approved Standards Methodologies (tCO_2e)	Co-benefits
AGRICULTURE (ICLF; ICL; BNF; Recovery of degraded pastures; Treatment of Animal Waste)	**High Potential** Justification: Low abatement costs; trend in government plans and programs that stimulate credit generation. Ex: ABC+ Plan.	**Medium Potential** Justification: Few projects with additionality, but there is a high demand for credits from NBS projects in developing countries.	**High Potential** Justification: Preference for offsets from NBS in developing countries, combined with low abatement cost.	Revenue Generation (up to US$ 9.8 billion in pasture recovery; US$ 1.7 billion in BNF and US$ 8.9 billion in ICL and ICLF systems); Job Creation; Increased Productivity; Strengthening of small producers; Increased Food Security; Increased Biodiversity.
FOREST (Forest Management; Reforestation)	**High Potential** Justification: Low abatement costs; trend in government plans and programs that stimulate credit generation. Ex: Forest +, Forest + Carbon, PNPSA.	**Medium Potential** Justification: Few projects with additionality, but there is a high demand for credits of NBS projects in developing countries.	**High Potential** Justification: Preference for offsets from NBS in developing countries, combined with low abatement cost.	Revenue Generation (up to R$ 44 bi in forest parks); Job Creation (7 million jobs currently generated; up to 88,000 jobs in forest parks); Increased Productivity; Increased Brazilian competitiveness on the international scene; Increased Biodiversity; Regulation of the hydrological cycle and microclimates; Greater land regularization; Increased diversity of products exploited in Forest Management Units; Possible Reduction in the incidence of respiratory diseases.
ENERGY (Hydrokinetic turbines; Repowering of hydroelectric plants; Offshore Wind Power Plants; Floating Solar Power Plant; Cogeneration; Second Generation Ethanol Green Hydrogen)	**High Potential** Justification: Possibility of including different alternative sources of energy.	**Medium Potential** Justification: presence of additionality potential only in technological innovation projects such as green hydrogen production, among others.	**Does not apply** Justification: Exclusion of renewable energies certification standards.	Job creation (about 839,000 jobs in biofuel production; 14,500 jobs generated in CDM projects; 166,000 jobs in solar power generation; 498,000 jobs in the wind energy sector); Increased Productivity; Reduction of Operating Costs; Energy Security.
Demand risk	**Medium Risk** Appetite linked to the buyer country and acceptance of corresponding adjustment.	**Medium Risk** Undefined project type accepted; increased costs due to increasing methodological rigor and acceptance of corresponding adjustment.	**Low Risk** Increasing and complex methodological rigor.	

Source: Authors' elaboration, based on the information referenced throughout the document.

RECOMMENDATIONS AND KEY MESSAGES

Given the opportunity to operate in the global carbon markets and the highlight for the agriculture, forest and energy sectors, it is understood that there is a path to be followed by the Brazilian government and the private sector to unlock and leverage such opportunities for revenue generation, income, health, and social welfare. That said, and based on the information and discussions brought in this report, it is recommended to the Brazilian government:

• **Covid-19's post-pandemic economic recovery packages should encourage sustainable development and carbon neutrality** using regulation mechanisms and carbon pricing instruments, as in developed countries. It is noteworthy that carbon markets have the potential to unlock financial opportunities for these recovery plans and accelerate the sustainable growth of the Brazilian economy. As carbon credits are a bridge to necessary emissions reduction, it is necessary to maintain emission reduction efforts by encouraging environmental conservation and protection, carrying out cleaner economic activities, promoting technological development, and fostering innovation.

• **Brazil must deepen its knowledge about mitigation efforts needed to meet the NDC to reduce emissions and achieve its goals as soon as possible,** prioritizing the fight against illegal deforestation as a basic premise, but taking into account that the fight against deforestation, broadly, is strategic in a context where there is a great opportunity for recovery of degraded areas and increased productivity. With the presentation of clear and reliable strategies on how to achieve its NDC with sector-by-sector goals, the country is more likely to regain internationally indispensable credibility and prestige for trade relations under the Paris Agreement. This way, the country could take advantage of lower costs in the short term (options in regret) to generate revenue by negotiating surpluses to targets through the Article 6.2 mechanism and capture higher future carbon prices in medium and long-term negotiations. Conservative projections of carbon futures prices indicate that the country could generate positive net revenue of $19 billion by 2030 by negotiating surplus reductions. If it invests more in achieving more short-term reductions, that revenue could reach $27 billion between 2020 and 2030 and $40 billion between 2030 and 2035.

• **Organize, in partnership with the private sector, the set of actions and activities and/or projects that would form a robust and attractive Brazilian ITMO for potential partner countries,** considering the existing plans and policies in a comprehensive manner and the high potential of this mechanism for the three sectors prioritized in this report, Agriculture, Forests and Energy. Brazil has great potential to become a seller of emission reduction (mitigation) results, especially in a scenario with the inclusion of the Forest sector, and may sell results corresponding to the reduction of about 1,000 $MtCO_2$ in 2030.

• **Given the compliance with the NDC and the robustness in MRV, pay attention to the potential that current policies and programs, such as Abc+ Plan, have for Article 6.2 (ITMO)** by including in their coverage different sizes of projects generating aggregate credits (e.g., a large group of small entrepreneurs). Such consolidations can increase the results of these programs and return of socioeconomic benefits and be accounted in the Article 6.2 mechanism in a scaled-up manner provided they have enhanced monitoring and verification, as already recommended.

• **Brazil should strongly defend, during the COP 26 negotiations on Article 6.4, the inclusion of project types from the Agriculture and Forest sectors,** since the best credit generation opportunities for the country are found in these sectors due to their high mitigation potentials, 2,419 and 2,565 $MtCO_2e$, and low abatement costs, between -1978 and 1.99 and between -0.38 and 9.22 US$/$tCO_2e$[32], respectively, reiterating the importance of nature-based solutions for the mitigation and adaptation to climate change in the country.

• **In addition to the Agriculture and Forest sectors, Brazil should advocate the inclusion of energy sector projects in the Article 6.4 negotiations,** since this

32. When the cost is negative it is understood that mitigation incurs net benefits, that is, in addition to enabling a reduction in CO_2e emissions, it provides financial return over the life of the technology and/or the implementation horizon of low carbon activity. On the other hand, if the cost is positive, emission mitigation will require financial effort for the agent, except through carbon pricing in the market.

sector has not been eligible for the voluntary market since 2019 and has a mitigation potential mapped to Brazil that contains technological innovation to be exploited as CSP, and the use of green hydrogen.

• **Review the national position to contribute to an international consensus on the corresponding adjustments in the overall accounting of emission reductions under Article 6** since non-acceptance damages the country's reputation for environmental policy that reverberates in trade relations, threatens the environmental integrity of the Paris Agreement, and creates barriers to additionality by its complex measurement.

• **Propose and position itself in favor of a transition of carbon credits from CDM projects on a temporary basis that minimizes the impacts on the climate integrity of the Paris Agreement** so that this transition does not become a commercial and reputational risk for Brazil in the face of its main buyers of carbon credits, who will not accept such credits, and for financial and legal certainty to ongoing CDM projects.

• **Maintain opinion in support of the equivalence of the Principle of General Mitigation of Global Emissions (OMGE) and the Share of Proceedings (SOP) in the instruments of Articles 6.2 and 6.4** since the price increase resulting from the adoption of these principles in transactions in the two instruments would be advantageous for countries such as Brazil that have lower costs to meet and exceed the goals of their NDCs. In addition, it is essential to feed resources for the management and governance of Article 6, as well as for climate adaptation.

• **Define a competent and responsible national authority for the accounting of transactions under Article 6 and to operationalize the corresponding adjustments with cross-cutting climate governance** to provide security to credit buyers, transparency to the system, and to prove the actual GHG reductions, maintaining environmental integrity.

• **Take advantage of the windows of opportunities with discussions on carbon markets under Article 6 for the creation of a regulated carbon market in Brazil, along the lines of the proposals of the PMR Brazil Project.** This market would be a clear demonstration of the government's commitment to carbon pricing, bringing regulatory stability to the country and transmitting security to the private sector to make long-term investments in low-carbon technologies. In addition, this market would serve as a benchmark for prices and mitigation options to guide the country's participation in international market instruments, both in the Paris Agreement and in possible negotiations of a CBAM.

• **Foster the potential for economic development, social equity, and ecological balance generated by carbon markets.** The carbon market model to be advocated by Brazil must incorporate among its main objectives: the protection of biodiversity, equitable access to sustainable development, and the eradication of poverty and climate justice, in harmony with the Paris Agreement and the Climate Convention. It should also:

- Provide for the protection of indigenous populations, *quilombolas*, traditional communities, and the primary producer;
- Mitigate the distortions of financial speculation;
- Provide for environmental and human rights safeguards, ensuring that projects resulting in: use of child and/or slave labor are excluded; loss of biodiversity and/or destruction of ecosystems; unemployment of the local population and social exclusion; increased vulnerability of food production systems; prejudice or unavailability of measures to adapt to the effects of climate change; contamination of soil, water bodies or damage to the air quality of other ecosystem services.

