CHAPTER 5

ENHANCEMENTS TO THE WASTE MANAGEMENT BASED ON CDM: GOVERNANCE, NEW TECHNOLOGIES AND BETTER PRACTICES IN THE SECTOR[1]

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1 INTRODUCTION

When the Brazilian Government adopted the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 (Brasil, 1992), it made the commitment to periodically draw up the national inventory of emissions and anthropogenic removals of greenhouse gases (GHG), not controlled by the Montreal Protocol, and publish their results.[4]

The abovementioned inventory should be developed using the GHG emission estimation methods developed by the Intergovernmental Panel on Climate Change (IPCC, 2000, chapter 5) adopted by the Conference of the Parties of the UNFCCC.

The IPCC methods are applied worldwide to develop GHG emissions inventories.

As a country party to the UNFCCC, the Brazilian Government adopted the Kyoto Protocol in 1997 at the 3rd Conference of the Parties (COP 3). In the Protocol, UNFCCC Annex 1 countries[5] committed themselves to reducing their emissions by 5% below 1990 levels in the commitment period from 2008 to 2012. Although Brazil, one of the non-Annex 1 countries to the UNFCCC, participated in the Kyoto Protocol projects (CDM), it was without undertaking a quantified emission reduction commitment such as Annex 1 countries of the UNFCCC.[6]

The waste sector is one of the sectoral scopes in which CDM projects can be carried out under the Kyoto Protocol.[7] In Brazil, by 2015, 12% of the CDM

1. This chapter essentially reveals the experience of one of the authors in the waste sector in order to show how the CDM has entered the waste management agenda as a stimulating enhancement of management (note from the editors).

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4. National Inventories are available at: http://sirene.mctic.gov.br.

5. Annex 1 countries to the UNFCCC are countries that make up the European Union, Oceania, plus the United States of North America, Canada and Japan.

6. For further information on UNFCCC and Kyoto Protocol, see Chapter 1 (note from the editors).

7. Annex A of the Kyoto Protocol lists all sectoral scopes for project development and can be consulted in: goo.gl/YiLyZo.

projects were related to the enhancement of waste management, in which 59 projects were implemented in landfills, contributing to the emission reduction of 1.7 million tCO_2 equivalent in the period 2003- 2015.

This chapter discusses the impacts, lessons learned and legacy of the CDM in the waste sector in Brazil. The CDM had been adopted in 1997 and came into force in 2005. It is provided in Art. 12 of the Kyoto Protocol.

2 QUANTIFICATION OF GHG EMISSIONS FROM WASTE TREATMENT AND DISPOSAL

GHG quantification methods can be: those used in CDM projects, those used in national GHG emission inventories and those used in corporate GHG emissions inventories.

2.1 Quantification of GHG in CDM projects

The methods used on the estimates of the Clean Development Mechanism (CDM) projects are developed and approved by the UNFCCC to estimate the amount of avoided GHG emission. In addition to the principles considered in the IPCC methods described below, CDM project methods quantify and consider future decreases in avoided GHG emissions from project-related activities and include rigorous registration mechanisms, performance guarantees, redundancy and safety of the data. The issuance of Certified Emission Reductions (CER) must follow a certification procedure in the language of the host country of the project and in English. Besides the object of certification, the project includes an institution responsible for designing the project, two different certifying units, one accrediting agency, the designated national authority of the host country of the project and a division focused on the management and monitoring of CDM projects of the UNFCCC.

In order for the CDM projects in the waste sector to materialize the Emission Reductions Certificates, approximately 116 methodologies were approved, about seven of them associated with the waste sector. More than 25 consolidated CDM project methodologies were approved as well, having 4 associated with the waste sector and other nearly 100 small scale methodologies, where 5 are associated with the urban solid waste, rural waste and effluent treatment.

The estimation of avoided GHG emissions by soil disposal is initiated by the estimated methane generation due to the disposal in the soil, considering the amount and composition of waste, climate, the quality of the operation of the final disposal site and the premises. The amount of captured methane and put through combustion represents the avoided GHG emission, discounting the amounts that would be destroyed without the project and the GHG amounts emitted by additional activities caused by the CDM project.

The organic material deposited in the soil by anaerobic processes of decomposition is degraded, generating methane for decades. Therefore, estimates of methane generation in a landfill require data from decades of waste disposal in the soil.

Voluntariness and additionality are requirements of the methodology adopted in CDM projects, that is, the implementation of the project should not be mandatory and the resources originated by the remuneration of the emission reductions should favor their execution, respectively. CDM projects consider future reductions in avoided emissions due to emissions that would occur even in their absence (baseline emissions). Measurement and recording of avoided GHG emission quantities are also part of the CDM.

In addition to each CDM project, the prerequisites for the CDM idea to be materialized required the preparation, approval and review, under the UNFCCC, of CDM project methods, a project accreditation and monitoring certification, operating and ensuring the credibility of each carbon credit registered. All this was done with carbon credits resources.

