CHAPTER 4

EXPERIENCIES AND LESSONS OF CDM IN THE ENERGY SECTOR

Adelino Ricardo J. Esparta[1]
Karen M. Nagai[2]

1 THE ENERGY SECTOR: INTRODUCTION

This chapter addresses the Clean Development Mechanism (CDM) in the context of the energy sector and includes the following sectoral scopes presented in Annex A of Kyoto Protocol (UNFCCC, 2015):[3]

- energy industries (renewable/non-renewable sources);
- energy distribution;
- energy demand;
- transportation; and
- fugitive emissions from fuels (solid, oil or gas).

The indicated scopes include the following activities: *i*) power generation – either off-grid or grid-connected; *ii*) grid connection of isolated systems; *iii*) energy efficiency measures; *iv*) fuel or raw material switch; *v*) energy distribution; vi) transportation; and *vii*) fugitive emissions from fuels.

The energy component is considered in most of the registered Brazilian CDM projects. This chapter includes, for example, the industry initiatives, which involve the energy issue through the switching or replacing of fuels – by using renewable ones or less carbon-intensive fuels –, energy efficiency measures and thermal energy generation, through the use of renewable fuels (residues from forestry and agricultural activities). The energy generation from the treatment of waste gases will not be addressed in this chapter, but in the chapter dedicated to biogas and biomethane (Chapter 5 – *Waste*).

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1. Chemical engineer and researcher at the Research Center for Natural Gas Innovation, at the University of São Paulo (RCGI/USP).

2. Environmental manager and collaborator at Ecopart Assessoria Ltda.

3. Sectoral scopes are categories of greenhouse gas (GHG) sources, or groups of activities applicable to CDM projects activities or CDM activity programs. They are based on the sectors and source categories established in Annex A of Kyoto Protocol. One CDM project activity, or one CDM activity program, can be classified in more than one sectoral scope.

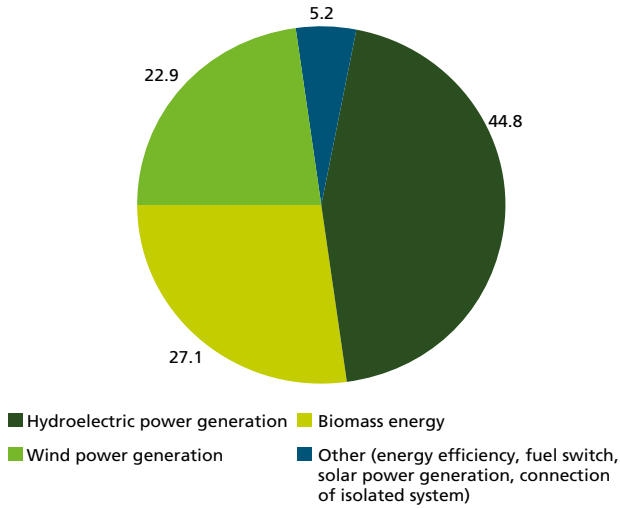
2 ANALYSIS OF THE REGISTERED ENERGY PROJECTS

Up to June 2017, 342 CDM projects were registered in Brazil, of which 210 are projects involving the generation, transmission or consumption of energy, 68.6% of them are large-scale projects and 31.4% are small-scale projects.[4,5] Under the *Programme of Activities* (PoAs), among the ten ones that have been registered in Brazil, seven of them are renewable energy generation projects and the other three involve the recovery and destruction or energetic use of methane (CH_4).[6]

Technologies implemented in the energy sector can be categorized into: *i)* electricity generation to the National Interconnected System (SIN, from the Portuguese "Sistema Interligado Nacional"), which includes wind, solar, hydroelectric and thermoelectric generation with renewable biomass as an independent power producer (IPP); *ii*) off-grid generation (isolated systems) in the condition of power auto producer (APE); *iii*) connection of isolated systems to the SIN; *iv*) fuel switch; *v*) energy efficiency; and *vi*) thermal energy from biomass.

Out of the 210 registered energy projects, 94 are hydroelectric projects, 57 are wind farms, 48 of biomass, 6 of fuel switch, 3 of energy efficiency, 1 of connection of isolated system and 1 of solar generation (chart 1).

CHART 1
CDM projects registered in Brazil involving energy (March 2017)
(In %)



Source: Centre on Energy, Climate and Sustainable Development of the United Nations Environment Program (UNEP). Available at: https://goo.gl/HQjdLY. Accessed on: March 28th, 2017.

4. Except for projects involving biogas and biomethane.

5. Data obtained on the website of the Centre on Energy. Climate and Sustainable Development of the United Nations Environment Program (UNEP). Available at: goo.gl/vr99Rp. Accessed on: March 28th, 2017.

6 The United Nations Framework Convention on Climate Change (UNFCCC). Project Search 2017. Available at: goo.gl/y4rrGL. Accessed on: May 30th, 2017.

Only one wind power project is for off-grid generation. The remaining wind, hydroelectric and solar projects are connected to the national grid. Regarding the biomass projects, 39 out of 48 registered projects generate electric power for the grid; the other nine projects only involve thermal power and/or fuel switch.

Regarding the issuance of *certified emission reductions* (CERs), out of the 122,324 $ktCO_2e$ issued, 25,269 $ktCO_2e$ are from energy projects (20.7% of the total). The remaining CERs are divided into: nitric acid plants (N_2O abatement, 45.8%); landfill gas (25.2%); methane avoidance from manure and waste water (3.5%); reforestation (3.5%); avoidance of sulfur hexafluoride emissions (SF_6) and perfluorocarbons (PFCs) emissions (1.3%); avoidance of fugitive emissions from coal production (0.1%); and substitution and recycling of carbon dioxide (CO_2) (0.01%) (table 1).

Although the nitric acid plants, with five projects, account for only 1.5% of the registered projects, they are responsible for 45.8% of the issued credits, due to the high global warming potential of nitrous oxide (N_2O).

TABLE 1
Quantity and representativeness of registered CDM projects and CERs issuance – Brazil (March 2017)

Type	Registered projects	Registered projects (%)	Credits issued (kRCE)	Projects issued (%)
Energy	210	61.4	25,269	20.7
Biomass as energy source	48	22.9	9,410	37.2
Interconnection of isolated systems	1	0.5	316	1.3
Energy efficiency	3	1.4	353	1.4
Fuel switch	6	2.9	712	2.8
Hydropower	94	44.8	14,135	55.9
Windpower	57	27.1	343	1.4
PV generation	1	0.5	0	0.0
Other projects	132	38.6	97,055	79.3
Total	**342**	**-**	**122,324**	**-**

Source: United Nations Environment Program (UNEP). Available at: goo.gl/ih3zxB. Accessed on: March 28th, 2017; The United Nations Framework Convention on Climate Change (UNFCCC), 2017. Available at: goo.gl/y4rrGL. Accessed on: May 30th, 2017.