• **Brazil also needs a series of institutional measures that will enable a good operation of carbon markets and that are independent of the regulation of Article 6 of the Paris Agreement:**

- **The creation of a national emission reporting system** that is easily accessible and integrated with other systems, which provides transparency in data and includes results of deforestation control systems and REDD+ information, in line with the robustness demanded in the ongoing discussions in bill 528/2021 by monitoring, reporting, and verification;
- **The creation of integrated MRV systems of carbon credit projects,** aligned with internationally accepted scientific criteria which allow the standardization of credits avoiding the scarcity of high-quality credits. These systems provide economic incentives market instruments are capable of remunerating sustainable production systems, integrated data management, and access to the actions adopted, favouring its continuous improvement and transparent management;
- **The definition of the roles of subnational governments in an integrated MRV system** that will allow accounting between the entities of the federations;
- **The adoption of digital technology for MRV and certification processes** to optimize processes to decrease their efforts and implementation deadlines, which tend to be longer with the evolution of technical requirements and methodological complexity;
- **The prioritization of processes related to the legal fulfilment of sustainable projects** so that their regulatory process does not become an obstacle to their implementation;
- **The incorporation of an intersectoral architecture** that allows the monitoring of the mitigation result of all programs and public policies related to the NDC sectors.

For the private sector to support the development of this market and the advantages of its socio-economic benefits, this report brings the following recommendations:

• **Commit to long-term contracts for the purchase of carbon credits,** thus allowing long-term projects to have a greater positive impact on the environment and society.

• **Support reducing bureaucratization and simplification of transaction processes, as well as advocate the adoption of digital technology for MRV and carbon credit certification processes.**

• **Invest in credits from the Agriculture and Forest sectors** that have been identified in this report as the sectors with the highest supply potential. It is considered that investment in nature-based solutions should ensure maximum sustainability benefit and regeneration, in addition to minimizing social and environmental damage.

- **As for the agriculture sector, projects should focus on the recovery of degraded pastures (RDP) and integrated tillage, livestock, and forest systems (ICLF)** considering that 98% of the sector's rebate potential is in the strategy of intensification of beef cattle which includes RDP and that ICLF systems have negative abatement costs, highlighting its potential for net revenue generation, in addition to having numerous associated co-benefits such as increasing local biodiversity;
- **As for the forest sector, projects should focus on reforestation** for the short term due to the ease of implementation provided that they are based on an economic logic that justifies it, **sustainable forest management and forest restoration**, respecting the biome biodiversity regeneration.

• **Include the participation of indigenous and traditional populations directly affected in discussions about projects in the Forest sector,** considering their historical contribution to environmental preservation.

• **Expand the effort to reduce and remove GHG emissions** by investing in technological development and innovation, as recommended by initiatives such as the Science-Based Target Initiative (SBTi), using compensation mechanisms as transition tools, within an integrated strategy aimed at promoting sustainable development and avoiding economic losses arising from the trend proposed by green deals to use large-scale carbon border adjustments.

- Invest in projects that generate income and wealth for peoples, communities, small producers ensuring that they have economically viable alternatives to keep the forest standing and its rich socio-biodiversity (their way of living, their cultures, and traditional knowledge).

• **Establish partnerships that make innovative projects for emission reduction viable and removal of GHG from the atmosphere, as well as:**

- Siemens Energy and Braskem that together reduced Braskem's GHG emissions and water consumption, bringing greater efficiency in production;
- Natura, which, in partnership with the Cooperative of Economic Reforestation Consorciado and Adensado (RECA) developed the first carbon offset project within its productive chair, called Circular Carbon (or carbon insetting), which seeks to contain deforestation in the Amazon and remunerates the environmental service provided by the family farmer in the conservation of the standing forest. The project is the result of the Natura Carbono Neutro program launched in 2007 to account for, reduce and neutralize Natura's GHG emissions;
- Based on cutting-edge science and technology, Bayer, in partnership with Embrapa and a team of experts, launched the PRO Carbono program. The initiative encourages and supports producers in adopting even more sustainable management so that they can increase their productivity and increase carbon sequestration in the soil. Participating farmers are part of a benefits ecosystem that goes beyond the agricultural chain, being rewarded not only for what and how much they produce, but also for how they produce;
- Schneider and Walmart, which created the Gigaton PPA (GPPA) program to educate the company's supply chain on renewable energy purchases through aggregate energy purchase (PPA) contract to avoid emissions of 1,000 $MtCO_2$ by 2030;
- Suzano's partnership with Procter & Gamble and the WWF are together developing restoration plans for various degraded forests in the Brazil's Atlantic Forest biome, including monitoring methodology, impact evaluation, social engagement, and agroecological transition to rehabilitate the productive portions of the properties of local small farmers.

In a scenario where rules and regulations will still be defined, it is understood that this study has this point as a limiter. However, the placement of efforts and the search for consensus to create a broad, functional, and modern regulatory framework will allow the full development of opportunities and mitigation of exposed risks. Thus, it is recommended the development of new studies in the area of carbon markets in Brazil after the regulation of Article 6 of the Paris Agreement, to refer to the potentials/estimates presented in this report in the light of the parameters to be established such as the types of projects and methodologies that will be accepted in each of the markets.

BIBLIOGRAPHIC REFERENCES

ABIVIDRO. **Guia - Reciclagem do Vidro**. Available at: https://abividro.org.br/wp-content/uploads/2019/01/Abividro-Guia-Reciclagem-do-Vidro.pdf. Accessed in: 9 jun. 2021.

ABSOLAR. **Energia solar: mais empregos e sustentabilidade para o Brasil**. ABSOLAR, 2021a. Available at: https://www.absolar.org.br/artigos/energia-solar-mais-empregos-e-sustentabilidade-para-o-brasil/. Accessed in: 8 jun. 2021.

ABSOLAR. **Geração própria de energia solar atinge R$ 28 bilhões em investimentos e 166 mil empregos acumulados no País**. *In*: ABSOLAR. 2021b. Available at: https://www.absolar.org.br/noticia/geracao-propria-de-energia-solar-atinge-r-28-bilhoes-em-investimentos-e-166-mil-empregos-acumulados-no-pais/. Accessed in: 10 jun. 2021.

ALBRAS. ANEXO 3 - CONTRIBUIÇÃO DO PROJETO DE REDUÇÕES DE EMISSÕES DE GASES DE EFEITO ESTUFA NA ALBRAS, ALUMINIO BRASILEIRO S.A. PARA O DESENVOLVIMENTO SUSTENTÁVEL. *[S. l.: s. n.]* Available at: https://antigo.mctic.gov.br/mctic/export/sites/institucional/ciencia/SEPED/clima/mecanismo_de_desenvolvimento_limpo/submetidos/aprovados_termos_resolucao_1/publicacoes/206/Anexo-III-da-Resolucao-n.-1.pdf. Accessed in: 9 jun. 2021.

ANEEL. **Sistema de Informações de Geração da ANEEL SIGA**. 2021. Available at: https://app.powerbi.com/view?r=eyJrIjoiNjc4OGYyYjQtYWM2ZC00YjllLWJlYmEtYzdkNTQ1MTc1NjM2IiwidCI6IjQwZDZmOWI4LWVjYTctNDZhMi05MmQ0LWVhNGU5YzAxNzBlMSIsImMiOjR9. Accessed in: 10 jun. 2021.

ANTONACCIO, L.; ASSUNÇÃO, J.; CELIDONIO, M.; CHIAVARI, J.; LEME LOPES, C.; SCHUTZE, A. **Ensuring Greener Economic Growth for Brazil**. 2018. Available at: https://www.climatepolicyinitiative.org/publication/ensuring-greener-economic-growth-for-brazil/. Accessed in: 8 jun. 2021.

BACEN, B. C. do B. **Matriz de Dados do Crédito Rural - MDCR - Portal de Dados Abertos do Banco Central do Brasil**. 2019. Available at: https://dadosabertos.bcb.gov.br/dataset/matrizdadoscreditorural. Accessed in: 19 may. 2021.

BLAUFELDER, C.; LEVY, C.; PINNER, D. **A blueprint for scaling voluntary carbon markets to meet the climate challenge**. 2021. Mckinsey. Available at: https://www.mckinsey.com/business-functions/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenge. Accessed in: 14 may. 2021.

BNDES. **Etanol 2G: inovação em biocombustíveis**. BNDES, 2016. Available at: http://www.bndes.gov.br/wps/portal/site/home/conhecimento/noticias/noticia/etanol-2g-inovacao-biocombustiveis. Accessed in: 16 jul. 2021.

BNDES; EPE. **Acordo de cooperação no 21.5.0017.1, que entre si celebram o Banco Nacional De Desenvolvimento Econômico e Social – BNDES e a Empresa de Pesquisa Energética, para cooperação com vistas a estudar a viabilidade de instrumento de transferência de recursos financeiros das empresas de óleo e gás (O&G) para atividades de sequestro e armazenagem de carbono no setor florestal, a título de compensação de emissões de carbono e de alcance de outros benefícios coletivos relacionados à água, biodiversidade, controle de erosão, equilíbrio do microclima, dentre outros**. Available at: https://www.epe.gov.br/sites-pt/acesso-a-informacao/convenios-acordos-de-cooperacao/acordos-de-cooperacao/Documents/Acordo%20de%20Coopera%c3%a7%c3%a3o%20BNDES-EPE_assinado.pdf. Accessed in: 4 aug. 2021.

BRASIL. **Floresta + Carbono incentiva conservação de vegetação nativa**. 2020. Available at: https://www.gov.br/pt-br/noticias/meio-ambiente-e-clima/2020/10/floresta-carbono-incentiva-conservacao-de-vegetacao-nativa. Accessed in: 30 jul. 2021.

BRASIL. **Projeto PMR Brasil**. 2021a. Available at: https://www.gov.br/fazenda/pt-br/orgaos/spe/pmr-brasil/pmr-brasil. Accessed in: 9 jun. 2021.

BRASIL. **LEI Nº 14.119, DE 13 DE JANEIRO DE 2021.** Brasília: Diário Oficial da União, 2021 b. *E-book*. Available at: https://www.in.gov.br/web/dou. Accessed in: 20 may. 2021.