2.2 Quantification of GHG in National Inventories

The quantification of GHG emissions used in the preparation of national inventories follows the method prescribed by the IPCC (1995) and approved by the UNFCCC, which is divided into five sectors: energy, agriculture, land use, change in the land use and forestry, waste and emissions from industrial processes. The UNFCCC also approved the use of the *Guide to Good Practices for Inventory Preparation* (IPCC, 2000), which considered the same five sectors. In this guideline to good practices, the land use, the change in the land use and forestry sectors are added to agriculture and livestock sector, resulting in agriculture, forestry and other land uses sector.

The GHG emissions inventory methods from IPCC subdivide the waste sector into: urban solid waste, industrial solid waste, domestic sewage and industrial effluent.

The method recommends that the estimated emissions from the treatment or disposal of rural waste be added to the others in the agricultural sector. The IPCC method also recommends that the estimation of GHG emissions from the use of fossil fuels in the waste transportation and GHG emissions from the waste incineration should be accounted for in the power sector, when carried out with the waste-to-energy processes.

In national calculations, the IPCC requires the estimation of emissions from thermal treatment of municipal solid waste and industrial waste, and also provide for the accounting of emissions from disposal of municipal solid waste in the soil, from sewage treatment and the treatment of industrial effluents and their launch into bodies of water. The latter is limited only to the most representative economic activities.

The estimation of emissions due to the thermal treatment of municipal solid waste considers the treated amount, the composition of the treated waste, the possible addition of complementary fuel and the type of incinerator, which may be a pyrolysis or gasifier reactor. The product of the emission factor of each treatment option and the mass of treated waste correspond to the GHG emission from the waste fraction submitted to this type of treatment.

Estimates of emissions from domestic sewage treatment consider the amount of organic load generated and treated and the treatment option, as well as the quantities of organic load released directly into untreated water bodies. The product between the amount of organic loads and the emission factor of each option defines the emission of GHG.

2.3 Quantification of GHG in corporate inventories

In addition to the methods used to prepare national GHG inventories and the methods used to develop CDM projects, there are methods for developing corporate inventories and methods for developing subnational inventories – which may be regional, state, metropolitan or municipal.

The corporate GHG emissions inventories differ from the national inventory methods and methods used in CDM projects, mainly due to the way GHG emissions are consolidated. They use the principles of the IPCC proposed methodology. The corporate inventory method determines that estimates may be divided into direct and indirect emissions,[8] or indicating the emissions liability. The responsibility for the emissions may be: corporate or operational, that is, the person in charge of emissions may be the owner of the project or the person in charge of the project's operation (GHG Protocol, [s.d.]).

Life cycle analysis applied to GHG emissions estimates and carbon footprint estimates[9] are options that use the GHG estimation principles of IPCC methods and can contribute to enhance the understanding and improvement of GHG management. In this sense, the CDM experience in the waste sector led to the implementation of inventories in order to obtain the possible gains from the mechanism and, consequently, corroborated the governance of waste treatment and disposal companies.

8. Direct GHG emissions, according to the GHG Protocol, are Scope 1 emissions; indirect GHG emissions, according to the GHG Protocol, are Scope 3 emissions. Emissions from the consumption of electric energy, according to the GHG Protocol, are Scope 2 emissions.

9. The term "carbon footprint" refers to an estimated GHG emission corresponding to the production of a good or to the performance of a service.

The years of operation of CDM projects in the waste sector have led to changes in waste management in Brazil. When proposing a CDM project in a landfill,[10] the waste disposal manager materializes the good sanitary performance and allows the possibility of biogas extraction from the landfill.

With the implementation of a CDM project in a landfill, two collaborative and sometimes, conflicting activities are established in the landfill hosting the project. On one hand, the waste disposal is performed according to the landfill project. This arrangement prioritizes the aspects of compaction, stability and the flow of fluids. On the other hand, the installation of pipelines for the collection, for the transportation, for the processing and combustion with the use of biogas are privileged.

Aware of the new reality, the landfill manager starts to control the waste disposal at the landfill. The manager tends to maximize the generation of biogas, preventing the disposal of contaminant residues or inhibitors of anaerobic activity.

The sanitary landfill now has the potential for energy generation and leaves behind the negative aspects that have always characterized dumpsites.

Finally, in terms of quantification, it is still worth discussing the possible equivalence factors used to estimate emissions in terms of equivalent carbon dioxide (CO_2equivalent) in relation to their relative uncertainty. For the purposes of calculating the sector's emissions, since the emissions are related to methane, it is necessary to calculate the equivalence between methane and carbon dioxide.

For this purpose, two options are presented in the literature: the global warming potential (GWP) (Houghton et al., 1996), and the global temperature potential (GTP) (Myhre and Shindell, 2013, p. 714). These equivalence factors, which vary significantly, allow to express the different GHGs in terms of equivalent carbon dioxide (CO_2equivalent). GTP indicates that one ton of CH_4 is equivalent to four tones of CO_2 equivalent and the GWP indicates that one ton of CH_4 may equal from 21 to 28 tons of CO_2 equivalent. In this regard, during the first commitment period of the Kyoto Protocol, CDM projects used exclusively GWP equal to 21, that is, one ton of CH_4 equals 21 tons of CO_2 equivalent. When GHG estimates are presented in terms of CO_2equivalent, it is essential to indicate the equivalence factor used.

