BARRIERS ASSOCIATED TO THE RECOVERY OF METHANE FROM LANDFILLS IN BRAZIL

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Abstract

The Brazilian inventory of methane generated by municipal solid wastes (MSW) has estimated nearly 805 gigagrams of methane per year for 1994. Nationwide, MSW generation is estimated in 59 thousand metric tons per day, with a variable composition and per capita rates of generation from region to region. With high population largely concentrated in urban areas, relatively high amount of organic matter in the waste content and high average temperatures there are favorable conditions to methane production and therefore to recovery initiatives in order to mitigate the emissions of this greenhouse gas. Nevertheless, reality shows an opposite pattern: basically no methane is recovered from landfills in the country. Several restrictions are to mention, after years of tentatives to implement waste-to-energy systems. This paper aims to discuss the main barriers identified to achieving the benefits represented by this opportunity and to suggest ways in order to overcome these constrictions.

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Introduction

With 160 million inhabitants, 78% urban, Brazil is the fifth largest country in area and the world's 10th economy in terms of GNP by 1999. According to the national inventory of methane by wastes, nearly 805 gigagrams (thousand metric tons) were generated in 1994. Municipal solid wastes (MSW) were the major share, equivalent to 84% of total. Nationwide, MSW generation is estimated in 59 thousand metric tons per day, with a variable composition and per capita rates of generation from region to region. Of these figures, 76% are open dumped and 23% disposed in landfills - controlled or sanitary. Largely populated metropolitan regions, produce up to 16 million tons of MSW per day, a high load with a relatively high organic content. These, under tropical and subtropical climates, provide favorable conditions to methane production and therefore to recovery initiatives in order to mitigate the emissions of this greenhouse gas. An assessment of 13 landfills across the country [1] has estimated reserves ranging from 9,7 to 14,8 thousand million cubic meters of methane, with an overall generation rate from 303 to 578 million cubic meters per year, capable to provide 60 to 144 MW of electricity. About 50% of all Brazilian emissions from wastes - including wastewater - arise from 13 landfills. Only two landfills represent 25% of country total emissions: Bandeirantes landfill in São Paulo and Gramaxo site in Rio de Janeiro. Nevertheless, reality shows an opposite pattern: basically no methane is recovered from landfills in the country. Several restrictions are to mention, after years of tentatives to implement landfill gas (LG) waste-to-energy (WTE) systems.

MSW: barriers to methane recovery

There are several interrelated restrictions to LG-to-energy projects. The following list is a tentative of describing separately each.

Lack of data

The reluctance of potential investors for landfill gas is undoubtedly due to lack of accurate data, either for gas production as regarding a comprehensive market survey for the energy to be produced. Not withstanding the huge potential estimated for methane recovery in Brazilian landfills, there is little information available. A comprehensive site assessment must cover a vast array of items: depth and area of site, waste type, age, input rate, potential users (distance, fuel to be replaced, modifications to user's plant), impact of existing gas migration control scheme. If this assessment is encouraging, a preliminary economic evaluation of the project covering gas quality and quantity, gas pressure (static and - if necessary - pumping tests), technology to be applied (well or trenches). Then, is to be

conducted a re-evaluation covering aspects like design, safety, legislation, planning approvals, contracts with users, capital operation and maintenance costs, commissioning and operation.

So far, there are known two preliminary assessments conducted by the U. S. EPA by 1997. In this remarkable initiative [1], there are recommendations for specific site measurements to obtain methane generation decay rates. Preliminarily, were assumed north-american figures, under two scenarios: low and high production, respectively with k=0.04/yr and 0.10/yr, according to average rainfall (threshold level is 635 mm/yr.). The report also attributes similar chemical composition of waste to the country's largest 21 municipalities, assumption is based in the composition of São Paulo wastes, considered an indicative to other cities. In another survey [2], the U.S. EPA assessed 6 landfill sites in São Paulo, with limited monitoring measurements and conservative estimates. Results are summarized below:

São Paulo landfill characteristics and results expected [2]

Landfill	**Characteristics**	**Landfill**	**Characteristics**
Vila Albertina	deposited 9.25 Mt MSW opened 1977 closed 1993 potential project size 4.1 MW potential fuel* 2800m^3/h project life 15 years capital costs** $2.7-6.8 million	Bandeirantes	
Santo Amaro	deposited 15.29 Mt MSW opened 1976 closed 1995 potential project size 6.5 MW potential fuel* 4400m^3/h project life 15 years capital costs** $4.2-10.8 million	Sao Joao	deposite
Sapopemba	considered not viable	Sao Mateus	considered not viable

* medium Btu ** lower value refers to direct use as fuel; higher to electricity generation

In São Paulo and Rio, based on these reports, were opened bidding for tenders to the exploration of WTE landfill gas systems, with gas production rates varying considerably from site to site. The winners for Bandeirantes and São João landfills claimed contractual renegotiations alleging changes in the energy scenario. Indeed, both the public electricity and the gas supplying companies were privatized in the meantime. Thus, discounts in transmission have become more difficult to obtain, as well as favorable price negotiations. The approval phase also witnessed some difficulties in explaining to financial auditors the environmental driving forces behind an electricity generation project owned by a municipality. In spite of these and other obstacles, agreements are still undergoing. End use options currently discussed for the produced energy include: industrial heat to a nearby located industry; selling electricity to the grid attached to an abatement in bills charged to the municipality; producing electricity for peak loads in exchange of supply for city operated electrical buses and LG use in trucks as a fuel. These two landfills also generate about 1,000 cubic meters of leachate per month. Such effluents are transported in trucks to the Barueri wastewater treatment plant, distant 15 kilometers from Bandeirantes landfill and nearly 40 km from São João site (an operation that costs roughly half million U.S. dollars a month, for both areas). In exchange, Bandeirantes landfill receives dry sludge from Barueri. The trade is to become unbalanced soon, since the landfill will be closed and leachate still produced. An on-site anaerobic digester could tackle - at least partially - such problems, reducing costs and providing more fuel gas.

Methane production is closely related to the organic fraction in MSW. A review conducted in 1996 [3] relates to Brazil an organic content range between 50% and 80% by weight,

higher than those from Japan (42%), USA (23%), Sweden (45%), Netherlands (30%), Germany (27%) and Canada (29%). Brazilian organic fraction varies considerably, as well as waste generation rates per capita. For the national inventory [4], was assumed for the country the urban per capita rate of 0.5 kg MSW/day, within the range of 0.4 to 0.7 kg MSW/inhab.day [3] obtained in a previous assessment conducted by Cetesb, the State of Sao Paulo Environment Agency.

Few appropriate landfills

In order to provide high and stable rates of gas generation, landfills must be properly designed, constructed and maintained. Cetesb has conducted a survey of state landfill sites, the most comprehensive reference to date [5]. This comprehensive study covered several aspects, some directly related to LG production. In this paper were highlighted the adequacy of gas drainage systems and the depth of water table. In terms of number of municipalities, only 27 out of 645 (4.2%) dispose their MSW in adequate systems and 116 (18%) utilize controlled systems. Therefore, municipalities that dispose MSW in inadequate systems are the absolute majority (77.8%). Only 10,9% of more than 18.2 thousand tons of MSW generated per day are disposed in systems considered adequate under the sanitary standpoint, given its locational, operational and technological characteristics. The majority of these, however, generate less than 10 daily metric tons of waste. Regarding only the aspect gas drainage, 84 out of 645 had systems considered "sufficient" (without any measurement); 21 were considered insufficient and the rest, non-existent. Probably a fairly great number of considered "sufficient" gas drainage systems would not be sufficient to WTE system. Out of these 84 "sufficient" sites, 70 had reported water table depth of more than 3 meters from the landfill base - therefore suitable for LG recovery - and in the other 10, water tables were between 1 and 3m from landfill base - subjecting the landfill to flooding during the rain season.