BRASIL. **MME divulga balanço do RenovaBio em 2020 e metas de redução de emissões para 2022-2031**. 2021c. Available at: https://www.gov.br/mme/pt-br/assuntos/noticias/mme-divulga-balanco-do-renovabio-em-2020-e-metas-de-reducao-de-emissoes-para-2022-2031-1. Accessed in: 27 may. 2021.

BRASIL. **Projeto de Lei nº 528/2021. Regulamenta o Mercado Brasileiro de Redução de Emissões (MBRE), determinado pela Política Nacional de Mudança do Clima – Lei no 12.187, de 29 de dezembro de 2009**. Brasília: Câmara Dos Deputados, 2021 d. *E-book*. Available at: https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=1965628. Accessed in: 14 set. 2021.

BRASIL. **PIB do setor agropecuário apresentou crescimento de 2% em 2020**. 2021e. Available at: https://www.gov.br/agricultura/pt-br/assuntos/noticias/pib-do-setor-agropecuario-apresentou-crescimento-de-2-em-2020. Accessed in: 8 jun. 2021.

BRASIL. **Em momento de transição energética, Brasil amplia ainda mais consumo de renováveis nos transportes**. 2021f. Available at: https://www.gov.br/mme/pt-br/assuntos/noticias/em-momento-de-transicao-energetica-brasil-amplia-ainda-mais-consumo-de-renovaveis-nos-transportes. Accessed in: 9 jun. 2021.

BRASIL, Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Inovação, Desenvolvimento Rural e Irrigação. **Plano setorial para adaptação à mudança do clima e baixa emissão de carbono na agropecuária com vistas ao desenvolvimento sustentável (2020-2030): visão estratégica para um novo ciclo**. 2021 g. Available at: https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/plano-abc/arquivo-publicacoes-plano-abc/abc-portugues.pdf/view. Accessed in: 20 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para agricultura, florestas e outros usos do solo (AFOLU)**. 2017 a. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL. Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Sumário executivo: modelagens setoriais e opções transversais para mitigação de emissões de gases de efeito estufa**. p. 78, 2017b. Available at: https://antigo.mctic.gov.br/mctic/export/sites/institucional/ciencia/SEPED/clima/arquivos/projeto_opcoes_mitigacao/publicacoes/Sumario-Executivo_Modelagem-setoriais.pdf. Accessed in: 14 set. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de biocombustíveis**. p. 155, 2017 c. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de fontes renováveis de geração elétrica**. p. 285, 2017 d. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de termelétricas e termonucleares**. p. 159, 2017 e. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de transportes**. p. 459, 2017 f. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de ferro-gusa e aço**. p. 167, 2017 g. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor químico**. p. 171, 2017 h. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de outras indústrias**. p. 79, 2017 i. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de papel e celulose**. p. 121, 2017 j. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de cimento**. p. 107, 2017 k. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASIL, Ministério da Ciência, Tecnologia, Inovações e Comunicações. **Modelagem setorial de opções de baixo carbono para o setor de metalurgia de metais não ferrosos.** p. 111, 2017 l. Available at: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/opcoes_mitigacao/Opcoes_de_Mitigacao_de_Emissoes_de_Gases_de_Efeito_Estufa_GEE_em_SetoresChave_do_Brasil.html#:~:text=O%20Projeto%20%2D%20Op%C3%A7%C3%B5es%20de%20Mitiga%C3%A7%C3%A3o,auxiliar%20a%20tomada%20de%20decis%C3%A3o. Accessed in: 19 may. 2021.

BRASKEM. **POLIETILENO VERDE I'M GREEN™**. 2021. Available at: http://plasticoverde.braskem.com.br/site.aspx/PE-Verde-Produtos-e-Inovacao. Accessed in: 9 jun. 2021.

CANADA, E. and C. C. **Canada-Chile Agreement on Environmental Cooperation: overview**. 2010. international treaties. Available at: https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-countries-regions/latin-america-caribbean/canada-chile-environmental-agreement/overview.html. Accessed in: 2 aug. 2021.

CANADA, E. and C. **C. Support for the implementation of Mexico and Chile's Nationally Determined Contributions (NDCs)**. 2017. policies;international treaties. Available at: https://www.canada.ca/en/services/environment/weather/climatechange/canada-international-action/mexico-chile-support-implementation-respective-nationally-determined-contributions.html. Accessed in: 2 aug. 2021.

CAREPA, J. 5 noções fundamentais sobre créditos de carbono. *In*: Blog WayCarbon. 30 mar. 2021. Available at: https://blog.waycarbon.com/2021/03/creditos-de-carbono/. Accessed in: 12 jul. 2021.

CARILLO PINEDA, A.; CHANG, A.; FARIA, P.; SBTI. **FUNDAMENTOS PARA ESTABELECER METAS DE ZERO EMISSÕES LÍQUIDAS COM BASE CIENTÍFICA NO SETOR EMPRESARIAL**. CDP, 2020. Available at: https://sciencebasedtargets.org/resources/files/Net-Zero_Full-Paper_Portuguese-from-Portugal.pdf. Accessed in: 7 jul. 2021.

CEBDS. **Oportunidades e Desafios das Metas da NDC Brasileira - Setor Agropecuário**. 2017 a. Available at: https://cebds.org/publicacoes/oportunidade-e-desafios-das-metas-da-ndc-brasileira/#.YKZwKC1Q2Rs. Accessed in: 20 may. 2021.

CEBDS. **Oportunidades e Desafios das Metas da NDC Brasileira - Setor Florestal**. 2017 b. Available at: https://cebds.org/publicacoes/oportunidade-e-desafios-das-metas-da-ndc-brasileira/#.YKZwKC1Q2Rs. Accessed in: 20 may. 2021.

CEBDS. **Oportunidades e Desafios das metas da NDC Brasileira para o Setor Empresial - Setor de Energia**. 2017c. Available at: https://cebds.org/publicacoes/oportunidade-e-desafios-das-metas-da-ndc-brasileira/#.YMITBC1Q2Rs. Accessed in: 10 jun. 2021.

CEBDS. **Oportunidades e Desafios das metas da NDC Brasileira para o Setor Empresial - Setor de transportes**. 2017d. Available at: https://cebds.org/publicacoes/oportunidade-e-desafios-das-metas-da-ndc-brasileira/#.YMITBC1Q2Rs. Accessed in: 9 jun. 2021d.

CEBDS. **Estratégias de Desenvolvimento de Baixo Carbono para o Longo Prazo**. Available at: https://d335luupugsy2.cloudfront.net/cms/files/14773/1553453509cebds.org-cebds-longoprazo-port-navegavel.pdf. Accessed in: 9 jun. 2021e.

CEBDS. **Oportunidades e Desafios das metas da NDC Brasileira para o Setor Empresial - Setor Industrial**. 2017f. Available at: https://cebds.org/publicacoes/oportunidade-e-desafios-das-metas-da-ndc-brasileira/#.YMITBC1Q2Rs. Accessed in: 9 jun. 2021.

CEBDS. **Precificação de carbono na indústria brasileira**. CEBDS; CPLC, 2018 a. *E-book*. Available at: https://d335luupugsy2.cloudfront.net/cms/files/14773/1560047534CEBDS_PrecificacaoCarbono_Portugues_04-04.pdf. Accessed in: 27 may. 2021.

CEBDS. **Precificação de Carbono na Indústria Brasileira**. Available at: https://d335luupugsy2.cloudfront.net/cms/files/14773/1555424210CEBDS_PrecificacaoCarbono_Portugues_04-04.pdf. Accessed in: 9 jun. 2021b.

CEBDS. **Nota Técnica: Webinar sobre o marco regulatório do mercado de carbono no Brasil**. 2020. Available at: https://cebds.org/wp-content/uploads/2020/11/cebds.org-visao-geral-dos-mercados-de-carbono-objetivos-dinamicas-e-desempenho-20201026-nota-tecnica-webinar-marco-regulatorio-mercado-carbono-1.pdf. Accessed in: 26 may. 2021.

CEBDS. **Neutralidade Climática: Uma Grande Oportunidade**. 2021. Available at: https://cebds.org/wp-content/uploads/2021/04/cebds.org-neutralidade-climatica-uma-grande-oportunidade-carta-neutralidade-13-04.pdf. Accessed in: 14 set. 2021.

CEBRI. **Mercado de Carbono e Artigo 6: perspectivas para a área florestal**. 2021. Available at: https://www.cebri.org/br/evento/343/mercado-de-carbono-e-artigo-6-perspectivas-para-a-area-florestal. Accessed in: 10 aug. 2021.

CNI. **Mecanismo de Desenvolvimento Sustentável e Competitividade Industrial**. 2020. Available at: http://portaldaindustria.com.br/publicacoes/2020/11/mecanismo-de-desenvolvimento-sustentavel-e-competitividade-de-industrial/. Accessed in: 9 jul. 2021.

CNI. **Florestas - Portal da Indústria**. 2021a. Available at: http://www.portaldaindustria.com.br/cni/canais/industria-sustentavel/temas-de-atuacao/florestas/. Accessed in: 22 jul. 2021.

CNI. I**mportância da indústria**. 2021b. Available at: http://portaldaindustria.com.br/estatisticas/importancia-da--industria/. Accessed in: 9 jun. 2021.

CNN. **Parques brasileiros podem gerar um milhão de empregos no país, diz pesquisa**. 2021. Available at: https://www.cnnbrasil.com.br/business/2021/07/17/parques-brasileiros-podem-gerar-um-milhao-de-empregos--no-pais-diz-pesquisa. Accessed in: 22 jul. 2021.