3 ELECTRICITY INTO TO THE GRID

3.1 Simplicity and robustness of the methodologies

Based on the analysis of the Brazilian CDM projects, a significant participation of grid-connected electricity generation from renewable energy sources, can be noticed. Some factors can be mentioned regarding this significant participation in relation to other types of projects.[7]

In the case of "greenfield" projects, i.e. new plants, which represents the largest portion of registered projects – the baseline scenario is determined[8] as the electric power generated by the project, replacing the electric power that would be generated by a combination of existing and new (others that would be built) plants, reflected in the grid emission factor. Therefore, the only parameters required for the calculation of baseline emissions and, consequently, the determination of the CERs, are the electric power generated by the CDM project and the emission factor of the grid. The Brazilian emission factors have been made available by the Brazilian Designated National Authority (DNA) since 2007 (Brazil, [s.d.]).[9]

Even for cases of expansion and/or retrofit of existing generation plants, the calculation remains very simple. The baseline scenario is identified by the electric power generated by the project before CDM. Thus, emission reductions are directly determined by the difference between the previous generation in the baseline scenario and the generation after the expansion and/or retrofit. Therefore, the additional generation after the expansion and/or retrofit multiplied by the CO_2 emission factor of the grid results in the baseline emissions of the project.

Therefore, the emission scenario of the baseline is easily defined by the methodology, and the accounting of the emission reductions depends – almost exclusively – on the energy generation dispatched to the grid, which is monitored by the project participants (PPs) independently of a GHG emission reduction project or not.

3.2 Monitoring plan without procedures unrelated to the operation

All information regarding energy generation and its reliability, as well as the appropriateness of the operation of the plants, are required during the project validation/verification. Thus, electricity generation data, calibration of meters,

7. This analysis does not include electric power generation projects from biomass residues, since there was a significant reduction in the records of these types of projects from 2006, most probably due to the substitution, in the perception of the authors, of the extremely simple methodology AM0015 – Bagasse-based cogeneration connected to an electricity grid – by the extremely complex ACM0006 – *Electricity and heat generation from biomass.*

8. ACM0002 – Large-scale methodology for grid-connected electricity generation from renewable sources.

9. The emission factors of the construction and operation margin are available on the website of the Brazilian Designated National Authority (DNA), information since 2006. Such factors are calculated using the dispatch data analysis method and the simple adjusted method.

operating license, among others, are easily obtained, as they are part of the operating routines of the projects, without the need for: the installation of additional monitoring equipment, outsourced labor force, specialized training of operators or changes in the plant's work routine.

In addition, the monitoring of electricity carried out by the PPs can be easily verified with data from third parties regularly operating in the market. This is the case of the Electric Energy Trading Chamber ("Câmara de Comercialização de Energia Elétrica" – CCEE)[10] via the online Energy Data Collection System (SCDE), or even the data from the local energy concessionaire/distributor, just to mention some of the evidence and official documents most commonly use to confirm this information.

There are examples of additional projects that remained unfeasible, due to physical and financial constraints related to the implementation of additional monitoring required by the CDM. As an example, the AMS-II.E methodology – Energy efficiency and fuel switching measures for buildings – requires monitoring by energy efficiency measures, which cannot be simply accounted from the consumption of electricity directly, as it includes actions that may have some degree of subjectivity on the direct influence of the CDM project. As example, it can be mentioned the improvement of operation management and maintenance through the adoption of procedural changes, the establishment of best practices, the replacement of lamps, among others. The difficulty in unequivocally accrediting any reduction of electricity consumption directly to the actions of the CDM project, and the difficulty in precisely linking individual measures each MWh consumption avoided were the reasons given for the rejection of energy efficiency projects in a supermarket chain involving 94 branches distributed in seven Brazilian states.[11]

In the case of the electricity generation connected to the grid, there are no difficulties in accrediting improvements, and not even the need for procedures apart from the normal operation of the projects, which, consequently, simplifies the work and reduces the project's implementation, operation and transaction costs.

3.3 Autonomy from the participation of third parties

Due to the size of the grid-connected electric power generation projects, there is no need, normally, for a wide variety of monitoring actions, which can greatly increase operating costs. Examples of such actions can be observed in microscale projects (energy efficiency projects or household-scale electric power generation),

10. The Electric Energy Trading Chamber (CCEE) is an institution created in 2004, replacing the Wholesale Electric Energy Market (MAE), as a result of the new Brazilian electric power sector framework. It is responsible for managing the commercialization of electric power in the interconnected system.

11. Available at: https://goo.gl/8Ey1rd. Accessed on: June 16th, 2017.

when monitoring/follow-up actions of the operation of each equipment must be individually programmed, even if there is a possibility of sampling. Thus, the PPs of power generation do not depend on the confirmation and/or exchange of information with third parties, who may bring the need for additional procedures, such as the signing of individual contracts and preventive maintenance in a pulverized manner. In cases of household-scale electric power generation, for example, in order to develop the CDM process, individual participation and consultation are necessary for several participants, which bring bureaucracy to the project development and also raises its costs.

In conclusion, it is quite reasonable to assume that more simplified emission reduction calculation and procedures for demonstrating the baseline scenario, carrying out monitoring without the need of additional procedures and/or equipments, as well as the autonomy in participation of third parties, very likely contributed to a more intensive development of grid-connected electric power generation CDM projects.

4 RELEVANT EVENTS FOR THE DEVELOPMENT OF CDM PROJECTS IN THE ENERGY SECTOR IN BRAZIL

4.1 Review and consolidation of methodologies: biomass and cogeneration projects

Brazil has a significant potential for generating electricity to the grid with the use of biomass residues, but there are still many barriers to further development in the sector. In a way, CDM has helped, for some time, in making these projects more attractive. But this typology of projects is an example of how frequent revisions of calculation methodologies and somewhat academic demands – in other words, little related to the reality of the operation of actual projects – may influence the development of the sector. Due to the importance of cogeneration with biomass to Brazil, participants in some Brazilian projects proposed and obtained the approval, in September 2004, of the large-scale methodology AM0015, specifically for the use of sugarcane bagasse in the generation of electricity to the grid. The methodology was extremely simple and very similar to those employed for power generation from hydroelectric and wind turbine generators (WTGs). While AM0015 was valid – registration requests were allowed until December 25th, 2005; i.e. that is, during the period of approximately fifteen months of validity – 24 large-scale projects were registered using it. AM0015 was replaced by the consolidated methodology ACM0006, which is much more detailed and with the introduction of several complex restrictions and unclear parameters and constraints; for example, the efficiency of hypothetical multiple uses of biomass waste.

Since its adoption, the ACM0006 methodology has become increasingly complex by adopting different types of theoretical scenarios for the generation of electricity, heat/steam, mechanical energy, biomass and biogas. Currently ACM0006 methodology has seventy pages, not considering the related referred tools on which the methodology is also based.

