CHAPTER 13

GLOBAL COOPERATION AND CHALLENGES OF SUSTAINABLE DEVELOPMENT: CDM RESULTS AND LESSONS LEARNED FOR THE DESIGN OF NEW FINANCIAL MECHANISMS

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1 INTRODUCTION

By July 2018, the Paris Agreement had been signed by 195 countries, of which 176 ratified it (UNFCCC, 2018b). This inspires hope that the global community will be able to define a multilateral governance that is effective in curbing global climate change. The objective defined by the Agreement is to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" (UN, 2015).

In order to achieve this objective, henceforth referred to as "below 2°C Scenario", the Paris Agreement is based on Nationally Determined Contributions, which are prepared by each Party (UNFCCC, 2018a) based on the self-assessment of their responsibilities and respective capacities for climate change mitigation. This process of self-defining objectives is different from the approach of the Kyoto Protocol (UN, 1997).

The Protocol, negotiated in 1997 and adopted in 2005, is based on the principle of "common but differentiated responsibilities and respective capabilities" (UN, 1997), instituted by the United Nations Framework Convention on Climate Change – UNFCCC, negotiated in 1992. Based on this concept, the UNFCCC defines as "Annex I" the group of countries that are industrial economies or economies in transition, and as "Non-Annex I" the group of developing countries.

Building from this differentiation, the Kyoto Protocol provides that Annex I countries are responsible for leading mitigation efforts through the definition of absolute targets to reduce their national GHG emissions. At the same time, the

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Protocol defines that developing countries do not have the same responsibility or capacity to act on climate changes. Thus, Non-Annex I countries are not bound to formal mitigation targets. The justification is the understanding that their "priority is socioeconomic development and poverty eradication" (UN, 1992).

In order to uphold their right to socioeconomic development, while at the same time promote mitigation opportunities in developing countries, the Kyoto Protocol created the Clean Development Mechanism – CDM). The CDM's objectives are "to assist Parties not included in Annex I in achieving sustainable development (…) , and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under" (UN, 1997).

From the environmental standpoint, the CDM has played a key role in connecting[3] the industrialized countries in Annex I, which are characterized by high mitigation costs arising from the need to replace existing fossil fuel based infrastructures, with developing countries that offer opportunities to avoid emissions growth through investments that promote the clean development of their economies.

Unfortunately, this rationale of the Kyoto Protocol and the international cooperation through the CDM, faced a series of criticisms and problems that prevented its evolution. Although it is not the purpose of this text to detail these discussions, we present a brief summary of the main difficulties:

1) Lack of balance between supply and demand for carbon credits: because of the non-ratification of the Kyoto Protocol by the United States and the omission and withdrawal of Canada,[4] the countries of the European Community, Australia and Japan were the parties with real demand for Certified Emissions Reductions (CERs) generated by the CDM. This did not only limited aggregate demand but also the ambition of countries to continue and broaden their engagement in the context of the second commitment period of the Kyoto Protocol between 2012 and 2020.

2) Transfer of resources and investments: although the transfer of funding from industrialized countries to developing countries is capable of reducing the overall cost of mitigation, there was concern that it would be detrimental to the growth of industrialized economies. Another criticism was that a cost reduction mechanism would not be in line with the concept of differentiated responsibilities. The reasons for this criticism

3. In the theory of environmental economy, pricing mechanisms lead to equalization of marginal costs of reducing pollutants among the participating economic agents, minimizing the aggregate cost of meeting the objective of reducing pollution levels.

4. Following ratification in December 2002, Canada withdrew from the Kyoto Protocol on December 15th, 2011, effective on December 15th, 2012.

would be that industrialized countries should demonstrate their leadership through costly domestic efforts, rather than promoting and purchasing more cost-effective mitigation outcomes in developing countries.

3) Lack of understanding of the nature of an avoided emission: as a result of low energy consumption and the low socioeconomic level of the developing countries, there is an opportunity to promote investments capable of promoting economic expansion and, at the same time, preventing the increase emissions. Unfortunately, the concept of avoided emissions, which underlies most CDM projects presented, was questioned, while the concept of a reduction in historical emissions, which prevails in industrialized countries, was easier for stakeholders to understand.

4) Inquiries regarding the environmental integrity of CERs: in the absence of own reduction targets by developing countries (Non-Annex I), the CDM depends on methodologies for the measurement and certification of emission reductions in relation to a specific baseline for each project. The result of this situation was the creation of highly complex and expensive certification methodologies and procedures. Despite this effort, which generated high costs and risks for the projects, the criticism undermined the prestige and role of the CDM as a tool for international cooperation.

5) Focus on end-of-pipe projects: concern about the environmental integrity of CERs led to the popular understanding that only projects whose financial viability depended exclusively on the sale of carbon credits would be truly additional. The consequence of this view is that only greenhouse gas abatement projects at the end of the process and without additional economic benefits are seen as legitimate by a relevant part of stakeholders. In turn, structural and capital-intensive projects, such as renewable energy investments, face questions and criticism because they receive other revenues.

In the context of the lack of alignment of Annex I countries and growing criticism in relation to mechanisms for cooperation with developing countries, there has been a need to reform international climate policy and its mechanisms. Unfortunately, the slow pace in defining reforms and, lastly, the lack of agreement on a second commitment period of the Kyoto Protocol from 2012 onwards, has led to a crisis with serious impacts for countries and investors who had worked with an expectation of continuity of the economic instruments established by the Kyoto Protocol.