EUROPEAN COMISSION. **Pacto Ecológico Europeu (mecanismo de ajustamento das emissões de carbono nas fronteiras)**. 2020a. Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12228-Pacto-Ecologico-Europeu-mecanismo-de-ajustamento-das-emissoes-de-carbono-nas-fronteiras-_pt. Accessed in: 6 jul. 2021.

EUROPEAN COMISSION. **Stepping up Europe's 2030 climate ambition Investing in a climate - neutral future for the benefit of our people**. European Comission, 2020 b. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:749e04bb-f8c5-11ea-991b-01aa75ed71a1.0001.02/DOC_1&format=PDF. Accessed in: 6 jul. 2021.

EUROPEAN COMISSION. **Carbon Border Adjustment Mechanism**. 2021. Text. Available at: https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661. Accessed in: 4 aug. 2021.

COMMITTEE ON CLIMATE CHANGE. **Building a resilient recovery from the COVID-19 crisis**. 2020. Available at: https://www.theccc.org.uk/publication/letter-building-a-resilient-recovery-from-the-covid-19-crisis-to-prime--minister-boris-johnson/. Accessed in: 16 jul. 2021.

CONFEDERACIÓN SUIZA Y REPÚBLICA DEL PERÚ. **Acuerdo entre la Confederación Suiza y la República del Perú para la implementación del Acuerdo de París**. 2020. Available at: https://cdn.www.gob.pe/uploads/document/file/1399894/Convenio%20en%20espa%C3%B1ol.pdf. Accessed in: 14 set. 2021.

COZIJNSEN, J. **CO_2 deals important for Paris Accord. In: 2020**. Available at: https://www.emissierechten.nl/column/recent-co2-deals-reveal-importance-for-paris-accord/. Accessed in: 30 jul. 2021.

CPLC. **Carbon Pricing Dashboard | Up-to-date overview of carbon pricing initiatives**. 2021a. Available at: https://carbonpricingdashboard.worldbank.org/map_data. Accessed in: 26 may. 2021.

CPLC. **What is Carbon Pricing?**. 2021b. Available at: https://carbonpricingdashboard.worldbank.org/what-carbon-pricing#Article6. Accessed in: 3 abr. 2021.

DE CLARA, S. **Article 6.2 of the Paris Agreement**. 2021. Available at: https://www.youtube.com/watch?v=oXt-7syyiUlw&ab_channel=Laborat%C3%B3riodeInova%C3%A7%C3%A3oFinanceira. Accessed in: 8 jul. 2021.

DICHRISTOPHER, T. **Experts explain why green hydrogen costs have fallen and will keep falling**. 2021. Available at: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/experts-explain--why-green-hydrogen-costs-have-fallen-and-will-keep-falling-63037203. Accessed in: 11 jun. 2021.

DIRECCIÓN DE CAMBIO CLIMÁTICO. **Press release: 32 leading countries set benchmark for carbon markets with San Jose Principles**. In: 13 out. 2019. Available at: https://cambioclimatico.go.cr/press-release-leading-countries-set-benchmark-for-carbon-markets-with-san-jose-principles/. Accessed in: 2 aug. 2021.

DOMINGUES, E. P.; CARDOSO, G.; MAGALHÃES, A. S. **Desmatamento zero na Amazônia é factível e traz benefícios econômicos e ambientais**. p. 10, 2021.

DONOFRIO, S.; MAGUIRE, P.; ZWICK, S.; MERRY, W. **Voluntary Carbon and the Post-Pandemic Recovery**. p. 16, 2020 a.

DONOFRIO, S.; MAGUIRE, P.; ZWICK, S.; MERRY, W.; WILDISH, J.; MYERS, K. The Only Constant is Change - State of the Voluntary Carbon Markets 2020 Second Installment Featuring Core Carbon and Additional Attributes Offset, Volumes and Insights. **Ecosystem Marketplace Insights Brief**, 2020 b. Available at: https://app.hubspot.com/documents/3298623/view/101893633?accessId=bf5d12. Accessed in: 27 may. 2021.

ENVIRONMENTAL DEFENSE FUND. **Cost-Effective Emissions Reductions beyond Brazil's International Target: Estimation and Valuation of Brazil's Potential Climate Asset**. EDF, 2016. Available at: http://www.edf.org/sites/default/files/cost-effective-emissions-reductions-brazil.pdf. Accessed in: 7 jul. 2021.

EPBR. **Brasil revisa meta de emissões de carbono e promete neutralidade até 2050**. *In:* 22 abr. 2021. Available at: https://epbr.com.br/brasil-revisa-meta-de-emissoes-de-carbono-e-promete-neutralidade-ate-2050/. Accessed in: 19 aug. 2021.

EPE. **Estudos de Longo Prazo - Papel da Biomassa na Expansão da Geração de Energia Elétrica**. 2018. Available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-457/Biomassa%20e%20Expansão%20de%20Energia.pdf. Accessed in: 10 jun. 2021.

EPE. **Precificação de carbono: riscos e oportunidades para o Brasil**. 2020. Available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-549/NT%20EPE-DEA--GAB-014-2020%20-%20Precifica%C3%A7%C3%A3o%20de%20C_final_05012021.pdf. Accessed in: 29 jul. 2021.

EUROACTIV. **French Authorities Position Paper. 2020**, p. 3. Available at: https://www.euractiv.com/wp-content/uploads/sites/2/2020/04/French-position-paper.pdf. Accessed in: 14 sep. 2021.

EUROACTIV. **China steps up climate fight with emissions trading scheme**. In: Www.euractiv.com. 16 jul. 2021. Available at: https://www.euractiv.com/section/climate-environment/news/china-steps-up-climate-fight-with--emissions-trading-scheme/. Accessed in: 3 aug. 2021.

EVANS, S.; GABBATISS, J. **In-depth Q&A: How 'Article 6' carbon markets could 'make or break' the Paris Agreement | Carbon Brief**. 2018. Available at: https://www.carbonbrief.org/in-depth-q-and-a-how-article-6-carbon--markets-could-make-or-break-the-paris-agreement. Accessed in: 9 jul. 2021.

FEDERATIVE REPUBLIC OF BRAZIL. **Intended Nationally Determined Contribution**. 2016. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/BRAZIL%20iNDC%20english%20FINAL.pdf. Accessed in: 14 sep. 2021.

FERREIRA, T. V. B. **Roadmap eólica offshore brasil**. EPE, 2020. Available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-456/Roadmap_Eolica_Offshore_EPE_versao_R2.pdf. Accessed in: 14 sep. 2021.

FOREST TRENDS' ECOSYSTEM MARKETPLACE; DONOFRIO, S.; MAGUIRE, P.; MERRY, W.; ZWICK, S. **Financing Emissions Reductions for the Future**. 2019. Available at: https://app.hubspot.com/documents/3298623/view/63001900?accessId=eb4b1a&__hsfp=3827167342&__hssc=251652889.1.1625771831877&__hstc=251652889.6c64c8476f960635a34450682c8a198f.1620054426272.1625698735862.1625771831877.6. Accessed in: 9 jul. 2021.

FSC. **Open Letter: Timber Importers Call for More FSC-Certified Area in Brazil**. 2021. Available at: https://fsc.org/en/newsfeed/open-letter-timber-importers-call-for-more-fsc-certified-area-in-brazil. Accessed in: 5 aug. 2021.

GLOBAL CCS INSTITUTE. **Global Status of CCS**. 2020. Available at: https://www.globalccsinstitute.com/wp-content/uploads/2021/03/Global-Status-of-CCS-Report-English.pdf. Accessed in: 05 aug. 2021.

GOLD STANDARD. **GSF Registry**. 2021a. Available at: https://registry.goldstandard.org/projects?q=&page=1&-countries=BR. Accessed in: 5 ago. 2021.

GOLD STANDARD. **Fee Schedule**. 2021b. Available at: https://globalgoals.goldstandard.org/fees/. Accessed in: 19 aug. 2021.

GOLD STANDARD. **Gold Standard - Market Report 2020**. 2021c Available at: https://www.goldstandard.org/sites/default/files/gold_standard_market_report_2020.pdf. Accessed in: 26 may. 2021b.

GOULDSON, A.; SUDMANT, A.; KHREIS, H.; PAPARGYROPOULOU, E. **The Economic and Social Benefits of Low-Carbon Cities: A Systematic Review of the Evidence**. p. 92, 2018.

GREINER, S.; KRÄMER, N.; LORENZO, F. D.; MICHAELOWA, A.; HOCH, S.; KESSLER, J. **Article 6 piloting: State of play and stakeholder experiences**. Climate Focus, Perspectives Climate Group, 2020. *E-book*. Available at: https://www.climatefinanceinnovators.com/wp-content/uploads/2020/12/Climate-Finance-Innovators_Article--6-piloting_State-of-play-and-stakeholder-experiences_December-2020.pdf. Accessed in: 18 may. 2021.

HETTIARACHCHI, H.; KSHOURAD, C. Chapter 9 - Promoting Waste-to-Energy: Nexus Thinking, Policy Instruments, and Implications for the Environment. *In:* KUMAR, S.; KUMAR, R.; PANDEY, A. (org.). **Current Developments in Biotechnology and Bioengineering**. Elsevier, 2019. p. 163–184. E-book. Available at: https://www.sciencedirect.com/science/article/pii/B9780444640833000099. Accessed in: 14 jul. 2021.

HOULDER, V.; LIVSEY, A. **Precificação efetiva do carbono é cada vez mais urgente | Mundo | Valor Econômico**. 2021. Available at: https://valor.globo.com/mundo/noticia/2021/02/09/precificacao-efetiva-do-carbono-e-cada-vez-mais-urgente.ghtml. Accessed in: 9 jul. 2021.