Sixty-four project design documents have been published since then, and began their validation in Brazil, but only two cogeneration projects obtained the registration, one in 2007 and another in 2011, and other two were rejected – in 2008 and 2009. Only 6 out of the 24 projects registered with AM0015 could renew their crediting period with the use of ACM0006. The sector has grown in the period, but it still holds great unfulfilled potential, and although it would make sense, the CDM, unfortunately, does not represent a realistic incentive for the sector.

4.2 Methodological uncertainties and pressure from stakeholder groups: large hydropower plants – additionality and reservoirs

The discussion on the additionality of large-scale hydroelectric power plants has always been present in the CDM. Stating that large hydroelectric projects are additional has always caused discomfort to many stakeholders.[12]

In its turn, the *tool for the demonstration and assessment of additionality* was developed in an attempt to objectively demonstrate whether a given project is additional or not. In the case of energy projects, which receive other revenues than possible emission reduction credits and could be developed by any other developer, the feasible demonstration of additionality is essentially carried out through the financial analysis. The other option is the barrier analysis, but this one is practically not used, due to extreme subjectivity and impossibility of being unequivocally demonstrated in practice. Therefore, the additionality tool can be considered a good tool, when it comes to establish means to define: *i*) realistic alternatives to the implementation of the project; *ii*) the pioneering projects and what is common practice in the market; *iii*) the obstacles faced by the projects; and *iv)* the financial attractiveness of the project and alternatives.

It surely is very unlikely that an entrepreneur will invest in a project that is not very financially attractive and depends exclusively on very uncertain funding as the trading of emission reduction credits; for this reason, the tool for demonstration and assessment of additionality aims at describing the steps for a rational and reasonable analysis and it is, in the authors' opinion, a valid way to evaluate the additionality of the project from a theoretical point of view. Obviously, there are discussions regarding its effectiveness, but the authors consider that the application

12. Stakeholders who are directly or indirectly involved by the project implementation.

of a concept that can be very subjective and essentially theoretical (the scenario of the absence of the project is counterfactual) has to use some flexibility. This is exactly what happens in the abovementioned tool, for example, by acknowledging that a rational investor – when comparing two economically feasible alternatives – would choose the one that is financially more attractive. That being said, the project does not necessarily need to be unfeasible and then become feasible exclusively by revenues from the emission reduction credits to be additional.

BOX 1

Comments from the public consultation process for CDM in hydroelectric power plants

In the consultation process of the stakeholders, during the validation phase, large hydroelectric plants – such as the Santo Antonio, Teles Pires and Jirau hydropower plants (HPP) – received several negative comments regarding additionality, reservoir emissions, environmental impacts, and the licensing process in Brazil.[1] The PPs responded to all comments based on the ACM0002 methodology, procedures and tools approved by the CDM Executive Board for the validation of projects. Even though they received apparently severe criticism, such projects were registered as CDM project activities. In the authors' opinion, this happened essentially because the criticism was focused much more on processes and regulators, for example, when the effectiveness of the additionality tool was questioned, rather than the characteristics of the projects themselves.

Prepared by the authors.

Note: [1] For example, comments on the Santo Antonio hydroelectric power plant (HPP) project are available at: goo.gl/Apf91Q. The response of the project participants (PPs) can be found in the link available at: goo.gl/isEmZH. Accessed on: April 30th, 2018.

Hydroelectric power is very important for the Brazilian electric power sector. However, only run-of-river (RoR) projects or projects built in existing reservoirs were eligible in the first methodologies related to hydropower plants. The concept of run-of-river was never precisely defined in the scope of the CDM, but this did not prevent the registration of thirteen projects in Brazil in 2006. However, the potential for CDM projects in hydroelectric plants with new reservoirs and not ROR systems has always existed. But it was only after version 6 of ACM0002, in July 2006, that hydroelectric plants with new reservoirs became eligible, through the introduction of the concept of power density, derived from Brazilian reference studies (Brazil, 2006).

For hydroelectric power project activities that result in single or multiple reservoirs, the following criteria must be observed:

- the methodology is not applicable if the power density of the project activity is lower than or equal to 4 W/m^2;
- CH_4 and CO_2 emissions from the reservoir should be considered if the power density of the project activity is greater than 4 W/m^2 and lower than or equal to 10 W/m^2; and
- emissions from the water reservoir are set as zero if the power density of the project activity is greater than 10 W/m^2.

The first Brazilian project that was clearly not ROR was registered in May 2008 (Fundão-Santa-Clara Energy Complex – CEFSC), which includes a hydroelectric plant with a power density of 6.13 W/m^2. Several others have been registered since then.

The power density and emission limit-values were defined based on the eligibility recommendation of the CDM Methodology Panel (UNFCCC, 2006b). Based on empirical data from Brazilian reservoirs, estimates were demonstrated for hypothetical reservoirs with 10 W/m^2 of power density and 60% of capacity factor, which resulted in emissions ranging from 20.14 to 76.40 kgCO_2e/MWh. From these figures, the CDM Executive Board took the conservative decision of adopting emissions of 90 kgCO_2eq/MWh for reservoirs with power density greater than 4 W/m^2 and lower than or equal to 10 W/m^2.

In order to confirm the conservativeness of the procedure – under the approved CDM methodology –, table 2 was prepared using the latest literature compilation data available for Brazilian hydroelectric power plants (HPPs) (Demarty and Bastien, 2011).

TABLE 2
Greenhouse gas (GHG) emissions from HPPs

Dam/reservoir	Total annual emissions	Age of reservoir	Area of reservoir	Installed capacity	Power density	Annual emission factor of the reservoir
	10^6 tCO_2eq	Years	km^2	MW	W/m^2	gCO_2eq/m^2
Miranda	0.15	1	70	408	5.83	2.14
Serra da Mesa	2.14	1	1,784	1,275	0.71	1.20
Xingo	0.16	4	60	3,000	50.00	2.67
Tucurui	28.73	5	2,875	8,370	2.91	9.99
Segredo	0.09	6	82	1,260	15.37	1.10
Itaipu	0.20	7	1,350	12,600	9.33	0.15
Samuel	2.60	11	560	216	0.39	4.64
Balbina	2.43	16	2,360	250	0.11	1.03
Barra Bonita	0.57	35	334	141	0.42	1.71
Três Marias	4.21	36	1,155	396	0.34	3.65

Source: Demarty and Bastien (2011).
Prepared by the authors.

From the available figures, it is clear that, under certain circumstances, there is potential for large gross amounts of GHG emissions. However, all plants with high gross CO_2 emissions would not be eligible in the context of the CDM because their power densities are all lower than 4 W/m^2 – highlighted in red in table 2.

Using generation data of 2012, it is possible to estimate the emission factor of the plants in table 2 that are eligible in the CDM (table 3). It should be noted that the calculation is performed using gross emissions, without the distinction between emissions due to the reservoir and natural emissions. From these estimates, the rationale is very clear and, in some cases, it is also clear the excessive conservatism of the limits used in CDM projects.