In the context of this crisis, the international community began negotiations for a new agreement that could overcome the differentiation of countries into groups and thus minimize the economic distortions that occur between countries with

differences in their ambitions and mitigation costs. The outcome of this negotiation was the Paris Agreement, of 2015, which replaces the more normative regulatory logic of the Kyoto Protocol, an approach that is called *top down*, by the logic of self-definition of objectives, targets and mitigation policies by each country, in a so-called *bottom up* approach.

The advantage of this new process of sovereign definition of plans and targets is that countries have the autonomy to define their mitigation objectives and policies in relation to climate change in a way that fits their situation in terms of the availability of natural and financial resources, as well as to their socioeconomic demands and regulatory capacities. The disadvantage of this process is that industrialized countries remain subject to high mitigation costs, while developing countries continue to lack the necessary financial and human capital to avail of their clean development opportunities.

In any case, this process of self-determination was decisive for the success of the Paris Agreement, that is, to gather all countries into an agreement that abandoned country differentiation by development category. Nevertheless, it also made it difficult to compare and aggregate the different and often idiosyncratic country specific targets and policies. In addition, the logic of individual goal-setting neglects the potential of international cooperation that is essential to mobilize financial and technological resources and thus mitigate the overall costs of climate change mitigation. Based on this fact, together with adopting the Paris Agreement, the UNFCCC "notes with concern that the estimated aggregate greenhouse gas emission levels (...) resulting from the NDCs do not fall within least-cost 2°C Scenarios, (...) and also notes that much larger emission reduction efforts will be required" (UN, 2015).

In fact, recent assessments show that the aggregate of the proposed NDCs leads to an increase of 3.2°C in the mean global temperature by 2100 and that the "below 2°C scenario" objective requires a significant increase in efforts (UNEP, 2017). In order to address this gap between the mitigation objective defined by the Paris Agreement and the aggregate ambition of its members, the Agreement presents a number of mechanisms, focused on three elements (UN, 2015), according to the following provisions.

1) The Agreement provides for NDCs to be revised every five years to promote increasingly ambitious commitments that can meet the "below 2°C Scenario".

2) Article 9 of the Paris Agreement states that "developed countries must provide financial resources to assist developing countries in both mitigation and adaptation" (UN, 2015). As already agreed within the framework of the Convention, this commitment entails the collective mobilization of

US$ 100 billion per year between 2020 and 2025 to promote mitigation and adaptation actions in developing countries, as well as a commitment to increase the volume of resources in the period after 2025.

3) Article 6 of the Paris Agreement allows Parties to look for "voluntary cooperation in implementing their Nationally Determined Contributions (NDCs) to allow greater ambition in their mitigation and adaptation actions and to promote sustainable development" (UN, 2015). In order to regulate such cooperation, the Agreement defines the possibility of using "internationally transferred mitigation outcomes" (UN, 2015) as long as such transfers promote sustainable development and are subject to a governance that can ensure transparency and environmental integrity, with a focus on avoiding double counting of results in the context of NDCs in the respective countries.

In addition, Article 6, paragraph 4, establishes a mechanism that can "contribute to the mitigation of greenhouse gas emissions and to support sustainable development", which seeks to "encourage and facilitate participation in mitigation of greenhouse gas emissions by public and private entities" (UN, 2015). The objectives and the rationale for this mechanism are generally compatible with the Kyoto Protocol's CDM rules. The differences are that the Paris Agreement puts additional emphasis on the contribution to sustainable development and adds the requirement that "emissions reductions resulting from the mechanism (...) shall not be used to demonstrate achievement of the host Party's NDC if used by another Party to demonstrate achievement of its NDC".

Based on this context, the Parties to the Paris Agreement are in the process of negotiating the regulation of their various elements and thereby defining the effective instruments and procedures for the post 2020 period. At the same time, countries are in the process of regulating the implementation of their NDCs, as well as reflecting on the use of the mentioned international cooperation mechanisms.

Aiming at supporting the process of discussing and defining such new mechanisms, this article presents an assessment of the current Brazilian economic situation, as well as the experiences in the use of the CDM, and a reflection on the role of climate financing mechanisms in the current Brazilian economy. From this analysis, the article proposes a series of conclusions and recommendations that seek to contribute to the design and definition of public policies in this area.

2 BRAZIL FROM THE PERSPECTIVE OF GLOBAL CLIMATE POLICIES

Brazil is a player of great relevance for a sustainable low carbon world. Its success in mitigating climate change and defining a path of sustainable development is essential for the conservation of its biodiversity and its environmental services, as

well as for meeting the international demand for food, raw materials and low-carbon manufactured products. Aware of this responsibility, Brazil has been a proactive actor both in international diplomacy and in the definition of domestic policies to mitigate climate change.

On the diplomacy side, Brazil stood out as the host of the 1992 United Nations Conference on Environment and Development, which resulted in the negotiation of the UNFCCC, which remains the fundament of international climate policy negotiations. In addition, Brazil is credited with the creation of the CDM and the country has been a proactive and decisive player in the negotiations and regulations of subsequent climate agreements, as well as their economic mechanisms. More recently, the Brazilian State, in partnership with the European Community, presented the proposal for the Sustainable Development Mechanism, which was the basis for the creation of the mechanism mentioned in Article 6, paragraph 4, of the Paris Agreement (European Commission, 2015).

On the domestic climate policy side, Brazil also took the lead in integrating the CDM in the definition of domestic policies and incentives to promote mitigation activities. The country began to develop the first CDM projects in 2001, the same year of the definition of CDM rules and procedures, and four years before the full ratification of the Kyoto Protocol. Initially, the focus was the development of biomass cogeneration projects, as well as the abatement of methane emissions and other gases with greater global warming potential. After that, CDM development activities extended to projects of fossil fuel substitution and small hydroelectric power plants. In this initial phase of the CDM, Brazil saw the engagement of new agents and investors, small and medium Brazilian companies, as well as international investors and consultants that were attracted by the carbon credits generated from such GHG mitigation investments.