10. According to National Survey on Basic Sanitation (IBGE, 2010a, p.185), the landfill is a "final disposal facility for solid urban waste through its adequate disposal on the ground, under permanent technical and operational controls, so that neither waste, nor its liquid and gaseous effluents may cause damage to public health and/or the environment. To that end, the landfill must be located, designed, installed, operated and monitored in accordance with the current environmental legislation and the official technical standards governing this matter".

3 GHG EMISSIONS BY THE WASTE SECTOR IN THE WORLD, IN BRAZIL AND IN THE STATE OF SÃO PAULO

On a global scale, in 2005, 49Gt of CO_2equivalent were emitted (Bogner et al., 2008). According to these authors, the emission of methane due to the treatment and waste disposal in that same year was estimated at 1.4 Gt of CO_2equivalent or 3% of the total. In Brazil, in 2010, the emission of methane as a consequence of the disposal of residues in the soil represented 2.2% of total GHG emissions (BRAZIL, 2015, p.42).

The reduced fraction of GHG emissions from the waste sector in Brazil partially reflects the precariousness of the sector. The rate of waste collected is relatively low when compared to the rates of the European Union and North American countries.

The estimation of GHG emissions from the waste sector takes into account treatment alternatives, however, in Brazil, the disposal of municipal solid waste in the soil is the most used option; treatment options, whether they are biological or thermal, are practically non-existent. Waste disposal in dumpsites[11] prevails.

According to the National Energy Balance, of the Energy Research Company (EPE, 2015, p.182), the installed capacity of electrical generation from biogas in Brazil reached 80MWe in 2013, largely due to the success in efficient energy utilization of this energy source in the state of São Paulo. Alves (2017, p.25) made considerations regarding the possibility of electricity generation from biogas and estimated for the hypothesis of waste disposal in the soil, energy recovery and use of biogas, an upper limit of electricity generation of 700MWe.

Table 1 shows GHG emissions from waste management in Brazil in the 1990 -2015 period. The amount of methane emitted in the country increased from 1990 to 2003. As a consequence of methane recovery projects, the growth rate was reduced from 2003 onwards, starting with the first commitment period of the Kyoto Protocol.

11. According to the National Survey on Basic Sanitation (IBGE, 2010a, page 214), dumpsites are a "place used for the disposal of raw garbage, on the ground, without any special care or technique. The open pit is characterized by the lack of measures to protect the environment or public health".

TABLE 1
Methane emitted by the management of MSW (1990-2015)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					[thousand tCH_4]					
Brazil	795	823	852	879	907	933	960	989	1,017	1,046
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
					[thousand tCH_4]					
Brazil	1077	1108	1,143	1,171	1,158	1,173	1,200	1,195	1,175	1,186
Year	2010	2011	2012	2013	2014	2015				
					[thousand tCH_4]					
Brazil	1,260	1,325	1,397	1,400	1,500	1,500	--	--	--	--

Sources: By 2012: MCTI (2014, p. 158-161). From 2013 to 2015: MCTIC (2017, p. 47).

4 CDM PROJECTS IN THE WASTE SECTOR AROUND THE WORLD AND IN BRAZIL

In the early years of the 21st century, the recovery and the energetic use of biogas was widely practiced in North America and Europe. In Brazil, they were still seen with distrust by the public manager of the waste sector regarding their technical efficiency and financial viability. Only academic experiments thrived in Brazil. The Kyoto Protocol contributed decisively to the emergence of methane capture and combustion undertakings and electricity generation, such as the thermoelectric plants in the Bandeirantes landfill and the São João landfill, both in the city of São Paulo.

Between 2004 (before the Kyoto Protocol) and 2014, non-Annex 1 countries submitted more than 8,100 CDM projects; among them, more than 1,000 projects, or approximately 12% of total projects, were from the waste sector (UNFCCC, 2016).

During the first commitment period of the Protocol 422 CDM projects were submitted to the designated national authority of Brazil, 59 of which were biogas recovery and combustion in landfills of municipal solid waste, keeping the world average.

Listed by Cetesb (2014), the CDM projects in the waste sector represented a voluntary initiative to adapt sites where the waste was disposed of on soil. The estimate of GHG generation, the record of the quantity of the GHG collected and the avoided GHG emission record were incorporated to the waste management in the landfills where the CDM projects were installed.

The following projects are some of the 59 CDM projects in the waste sector in Brazil that have shown some prominence in terms of their pioneering in different dimensions of the corresponding emissions management practice: financing, technology, and commercialization of certified emission reductions.

4.1 Nova Gerar

The first CDM project in Brazil and in the world that associated the reduction of GHG emissions with the generation of electricity with biogas and the elimination of a dumpsite that was replaced by a landfill in the city of Nova Iguaçu, Rio de Janeiro.

4.2 Bandeirantes

The Bandeirantes landfill, located in the northern part of the city of São Paulo, received the waste collected in the north and west zones of the city from 1979 to 2007. Forty million tons of waste was accumulated on 140 hectares. In 2004, the project to generate biogas-based electricity with a 20MW capacity started operating in this landfill, recovering approximately 70% of generated biogas that up to then used to be released into the atmosphere. Methane was then used as fuel in the thermoelectric plant installed there. In 2016, nine years after the closing of the landfill, the amount of recovered biogas was still sufficient to supply the thermoelectric plant with a 5MWe power.[12]

The electricity generated by an accounting resource compensated for the electricity consumed by the agencies of a large private bank operating throughout the country, the Unibanco.