TABLE 3
Estimates of emission factors in eligible plants in the CDM (2012)

Dam/reservoir	Total MWh[1]	Área (m^2)	Total emissions (tCO_2e)	Power density (W/m^2)	Emission factor ($kgCO_2e/MWh$)
Miranda	2,096,372	70,000,000	150,000	5.83	71.55
Xingo	19,673,435	60,000,000	160,000	50.00	8.13
Segredo	5,993,278	82,000,000	90,000	15.37	15.02
Itaipu	89,204,754	1,350,000,000	200,000	9.33	2.24

Source: Demarty and Bastien (2011).
Prepared by the authors.
Note: [1] Source: The National Electricity System Operator.

From the results, it can be concluded that the approved ACM0002 methodology is conservative in relation to the reservoir emissions for most of the eligible cases.

However, it should be recognized that additional efforts are required to develop a robust measurement protocol, aiming to estimate GHG emissions from water bodies more accurately.

The market, on the other hand, defines the criteria for the purchase of carbon credits from large-scale hydroelectric projects. Thus, even if large projects generate credits, if there are no buyers for these credits, the incentive will not exist in practice.

In 2007, developers of hydroelectric projects and buyers of carbon credits went through regulatory uncertainties in the European Union (EU) regarding eligibility of credits generated by hydroelectric plants with installed capacity above 20MW. At the time, there were rumors about the ban on the marketing of these credits on the European market, which paralyzed several ongoing negotiations.

In 2008, the EU began to require projects with installed capacity above 20MW to be assessed against the criteria of the World Commission on Dams (WCD),[13] so that the credits generated by those projects became eligible in the

13. The World Commission on Dams (WCD) has seven principles: *i*) public acceptance and consultation of stakeholders; *ii*) assessment of comprehensive options; *iii*) assessment of existing dams; *iv*) sustainability of rivers and livelihood; *v*) recognition of entitlements and shared benefits; vi) ensuring compliance; and *vii*) sharing of rivers for peace, development and security (WCD, 2000).

EU Emissions Trading Scheme.[14] Likewise, buyers in the voluntary market also began to require such certification.

BOX 2
Calculation of reservoir emissions

Project emissions from water reservoirs are calculated according to the following equation:[1]

$$PE_{HP,y} = \frac{EF_{Res} \times TEG_y}{1000} \quad (1)$$

In which:

$PE_{HP,y}$ Project emissions from hydroelectric plants reservoirs in year y (tCO2e);

EF_{Res} Default emission factor for reservoirs emissions of hydroelectric power stations; namely, 90 kg CO2e/MWh;

TEG_y Total electricity produced by the project activity, including the electricity supplied to the grid and the electricity given to the internal loads, in the year y (MWh).

The power density of the project activity is determined by the following equation:

$$PD = \frac{Cap_{PJ} - Cap_{BL}}{A_{PJ} - A_{BL}} \quad (2)$$

In which:

PD Power density of the project activity, in W/m2;

Cap_{PJ} Installed capacity of the hydroelectric plant after the implementation of project activity (W)

Cap_{BL} Installed capacity of the hydroelectric plant prior to the implementation of the project activity (W). For new hydropower plants, this value is zero;

A_{PJ} Area of single or multiple reservoirs measured on the water surface, after implementation of the project activity, when the reservoir is full (m^2);

A_{BL} Area of single or multiple reservoirs measured on the water surface, before implementation of the project activity, when the reservoir is full (m^2). For new reservoirs, this value is zero.

Although the determination of the methodology for the A_{BL} parameter is zero for new reservoirs, some projects were registered discounting riverbeds. Thus, A_{BL} is the surface area of the river before the implementation of the project, and therefore the area considered for power density calculation purposes is the difference between the reservoir area and the existing river channel area. This approach is based on the clarification provided by the CDM Executive Board, which reads: "in order to calculate the power density, the correct equation will be the increased power capacity divided by the increased flooded area measured in the water surface".[2]

Prepared by the authors.

Notes: [1] ACM0002 – large-scale methodology – consolidated baseline methodology for grid-connected electric power generation from renewable sources. Most recent version available at: http://cdm.unfccc.int/methodologies/index.html.

[2] Request for clarification for approved large-scale CDM methodology, AM_CLA_0049 – calculation of power density. Available at: goo.gl/KQUzLu. Accessed on: December 20th, 2017.

14. Mandatory program for limitation and trading of emissions that allows the use of carbon credits from the mechanisms of the Kyoto Protocol. Available in: http://www.co2offsetresearch.org/policy/EUETS.html; goo.gl/uepkj6. Accessed on June 16th, 2017.

4.3 Lack of publicly available information and differences in interpretation of methodologies: CO_2 emission factor of the grid/interconnected system emission factor

Since the earliest discussions of the development of CDM projects in the energy sector in Brazil, it was clear that projects generating electricity from renewable sources would play an important role.

But at the outset, there was great difficulty for these projects, namely: how to calculate the grid emission factor. In the early 2000s, articles on the subject were published specifically for Brazilian grid grid (Esparta et. al, 2001, Esparta and Martins, 2002). However, this was only partially resolved with the publication of the first CDM approved methodologies: for small scale projects, version 2 of AMS-I.D, in December 2003; for large-scale projects, AM0015 and ACM0002, both in September 2004.

The emission factor of interconnected systems, for all methodologies, is calculated using the concepts of operating margin and build margin introduced for the Brazilian system by Meyers *et al.* (2000) and further elaborated by Sathaye *et al.* (2002). The idea is that when adding a new power plant to the installed system, there will be a marginal impact on the operation (electricity with the highest operating cost, which represents the operating margin, will be displaced) and the construction of new plants (the construction trend observed in recent years, the build margin, will change).

From the publication of the methodologies, a group of private companies sourced and processed publicly available information in order to make made available the first emission factors for the period 2004-2006 for the Brazilian interconnected system. Some projects were approved using these emission factors. The first project was registered in January 2006, and by the end of the first half of 2006, there were already thirty registered power generation by renewable sources.

However, as at the second half of 2006, differences in interpretation between the Brazilian Designated National Authority (DNA), the Interministerial Commission on Global Climate Change (CIMGC, from the Portuguese "Comissão Interministerial de Mudança Global do Clima"), and project proponents on what methods to use for operating margin calculation – the CIMGC required the use of the hourly dispatch data analysis method, which requires non-publicly available information – and which applicable system boundaries (the Southern, Southeastern + Center-West, Northern and Northeastern, four regions for the CIMGC and the South + Southeastern + Center-West + Northeastern + North, two regions for project proponents) made it difficult – or impossible – to approve projects in the sector during the period.