As a result of this dynamic, Brazil ranked third in the number of CDM projects and the mechanism proved to be an extraordinary instrument for mobilizing capital and promoting good practices in the search for more sustainable energy generation and production patterns. As a result, as of December 31st, 2008, Brazil had registered a total of 148 projects, with a capacity to reduce emissions of almost 20 million tCO_2e (tons of carbon dioxide – CO_2 equivalent) per year. Of this total, 76 projects offered the generation of renewable electricity with a capacity of 2,338 MW,[5] mainly from biomass and with small hydroelectric plants (SHPs).

Despite this success, the broadening of results depended on the next stage of regulatory evolution, defined in the context of the National Plan on Climate Change (Brazil, 2008) and the presentation of Brazil's Nationally Appropriate

5. Calculated with the data provided by UNEP Risoe CDM Pipeline of April 2018. Available at: https://bit.ly/2L5BZ7d.

Mitigation Actions (NAMAs) at the Climate Conference in December 2009 (Brazil, 2010). The Brazilian NAMAs set the ambitious goal of avoiding the increase in emissions by 36.1% to 38.9% when compared to business as usual projections, for the year 2020.

Although the Brazilian announcement to the United Nations had the format of voluntary targets, the country instituted the National Policy on Climate Change (NPCC) by Law No. 12,187/2009 and its regulation through Decree No. 7,390/2010. Particular emphasis is given to Article 6 of the NPCC which defines the instruments to promote reductions of greenhouse gas emissions, such as:

- specific credit lines of public and private financial agents (mainly the National Bank for Economic and Social Development – BNDES);
- public-private partnerships and authorization, permission, granting and concession for exploitation of public services and natural resources; and
- financial mechanisms that exist within the framework of the UNFCCC and the Kyoto Protocol.

With this combination of CDM and domestic incentive policies (Hauser and Medeiros, 2010), Brazil was able to diversify and accelerate the development of mitigation projects with increasingly transformational[6] scale. Of particular importance to this result was the BNDES' strategic performance in providing long-term financing for infrastructure projects with long capital amortization periods (Hauser et al., 2015).

This solution overcame the criticism that the CDM was not able to promote and fund transformational programs or projects because of the inability to mobilize sufficient resources. At the same time, this combination of the CDM and climate financing established by Brazil complied with the recommendation that the CDM be a tool to "support governments to achieve their mitigation objectives in a cost-effective way". (CDM Policy Dialogue, 2012).

Unfortunately, projects resulting from the investments promoted by the combination of the CDM as a pricing mechanism for emission reduction, and the climate funding offered by the BNDES, took between two and five years to be licensed and built. However, such a deadline, which is normal for investments in infrastructure, has resulted in an effective registration and commissioning of projects only at or after the end of the first Kyoto period in 2012. In the absence of a second commitment period and new demand for CERs, the prospects for

6. In the context of climate literature, the term "transformational" describes strategies for mitigation and adaptation to climate change that differ in scale, degree of innovation or their programmatic and spatial impact compared to incremental mitigation or continuous improvement strategies (Gillard et al., 2016). In the context of the Brazilian NPCC, this term can describe government programs to promote renewable energy in a cross-cutting and large scale.

private and public investors to obtain adequate returns have been thwarted. This led to significant economic losses, which will be analyzed below.

This loss of complementary revenues in foreign exchange came at a time of economic crisis, which led to a decline in the Brazilian gross domestic product (GDP) of 8.1% in the period between 2014 and 2016, with a sharp decline in investments of nearly 30% (Castro, 2018). Although the causes of this situation are complex, part of its origin lies in a serious hydrological crisis that showed the costs and difficulties of the expansion of the electricity sector based on variable electricity sources such as wind, as well as hydroelectric plants without accumulation reservoirs, a strategy that was promoted by the CDM and Brazil's NPCC.

As a consequence of this situation, the Brazilian government was forced to reduce incentives for investments in renewable energy and other types of infrastructure. According to data from ABDIB (2017), investments in infrastructure in Brazil[7] fell by an average of 2.1% of the GDP between 2004 and 2014, to 1.5% in 2017. A minimum of 3.0% would be required so that Brazil could maintain its existing capital stock.

In order for Brazil to actually overcome its infrastructure shortfalls, the Infra 2038 Project initiative[8] recommends increasing investments to 6.5% of the GDP over the course of twenty years. According to the authors, this effort is necessary so that the country can achieve gross fixed capital formation of 77.0% of the GDP, a rate considered compatible with the pattern of developed countries, like the United States or Spain.

Achieving this level of investments in energy generation and transmission infrastructure, sustainable transport and logistics, effluent and waste treatment, as well as in Brazil's industrial park, is essential so that the country can achieve an adequate level of social development. To the same extent, the recovery of the Brazilian economy is essential if the country is to finance the conservation and sustainable use of its natural resources and to play its role as a producer of low-carbon food, raw materials and manufactured goods, contributing to a decarbonized world.

3 CDM BACKGROUND, EVOLUTION AND OUTCOMES IN BRAZIL

Over the last fifteen years, since the beginning of validation of the first Brazilian CDM project in December 2003,[9] a total of 756 projects, including 740 individual large-scale and small-scale projects and 16 PoAs (programs of activities) were presented by the country. Of this total, as of June 2018, 342 CDM projects and

7. It includes energy, transportation, sanitation and telecommunications. Oil and gas are not included.

8. For further information, please go to: https://bit.ly/2MYK1yY.

9. The Salvador Bahia Landfill Gas Management Project, developed by SUEZ Environment, was the first CDM project to start a public consultation process in Brazil.