The project benefited from the Law No. 10,438/2002, which exempted the transmission and distribution from the biogas-based electricity taxes.

Fifty percent of the carbon credits generated by the project were reverted to the city hall of the city of São Paulo. Certified emission reductions (CERs) were auctioned at the Commodities & Futures Exchange, generating approximately BRL 35 million that should be spent on improvements in the surrounding areas of the landfill.

4.3 São João

The São João landfill, located in the eastern part of the city of São Paulo received the waste collected in the eastern and southern parts of the city from 1992 to 2007. Twenty-six million tons of waste was accumulated on 80 hectares. In 2008, another project to generate biogas-based electricity was put into operation.

Developed by the same designers who implemented the Bandeirantes landfill thermoelectric plant, the biogas thermoelectric plant at the São João landfill operated initially with 20 MW. The same 50% transfer condition of the CERs granted to the municipal government was applied in this project.

12. Personal communication with Mr. Anderson, the project manager of the Bandeirantes and São João projects, engineer at Biogas-Ambiental.

4.4 Jardim Gramacho

Between 1976 and 2014, approximately 60 million metric tons of waste collected in nearby cities were deposited in Jardim Gramacho, in the city of Duque de Caxias, located on northwestern Rio de Janeiro, on the shores of Guanabara Bay and occupying about 150 hectares. In 2013, the waste management facility started operating, aiming at the use of methane thermal energy in the Petrobras refinery of Duque de Caxias (Reduc). The thermal power of 9,000 Nm^3CH_4.h-1 obtained from biogas replaced the equivalent natural gas energy.

4.5 Tremembé

The ONYX SASA landfill, with over 2 million m^3 waste capacity, in an 80 hectares area, opened in 1996 and received waste from cities and industries in the region of Vale do Paraíba, in the state of São Paulo. From 2003, the slurry treatment of waste collected in the landfill in an evaporator with the use of biogas as energy source started operating.

4.6 Marca

In 1995, the Marca landfill opened, operating in the city of Cariacica, receiving waste from the Metropolitan Region of Vitória, state of Espirito Santo. This was the third project approved in Brazil. In this landfill, the CDM project in addition to reducing GHG emissions into the atmosphere has been integrated into a series of other activities focused on sustainability, such as separation and recycling of paper, plastics and inert waste. The management of the landfill encouraged the installation of recycling cooperatives, primarily employing the neighboring landfill population in need.

5 OTHER OPTIONS FOR GHG REDUCTION PROJECTS IN THE WASTE SECTOR

5.1 Recovery and energetic use of biogas in breweries

The Brazilian brewing industry, which traditionally adopted anaerobic technology to treat its effluents, has optimized its production process by fully utilizing upflow anaerobic sludge blanket digestion to treat its effluents. The brewing industry recovered the biogas generated and burned it with low efficiency and without energy utilization. In 2004, boiler burners were adapted for the use of biogas with high content of methane.

According to the rules of the CDM projects, projects developed by breweries in Brazil were highly profitable. In practical terms, the biogas that would previously go to a low efficiency burner, started to be sent to boilers that burned fuel oil or natural gas. Even though this was a partial replacement, it proved to be quite cost-effective, but did not meet the criterion of financial additionality imposed by the CDM projects and thus all brewery projects were excluded from the Kyoto Protocol and the emissions avoided were not included in the activities of the Kyoto Protocol. No brewery project, being profitable, was classified as a CDM project.

In short, the reduction promoted by brewery projects, by not being commercialized, led to a real reduction compared to the reductions in CDM projects, which were marketed and transferred to the accounts of the carbon credit buyer country.

5.2 Recovery and energetic use of biogas in pig farming

During the first commitment period of the Kyoto Protocol, over 2,000 pig farms in all regions of Brazil deployed linear anaerobic reactors covered by PVC banners to treat their waste. In these devices, generated methane was collected, measured and burned in burners.

A large national food industry was responsible for approving the first project of the Brazilian Program of Activities (PoA) in the UNFCCC, with the inclusion of CDM Project Activity (CPA).

Among the properties that hosted CDM projects, almost all of them chose for the simple methane burning. A few others, unrelated to carbon credits, besides the treatment of their waste, promoted the recovery of biogas with the installation of electric power generators, burners and heat exchangers benefiting from the generation of energy and cogeneration with projects of high profitability.

In its few years of existence, the CDM of the Kyoto Protocol created conditions for the materialization of projects that could not prosper in Brazil, although successful in European Union and North American countries. A new economic activity arose in the country.

6 THE CONTRIBUTION TO THE SUSTAINABLE DEVELOPMENT OF CDM PROJECTS IN THE WASTE INDUSTRY IN BRAZIL

Rotondaro (2007) evaluated the contribution to sustainable development of CDM projects in the Brazilian waste sector and noticed that the criteria listed in Annex III of Resolution No. 1 of the Interministerial Commission on Global Climate Change (CIMGC, 2003) are not sufficient to foster social and environmental benefits beyond the generation of carbon credits,[13] as determined by the Kyoto Protocol.