Since some types of toxic wastes inhibit bacterial methanogenesis, one of the main issues to address in terms of gas production is the presence of hazardous wastes in landfills originally designed for MSW. In the State of São Paulo 535 thousand metric tons of hazardous wastes are generated per year. These should be incinerated in five large scale units, which full capacity (never practically achieved) is of only 21 thousand tons per year (or less than 20% of the hazardous wastes generated). There is also only one landfill in the region authorized for hazardous wastes disposal. Therefore there are strong evidences that MSW landfills also receive large amounts of hazardous wastes. In spite of the legislation and enforcement applied, sector specialists believe that a good share of hazardous wastes is being inadequately disposed by contractors with less scruples, at cheaper fees. [6]

Unskilled operational and technical staff is a typical characteristic of solid wastes service companies. Poor maintenance of vehicles allied to obsolete technologies, equipment and installations plague the majority of service companies and cities.[7] Construction flaws in landfills affect biogas production and its composition through factors such as: a) lack of homogeneity in internal mass density; b) inadequate distribution in mass composition

(organic, inerts and other); c) different levels of permeability to gas and leachate; d) eventual and unpredictable gas "bubbles" or large flooded volumes inside the landfill, due to rainfall, saturation or ruptures in drainage lines and; e) unpredictable mass movements, non-continuous, due to complex soil mechanics and loss of organic matter during collection, transport or distribution of MSW in the landfill.

Even in the most promising landfills constructive conditions are a barrier to landfill gas recovery. The U.S.EPA reports [2]: a) air infiltration through gas vents; b) permeable cap material; c) interconnections of gas vents with leachate drains causing air infiltration and; d) high liquid levels interfering with landfill gas collection. Proposed solutions were: a) vent design modifications and sealing; b) use of impermeable soil or liners; c) installation of active well bore seals; d) flow control valves and horizontal gas collectors; d) re-grade of landfill surfaces to minimize ponding and; e) leachate pumping from critical extraction points.

Lack of effective regulations and enforcement

More than 75% of MSW generated in the country are dumped or discarded illegally. Despite the various regulations and policies issued , the government faces the difficulty to control the illegal dumping as well as monitoring and enforcing legally allowed penalties. As environmental enforcement and control is attributed to State agencies and MSW management is a municipal duty, many times municipalities ignore environmental problems caused by wastes. Enforcement is very hard to ensure due to lack of institutional, human and material resources. Fragmented decision making creates superposition and conflicts among the various levels of existent legislation. There are many unclear boundaries for legal responsibility according to the type of waste. In the beginning of 1998, the approval of the Environmental Crimes Law - establishing heavy sanctions to those responsible for the adequate disposal of waste - had given hopes to waste disposal contractors. However, a further legislation provided an extension in the deadline for companies to adapt to the directive. Emissions of greenhouse gases are not covered by pollution emission standards. It is expected that future regulations direct new developments to emissions-preventive technologies.

Policy discontinuity and poor coordination amongst governmental actors.

In the country, solid wastes collection and disposal are municipal attributions. The vast part of landfill sites are also owned by municipalities and funded mostly by taxes. Deficiencies derive from discontinuity of administration plans and programs and inadequate definition of roles and responsibilities [7]. A large number of governmental bodies are involved in overlapping aspects of the solid waste management [1]. State and municipal legislation issued are many times redundand ant conflictive. Environmental agencies, with a lack in manpower, share their resources controlling several different sources and concentrate efforts on applying the legislation to basic items, such as landfill coverage or leachate control, considering secondary the gas recovery aspect. Many times the only available areas for MSW are not adequate areas. This difficulty is evident in large metropolitan areas, with

high rates of waste production. Integrated management schemes are rare due to lack of coordination, logistic and political reasons.

Discontinuity and other inappropriate political actions destine to failure specific successful projects in execution. Many times the problem is internal to an executive administration body, with political disputes and bureaucracy between departments. Inadequate administrative practices are another reported item to mention: waste collection and disposal is a very attractive option to private contractors, since loads are paid by weight and trip. Some wastes can have a higher moisture content or heavy inerts systematically added, or even travel long distances to the final destination, resulting in higher earnings to contractors.