10 PoAs,[10] with a total of 25[11] component project activities (CPAs), were effectively registered in the UNFCCC.

Unfortunately, such figures do not let us evaluate which projects were implemented effectively, or which ones are still operational. For the purposes of our analysis, we assume that only registered projects have been effectively implemented, disregarding that some projects have been carried out without effective registration by the United Nations.[12] This perspective, in turn, neglects the fact that some projects may have achieved registration, but that their implementation or operation has become unfeasible despite this achievement.

In any case, 170 projects have actually been able to issue carbon credits, a fact that proves their implementation, although it is believed that there have been cases of projects that have subsequently been discontinued. Thus, based on such simplifications, we elaborated a series of evaluations with the purpose of describing the evolution and the effects of the CDM in the context of Brazilian climate policy.

3.1 Project assessment by categories

The main objective of the analysis is to assess the impact of the CDM on the mobilization of capital for different types of investments. In order to conduct this analysis, we aggregate the data of 336[13] projects and 25 CPAs registered in Brazil in groups that show homogeneity in terms of nature of GHG reduction technology, Capex, and, in the case of renewable energies, their electricity generation capacity. The data were obtained from several databases.[14]

Table 1 represents relevant information about projects, besides a first assessment of results.

10. CDM insights data from April 2018. Available at: https://bit.ly/2MqBuEI.

11. Data and accounting from UNEP Risoe CDM Pipeline April 2018 (available at: https://bit.ly/2L5BZ7d) were used. That aggregates the CPAs according to submission groups. Following that logic, a total of 1,050 CPAs from the PoA Methane capture and combustion from the Animal Waste Management System (AWMS) of the 3S Program farms of the Healthy Sustainability Institute is aggregated into three groups of 1,961 and 88 CPAs, respectively.

12. Failure to achieve registration does not necessarily mean that the project is not capable of generating emission reductions with additionality. This is explained by the fact that the investment decision is often irreversible and that the subsequent registration in the CDM is often made impossible by methodological changes or by the post-2012 carbon market crisis.

13. For the purposes of this assessment, six registered projects with aggregate emission reduction capacity of 104 $ktCO_2$ were neglected for lack of data on their specific investment cost (CAPEX).

14. Data from April 2018 of UNEP Risoe CDM Pipeline and PoA Pipeline were used, available at: https://bit.ly/2L5BZ7d; of the IGES CDM Project Database, available at: <https://bit.ly/2IzZqDA>; and UNFCCC CDM Insights, available at: https://bit.ly/2MqBuEI.

TABLE 1
Definition and characteristics of the main categories of CDM projects registered in Brazil

Type of project	Number of projects	$ktCO_2e$ per year of reduction	Investment MUS$	Reduced US$/$tCO_2e$	US$/kW of generating capacity	Credits issued
Renewable energy	210	27,579	31,152	2,101	2,150	24,769
Bioelectricity	40	2,147	3,427	4,329	3,287	9,271
Wind power	68	8,247	10,472	1,425	1,880	976
Hydroelectricity	98	16,857	16,364	1,484	1,823	14,522
Solar energy	4	328	889	9,601	3,416	
Methane abatement	126	18,039	608	53	1,690[1]	40,734
Fugitive Emissions Abatement	7	6,735	45	25		61,311
Fuel change and energy efficiency	15	1,057	151	158	1,336[2]	2,479
Reforestation	3	244	62	760		4,239
Total	**361**	**53,654**	**32,019**	**1,234**	**2,097**	**133,531**

Sources: UNEP, IGES CDM Project Database and UNFCCC.
Notes: [1]. This number relates to 25 projects with capacity of 250MW that use methane for electric generation.
[2]. This number relates to 2 projects with capacity of 165MW that use residual energy and gases in the steel industry.

The data presented in table 1 show that the 361 projects that have been registered have a greenhouse gas emission mitigation potential of almost 54 million tCO_2e per year. The category of renewable energy, with 210 projects (58%) and disaggregated in bioelectricity, wind, hydroelectricity and solar energy sources, accounts for a reduction of 27 million tCO_2e per year, equivalent to 51% of the total potential. The second most relevant category is formed by 126 methane abatement projects. This category includes the burning and use of landfill gas, the treatment of waste and effluents and the abatement of methane emissions in the production of charcoal. The aggregate mitigation potential is 18 million tCO_2e per year. The third relevant category in terms of emission reduction potential covers seven fugitive emissions reduction projects of nitrous oxide,[15] perfluorinated compounds (PFC)[16] and sulfur hexafluoride (SF_6).[17] Although Brazil has few

15. Nitrous oxide is a waste gas generated in the production of nitric acid. Brazil has four registered CDM projects that use catalysts to destroy nitrous oxide and thus avoid its emission, with only three issuing a total of 1.7 million CERs. In addition, nitrous oxide is a byproduct of the adipic acid production produced by Rhodia at the Paulínia plant in São Paulo. The project No. 116 "*N_{20} Emission Reduction in Paulínia, SP, Brazil*" is the only CDM project of this type in Brazil and, alone, corresponds to the issuance of 54,353 million CERs. Thus, a single project corresponds to 89% of the issuance of CERs in this category and 41% of the generation of CERs in Brazil as a whole.

16. Tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) are byproducts of aluminum production, and project No. 1860, PFC Emission Reductions at ALBRAS, Alumínio Brasileiro S.A., registered on January 4th, 2009, allows for the reduction of their emissions through operational control improvements. Despite the completed record, the project never actually issued CERs.