The commitments made by Brazilian CDM projects, in compliance with Annex III of CIMGC Resolution No. 1 (2003), are not necessarily monitored by

13. For further information on this topic, it is recommended to read Chapter 8 of this publication, since it discusses carefully and critically, from the perspective of its author, the relevance and efficiency of the criteria adopted by Brazil to verify CDM Projects' contribution to sustainable development (note from the editors).

the designated national authority and, therefore, it is not possible to be ascertained whether or not they have been fulfilled or to what extent. However, despite its debatable effectiveness, the criteria set forth in Annex III of the CIMGC Resolution 1 were an attempt to materialize this concept as proposed by the Kyoto Protocol.

7 CONTRIBUTION OF CDM PROJECTS IN THE WASTE SECTOR TO GHG EMISSIONS REDUCTION IN BRAZIL

Observing the amounts of biogas recovered during the operation of CDM projects in landfills and comparing them with the methane emissions originally projected by the project developers, Santos (2014, p. 101) considers that the recovery of biogas can vary from 12% to 141% compared to initial estimates. All this variation has different justifications, for instance: project planning mistakes, variation in the quality of landfill operation or different efficiencies in drain distribution, and consequently the quantities collected and burned differ from the projected generations. At the Adrianopolis landfill, in the state of Rio de Janeiro, for example, 12% of the estimated methane was collected and destroyed. At the Caieiras landfill there was a deceptive 141%-efficiency in the methane collection and combustion.

The amounts of methane recovered annually from CDM projects were recorded by the CIMGC and are presented in table 2, which also highlights the relevance of State of São Paulo in the execution of methane recovery projects in landfills, which, in the period 2003-2010, contributed with up to 42% of the recovery of the national GHG emissions from the solid waste sector.

TABLE 2
Methane recovered (R) in Brazil in the state of São Paulo (2003-2015)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
							[thousand $tCH_4.year^{-1}$]						
Brazil	1	44	61	73	123	192	230	240	200	220	140	180	180
São Paulo	1	30	35	42	94	147	171	168	146	141	52	60	22

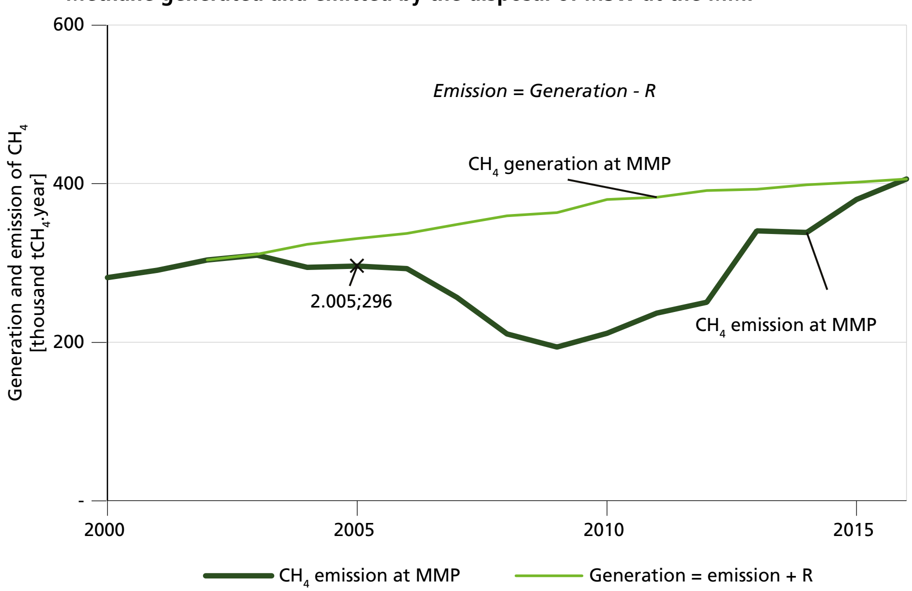
Sources: Data of Brazil from 2003 to 2010: MCTI (2015, p. 28). Data of Brazil from 2011 to 2015: MCTIC (2017, p. 47). Data of São Paulo from 2003 to 2015: Alves (2017, p. 139).

Having a methane recovery and methane combustion project as a reference, the non-use of this technology for the recovery and destruction or utilization of the methane density in biogas present in landfills allows a 150% higher methane emission, considering the same amount of waste.

Analyzing the state of São Paulo, particularly, since 1997 the intensification of inspection, investments and technical support for the adequacy of waste disposal sites on the soil have caused the reduction of dumpsites, making landfills more prevalent in that state. Consequently, the necessary improvement in the operation of final disposal sites intensified methane emissions until 2003, the year the CDM projects started to operate.

However, the implementation of methane capture projects in landfills led to a decrease in the theoretical methane emission (calculated and representing what would have been emitted without the projects), given the high gas recovery recorded between 2000 and 2015 in the state. Chart 1 shows the generation and emission of CH_4 at the São Paulo Macrometropole (MMP) (Macrometropole Paulista), the most developed region of the state, and where all the CDM projects for landfills in that state were concentrated.