IBÁ. **Mudanças Climáticas: contribuições das árvores plantadas**. 2017. Available at: http://iba.org/images/shared/Biblioteca/Iba_no_Papel_2_Mudancas_Climaticas.pdf. Accessed in: 14 sep. 2021

IBRAM. **Programa Siderurgia Sustentável permite que o carvão vegetal seja o principal combustível de grandes siderúrgicas**. In: IBRAM. 20 may 2021. Available at: https://ibram.org.br/noticia/siderurgias-utilizam-carvao-vegetal-como-principal-combustivel/. Accessed in: 9 jun. 2021.

IEA. **Renewables 2020 Data Explorer – Analysis**. 2020. Available at: https://www.iea.org/articles/renewables-2020-data-explorer. Accessed in: 11 jun. 2021.

IETA; UNIVERSITY OF MARYLAND; CPLC. T**he Economic Potential of Article 6 of the Paris Agreement and Implementation Challenges**. Creative Commons Attribution CC, 2019. Available at: https://www.ieta.org/resources/International_WG/Article6/CLPC_A6%20report_no%20crops.pdf. Accessed in: 17 may 2021.

IETA. **GHG Market Sentiment Survey 2021**. 2021. Available at: https://www.ieta.org/resources/Resources/GHG_Market_Sentiment_Survey/IETA%20GHG%20Market%20Sentiment%20Survey%202021%20Report%20web.pdf. Accessed in: 6 jul. 2021.

IIF. **Taskforce on Scaling Voluntary Carbon Markets**. IIF, 2021. Available at: https://www.iif.com/Portals/1/Files/TSVCM_Summary.pdf. Accessed in: 8 jul. 2021.

INSTITUTO ETHOS. **IEC lança posicionamento sobre precificação do carbono - Instituto Ethos**. 2016. Available at: https://www.ethos.org.br/conteudo/posicionamentos/iec-lanca-posicionamento-sobre-precificacao-do-carbono/. Accessed in: 16 jul. 2021.

IPCC. **Glossary — Global Warming of 1.5 oC**. In: 2018. Available at: https://www.ipcc.ch/sr15/chapter/glossary/. Accessed in: 7 jul. 2021.

IPCC. **Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change**. Cambridge University Press, 2021. Available at: https://www.ipcc.ch/report/ar6/wg1/#FullReport. Accessed in: 18 aug. 2021.

IPÊ. **Sistemas Agroflorestais (SAFs)**. 2021. Available at: https://www.ipe.org.br/saf. Accessed in: 8 jun. 2021.

IPEA. **Biodiesel - O combustível do futuro**. 2005. Available at: https://www.ipea.gov.br/desafios/index.php?option=com_content&view=article&id=865:reportagens-materias&Itemid=39. Accessed in: 11 jun. 2021.

IPEA. **Legado Do MDL - Impactos e lições aprendidas a partir da implementação do Mecanismo de Desenvolvimento Limpo no Brasil como subsídios para novos mecanismos**. IPEA, 2018. Available at: https://antigo.mctic.gov.br/mctic/export/sites/institucional/ciencia/SEPED/clima/arquivos/livro_legado_do_mdl.pdf. Accessed in: 9 jul. 2021.

IRENA. **Renewable Energy and Jobs - Annual Review 2019**. 2019. Available at: https://www.irena.org/publications/2019/Jun/Renewable-Energy-and-Jobs-Annual-Review-2019. Accessed in: 11 jun. 2021.

ITAÚ UNIBANCO. **Project Carbon**. Available at: https://www.itau.com.br/sustentabilidade/Download.aspx?Arquivo=6Pckr9OzGzQltPzwktWF0A==. Accessed in: 22 jul. 2021.

JORNAL DA USP NO AR. **Projeto Amazônia 4.0 incentiva economia da região de forma sustentável**. 2021. Available at: https://jornal.usp.br/atualidades/projeto-amazonia-4-0-incentiva-economia-da-regiao-de-forma-sustentavel/. Accessed in: 27 may. 2021.

KERSCHNER, S.; SMITHERS EXCELL, J.; CROWLEY, N.; YORK, I. **Scaling Voluntary Carbon Markets: The Final Report | White & Case LLP**. 2021. Available at: https://www.whitecase.com/publications/alert/scaling-voluntary-carbon-markets-final-report. Accessed in: 19 may. 2021.

KÖBERLE, A. de C. **IMPLEMENTATION OF LAND USE IN AN ENERGY SYSTEM MODEL TO STUDY THE LONG-TERM IMPACTS OF BIOENERGY IN BRAZIL AND ITS SENSITIVITY TO THE CHOICE OF AGRICULTURAL GREENHOUSE GAS EMISSION FACTORS**. 2018. - COPPE/UFRJ, 2018. Available at: https://pantheon.ufrj.br/bitstream/11422/12262/1/AlexandreDeCarvalhoKoberle-min.pdf. Accessed in: 23 aug. 2021.

KRAUSE, E. et al. **International Carbon Action Partnership (ICAP) Status Report 2021**. p. 173, 2021.Available at: https://icapcarbonaction.com/en/?option=com_attach&task=download&id=723. Accessed in: 14 sep. 2021.

KRUG, T. **Modalidades e Procedimentos para Atividades de Projeto de Florestamento e Reflorestamento no Mecanismo de Desenvolvimento Limpo: uma Síntese**. p. 19, 2004.

LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE; UNIVERSITY OF LEEDS. **Policy brief - Pricing carbon during the economic recovery from the COVID-19 pandemic**. 2020. Available at: https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2020/05/Pricing-carbon-during-the-recovery-from-the-COVID-19-pandemic.pdf

MACHADO, N. **Hidrogênio verde pode ficar competitivo até 2030, com renováveis mais em conta | Diálogos da Transição**. In: Epbr. 7 jan. 2021. Available at: https://epbr.com.br/hidrogenio-verde-pode-ficar-competitivo-ate-2030-com-renovaveis-mais-em-conta/. Accessed in: 26 may. 2021.

MANZATTO, C. V.; DE ARAUJO, L. S.; ASSAD, E. D.; SAMPAIO, F. G.; SOTTA, E. D.; VICENTE, L. E.; PEREIRA, S. E. M. **Mitigação das emissões de Gases de Efeitos Estufa pela adoção das tecnologias do Plano ABC: estimativas parciais**. 2020. Available at: https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1123612/mitigacao-das-emissoes-de-gases-de-efeitos-estufa-pela-adocao-das-tecnologias-do-plano-abc-estimativas-parciais. Accessed in: 14 sep. 2021.

MARKESTRAT; FAVA SCARE, R.; SCIENCIA DO PRADO, L.; JUNQUEIRA, M.; TEIXEIRA, I.; BEGAS, M. **MODELO PARA ATUAÇÃO NO MERCADO DE CRÉDITOS DE CARBONO PARA A AGRICULTURA**. Markestrat Agribusiness, 2020.

MATSUI, N. **Brasil manifesta interesse em aderir a programa preparatório para precificação de carbono**. 2021. Available at: https://oglobo.globo.com/epoca/guilherme-amado/brasil-manifesta-interesse-em-aderir-programa-preparatorio-para-precificacao-de-carbono-1-24994862. Accessed in: 2 aug. 2021.

MIAN, R. **Raízen vai construir sua segunda planta de etanol celulósico**. 2021. Available at: https://www.udop.com.br/noticia/2021/06/25/raizen-vai-construir-sua-segunda-planta-de-etanol-celulosico.html. Accessed in: 4 aug. 2021.

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES (MCTIC); MINISTÉRIO DAS RELAÇÕES EXTERIORES. **SEGUNDO RELATÓRIO DE ATUALIZAÇÃO BIENAL DO BRASIL**. 2017. Available at: http://educaclima.mma.gov.br/wp-content/uploads/2019/09/BUR-2-2017-português.pdf. Accessed in: 9 jun. 2021.

MINISTÉRIO DA FAZENDA. **Brazil Country Program for the Green Climate Fund - GCF**. 2018. Available at: https://www.gov.br/produtividade-e-comercio-exterior/pt-br/assuntos/assuntos-economicos-internacionais/fundo-verde-do-clima/arquivos/brazil-gcf-country-program-english.pdf

MINISTÉRIO DE MINAS E ENERGIA. **Estudos do Plano Decenal de Expansão de Energia 2030 - Oferta de Biocombustíveis**. 2020. Available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-490/topico-522/PDE%202030%20-%20Oferta%20de%20Biocombustiveis.pdf. Accessed in: 10 jun. 2021.

MINISTÉRIO DE MINAS E ENERGIA; EPE. **Balanço Energético Nacional 2020: Ano base 2019**. 2020. Available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-479/topico-528/BEN2020_sp.pdf. Accessed in: 9 jun. 2021.

MOREIRA, A. **UE prevê taxa de carbono sobre aço, ferro, alumínio, cimento, fertilizantes e eletricidade em 2023**. 2021. Available at: https://valor.globo.com/mundo/noticia/2021/06/09/brasil-pouco-afetado-por-proposta-inicial-de-taxa-de-carbono-da-ue.ghtml. Accessed in: 8 jul. 2021.

MOREIRA, M. M. R.; SEABRA, J. E. A.; LYND, L. R.; ARANTES, S. M.; CUNHA, M. P.; GUILHOTO, J. J. M. Socio-environmental and land-use impacts of double-cropped maize ethanol in Brazil. **Nature Sustainability**, v. 3, n. 3, p. 209–216, 2020.

NATURA. **Relatório Anual Natura**. [S. l.: s. n.]. Available at: https://static.rede.natura.net/html/2019/a-natura/pdf/relatorio_anual_natura_2018.pdf.