From the beginning of 2007, the CIMGC initiated the publication of emission factors, according to the assumptions considered most appropriate by the commission itself (operating margin for dispatch data and four electrical systems). Even so, these assumptions were questioned by PPs, who favored the use of 100% publicly available data. The matter was only finally resolved after a public hearing held in December 2007, which resulted in the publication of Resolution CIMGC No. 8,[15] which defined the whole SIN as a single system and accepted other calculation methods for the operating margin prepared by the project participants.

Discussions on the emission factor are an example of the persistence and perseverance of PPs, which were able to have other emission factors approved in methods other than those initially prescribed by the DNA. Such discussions, their repercussions, and the learning about how to deal with different views, of the project developers and the government regulator in the case, are part of the CDM's legacy for grid-connected power projects.

4.4 Proinfa Projects and the governmental ownership of credits

The Brazilian Alternative Energy Sources Incentive Program (known as Proinfa from the Portuguese "Programa de Incentivo às Fontes Alternativas de Energia Elétrica") – created by Law No. 10,438, of April 26th, 2002 – aimed at increasing the participation of alternative renewable sources (small hydroelectric power plants – SHPs, wind power plants and biomass thermoelectric projects) in the generation of electricity, privileging entrepreneurs who had no corporate links with generation, transmission or distribution concessionaires.[16] The law that created the program did not provide ownership of possible carbon credits. However, in its regulation, two years later (Decree No. 5,025 of March 30th, 2004), the reduction of GHG emissions under the Kyoto Protocol was explicitly stated as one of the objectives of the program, to the point that financial resources of the Proinfa account were allocated to Eletrobras ("Centrais Elétricas Brasileiras", the federal state-run utility), with the objective of pursuing financial benefits from the CDM.[17] Some PPs with generation units in the program tried to register their projects in the CDM without the direct participation of the Federal Government. The vast majority of those who tried were harshly questioned about ownership of CERs, but a few[18] were able to register. But despite the desire of the Federal Government and the great

15. Resolution No. 8 of the Interministerial Commission on Climate Change (CIMGC), of May 26th, 2008. Available at: https://goo.gl/yxZ64S. Accessed on Dec. 22nd, 2017.

16. Available at: http://www.aneel.gov.br/proinfa. Accessed on Dec. 27th, 2017.

17. For example, the Annual Plan of the Brazilian Alternative Energy Source Incentive Program (Proinfa) 2013, produced by the Centrais Elétricas Brasileiras SA (Eletrobras, 2012), indicates specific coverage for the development of the activities aimed at obtaining carbon credits from the program, in the amount of just over BRL20.6 million.

18. For example, the Cerradinho and Couripe thermal electric plants, the Água Doce wind farm, the Aquarius small hydroelectric plant and the Osorio wind farm.

effort in human and financial resources, Eletrobras found it very difficult to register the Proinfa projects in the CDM. Only in October 2012, four groups of SHP projects and wind farms started the validation process, but until December 2017, no project had been registered and, consequently, the possible financial benefit of the mechanism was lost. The experience would merit further discussion – which unfortunately will not be possible here – to accurately understand the difficulties and problems, and finally try to avoid them in similar future situations.

5 ELECTRIC POWER SECTOR

In order to evaluate the impact of the CDM on the electricity sector, the projects that started operations and registered under the mechanism are analyzed in the next paragraphs. For this purpose, the following observations shall be considered:

1) Operations startup is based on ANEEL's (Brazilian Electricity Regulatory Agency) generation database; data collected on June 6th, 2017.
2) Only projects that started operations as Independent Power Producers (IPP) according to the Brazilian regulation are included. Therefore, projects involving micro-scale hydropower, solar photovoltaic power plants and and thermonuclear power plants were not included (such entrepreneurships are under the Brazilian regulation either captive generators or public services).
3) The first Brazilian power generation CDM project was registered on November 18th, 2004.[19] However, registered CDM projects started operations before that (for example, in 2000), as there was the possibility of obtaining retroactive credits for projects submitted to registration by March 31st, 2007 (UNFCCC, 2006a).
4) There are CDM projects that started operating before 2000, and therefore their registration in the mechanism refers to expansion and/or retrofit projects, as it is the case of most sugarcane bagasse cogeneration projects. Thus, for example, despite the fact that ANEEL indicates that a certain plant came into operation in 1994, for example, the CDM project is related to expansion and/or retrofit carried out by the entrepreneur after 2000.
5) CDM projects for the generation of electricity by biogas were not included, since it was not possible to correlate the projects identified by ANEEL with the projects registered on the website of the United Nations Framework Convention on Climate Change (UNFCCC). In addition, this type of project will be discussed in Chapter 5 (*Waste*).

19. The first project registered by the CDM was "NovaGerar" – a project on energy from landfill gases. Available at: https://cdm.unfccc.int/Projects/DB/DNV-CUK1095236970.6/view; goo.gl/CYdvYx.

Since the first CDM project was registered, at the end of 2004, the authors decided to evaluate two periods, ten years prior to and after 2005 in order to try and understand the impact of the mechanism in the sector. In the period 1996-2005, 164 projects started operating as Independent Power Producers (IPP), of which 42 were registered in the CDM – that is, 25.6% of the total (table 4).

Considering the period 2006-2015, 742 projects started operation, of which 221 are CDM projects – that is, 29.8% of the total (table 4).

TABLE 4
Number of projects that started operation, by source and CDM representativeness (1996-2005/2006-2015)

Period	1996-2005			2006-2015		
Source	Number of projects that started operating	Number of CDM projects	CDM (%)	Number of projects that started operating	Number of CDM projects	CDM (%)
TPP[1]	89[2]	17	19.1	180[3]	4	2.2
SHP	48	22	45.8	223	78	35.0
HPP	25	3	12.0	36	8	22.2
WindPower[4]	2	0	0.0	301	131	43.5
Total	**164**	**42**	**25.6**	**740**	**221**	**29.9**

Source: ANEEL. Available at: https://goo.gl/oGuhgT; UNFCCC (2017).
Prepared by the authors.
Notes: [1] Thermal Power Plant.
[2] Of which 38 are renewable (sugarcane bagasse, forest waste and rice husk).
[3] Of which 125 are renewable (sugarcane bagasse, forest waste, rice husk, elephant grass and biogas from municipal solid waste).
[4] Wind power plants.

Since projects that began operations from 2000 onwards could ask for retroactive credits, another analysis was carried out considering the period before and after 2000. From 1990-1999, 42 projects started operating, of which five thermoelectric plants (UTE from the Portuguese "Usinas Termo-Elétricas") were registered in the CDM due to retrofit and expansion projects (11.9% of the total). In the following period (2000-2009), 332 projects started operating, of which 76 were registered in the CDM – that is, 22.9% of the total (table 5).

In the 2000-2009 period, six projects were rejected (two thermoelectric plants, three SHPs and a large-scale hydroelectric plant) and two projects withdrawn (both hydroelectric).