17. SF_6 is a gas with high global warming potential, used as an inert gas in electric circuit breakers and metallurgical processes. In Brazil, project No. 2486, Conversion of SF_6 to alternative SO_2 cover gas in the production of magnesium from the Rima Industrial group replaces the use of gas and thereby reduces greenhouse gas emissions. To date, the project has already issued 1,649 million CERs.

projects registered in this category, their potential for mitigation of greenhouse gases is 6.7 million tCO_2e per year.

Finally, fifteen fossil fuel substitution and energy efficiency projects with a potential reduction of one million tCO_2e per year and three reforestation projects with a mitigation potential of 244,000 tCO_2e per year were considered. Based on the definition of these groups, we evaluated the total capital invested in the different categories. In order to determine these values, we used several public databases[18] that reproduce data from Project Design Documents (PDDs) registered in the CDM for a total of 186 projects.

Unfortunately, not all PDDs provide this information explicitly[19] and for 175 projects it was necessary to determine Capex through the use of specific indicators, either by mitigation capacity (USD/ tCO_2e per year) or by USD/kW of installed capacity. In order to determine these indicators, the CDM database was used, as well as a recent U.S. Energy Information Administration (EIA, 2018) publication for renewable energy.

Based on this methodology, it is estimated that the CDM in Brazil helped mobilizing a total of US$ 32 billion in investments. Interestingly, the 210 renewable energy generation projects correspond to 97% of the total capital invested. This large capital mobilization is explained by the fact that the CDM was able to promote renewable energy generation investments with a total installed capacity of almost 20 GW.

Another factor to be taken into consideration is the notorious capital intensity of 1,800 USD/kW for hydroelectric or wind power generation and more than 3,000 USD/kW for solar or biomass generation. Along these lines, the capital needed to mobilize a potential reduction of one tCO_2e per year with these technologies is around USD 2,000. Although such figures may seem high, it is important to remember that these projects generate renewable energy for many decades and thus represent structural and transformational mitigation opportunities with numerous socioeconomic and environmental co-benefits.

The comparison shows that reforestation represents the second most capital-intensive activity, demanding investments of around USD 760 for each ton of CO_2 sequestered[20] per year. The third most capital-intense category is the various activities

18 Data from April 2018 of UNEP Risoe CDM Pipeline and PoA Pipeline were used, available at: https://bit.ly/2L5BZ7d; of the IGES CDM Project Database, available at: <https://bit.ly/2IzZqDA>; and UNFCCC CDM Insights, available at: https://bit.ly/2MqBuEI.

19. This is often the case for projects that have not presented a financial analysis for their demonstration of additionality.

20. Unlike other activities that reduce or prevent the emission of greenhouse gases, reforestation is able to remove CO_2 from the atmosphere and store carbon in timber. This sequestration capacity reduces over time to zero as forests grow to full maturity. This difference, and the fact that CO_2 can be released at the time of cutting, explains that reforestation CERs are considered to be temporary CO_2 removals. As a result, these credits are subject to lower market acceptance and prices.

of fossil fuel substitution and energy efficiency. While this is a heterogeneous group and the average may not be representative for the individual projects, the modest Capex of 158 USD/tCO_2e mitigated per year reinforces the view that this type of initiative has a substantial benefit to the climate and the energy efficiency of the Brazilian industry in general.

Finally, methane abatement activities, with a cost of USD 53 per tCO_2e mitigated per year, and fugitive emissions abatement, with a cost of 25 USD/tCO_2e per year represent the least capital intensive GHG abatement opportunities. A more detailed analysis of methane abatement activities shows that this category contains 25 methane projects for the generation of electric power with an aggregate capacity of 250MW.

For such activities, a Capex of 1,700 USD/kW is comparable to the specific cost of hydroelectricity and wind power, but the cost of 608 USD/tCO_2e mitigated per year is lower because of the benefit of methane destruction, which has a high global warming potential and thus leads to an increased volume in GHG mitigation. In the case of simple methane flaring, without energy utilization, investments are low with an average cost of USD 17 for a mitigation potential of one tCO_2e per year.

The fugitive emissions abatement group follows the same rationale of end-of-pipe mitigation, which does not demand structural changes in processes and simply avoids or eliminates emissions through filters, catalysts and flaring devices, or through the use of substitutes. Because of such simplicity, this type of mitigation is usually very easy and quick to implement, but offers no benefit other than avoided emission. Moreover, this type of project is often non-structural and imply the risk of returning to the previous common practice without emission abatement.

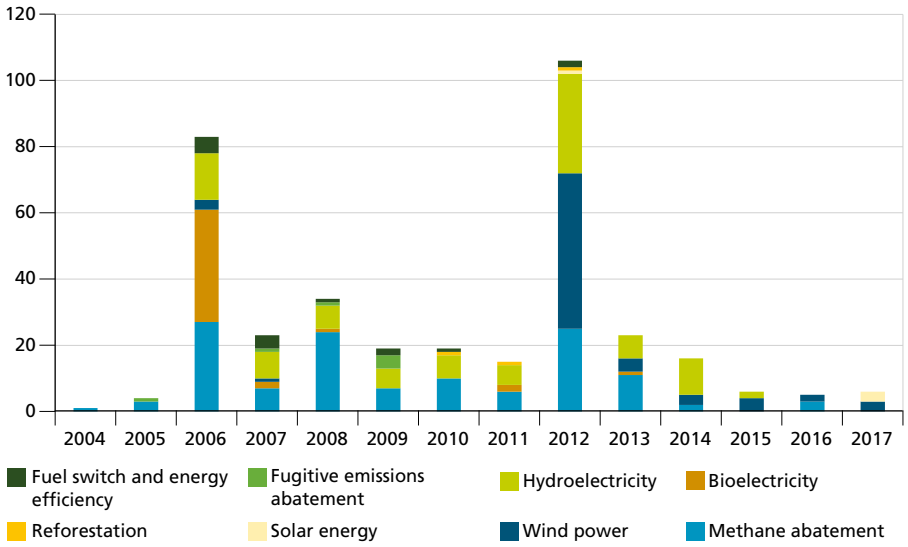
Based on the contextualization of these categories, it is now possible to evaluate mitigation results in terms of effectively issued CERs, as shown in the last column of table 1.