CHART 1
Methane generated and emitted by the disposal of MSW at the MMP

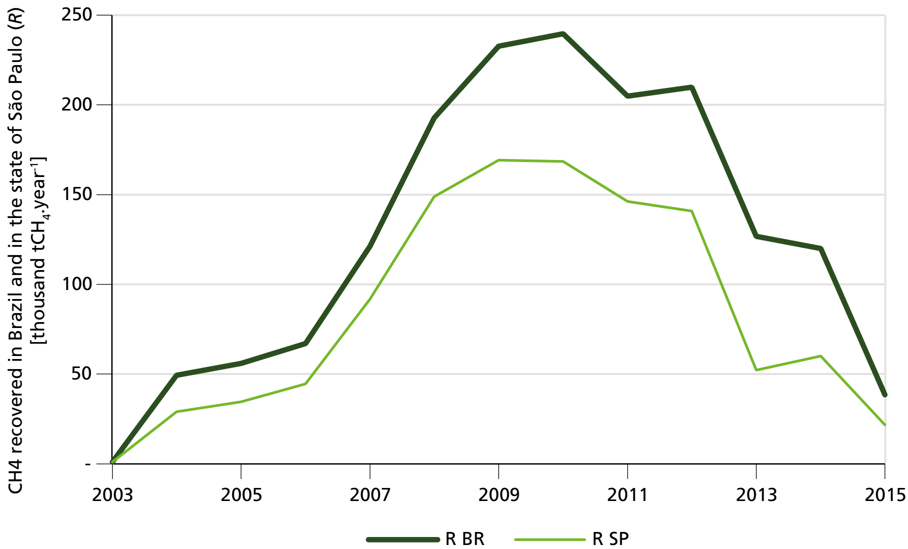


Source: Alves (2017, p. 142).

Chart 2 illustrates the information in Table 2. In Brazil and the state of São Paulo, carbon credit projects have been successful in reducing the sector's emissions in the country. With the end of the first commitment period of the Kyoto Protocol and changes in the trading conditions of Certified Emission Reductions (CER),[14] the quantities recovered decreased, leading to the discontinuation of an action that was profitable and environment-friendly.

14. For further information on market contingencies that have affected project continuity, as mentioned by the authors, see Chapter 12 (note from the editors).

CHART 2
Methane recovered (R) in Brazil and in the state of São Paulo



Source: Alves (2017, p. 143).

The non-adoption of a new commitment period under the Kyoto Protocol registered a drop in the demand for Certified Emission Reductions (CER) and CDM projects. The adoption of the Paris Agreement at the 21st Conference of the Parties (COP 21) in 2015, even with the establishment of a commitment to reduce Brazil's national emissions, without expressing any considerations regarding costs and the need for remuneration for avoided emissions, coincides with the low attractiveness of CDM projects and the return to pre-2003 conditions.

8 LESSONS LEARNED FROM CDM PROJECTS IN THE WASTE SECTOR IN BRAZIL

From 2008 to 2012, EU countries have complied with part of their quantified emission limitation and reduction commitments under Article 3 of the Kyoto Protocol, by acquiring Certified Emission Reductions of CDM projects, including those from the landfill sector in Brazil.

The end of the Protocol's first commitment period in 2012 had the effect of reducing the demand for Certified Emission Reductions, thus reducing the amounts offered by avoided emission quantities and reducing revenue from projects that included reducing emissions of methane.

During this period, this option proved to be feasible.

9 OBSTACLES AND OPPORTUNITIES TO THE CONTINUITY OF GOOD PRACTICES ADOPTED WITH THE CDM PROJECTS IN THE WASTE SECTOR

The first decade of the 21st century was a period of intense learning about the possibilities of recovery and waste-to-energy through biogas in Brazil. The little importance given by the state, federal and municipal governments to sanitation in the second decade of this century, time of this evaluation, is the main obstacle to the continuity of biogas recovery and waste-to-energy energy process.

The National Survey on Basic Sanitation (PNSB), the last major survey in the sanitation sector published by the Brazilian Institute of Geography and Statistics (IBGE), considering data from 2008, found out that 73% of the waste collected in the country was disposed of in dumpsites (IBGE, 2010, p. 60).

The ban on dumpsites is provided on the Art. 54 of the National Policy on Solid Waste (PNRS), 2010 (Appendix A), and should have occurred in 2014. However, very little has been done since its promulgation.

Bill (PL) No. 425 of 2014, approved by the Federal Senate and sent to the Chamber of Deputies, proposed extending the country's tolerance to the public manager who was not complying with the provisions of the National Policy on Solid Waste. The National Congress had not yet completed the process of that legislative bill by 2018.

The Federal Legislative Branch and the State and Municipal Legislative Branches, in addition to fully implementing the National Policy on Solid Waste, should consider possible waste management routes and the means for the adequate waste uútdisposal on soil as well as the possibilities of reduction or tax exemption applied to the acquisition of goods associated to the biogas energy production cycle.