Conservative thinking and lack of awareness

In spite of the possible uses for electric power generation, industrial heating and refrigeration, there are not any known use of landfill gas in Brazil. Gas recovery and cleanup techniques have achieved a fairly high degree of credibility, but prejudice against this source of energy is still prevalent. Ref. [7] mentioned negative ways in which citizens can react to waste-to-energy technologies: ignorance, indifference, uncertainty and, most of all, the recognized “not in my backyard” syndrome. Citizen opposition is also enhanced by increasing municipal taxes to pay for new technology, even when it means improving life quality. Authorities acknowledge the benefits of the landfill gas energetic recovery, but lack of means for a comprehensive assessment for evaluation of environmental and economic advantages of this option, compared to the usual waste management practices. Shortage of initiative in the private sector is inertial - and has its reasons. After years of changes in regulations and fluctuations in prices, local entrepreneurs have developed a risk resistance culture. This, allied to providers' expectation for sales-promoting regulations often destine new technologies to fail.

Difficulties associated to matching local energy supply and demand

Perspectives of raises in electricity prices after privatization and of shortages in supply are leading companies to guarantee their own generation. At least 50% of the major consumers already act as electricity self-producers - and the trend is an increase. More than reducing costs, this matter concerns also operational security. Due to the historical regulatory behavior of fixing prices without consideration to costs, prospective investors tend to view the sale of energy surplus to the grid risky business. The just recently opened market - still undergoing a de-regulation phase - presents no LG-to-electricity projects to benchmark. LG faces also a strong economic competition with sources such as oil and natural gas (supplied through the recently built Bolivian/Argentine pipelines or produced from offshore exploitation). Uneven price gaps are expected to decrease since operational costs associated to the production of landfill gas are not directly dependant upon the external prices or currency rate fluctuations. LG shares with natural gas some difficulties by the side of demand, like the restricted infrastructure in terms of distribution for use as a fuel in vehicles. Since landfill gas production volumes are relatively low if compared to the other

fuel supplies and gas grids are not designed to receive these contributions, consumption needs to be close enough to the source. Such cases exist, mainly for industrial heat or refrigeration, but require a careful economic-technical assessment and market survey.

Problems with technology providers

Suitable LG installations require drilling of wells, pipework and flame arrestors, gas boosters, pumps, flares, gas analyzers, flow meters, calorimeters, portable oxygen meters, methane detectors and meters, gas cleanup systems and low thermal value gas motors [8]. There is a considerable need for technology transfer to Brazil in the sector. However, it is very common to find technology providers taking advantage of purchasers' lack of knowledge - or sometimes negligence - and trying to sell systems that are obsolete, not environmentally compliant, or inappropriate by other means to the local needs. External suppliers offer their products but do not seem to be willing to conduct the whole vertical development, from preliminary assessments to final electricity sale to the grid, if project data are not available. Such flaws become to be negative feedback arguments against WTE systems. Moreover, difficulties in importing LG equipments are due to bureaucracy and high costs - taxes, shipping, demurrage, exchange rate amortization payoffs, amongst others.

Although the principles of gas cleanup and use as a fuel are theoretically known, to ensure the competitiveness of this option more R&D must be conducted prior to a real large scale project. The success of this very first project is crucial for the credibility of the alternative, showing to the potential investors the level of risk and benefit-cost.

Competition with recycling

Oppositors advocate that WTE schemes eliminate work opportunities in recycling [7]. Recovery of landfill anaerobically-produced gas is a competitor to composting, many times attached to pre-separation for recycling purposes. Cultural resistance often considers that WTE is worst than composting. In Brazil, very few people are aware of benefits from LG recovery, like leachate control, greenhouse gases emissions mitigation or control of contamination by vectors. Usually, an integrated MSW management approach considers that organic matter is to be treated aerobically by composting and the only mentioned energy obtained from waste is through incineration. These types of proposals, always attached to pre-selection of recyclables, usually end up without completion. Problems with these schemes, like pressure against incineration or difficulties with markets for recyclables affect the MSW management program as a whole.