NEWCLIMATE INSTITUTE; DATA-DRIVEN ENVIROLAB. **Navigating the nuances of net-zero targets**. Available at: https://newclimate.org/wp-content/uploads/2020/10/NewClimate_NetZeroReport_October2020.pdf. Accessed in: 9 jul. 2021.

NORDHAUS, W. D. **A New Solution: The Climate Club | by William D. Nordhaus | The New York Review of Books**. 2015. Available at: https://www.nybooks.com/articles/2015/06/04/new-solution-climate-club/. Accessed in: 5 aug. 2021.

OLIVEIRA, G.; ZAITUNE CURI, A.; SILVA FELINI, P.; FICARELLI, T. R. A. **IMPACTOS SOCIOECONÔMICOS E AMBIENTAIS DA GERAÇÃO DE ENERGIA EÓLICA NO BRASIL**. p. 84, 2020.

OLIVEIRA, M. G. F. **Roadmap tecnológico do cimento**. 2019._ Available at: https://coprocessamento.org.br/wp-content/uploads/2019/11/Roadmap_Tecnologico_Cimento_Brasil_Book-1.pdf. Accessed in: 23 aug. 2021.

PEROSA, B. B.; GURGEL, A. da C.; VICENTE, L. F.; VICENTE, A. K.; ARAUJO, L. S.-. **Agricultura de Baixo Carbono no Brasil: potencialidade e desafios para construção de um sistema MRV**. 2019. Available at: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/206622/1/Vicente-Agricultura-Carbono-2019.pdf. Accessed in: 14 sep. 2021

PIRIS-CABEZAS, P.; LUBOWSKI, R.; LESLIE, G. **Estimating the Power of International Carbon Markets to Increase Global Climate Ambition**. 2019. Available at: https://ceep.columbia.edu/sites/default/files/content/events/Lubowski%20et%20al.%20on%20Carbon%20Markets.pdf. Accessed in: 6 jul. 2021.

PLUME, K. **Farmers struggle to break into booming carbon-credit market**. In: Reuters. 8 abr. 2021. Available at: https://www.reuters.com/business/energy/farmers-struggle-break-into-booming-carbon-credit-market-2021-04-28/. Accessed in: 30 jul. 2021.

PREFEITURA DE BELO HORIZONTE. **5º Inventário Municipal de Emissões de GEE - Relatório técnico de atualização e extração de dados - período 2020**. 2021.

REGISTRO PÚBLICO DE EMISSÕES. **Emissões históricas do Programa Brasileiro GHG Protocol | Registro Público de Emissões**. 2019. Available at: https://www.registropublicodeemissoes.com.br/estatisticas/emissoes-historicas. Accessed in: 7 jul. 2021.

REGO, E. E.; TRINKENREICH, J.; SOARES, J. B.; MULLER, G. de M. **Resposta da Demanda: Conceitos, Aspectos Regulatórios e Planejamento Energético**. EPE, 2019.

REUTERS. China's carbon trading scheme makes debut with 4.1 mln T in turnover. **Reuters**, 16 jul. 2021. Sustainable Business Available at: https://www.reuters.com/business/sustainable-business/chinas-national-carbon-emission-trading-opens-48-yuant-chinese-media-2021-07-16/. Accessed in: 3 aug. 2021.

SANTOS, L. **Proposal for the Implementation of a Carbon Pricing Instrument in the Brazilian Industry: assessing competitiveness risks and distributive impacts**. 2018. Available at: http://rgdoi.net/10.13140/RG.2.2.32126.23368. Accessed in: 12 may. 2021.

SCHERER, **A. Agricultura sustentável tem potencial para fazer Brasil deslanchar no mercado de carbono internacional**. 2021. Available at: https://umsoplaneta.globo.com/sociedade/consumo-consciente/noticia/2021/04/16/agricultura-sustentavel-tem-potencial-para-fazer-brasil-deslanchar-no-mercado-de-carbono-internacional.ghtml. Accessed in: 12 may. 2021.

SEBRAE. **Cadeia de Valor da Energia Solar Fotovoltaica no Brasil**. [S. l.: s. n.] Available at: https://www.sebrae.com.br/Sebrae/Portal%20Sebrae/Anexos/Cadeia%20de%20Valor%20da%20Energia%20Solar%20Fotovoltaica%20no%20Brasil.pdf

SEEG. SEEG 8 **Análise das emissões brasileiras de gases de efeito estufa e suas implicações para as metas de clima do Brasil 1970-2019**. p. 41, 2020.

SEEG. **Total Emissions | SEEG - System Gas Emissions Estimation**. 2021. Available at: http://plataforma.seeg.eco.br/total_emission. Accessed in: 8 jun. 2021.

SEROA DA MOTTA, R. **As vantagens competitivas do Brasil nos instrumentos de mercado do Acordo de Paris.** 2021a. Available at: https://www.climaesociedade.org/post/vantagens-competitivas-brasil-acordo-de-paris. Accessed in: 12 may. 2021.

SEROA DA MOTTA, R. **O Caminho para Glasgow: Perspectivas para o Mercado de Carbono**. 2021 b. Available at: https://www.youtube.com/watch?v=otxtF3St0N4. Accessed in: 8 jul. 2021.

S&P GLOBAL. **Voluntary carbon market grows 6% on year in 2019**. 2020. Available at: https://www.spglobal.com/platts/en/market-insights/latest-news/coal/092220-voluntary-carbon-market-grows-6-on-year--in-2019-ecosystem-marketplace. Accessed in: 3 aug. 2021.

SUN, L.; LIU, W.; FUJII, M.; LI, Z.; REN, J.; DOU, Y. Chapter 1 - An overview of waste-to-energy: feedstocks, technologies and implementations. In: REN, J. (org.). **Waste-to-Energy**. Academic Press, 2020. p. 1–22. E-book. Available at: https://www.sciencedirect.com/science/article/pii/B978012816394800001X. Accessed in: 14 jul. 2021.

TAYLOR, K. LEAK: **EU's carbon border tariff to target steel, cement, power**. In: Www.euractiv.com. 3 jun. 2021. Available at: https://www.euractiv.com/section/energy-environment/news/eus-carbon-border-tariff-to-target--steel-cement-power/. Accessed in: 7 jul. 2021.

TUKI WASI. **The first installation campaign of Improved Cookstoves of the Tuki Wasi programme**. In: 5 fev. 2021. Available at: https://tukiwasi.org/en/notaprensa5/. Accessed in: 5 aug. 2021.

UCL; TROVE RESEARCH; LIEBREICH ASSOCIATES. **Future Demand, Supply and Prices for Voluntary Carbon Credits – Keeping the Balance**. p. 51, 2021.

UNCTAD. **A European Union Carbon Border Adjustment Mechanism: Implications for developing countries**. p. 31, 2021.

UNFCCC. **Brazil First NDC**. 2016. Available at: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party=BRA. Accessed in: 8 jun. 2021.

UNFCCC. **Achievements of the Clean Development Mechanism: Harnessing Incentive for Climate Action**. 2018. Available at: https://unfccc.int/sites/default/files/resource/UNFCCC_CDM_report_2018.pdf. Accessed in: 14 sep. 2021.

UNFCCC. **Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on the third part of its first session, held in Katowice from 2 to 15 December 2018. Addendum 1. Part two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement**. 2019. Available at: https://unfccc.int/documents/193407. Accessed in: 27 may. 2021.

UNFCCC. **Paris Agreement - Brazil's Nationally Determined Contribution (NDC)**. 2020. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf. Accessed in: 14 sep. 2021.

U.S. TRADE REPRESENTATIVE. **2021 Trade Agenda**. 2021. Available at: https://ustr.gov/about-us/policy-offices/press-office/fact-sheets/2021/march/fact-sheet-2021-trade-agenda-and-2020-annual-report. Accessed in: 3 aug. 2021.

VALOR ECONÔMICO. **Bernard Appy e Ana Paula Vescovi defendem tributação sobre carbono**. 2020. Available at: https://valor.globo.com/live/noticia/2020/08/26/bernard-appy-e-ana-paula-vescovi-defendem-tributacao-sobre-carbono.ghtml. Accessed in: 5 aug. 2021.

VERRA. **Verra Search Page**. 2021a. Available at: https://registry.verra.org/app/search/VCS/All%20Projects. Accessed in: 8 jul. 2021.

VERRA. **The CCB Program**. *In:* 2021b. Available at: https://verra.org/project/ccb-program/. Accessed in: 17 aug. 2021.

VERRA. **Verra - Data and Insights – April 2021**. 2021c. Available at: https://verra.org/datainsights/data-and-insights-april-2021/. Accessed in: 20 may. 2021.

VOTORANTIM. **Projeto de coprocessamento do açaí recebe prêmio da AmCham. In: Votorantim Cimentos - Institucional**. 17 dez. 2018. Available at: https://www.votorantimcimentos.com.br/noticia/projeto-de-coprocessamento-do-acai-recebe-premio-da-amcham/. Accessed in: 10 jun. 2021.

WORLD BANK. **Where Sun Meets Water: Floating Solar Market Report**. 2018. Text/HTML. Available at: https://www.worldbank.org/en/topic/energy/publication/where-sun-meets-water. Accessed in: 16 jul. 2021.

WORLD BANK. **State and Trends of Carbon Pricing 2019**. 2019a. Available at: https://openknowledge.worldbank.org/handle/10986/31755. Accessed in: 9 jul. 2021.

WORLD BANK. **Partnership for Market Implementation**. 2019b. Text/HTML. Available at: https://www.worldbank.org/en/topic/climatechange/brief/partnership-for-market-implementation. Accessed in: 2 aug. 2021.