On the other hand, international cooperation was very effective during the first decade of the century, led by the United States Government through initiatives such as Methane to Markets (MTM), at the second decade of the 21st century renamed as Global Methane Initiative (GMI).[15] In 2018, 43 countries participated in this cooperation.

In the United States, the Landfill Methane Outreach Program (LMOP),[16] which is part of the United States Environmental Protection Agency (US EPA), promotes the recovery and energetic use of biogas from landfills in the countries participating in the cooperation. In partnership with the Brazilian Ministry of Foreign Affairs (MRE) and the Ministry of Science, Technology, Innovations and Communications (MCTIC), GMI promoted technical meetings, supported the development of projects, publicized projects and brought together potential suppliers and project participants.

15. Available at: globalmethane.org/.
16. Available at: epa.gov/lmop.

The German-Brazilian Chamber of Commerce and Industry (AHK), reproducing the technological development and German experience, held annual meetings in Brazil to promote the diffusion of municipal solid waste treatment options, promoted meetings between potential Brazilian contractors, potential suppliers and German financing lines. As well as the Brazilian Ministry of Cities (MCidades), the Brazilian-German Project on Energy from Biogas (Probiogás)[17] has supported the expansion of the efficient use of biogas by inserting methane into the national energy mix and reducing emissions. Complementing the Brazil-Germany cooperation, the German Agency for International Cooperation (GIZ)[18] prospects the waste management market, fostering the use of more sustainable options.

In support of the use of biogas generated mainly in rural areas, the Brazilian Association of Biogas and Biomethane (ABiogás) promotes the insertion of biogas into the national energy mix, developing the segments involved in the production, regulation and use of this by-product of waste treatment.

The National Development Bank (BNDES) has maintained and publicized a credit line focused especially on sanitation projects.

The 2010 Demographic Census (IBGE, 2010) listed 5,565 municipalities with a total urban population of approximately 161 million inhabitants. This Census also shows that: 253 municipalities had an urban population of less than one thousand inhabitants; 3,551 municipalities had an urban population of less than 10 thousand inhabitants; and 5,315 municipalities had a population of less than 100 thousand inhabitants; 250 municipalities with an urban population of more than 100 thousand inhabitants; and 14 municipalities with an urban population of more than one million inhabitants.

Art. 45 of the National Policy on Solid Waste provides for the formation of intermunicipal consortia for the waste disposal on the soil. Such consortia will allow, for instance, the viability of adequate waste disposal in landfills with a more adequate scale, benefiting more than five thousand municipalities in the country.

10 FINAL CONSIDERATIONS ON THE CDM LEGACY TO THE WASTE SECTOR IN BRAZIL

Options such as the recovery and energetic use of biogas from anaerobic solid waste reactors or recovery and energetic use of landfill biogas, which, in the pre-CDM period, were both technically and financially disregarded and questioned, proved to be feasible and capable of, at the same time, reducing sanitation costs, contributing to good energy practices and reducing GHG emissions.

17. Available at: cidades.gov.br/saneamento-cidades/probiogas.
18. Available at: giz.de/de/html/index.html.

Successful CDM projects in this sector led to the creation of a market for parts, equipment and services. As a consequence, the design and operational planning of waste disposal sites in the soil or equipment for their treatment could take into account the aspect of the energy potential of biogas with less uncertainty.

Since the first decade of the 21st century, the previously discarded biogas generated in the upstream anaerobic upflow reactors from the country's breweries has replaced part of the oil or natural gas used in those breweries' boilers.

Similar to landfills, treatment of effluents in pig farming can generate methane when carried out under anaerobic conditions. With the implementation of linear anaerobic digesters, covered by PVC blankets, methane was no longer emitted, and started being recovered. This practice reduced GHG emissions, included an additional source of energy and improved sanitation in rural areas.

State governments, such as Rio de Janeiro and São Paulo, have created incentive programs for the energetic use of biogas, reducing taxes on industrialization, imports and trade of equipment used in the biogas generation chain.

The Brazilian Electricity Regulatory Agency (ANEEL), which established national targets for the generation of biogas-based electricity must quantify avoided GHG emissions, besides stimulating this practice (ANEEL, 2015).

At the end of the first commitment period of the Kyoto Protocol, thermoelectric plants started operating with biogas from 1 MW to 30 MW, without CDM resources[19]. This fact associated with the provisions of the National Policy on Solid Waste, as well as all the experience gained during the period in which the CDM projects were fully operational, suggests that large landfills may exist, serving large cities, and also other large landfills provided that they serve consortia of small municipalities. All these landfills may have economic, operational, energy and environmental viability.

Seemingly, according to the analysis presented, the CDM in the first place served to give credibility to the waste sector regarding the use of less intensive GHG technologies.

19. July 2014: landfill in Itajaí/SC, installed capacity between 2 MWe and 4 MWe; June 2015: landfill in Minas do Leão/RS, installed capacity between 9 MWe and 15 MWe; September 2016: landfill in Caieiras/SP, installed capacity 30 MWe; June 2016: Sant'Ana do Parnaíba/SP, installed capacity 4 MWe.