This analysis shows that the last category of fugitive emission abatement, which accounts for only seven projects and accounts for only 0.1% of the total investment, was responsible for issuing 61 million CERs, corresponding to 46.0% of all certificates issued by Brazil. Similarly, the category of methane abatement, with 126 projects, corresponds to 1.9% of investments and accounted for 41 million CERs, which corresponds to 31.0% of total certificates issued by Brazil. In turn, the category of renewable energy, which accounts for 97% of the investments mobilized, has been responsible for issuing only 25 million credits, which corresponds to 19% of all certificates issued by the country.

3.2 Assessment of the evolution in project registration

In order to deepen the evaluation of CDM results, we analyze their temporal evolution. Graph 1 identifies the number of projects registered over time, by category.

GRAPH 1
Evolution of CDM registry (2004-2017)
(In numbers by project per category)



Sources: UNEP, IGES and UNFCCC.
Prepared by the authors.

An evaluation of the graph above indicates that, over time, structural changes have occurred in the types of projects registered in the CDM. Initially, in 2006, the number of bioelectricity projects was large, but this type of project disappeared in subsequent years. The reason is that a methodological change in the CDM practically made it impossible to register this type of investment after 2006.[21] In the absence of this incentive, the registration and development of new projects of this category were limited in subsequent years, despite the great potential of biomass cogeneration in Brazil.

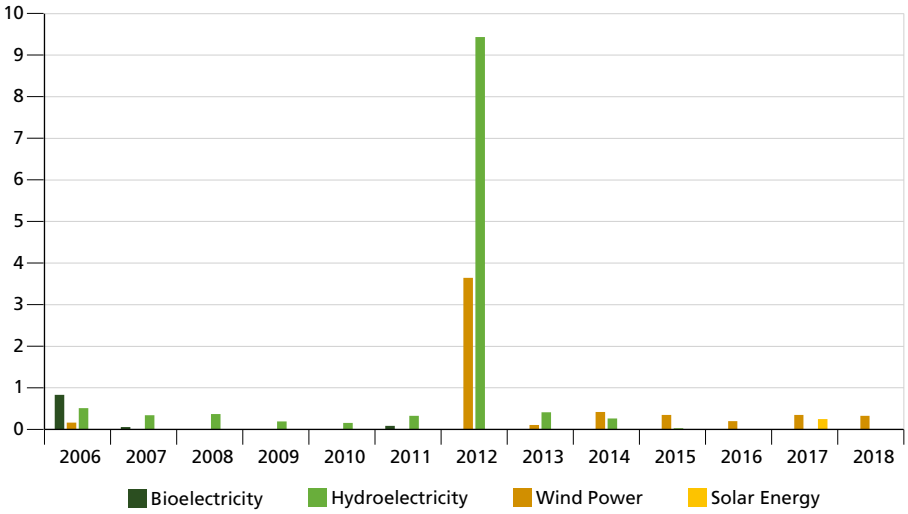
Another observation is that fugitive emissions abatement projects were developed before 2009. At that time, also a large part of methane abatement projects was developed. Finally, it is also interesting to note that there were practically no

21. Initially, bagasse-based cogeneration projects using the methodology AM0015: bagasse-based cogeneration connected to an electricity grid – Version 1.0, which allowed the submission of applications by December 25th, 2005, for registration in the year 2006. After this, bagasse cogeneration projects must use the more complex ACM0006, a fact that prevented the development of such new projects under the CDM. At the same time, few new projects of this kind were developed, a fact that indicates that the CDM was an important and effective support mechanism.

wind power projects before 2012 and that the first solar projects only recently obtained registration in 2017.

It is therefore of interest to assess the evolution of energy generation from renewable sources in a more specific way. For this purpose, graph 2 illustrates the evolution of renewable generation projects registration in terms of installed capacity. Data show that completion and registration of substantial hydro and wind power generation capacities occurred only at the end of the first commitment period of the Kyoto Protocol. This fact is explained by the long process of development, licensing and construction of these project types. As a consequence of this delay between the decision and conclusion of investments, projects were mostly commissioned at a time when carbon credit prices had already deteriorated.

GRAPH 2
Renewable energy project registration by capacity and type over time (2006-2018)
(In GW)