It is worth noting that the electric sector underwent deep restructuring in the 1990-2000 period, with the creation of new institutions, the de-verticalization

of the sector with the separation of the generation, transmission and distribution segments, as well as privatization programs, only to mention a few of the changes. The results of these initiatives are clearly observed with the analysis of the number of enterprises which started operations from 1990 to 1999 (42 projects) and between 2000 and 2009 (332 projects).

TABLE 5
Number of projects that started operation, by source and CDM representativeness (1990-1999/2000-2009)

Period	1990-1999			2000-2009		
Source	Number of projects that started operating	Number of CDM projects	CDM (%)	Number of projects that started operating	Number of CDM projects	CDM (%)
TPP	24[1]	5	20,8	137[2]	21	15,3
SHP	11	0	0,0	134	47	35,1
HPP	5	0	0,0	35	6	17,1
Wind Power	2	0	0,0	26	2	7,7
Total	42	5	11,9	332	76	22,9

Sources: ANEEL. Available at: https://goo.gl/oGuhgT. UNFCCC (2017). Available at: goo.gl/y4rrGL. Accessed on: May 30, 2017. Prepared by the authors.
Notes: [1] Of which 16 are renewable (sugarcane bagasse, forest waste).
[2] Of which 73 are renewable (sugarcane bagasse, forest waste, rice husk, biogas from municipal solid waste and blast furnace biomass gas).

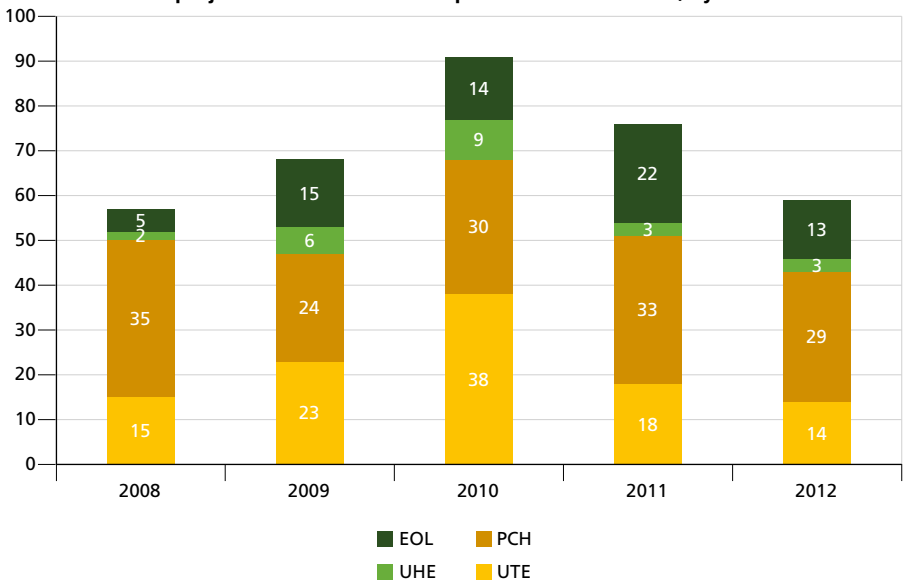
Taking into account only the first commitment period of the Kyoto Protocol (2008 to 2012), 351 projects started operations, of which 75 were registered in the CDM (chart 2).

Charts 3, 4, 5 and 6 show the start-up of projects in the 2008-2012 period, by type of source and number of projects registered in the CDM.

Small hydroelectric plant is the most registered type of energy project by 2012. After that year, wind farms dominated the market with 88.8% of total projects registered in the 2013-2016 period. During that period (2013-2016), only fourteen SHP projects were registered in the CDM, an amount previously registered annually. This reduction also reflects the decrease in the implementation of this type of project, with a decrease of almost 50% in the average number of projects that started operations compared to the average of the four previous years (2009-2012).

CHART 2

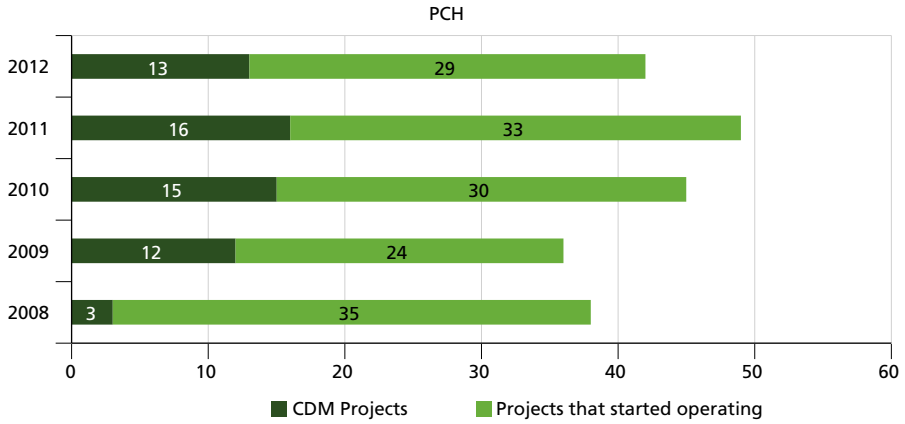
Number of projects that started their operation in 2008-2012, by source



Source: ANEEL. Available at: https://goo.gl/oGuhgT.
Prepared by the authors.

CHART 3

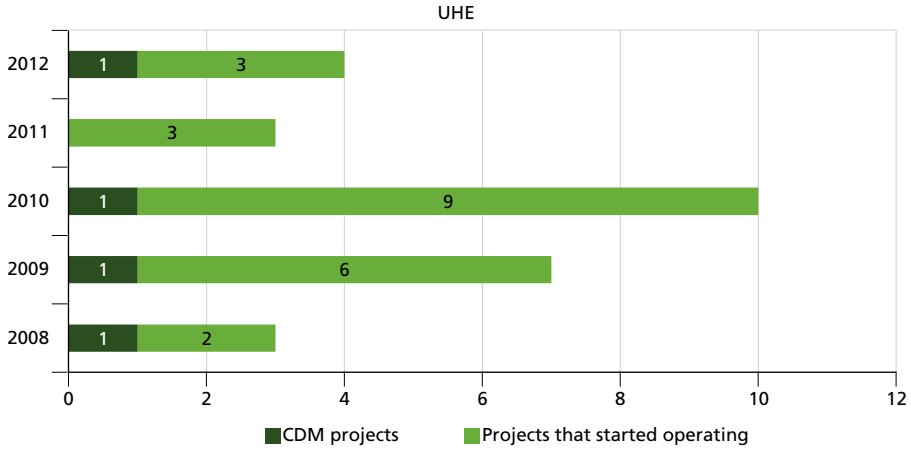
Number of SHPs that started operation and were registered in the CDM (2008-2012)



Source: ANEEL. Available at: https://goo.gl/oGuhgT. UNFCCC (2017).
Prepared by the authors.