WORLD BANK. **Síntese das análises e resultados do Projeto PMR Brasil**. Grupo Banco Mundial e Ministério da Economia, 2020. Available at: https://www.gov.br/produtividade-e-comercio-exterior/pt-br/assuntos/competitividade-industrial/pmr/relatorio-sintese-pmr.pdf. Accessed in: 27 may. 2021.

WORLD BANK. **State and Trends of Carbon Pricing 2021**. Washington, DC: World Bank, 2021 a. E-book. Available at: https://openknowledge.worldbank.org/handle/10986/35620. Accessed in: 27 may. 2021.

WORLD BANK. Aditivo Ao Componente 1 Da Fase De Implementação Do PMR Brasil - Subcomponente Florestal - Atividade B.2 - Quantificação do potencial de geração de ativos de carbono através de atividades florestais. **Projeto PMR Brasil**, p. 50, 2021 b.

WRI BRASIL. **Soluções baseadas na natureza são trunfo para recuperação econômica pós-pandemia**. 2020. Available at: https://wribrasil.org.br/pt/blog/solucoes-baseadas-na-natureza-sao-trunfo-para-recuperacao-economica-pos-pandemia. Accessed in: 11 jun. 2021.

WRI BRASIL; NEW CLIMATE ECONOMY. **Uma nova economia para uma nova era: elementos para a construção de uma economia mais eficiente e resiliente para o Brasil**. 2020. *E-book*. Available at: https://wribrasil.org.br/pt/publicacoes/nova-economia-brasil-eficiente-resiliente-retomada-verde. Accessed in: 19 may. 2021.

ANNEXES

ANNEX A – MITIGATION OPTIONS

Table A - 1: Potential and Abatement Costs of Measures in the Agriculture and Livestock Sector[33]

Measures	Abatement	% Total Abatement	Cost (US$/t$CO_2$e)	Total Cost (US$ milhões)
Integrated Systems	4,5	0.2	-1,978.00	-8,923
Low-Carbon Agriculture	37,3	1.5	-311.70	-11,618
Livestock Intensification	2,377.5	98.3	1.99	4,731
Total	**2,419.3**	**100**	**-**	**-15,810**

Source: Adapted from (BRASIL, 2017a).

Table A - 2: Potential and Abatement Costs of Forest Sector Measures[34]

Measures	Abatement	% Total Abatement	Cost (US$/t$CO_2$e)	Total Cost (US$ milhões)
Planted Forests	541	21	-0.38	-205
Reducing Deforestation	1.610	63	1.24	1,997
Forest Restoration	414	16	9.22	3,819
Total	**2,565.9**	**100**	**-**	**5,611**

Source: Adapted from (BRASIL, 2017a).

33. To calculate the costs, a discount rate of 8% was applied.
34. To calculate the costs, a discount rate of 8% was applied.
35. The referenced source (BRASIL, 2017a) does not present the discount rate used to calculate the abatement costs of the measures presented.

Table A - 3: Potential and Abatement Costs of Energy Sector Measures[35]

Subsector	Measures	Abatement (MtCO_2e)	Cost (US$/t$CO_2$e)
Biofuels	Increased electric power generation at the distilleries from the use of more severe conditions in the boiler (90 bar, 520°C) and the co-processing of straw	35.4 in 2050	Varies from -5.5 in 2030 to -2.3 in 2050
Hydroelectric	Installation of hydrokinetic turbines	547	Starting at 7 in 2030, reaching about 3.5 in 2050*
	Repowering existing plants	247	Less than 1, starting in 2030*
Wind	Wind power (Brazilian wind power potential at 100 meters high)	246.6	Average cost of 107 by 2050
Solar Energy	Electricity generation with solar concentrators (CSP) - solar-thermal power plants	Varies from 27.4 to 89.4 across plant technologies	Ranges from 145 to 793 between plant technologies
	Centralized photovoltaic (PV) generation	Zero direct GHG emission technology for both the REF and BC scenarios	High abatement cost for the beginning of the projection horizon, reaching 84 in 2050
Bioelectricity	Electric generation from biomass (TPP with a fluidized bed boiler whose steam cycle operates at 90 bar and 520°C, which would make the TPP reach a total efficiency of 32%)	14.5	74.5
Electricity transmission and distribution	Efficiency of electric power distribution systems	15.4	24,185
	Efficiency of electric power transmission systems	3.1	1,030
Gas and oil- and natural gas-fired thermoelectric plants	Replacing fossil fuels with liquid biofuels	The measures can reduce up to 47	Of around 40 US$/t$CO_2$ for biodiesel blend and above 400 US$/t$CO_2$ for the use of ethanol in gas turbines
	Increased efficiency - installation and recovery of low quality heat (WHRS) and introduction of flexible combined cycle plants	27	Strongly negative abatement costs over the period up to 2050, due to savings in fuel consumption.

Source: Own elaboration based on (BRASIL, 2017a); *(BRASIL, 2017d).

Table A - 4: Potential and Abatement Costs of Transport Sector Measures[36]

Mode	Profile	Measures	Abatement ($MtCO_2e$)	% Abatement total	Cost ($US\$/tCO_2e$)	Total Cost (US$ milhões)
Road	Freight	More efficient heavy-duty truck	124.1	7.9	68.39	8,487.04
	Passengers	Most efficient flex-fuel cars	110.48	7.0	20.74	2,291.70
	Passengers	Automobiles hybrids	208.07	13.2	441.98	91,962.27
	Passengers	Plug-in flex cars	68.8	4.4	502.55	34,575.09
	Passengers	More efficient Commercial	42.27	2.7	3.55	150.24
	Passengers	More efficient Urban Buses	91.46	5.8	-36.68	-3,354.86
Rail		More efficient trains	52.64	3.3	38.33	2,017.57
Water transportation	Waterway (diesel oil)	Waterway (diesel oil)	14.76	0.9	39.82	587.97
	Cabotage (fuel oil)	Cabotage (fuel oil)	59.64	3.8	16.52	984.98
Airplane	More efficient Aircraft	More efficient Aircraft	78.37	5.0	1.54	120.46
Change in Transportation	Passengers	Automobiles -> city buses and subway	664.85	42.2	0.07	44.29
	Freight	Cabotage (fuel oil)	59.64	3.8	16.52	984.98
		Total	**1,575.1**	**100**	**-**	**138,152**

Source: Adapted from (BRASIL, 2017f).

36. To calculate the costs, a discount rate of 8% was applied.
37. To calculate the costs, a discount rate of 8% was applied.
38. To calculate the costs, a discount rate of 8% was applied.

Table A - 5: Potential and abatement costs of the Cement Sub-Sector Measures[37]

Measures	Abatement ($MtCO_2e$)	% Total Abatement	Cost (US$/ tCO_2e)	Total Cost (US$ Millions)
Addition of slag carbide	24.80	27	-161.40	-4,002.72
Refractory insertion in the clinker kiln	8.10	9	-155.50	-1,259.55
Process control and optimization	4.10	5	-154.80	-634.68
Improvements in the combustion system	9.50	11	-143.10	-1,359.45
Adoption of high efficiency grate coolers	6.50	7	-69.90	-454.35
Multi-stage cyclone dry process	37.30	41	-7.00	-261.10
Total	**90.30**	**100**	**-**	**-7,971.85**

Source: Adapted from (BRASIL, 2017k).

Table A - 6: Potential and Abatement Costs of the Pig Iron & Steel Sub-Sector Measures[38]

Measures	Abatement ($MtCO_2e$)	% Total Abatement	Cost (US$/ tCO_2e)	Total Cost (US$ Millions)
Advanced control system	1.39	3	-330.35	-459.19
Scrap preheating	2.78	5	-281.49	-782.54
Advanced ETU for electricity production in integrated plants	6.69	12	-247.92	-1,658.58
Variable speed drives in the BOF	4.53	8	-231.35	-1,048.02
Oxy-fuel burners	1.77	3	-132.39	-234.33
Sensible heat recovery from the BOF	6.99	13	110.74	774.07
Heat recovery from hot air furnaces	1.21	2	-31.38	-37.97
Pulverized coal injection	6.09	11	-20.32	-123.75
Coke dry quenching	3.40	6	-14.19	-48.25
Waste heat recovery	3.00	6	24.74	74.22
Scope 21 Furnaces	9.60	18	50.14	481.34
Top pressure recovery turbine (TRT)	4.62	9	50.22	232.02
Coal Moisture Control	1.87	3	150.07	280.63
Total	**53.94**	**100**	**-**	**-2,550.34**

Source: Adapted from (BRASIL, 2017g).

Table A - 7: Potential and abatement costs of measures in the chemical subsecto[39]

Measures	Abatement ($MtCO_2e$)	% Total Abatement	Cost (US$/ tCO_2e)	Total Cost (US$ Millions)
Adoption of pre-reformer in methanol production	0.11	0.24	-70.0	-7.70
Hydrogen recovery in methanol production	0.17	0.36	-69.0	-11.73
Boiler monitoring and maintenance	3.84	8.23	-69.0	-264.96
Heat recovery in boilers	1.94	4.16	-65.0	-126.10
Adoption of low NOx burners in furnaces	0.82	1.76	-54.0	-44.28
Adoption of pre-reformer in ammonia production	0.38	0.81	-47.0	-17.86
Condensate recycling in boilers	2.74	5.87	-27.0	-73.98
Increased use of biomass in furnaces	2.43	5.21	-22.0	-53.46
Increased use of biomass in boilers	3.52	7.55	-20.0	-70.40
Process integration with pinch analysis in basic petrochemicals	2.36	5.06	4.0	9.44
Monitoring and maintenance of motor systems	9.06	19.42	4.0	36.24
Integration of processes with pinch analysis in ammonia production	0.22	0.47	24.0	5.28
Hydrogen recovery in ammonia production	0.79	1.69	25.0	19.75
Increased use of natural gas in boilers	5.31	11.38	78.0	414.18
Increased use of natural gas in furnaces	12.96	27.78	81.0	1,049.76
Total	**46.65**	**100**	**-**	**864.18**

Source: Adapted from (BRASIL, 2017h).