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APPENDIX A

GENERAL CONCEPTS ON THE BRAZILIAN NATIONAL POLICY ON SOLID WASTE

When dealing with projects in the waste sector, it is interesting to know the regime that is applicable to the development of projects in the area. In Brazil, the specific regulations in force date from 2010. The National Policy on Solid Waste was enacted (Brazil, 2010) eighteen years after the adoption of the United Nations Framework Convention on Climate Change (UNFCCC), thus establishing a series of innovations for solid waste management in Brazil.

The National Policy on Solid Waste defines waste as:

> Solid waste: any material, substance, object or good disposed as a result of human activities in society, whose final disposal must occur, aims at occurring or is obliged to occur at the solid or semisolid states, as well as gases and liquids within containers, whose peculiarities prevent them to be discarded in public sewers or water bodies, or require technical solutions or economically unviable solutions in the face of the best available technology (Brazil, 2010).

Another innovation in the wake of National Policy on Solid Waste is its Art. 9, which define the priority of waste management actions: no generation, followed by reduction, reuse, recycling (the 3R), treatment and environmentally adequate disposal of waste on the soil. The Art. 42, in turn, determines that the public branches establish inductive measures and financing lines that contribute to compliance with the hierarchy of waste management proposed by Art. 9. Picture A.1 illustrates the hierarchy of actions determined by the National Policy on Solid Waste.

The no-generation of waste presupposes rethinking consumption patterns and is represented by the elimination of disposals. It occurs, for example, by the use of returnable bags in place of disposable plastic bags. Reduction of waste generation occurs with the reduction of losses in the distribution of food, for example. Reuse is exemplified by the use of goods or materials repeatedly, for a long period, under their best conditions. Recycling is done by separating the goods, or materials, after its use, reinserting them into the productive process so as to providing new goods. In the production of recycled goods recycled materials replace raw materials, at least partially.

PICTURE A.1
Hierarchy of actions in managing municipal solid waste, according to the National Policy on Solid Waste

Source: Brazil (2010) *apud* Alves (2017, p. 44).

The treatment options can be thermal and biological. At the end of the second decade of the 21st century, incineration plants with or without heat recovery units, pyrolysis plants and waste gasification plants are operating in countries on a commercial scale. Both pyrolysis and gasification produce synthesis gas, which can be used as fuel.

In addition to the thermal treatment, the biological treatment, focused on the organic fraction of waste, can be aerobic or anaerobic. Both treatment options can produce fertilizers. The anaerobic option, in addition to the fertilizer, can produce methane with potential energetic use.

Other treatment options have been developed and can be established as a technical and economical option in a few years.

By inducing changes, the National Policy on Solid Waste differentiates the words *waste* and *residue*. *Waste* is the solid material remaining from *residues* after all recyclable materials have been removed and contain some recoverable value.

Art. 3 of the National Policy on Solid Waste (Brazil, 2010, p.3) maintains the public authority responsible for the management of MSW and imposes part of this responsibility on the manufacturer of the goods. This rule should be exercised by the adoption of sectoral agreements of reverse logistics[20] between the public authority and the manufacturers.

The National Policy on Solid Waste empowers the producer of goods to include in the cost of the product the means to either practice the 3R or discard the waste, and encourages the adoption of actions that ease such practices.

Article 54 of the National Policy on Solid Waste, in force since 2010, determined the banning on dumps in July 2014. In 2015, after failing in complying with this provision, the Federal Senate approved Bill No. 425/2014, extending the deadlines defined in the aforementioned article of the National Policy on Solid Waste. The obligation to dispose of waste at an appropriate location has been postponed in accordance with the dates and conditions set out in chart A.1.

CHART A.1
Changes in deadlines mentioned in Art. 54 of the PNRS for adequate waste disposal

Original date on the National Policy on Solid Waste	Date proposed by Senate Bill No. 425/2014	Condition of the bill
31/7/2014	31/7/2018	Capitals of states and municipalities belonging to metropolitan regions
	31/7/2019	Municipalities with a population of over 100 thousand inhabitants in 2010
	31/7/2020	Municipalities with population between 50 thousand and 100 thousand inhabitants in 2010
	31/7/2021	Municipalities with a population of less than 50 thousand inhabitants in 2010

Source: Brazil (2014).

Even though being a measure that aims to foster compliance with the National Policy on Solid Waste, this Bill rewards the public manager who fails to comply with the legislation. It is illegal to dispose of waste in inappropriate places since the approval of the Environmental Crimes Act (Law 9605/1998). As it has been pointed out in Art. 54, the penalty is "imprisonment from one to four years and a fine is imposed to those causing pollution by the discharge of solid waste in disagreement with the technical requirements" (Brazil, 1998).

In 2018, eight years after the approval of the National Policy on Solid Waste, there are no actions that indicate that the management of the MSW must be adapted so that waste is no longer disposed of in landfills, but in suitable places, mainly sent to landfills.

20. Reverse logistics is a principle introduced by the National Policy on Solid Waste and means to be an "instrument of economic and social development characterized by a set of actions, procedures and means to enable the collection and restitution of solid waste to the business sector, for reuse, in its cycle or in other productive cycles, or other environmentally appropriate final destination" (Brazil, 2010).

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