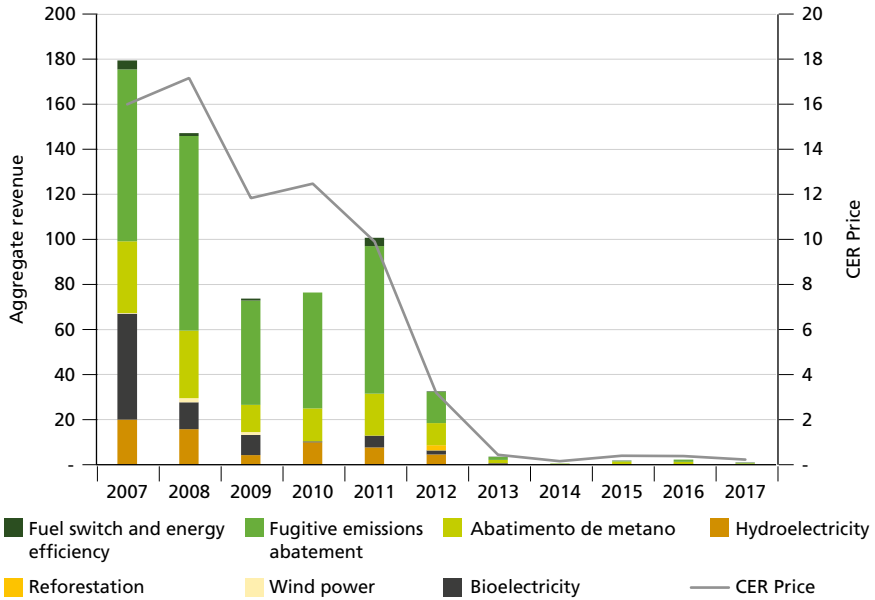
Sources: UNEP, IGES and UNFCCC.
Prepared by the authors.

3.3 Evaluation of credit issuance and revenue generation by project category

As can be seen, different types of projects have been concluded at different times of the CDM. Similarly, carbon credit prices deteriorated during the first commitment period of the Kyoto Protocol due to the lack of agreement on a second commitment period, as explained in section 1. In this sense, this combination of both developments over time indicates that different project categories obtained different economic benefits.

In order to estimate the revenues generated by each category of projects, it is possible to assume that investors sold their credits in the year of their actual issuance.[22] For an estimate of sale value, we take the average price of each year,[23] adding a 20% discount, in order to offset transaction and brokerage costs. Graph 3 presents the result of this revenue estimate for different categories.

GRAPH 3
Estimated revenue per CDM project category (2007-2017)
(In U$ millions)



Sources: CD4CDM/UNEP, UNFCCC and Quandl.
Prepared by the authors.

Graph 3 confirms that fugitive emissions and methane abatement categories have been able to take advantage of high prices at the beginning of the first commitment period of the Kyoto Protocol and have thus generated substantial revenues. Another category that benefited was bioelectricity and, to a lesser extent, some small hydroelectric plants that achieved CDM registration at the start of the first commitment period of the Kyoto Protocol.

22. In the case of credits generated before 2012, it is assumed that 11% of the credits were not sold. For credits generated after 2012, it is assumed that 56% of the credits issued were not sold. These ratios were calculated from carbon stock inventories still available and reported by the UNFCCC. The increase in the percentage of unsold credits in the post-2012 period is a direct result of the fall in prices.

23. Quandl. Available at: https://www.quandl.com/databases/SCF.

At the same time, it is clear that the activities of fuel replacement and energy efficiency, reforestation and renewable energy projects registered in 2012, including large hydroelectric plants and the numerous wind power projects to date, have obtained any economic benefit from the CDM. The results of this analysis, therefore, leads to the conclusion that the CDM was efficient in promoting GHG mitigation projects with low-cost and effort, but that transformational investments in important energy infrastructure were affected by the lack of continuity of this mechanism.

In this regard, Table 2 shows the effects of this distortion by comparing the different categories in terms of their share in the potential reduction and investments, as well as their participation in revenues generated by the mechanism.

TABLE 2
Comparison of revenues generated by different CDM project categories registered in Brazil

Type of Project	Projects (%)	Reduction (%)	Investment (%)	Credits (%)	Revenue generated	Revenue (%)	Revenue/ investment (%)
Renewable energy	58.0	51.0	97.0	19.0	142.4	23.0	0.40
Bioelectricity	11.0	4.0	11.0	7.0	75.8	12.0	2.20
Wind power	19.0	15.0	33.0	1.0	3.4	1.0	0.03
Hydroelectricity	27.0	31.0	51.0	11.0	63.1	10.0	0.40
Solar power	1.0	1.0	3.0	0.0	0.0	0.0	0.0
Methane abatement	35.0	34.0	1.9	31.0	121.2	20	19.0
Fugitive emissions abatement	2.0	13.0	0.1	46.0	342.7	55.0	383.0
Fuel replacement and energy efficiency	4.0	2.0	0.5	2.0	10.4	2.0	6.8
Reforestation	1.0	0.0	0.2	3.0	2.2	0.0	3.5
Total	**361 projects**	**53,654 $MtCO_2$ e per year**	**32,019 MUSD**	**133,5 $MtCO_2$ e**	**619 MUS$**	**100**	**1.9 (average)**

Sources: UNEP, IGES and UNFCCC.
Prepared by the authors.

An analysis of the figures above indicates that the fugitive emissions abatement category, which accounts for only 2% of projects, 0.1% of investments and 13% of the potential for reducing emissions, has generated revenue that represents almost 50% of all generated resources by the CDM. With their low capital intensity, these projects obtained a financial return of 383% on investments. Renewable energy generation infrastructure, in turn, accounted for 58% of projects and 97% of capital expenditures with mitigation potential of 51% of the total. This category generated only 23% of revenues, thus receiving an average financial contribution of 0.4% on the mobilized capital.

For the other categories of methane abatement, fuel switch and energy efficiency, the results seem more balanced, but it should be noted that these groups

are heterogeneous and require more specific discussion. Finally, the reforestation category appears to have produced interesting results that also deserve a more detailed analysis.[24]

4 CONCLUSIONS

The evaluation of Brazilian results and experiences with the CDM over the last decade provides a series of conclusions for the development of financial policies and mechanisms with better capacity to expand and improve the results of Brazil's socioeconomic development efforts. In a first estimate, it was found that the CDM was able to leverage a mitigation potential of almost 54 million tCO_2e per year, representing 2.6% of the national emissions in 2005, the year that generated the reference for the Brazilian NDCs. In addition, the mechanism was able to mobilize a total of US$ 32 billion in investments, which represents around 1.8% of GDP of US$ 1.796 billion in 2017.[25] Although these investments have taken place over several years, this contribution is significant today in the context of low infrastructure investments.