Table A - 8: Potential and abatement costs of measures in the heat and glass subsector[40]

Measures	Abatement ($MtCO_2e$)	% Total Abatement	Cost (US$/ tCO_2e)	Total Cost (US$ Millions)
Heat recovery (flat glass)	0.06	0.4	-53.90	-3.23
Replacement of coke with natural gas (lime)	11.47	81.1	1.15	13.19
Oxicombustion (flat glass)	1.25	9	41.40	51.63
Use of cullet as raw material (hollow glass)	0.16	1.1	63.80	10.19
Electrical melting (hollow glass)	1.06	7.5	105.60	112.44
Heating of cullet (hollow glass)	0.12	0.8	132.10	15.56
Heat recovery (hollow glass)	0.02	0.1	292.20	5.94
Total	**14.14**	**100**	**-**	**205.71**

Source: Adapted from (BRASIL, 2017i).

Table A - 9: Potential and abatement costs of measures in the aluminum subsector (non-additive measures)[41]

Measures	Abatement ($MtCO_2e$)	% Total Abatement	Cost (US$/ tCO_2e)	Total Cost (US$ Millions)
Use of insulating materials in furnaces	5.09	13	0.16	0.81
Heat Recovery	23.77	60.3	0.66	15.69
Optimizing combustion air flow	4.04	10	1.78	7.19
Pressure and leakage control in furnaces	4.65	12	4.22	19.62
Optimizing cell operation	0.06	0.2	5.00	0.30
Optimizing engines	1.65	4.2	5.51	9.09
Replacing Soderberg smelter with Prebake	0.12	0.3	326.08	39.13
Total	**39.38**	**100**	**-**	**91.84**

Source: Adapted from (BRASIL. 2017l).

39. To calculate the costs, a discount rate of 8% was applied.
40. To calculate the costs, a discount rate of 15% was applied.
41. To calculate the costs, a discount rate of 8% was applied.

Table A - 10: Potential and abatement costs of measures in the Paper and Pulp Sub-sector (non-additive measures)[42]

Measures	Abatement ($MtCO_2e$)	% Total Abatement	Cost (US$/ tCO_2e)	Total Cost (US$ Millions)
Maintenance of the paper boilers	2.77	17	-330.70	-915.71
Maintenance of auxiliary boilers	0.28	2	-330.55	-92.22
Paper Boilers with advanced process control	0.78	4.7	-302.27	-236.98
Paper boilers with condensate return	2.32	14	-259.16	-600.99
Using CondeBelt dryers	4.67	28.1	-215.60	-1,007.50
Paper Boilers with heat and steam recovery	0.21	1	-206.71	-42.38
Use of more efficient presses	5.02	30.1	-75.89	-380.74
Auxiliary boilers with advanced process control	0.08	0.4	71.35	5.64
Modifications to lime kilns	0.27	1.6	123.51	33.59
Auxiliary boilers with condensate return	0.23	1	192.25	44.99
Auxiliary boilers with heat and steam recovery	0.02	0.1	929.50	19.52
Total	**16.65**	**100**	**-**	**-3,172.78**

Source: Adapted from (BRASIL. 2017j).

42. To calculate the costs, a discount rate of 8% was applied.

ANNEX B - MARKET MECHANISMS OF ARTICLE 6 OF THE PARIS AGREEMENT

Frame B - 1: Differences between the mechanisms established by Articles 6.2 and 6.4 of the Paris Agreement

	Mechanisms	
	ITMO - Internationally Transferred Mitigation Outcomes - ARTICLE 6.2	**Emission Reduction Credit Mechanism - ARTICLE 6.4**
Definition	Trading of internationally transferred mitigation outcomes contracted directly between countries. The same country can buy or sell ITMOs without quantity limitation as long as it makes the corresponding adjustments.	Decentralized mechanism for carbon credit transactions between public and private entities.
	Mechanism that would allow a country that has met its NDC emissions reduction target to sell any overachievement to a nation that has fallen short of its own goals. Allowing countries to voluntarily trade "mitigation outcomes" for use in relation to the Paris Agreement. provided they promote sustainable development while ensuring environmental integrity and transparency.	The mechanism would create a new international carbon market. governed by a UN body. for trading emissions reductions created anywhere in the world by the public or private sector.
Quoted in the Paris Agreement articles	Article 6.2 and 6.3	Article 6.4. 6.5. and 6.6
Agents	Countries - Contracted trades between governments	Public and private entities
What is traded	Actual emissions resulting from mitigation	Carbon credit - estimated emissions from projects
Project type	No project is required. Government of the transfering country can design the public policies independently (or pre-existing policies) and the incentives for public and private projects that generate the emissions reductions and benefit sharing criteria generated in the ITMO.	It is not linked to public policy.
Credit Measurement	Not applicable	Credits are measured by the additional reductions to an emissions trajectory baseline that would occur without the implementation of the projects.
Transaction Process	Contracted between the Parties. accounted for and communicated to the managing body of the Paris Agreement without the need for its authorization.	A standardized process in which each activity requires authorization from both the host country and the Paris Agreement governing body before the carbon credit can be traded.

	Mechanisms	
	ITMO - Internationally Transferred Mitigation Outcomes - ARTICLE 6.2	Emission Reduction Credit Mechanism - ARTICLE 6.4
Transaction Costs	Lower	Higher due to regulatory requirements to ensure the additionality of the credits generated.
Project Development	Mitigation results are planned and executed with autonomy by the transferring party based on the contractual conditions.	Public or private entity sponsoring the project develops it with rules. modalities and procedures established by the Paris Agreement's governing body.
Verification and validation of results	The transferor country would be responsible for independently validating the contributions and remuneration. according to its own parameters best suited to the country's economic structure and emissions reduction path.	Performed by an independent credentialed auditor.
Approval and Registration	No approval required. Registration made between parties with the Paris Agreement governing body.	Designated National Authority (DNA) of the project's host country approves it and sends it for registration with the Paris Agreement body. Body designated by the Paris Agreement body registers and verifies the project and issues project carbon credit certificates.
Completion of the operation	The parties record the exchanges and the corresponding adjustments of their NDCs.	Registration of the issuance of the certificates that the carbon credit transactions in the Paris Agreement. Parties register the corresponding adjustments of their NDCs.
Market value	It depends on the consistency of the offered ITMO.	It depends on the quality of the project.
Perspectives for the regulation of articles	The article's regulations will define eligible mitigation activities. monitoring procedures. and the registration of transactions with the Paris Agreement's managing body. but will not address the methodology used to decrease GHG emissions in the country transferring the ITMOs;	Rules. modalities and procedures for the implementation of the market mechanism of Article 6.4 shall be approved by the Conference of the Parties. which shall also establish the aforementioned management body to oversee the application of these provisions.
Perspectives for Brazil after COP 26	In countries like Brazil. whose NDC is ambitious and economy-wide. an ITMO will indicate additional mitigation outcomes with climate integrity and much lower governance costs than 6.4 projects. And this will certainly be a commercial advantage for Brazil over countries with less ambitious NDCs that may be generating results that would be realized without the ITMO.	The country's successful experience in developing CDM projects adds value to the supply of credits via the Article 6.4 mechanism. but the costs of the entire process of validation and verification of the credits must be borne.
Principle of General Mitigation of Global Emissions (OMGE)	Although the text of Article 6.2 does not mention the OMGE. its application in the ITMO is also discussed. although the risk of losing additionality is lower than in the 6.4 mechanism. since in the ITMO the exchanges do not take place with project credits.	The principle of overall global emissions mitigation (OMGE) to increase the ambition of the Agreement. The aim is to mandate that a portion of the NDC increase from the corresponding adjustment of the selling country's NDC cannot be used by the purchasing country for compliance with its NDC. By reducing the adjustment volume of the buyer country. the implementation of the OMGE would cause an increase in the price of traded credits. The total value of transactions could grow to the benefit of host countries. but the price effect would encourage more domestic mitigation in buyer countries that could decrease demand for credits.
Share of Proceedings (SOP)	It is not made explicit in Article 6.2. For reasons of isonomy of treatment and funding potential. many Parties. such as Brazil. are suggesting that the SOP should also be adopted in ITMO transactions. as in the OGME.	Article 6.6 provides that part of the revenues from transactions in the Article 6.4 mechanism be used to finance other Article 6 management activities and climate adaptation actions in vulnerable countries. Its impact on prices is similar to that described for the OMGE.
Similar mechanism in the Kyoto protocol	It doesn't apply.	Clean Development Mechanism (CDM)
Regulatory Negotiations	The precise form of this "robust" Article 6.2 accounting is a major focus of the ongoing negotiations with several technical challenges. One being whether to consider targets and emissions for a single year or setting a carbon budget that covers several years.	The text under negotiation includes several baseline tests to ensure additionality.

Source: Evans and Gabbatiss (2018) and Seroa Da Motta (2021)

PREPARED BY:

ICC BRASIL
INTERNATIONAL CHAMBER OF COMMERCE
The world business organization

WAY CARBON

SPONSORED BY:

BAYER 125 anos BRASIL

bp

Microsoft

natura

suzano