CHART 4

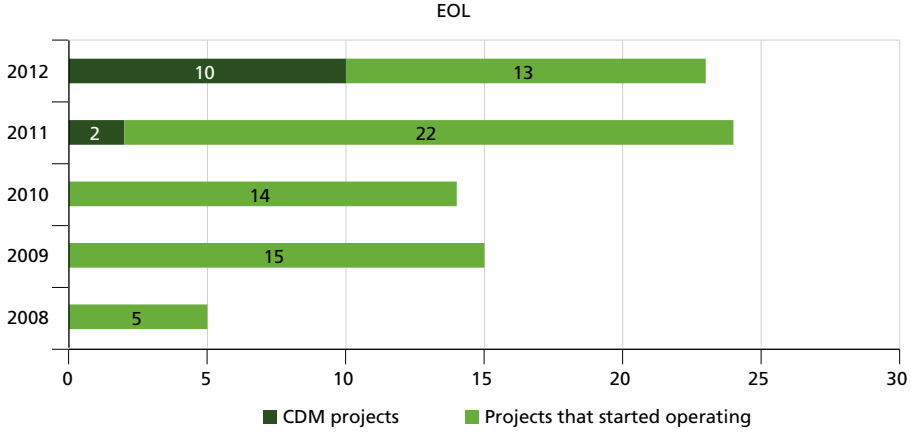
Number of HPPs which have started operation and registered under the CDM (2008-2012)



Sources: ANEEL. Available at: https://goo.gl/oGuhgT. UNFCCC (2017). Available at: goo.gl/y4rrGL. Accessed on: May 30th, 2017. Prepared by the authors.

CHART 5

Number of wind farms that started operation and registered under the CDM (2008-2012)



Source: ANEEL. Available at: https://goo.gl/oGuhgT. UNFCCC (2017). Available at: goo.gl/y4rrGL. Accessed on: May 30th, 2017 Prepared by the authors.

In 2008-2012, only four hydroelectric power plants were registered: July, 14th, Baguari, Engenheiro José Luiz Muller de Godoy Pereira (former Foz do Rio Claro) and Santo Antônio. It should be noted that some projects – for example, the Jirau and Teles Pires HPPs – were registered in the CDM in 2012; however, they started commercial operation after 2012 and, therefore, they were not considered for this analysis, given that it takes into account the year projects started operating and which

of these are CDM. The project registration deadline by 2012 due to uncertainties after the first commitment period was one of the criteria for many developers to initiate the CDM process in advance – before project commercial operation.

The Brazilian wind farms started regular registration under the CDM in the beginning of 2011. Before that, only two projects were registered as part of the mechanism.[20] Considering the post-2012 period (2013 to 2016), 323 wind farms started operating, of which 135 were registered in the CDM – that is, 41.8% of the total.

The rationing occurred in 2001/2002 to meet the demand had also an impact in the urgency of diversification of the electricity sources. Regarding the incentive to renewable sources, one of the government initiatives was the creation of the Brazilian Alternative Energy Sources Incentive Program (PROINFA), by Law Nr. 10,438, of April 26th, 2002.[21] Through PROINFA, biomass projects, SHPs and wind farms entrepreneurships were encouraged by offer of long-term (20 years) power purchase agreements signed between the project developers and Eletrobras. The purchase price of energy was established for each type of source with the floor of 80% of the national average final consumers' tariffs with the additional costs to the system are covered by all consumers consumers.

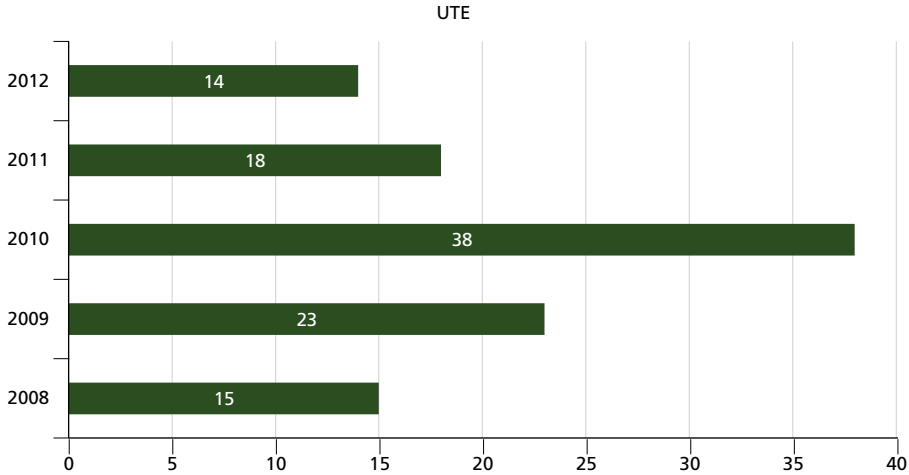
In the first phase of the program, projects were expected to start operating by December 2006. However, due to the difficulties faced by project developers and the lack of equipment supply – not only for wind turbines, but also for other types of projects, considering the booming world energy market and the need to comply with the index of nationalization in the short term – the last deadline defined for initiating the projects selected in the program was postponed to December 2010 (as determined by Law No. 11,943, of May 28th, 2009.[22]). As a reference, the price paid for wind farms under Proinfa in December 2013 reached BRL 361.86/MWh (Eletrobras, 2012); that is, three times the amount paid in the new energy auction for wind farms in 2013 – an average of BRL 120/MWh (CCEE, 2016).

In the period of 2008-2012, of the 69 wind farms that started operation, eighteen participated in PROINFA (26.1% of the total). In fact, this program made the scenario and the learning curve possible for the development of wind farms. Of the 415 wind farms currently in operation, 170 are part of PROINFA and/or CDM and five have been rejected in the CDM. The program has allowed the development of the wind industry in the country, which currently has a production capacity of around 750 MW of new installed capacity per year, reaching a nationalization rate of 70% (EPE, 2009). Although PROINFA has always considered participation in

20. "Água Doce" and "Osório" wind farms.
21. Available at: goo.gl/hDhdvS. Accessed on: June 29th, 2017.
22. Available at: https://goo.gl/iFr4A7. Accessed on: June 29th, 2017.

the CDM, after facing many difficulties during years in the attempt, Eletrobras still seeks the registration of these projects.

CHART 6
Number of thermal power plants that started operation and registered under the CDM (2008-2012)



Sources: ANEEL. Available at: https://goo.gl/oGuhgT. UNFCCC (2017). Available at: goo.gl/y4rrGL. Accessed on: May 30th, 2017. Prepared by the authors.

As observed in chart 6, no thermoelectric project was registered in the CDM in the 2008-2012 period. This is strongly due to the replacement of AM0015 by ACM0006 and subsequent reviews, as discussed earlier in this chapter. In 2009, a cogeneration project was submitted for registration with version 6 of ACM0006 and was rejected,[23] because according to the CDM-EB report (UNFCCC, [s.d.]), the project participants failed to demonstrate conservatism in selection of the reference plants and in the financial analysis of the project.