In addition, it is interesting to recognize that the total inflow of US$ 619 million over the period from 2008 to 2012 (some US$ 124 million per year), represents a return of 0.4% per year on the total of US$ 32 billion of capital mobilized by the CDM. Considering the low capital costs for currencies in dollars and euros of the last decade, this annual remuneration can be seen as a substantial support for such investments in Brazil. To be effective, such support obviously needs to be continued over the full 21 years that the CDM originally offered in order to remunerate capital intensive investments with long-term maturity.

Therefore, unfortunately, our analysis shows that the lack of sustainability and predictability of the CDM as a mechanism to encourage sustainable development has jeopardized projects with significant structural and transformational potential. On one hand, the CDM has channeled excessive financial rewards to end-of-pipe abatement projects with low-cost mitigation and no structural benefits. On the other hand, the CDM promoted large capital-intensive investments without adequate economic return, thus contributing, to the worsening of the economic crisis and retraction of investments in Brazil.

24. Considering the fact that the CERs of reforestation projects do not have the value of the traditional CERs, our model uses a discount of 75% to estimate their revenue. Nonetheless, this projection may still be optimistic as this type of credits had little demand.

25. The World Bank. Available at: https://bit.ly/2yXDDGq.

5 RECOMENDATIONS

From the experiences of the CDM, it is possible to conclude that the creation of international financial mechanisms can play a relevant role in the mobilization of investments in sustainable infrastructure, for the adequate treatment of waste and effluents, for industry technology updating, as well as for activities of reforestation. However, a series of strategies must be considered to avoid rent seeking and credit export by low-cost opportunities and to ensure that investments are targeted to strategic areas of the Brazilian economy. Below are a series of reflections to contribute to this discussion.

1) Legal security and long-term vision: the development of infrastructure projects or programs with transformational range and depth requires sound and predictable policies with long-term fundamentals. Any mechanism to be created in the future should prevent that investors are subject to instabilities, political interference or mechanisms without long-term sustainability and reliability. Along these lines, it is essential that new mechanisms to be created recognize the results already achieved in the context of the CDM so as not to deepen disbelief in relation to this type of economic instrument.

2) Complementarity of pricing and climate financing: Brazil's ambitious results are the consequence of the integration of domestic development and financing policies with the CDM as an international incentive, a strategy developed based on the Brazilian NPCC. Unfortunately, the current fiscal situation of the Brazilian Government does not allow the continuation of this policy and the low domestic savings rate of the Brazilian economy shows the need to attract more international investments. In this context, it is advisable to evaluate the Brazilian experience to develop solutions that ensure the synergistic combination of mechanisms for carbon pricing and climate financing and thus promote foreign direct investment in the areas that are strategic for the country's low emissions development.

3) Focus on promoting structural and transformational mitigation: it is understandable that the CDM has focused on low-cost mitigation, but in the context of the Paris Agreement, this tendency to prioritize the least cost mitigation should be re-evaluated. The reason is that the Paris Agreement provides that reductions resulting from cooperation mechanisms "shall not be used to demonstrate achievement of the host Party's NDC if used by another Party to demonstrate achievement of its NDC" (UN, 2015). Considering the need to account for the international transfer of mitigation results, the export of low-cost carbon credits without

additional development benefits may not be in the interest of the host country. Therefore, Brazil should promote policies and solutions that prioritize the sale and transfer of mitigation results of GHG mitigation activities with higher-cost or with important demand for the import of capital and technology.

4) Solving controversies about environmental integrity: the new Paris Agreement structure, with targets for all countries and the requirement to account for the international transfer of mitigation results, allows for overcoming criticism about the lack of environmental integrity of international flexible mechanisms. In order to take advantage of such an opportunity, it is important that Brazil promotes the definition of solid and transparent rules to authorize and account for transfers without risk of double counting by buyers and sellers. This type of transparency is fundamental to promote the use, and therefore, the demand for this type of mechanism and its mitigation results. In addition, recognition and accounting by the government can reduce the costs and difficulties of developing projects.

5) Establishment of a new sustainable development mechanism: the experience of the CDM and its focus on the minimum cost of abatement and no transformational effects for the host country indicates the need to encourage the use of a mechanism that is more effective in promoting truly transformative investments in order to promote the country's sustainable development objectives (UNBR, 2015). Therefore, the search for the minimum cost for mitigating greenhouse gases must be complemented by the search for solutions that can transform infrastructure, productive processes and social relations towards a more sustainable economy.

Based on these conclusions, it is important that Brazil aims at defining guidelines and policies that leverage the realization of low-cost emission reductions in the context of domestic policies and without exporting them. At the same time, it is recommended that Brazil seeks its insertion in a possible future carbon market to leverage investments with high intensity and cost of capital and the attraction of technologies and industries that are strategic for the low emissions development of the country.

The CDM provided important lessons for the discussion and definition of regulatory strategies. The main conclusion is that these solutions should be pragmatic, economically efficient and, to the extent possible, free of ideological, political and regulatory risks and interferences. In this moment of crisis in the Brazilian economy, the definition of new national and international mechanisms for carbon market and climate financing may be an opportunity to overcome the

lack of investment and to promote the environmental and economic efficiency of the Brazilian industry so that the country can play its essential role in decarbonizing the global economy.

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