Financing difficulties

Investments in sanitary programs systematically have decreased since 1968. Resources allocated by National Budget for “general sanitation” sub-program, which includes solid waste management, were historically spent without control and subjected to political

manipulations. Financial restrictions plaguing public cleansing services are generally caused by inadequate budgets and tariff structures, leading to non-equilibrated cash flows, insufficient revenues and absence of credit lines [7]. Few cities could pay for WTE plants or would choose to install and maintain biogas plants, when it is cheaper and well accepted by public opinion and environmental legislation to simply dump wastes in landfills. International issues like the greenhouse effect are almost always not considered, in face of other problems and priorities. High costs for WTE schemes, including selling of electricity, just seem far from Brazilian cities priorities and capabilities. High interest rates, around 20% per year makes almost impossible achieving a competitive payback for the LG option. Financing from private banks is difficult to obtain and expensive due to required guarantees and high spread rates. The national financing line require an environmental impact assessment to energy projects with more than 10 MWe of installed capacity.

Chronic problems in municipal budgets affect the access to possible funding sources for solid waste management investments. Foreign loans have changed their profiles towards private investments. Fiscal incentives are scarce and not directly related to LG projects. Fees depend upon the municipal capacity of providing services. Tariff revenues usually have already their destination determined, with little or no space for new projects. The emission of bonds and debentures is by law dependant upon the municipality's capacity of balancing revenues and expenditures. Moreover, there is the culture of sponsoring only large projects, considering smaller energy systems as not profitable.

Unwillingness in taking risks

Regarding landfill gas exploration, there is a high expectancy of return from the owners - prevailingly municipalities - of sites (and thus MSW and gas) against a strong reluctance by private investor in taking risks in turnkey projects. Landfill gas utilization is considered by the private sector as not commercially viable as there are no energy purchase agreements in place, under the new regulatory framework. Companies interested in the commercial opportunities will not be interested until they know the return they will get. Sale of energy will require also more management capabilities.

Instead of showing more initiative to encourage the private sector to become involved in landfill gas projects, municipalities prefer to avoid also political risks taken when proposing a WTE project. Landfill gas recovery policies are usually associated with other waste management initiatives. Since some of them are controversial to the public opinion - such as air pollution by incineration processes and odor released by composting - the whole program faces tough opposition by legislators and jurisdictors. Party predominance also give raise to not-in-my-backyard claims. By precaution, politicians tend to avoid new projects or, at least, slow it down.

Suggestions

These problems cannot be resolved separately. Political barriers are closely associated to cultural, that are related to economic. Training and awareness may be the first step.

Campaigns must cover beyond site owners and private companies. Integration with universities and decision makers is essential for the success of a gas recovery program. Then, after gathering sufficient data and acquiring technological knowledge, a first, well designed benchmark is fundamental. A comprehensive benefit-cost assessment could help private investors to manage the electricity generation system and municipalities to at least endorse economically feasible projects. An integrated waste management conducted by a condominium of municipalities may help matching the energy demand with the potential of determined landfills. Finally, must be combated deeply rooted problems of lack of coordination and political discontinuity. In order to have institutional and legal reforms is crucial the role of the mass communication media and the public pressure.

Governmental incentives could then provide conditions for better projects financing and funding. The private sector's collaboration provides the modernization of technical, managerial and operational structures. Interest in the climate change debate will of course run faster after the USA adhere to the Kyoto Protocol and/or after the implementation of projects under the Clean Development Mechanism.

Conclusion

Major barriers to LG energetic recovery in Brazil are associated to lack of information, awareness and coordination amongst actors. Few cites concentrate the vast majority of methane resources. There is no other way to reverse this situation than starting up a successful, strongly backed up real scale project.

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