Considering the assessment above, it is possible to state that the CDM was an important incentive for the development of renewable electricity generation projects during the first commitment period of the Kyoto Protocol. Of course, this was not the only factor taken into account for the implementation of the projects, but the CDM certainly played a role as an additional incentive.

The electric power sector reform carried out in the period prior to the CDM and the country's favorable investment environment also helped the development of these projects. Although the CERs could not be offered as a financial guarantee due to uncertainties in project registration and/or monitoring during verifications,

23. Santa Cruz S.A. – Sugar and alcohol – *Cogeneration project.*

it can be said that potential emission reduction credits improved the attractiveness of projects when considered in their cash flows.

6 OTHER ENERGY PROJECTS

In addition to grid-connected electricity generation projects within sectoral scope 1 (energy industries and renewable/non-renewable sources), there are other types of projects within sectoral scopes, such as scope 2 (energy distribution), 3 (demand of energy), 7 (transportation) and 10 (fugitive emissions). However, there are no Brazilian CDM projects registered under these scopes. The only initiative formally identified is that of the Pão de Açúcar Group, which involves scope 3 with energy efficiency measures; five projects were submitted for registration, but were rejected due to difficulties in monitoring requirements exactly as prescribed in the methodology.[24]

Emission reduction initiatives in these scopes exist; however, they did not take carbon credits into account. The high complexity of the validation, approval and registration process, as well as additional monitoring requirements, the high cost involved (hiring a specialized consulting firm and designated operational entity, registration fee, among other examples) and the high uncertainty of success in the registry influenced significantly so that the CDM was and is not considered.

An example is the expansion of the yellow line of the São Paulo Subway, in which there was a bidding process for feasibility analysis of the CDM project and partnership between the state of São Paulo and the Inter-American Development Bank (IDB) for the development of two CDM methodologies. However, the initiative has no publicly available results, and therefore the reasons for the non-continuity of the initiative as CDM project are not known.

There are several government and other institutions studies on the consideration of the CDM for expanding the use of biofuels – such as ethanol and biodiesel – and the fuel switch from diesel oil to natural gas in public transport, but there were no further repercussions.

Not only in the case of transportation, but also in other sectors, the government's difficulty in participating directly in economic mechanisms designed for the private sector such as the CDM is evident – as is the example of PROINFA. Only in the case of landfill biogas, municipal governments were able to participate in the initiative in a late manner, by questioning concessions without GHG capture and leaving the process for registration and responsibility for private entities. Here, the authors do not claim that this is the only possible solution, but only that it was the only one with a positive result in the first commitment period of the Kyoto Protocol.

24. Information on CDM rejected projects can be found at: https://cdm.unfccc.int/Projects/rejected.html. Accessed on July 19th, 2017.

In the industrial field, there are several studies on CDM opportunities in the sector, also involving the PoA, which are not implemented in practice. In the case of the industrial sector, some energy efficiency initiatives can be identified, but it is difficult to prove additionality, since they involve other revenues in addition to carbon credits due to reduced energy consumption. Moreover, the difficulties associated with monitoring measures by type of equipment are not always easy to apply, as in the case of the Pão de Açúcar Group project previously discussed.

Some reasons may be cited for the non-consideration of the CDM:

1) Proof of additionality in order to demonstrate lack of financial attractiveness for projects receiving revenues other than CDM and/or when there is regulation on a given emission reduction initiative, as is the case of energy efficiency measures applied to energy distributors;
2) Difficulties in monitoring equipment/measures;
3) High costs, high complexity and intense bureaucracy in the process of project registration and monitoring;
4) Uncertainties regarding successful validation and registration;
5) Uncertainties about the Kyoto Protocol and/or future markets;
6) Uncertainty about prices and volatility of a market that is extremely dependent on EU regulations.

7 CONCLUSION

Revenues from CDM carbon credits have unequivocally contributed to improving the attractiveness of projects in the electricity sector. The simplicity of the baseline definition and the calculation of emission reductions, monitoring without the need to install additional equipment or to implement complex procedures contributed to the greatest success in registering CDM projects of grid-connected electricity generation plants compared to other types of project.

A respectable CDM legacy is the development, acceptance and practical application of additionality assessment in a more robust, yet rather complex, way – including the assessment of alternatives to the project, financial analysis and barriers to project implementation, plus the survey of common practice – rather than simply by reducing emissions.

Another important legacy is the demonstration that it is possible to establish a process involving all stakeholders aiming acceptable solutions to complex situations, such as the acceptance of large hydroelectric plants and the determination of the CO_2 emission factor for grid-connected electricity generation. In these cases, the

process managed to define criteria and procedures that were reasonably applicable in practice, although the time needed for this definition have been somewhat extended in some situations.

A clear difficulty in the process was presented in the local approval procedures. In the case of Brazil, the process was often too long and involved several redundancies, not only in relation to the demands of the Convention on Climate, but also in relation to the national regulation, demanding many public and private resources and, consequently, making the process in Brazil more resource intensive and expensive than in other countries. The fact that the process was exceptionally very accelerated in the final half of the first crediting period (July to December 2012), showed that it is possible to do it in a more expedite way.

The aim of the criticism here is to identify problems and look for solutions, as it is undeniable that there is much room for improvement. The process is complex and overly redundant (all projects go through various levels of review, e.g. in Brazil, the Designated Operational Entity, the Designated National Authority (DNA) and the UNFCCC Secretariat), procedures are frequently revised and changed (in the 2008 to 2012 period, methodologies, tools, manuals, forms, etc. were revised annually or even more frequently), registration and issuance fees are absolutely unrelated to market prices, some types of projects, although very promising, produced very few projects (evidence of practical implementation difficulties, for example in transport and energy efficiency), to name just a few of the difficulties that deserve a closer look at possible market developments.

An example of intention that did not resulted in good results in practice is the desirable incentive to small-scale projects with the adoption of simplified procedures and expected lower fees, which in the end, has been diluted in higher costs of a more robust (more redundant in the praxis) of the procedures of registration and issuance. An evidence of that is the fact that projects of the same typology have essentially the same cost and require the same term regardless of whether they are small or large scale. The CDM-EB itself indirectly acknowledged some of these problems by promoting, albeit belatedly, the adoption of positive lists, automatic additionality and programme of activities.

Despite the difficulties, the authors are confident that the capacity built during the implementation of the CDM will be extremely useful for the definition of future mechanisms. The mechanism's contribution to the development of projects, methodologies and procedures is undeniable, as it is the basis for many voluntary markets and the promotion and encouragement of labels and other certification standards, as well as their complementary use with other certificates. For those who work in the sector there is no doubt: certified CDM emission reductions are the most credible "carbon credits" in the market.

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