Business Focus Series

Characterization of Landfill Sites in Brazil For Landfill Gas Recovery

February 1997

Prepared by:

U.S. Agency for International Development
Office of Energy, Environment, and Technology
Center for Environment
Bureau for Global Programs, Field Support, and Research

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ACRONYMS

ACESA	Association of Eletric Energy Concessionaires
ANEEL	Agencia Nacional de Energia Eletrica -- The National Agency of Electric Energy
BNDES	Brazilian National Development Bank
BTU	British Thermal Unit
CECA	Rio State Commission for Environmental Control
CETESB	Basic Sanitation Technology and Water Pollution Control
CFC	Chloroflourocarbons
CHESF	Companhia Hidro Elétrica do Sao Francisco
CND	National Council on Privatization
CNG	Compressed Natural Gas
COEMA	State Council for the Environment
CONAMA	National Council for the Environment
COPERSUCAR	Cooperative of Sugar Cane, Sugar and Alcohol Producers
DNAEE	Departmento Nacional de Aguas e Energia Eletrica -- National Department of Water and Electric Energy
EIA	Environmental Impact Assessment
ELECTROSUL	Centrais Elétricas do Sul do Brazil S.A.
ELECTRONORTE	Centrais Electricas do Norte do Brazil S.A.
EPA	Environmental Protection Agency
ESCELSA	The State of Espírito Santo Electricity Distribution Company
EST	Temporary Surplus Energy
ETIP	Energy Technology Innovation Project
ETST	Temporary Substitute Energy
FBDS	Brazilian Foundation for Sustainable Development
FEEMA	Rio State Environmental Control Agency
FURNAS	Centrais Elétricas S.A.
FIRCE	Central Bank Foreign Capital Registration and Supervision Office
GCC	Global Climate Change
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GNP	Gross National Product
IBAMA	Brazilian Institute of Environmental and Renewable Resources
IBGE	Instituto Brasileiro de Geografia e Estatistica
ICB	International Competitive Bidding
IDB	Inter-american Development Bank
INEE	National Institute for Energy Efficiency
INPE	National Institute for Space Research
INPI	National Institute of Industry Property
IPP	Independent Power Producers
ITAIPU	ITAIPU Bi-nacional Company
JICA	Japan International Cooperation Agency

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ACRONYMS (CONT.)

LFG	Landfill Gas
LIGHT	Servicos de Eletridade, S.A.
LRMC	Long Run Marginal Cost
MERCOSUL	Southern Common Market (Created when Brazil, Argentina, Paraguay, and Uruguay signed the Treaty of Asunción)
NEPA	National Environment Policy Act
NGO	Non-governmental Organization
NMOC	Non-methane Organic Compound
OECF	Overseas Economic Cooperation Fund
PETROBRAS	Brazilian Petroleum Company
PND	National Privatization Program
RFFSA	Federal Railroad System
SCF	Standard Cubic Feet
SISNAMA	National Environment System
SMA	State Secretariat for Environment
UNDP	United Nations Development Program
USAID	U.S. Agency for International Development

FOREWORD

This edition of the *Business Focus Series* provides a report on the *Characterization of Landfill Sites in Brazil for Landfill Gas Recovery*. It was prepared by the Energy Technology Innovation Project (ETIP) under contract to the USAID Office of Energy, Environment and Technology (USAID/G/ENV/EET) of the Center for Environment, Bureau for Global Programs, Field Support, and Research.

The authors gratefully acknowledge the extensive guidance, review, and support provided by Mr. Jefferson Seabright, Dr. Samuel Schweitzer, and Ms. Christine Wegman, USAID/G/EET; Mr. Edward Kadunc, Jr. and Mr. Augusto Juca, USAID Mission, American Embassy, Brasilia; Mr. Gilbert Donahue, Adjunct Counsel General, Sao Paulo; Ms. Sharon Villarosa, First Secretary, Economic Affairs and Ms. Cenia Wilkinson, Counsellor, Science, Technology, and Environment, both at the American Embassy, Brasilia; and Ms. Julia Guerrero, Principal Commercial Officer and Mr. Ricardo Rose, Business Development Specialist, both at the U.S. Commercial Center in Sao Paulo.

In addition, a number of Brazilian officials provided significant contribution to various aspects of the study as well as arrangements for the visit to the landfill sites throughout the country. The complete list of all public and private Brazilian officials contacting during the mission is included in Annex I of this report. However, we would like to especially acknowledge the information and guidance provided by Harldo Mattos de Lemos, Secretario de Coordenaciao dos Assuntos de Meio Ambiente, Ministerio Do Meio Ambiente, Dos Recursos Hidricos e Da Amazonia Legal; Demostones Barbosa da Silva, Deputy Director, Ministerio de Minas e Energia, DNAEE; Roberto Moreira Coimbra, Assessor do Coordenador Geral Ministerio de Minas e Energia, DNAEE; Eduardo Alberto Larrosa Bequiio, Coordenador Geral de Concessoes Ministerio de Minas e Energia, DNAEE; Hentique Santos, Assessor da Coordenacao Geral de Concessoes, Ministerio de Minas e Energia, DNAEE; Nida Chalegre Coimbra, Environmental Manager, Ministerio de Minas e Energia, Executive Secretary; and Casper Erich Stemmer Secretario de Coordenacao de Programas, Ministerio da Ciencia e Tecnologia Esplanada dos Ministerios.

The *Business Focus Series* includes reports on promising environmental and energy markets in developing countries. Reports are of varying length and content and may be regional, country-specific, or focused on a particular sector. To obtain more information about *Business Focus Series* reports, please contact the USAID Global Bureau's Office of Energy, Environment and Technology at (703) 875-4203.

SUMMARY

The rapid industrialization of Brazil has resulted in an alarming increase in the urban population of the country. Large cities such as São Paulo, have a daytime population which is as much as 25 percent greater than the fixed population of the city, predominantly due to daily migrant workers taking advantage of enhanced employment opportunities in the city. There has also been a steady migration of workers from the rural areas to the major cities over the last three decades. Currently, over 75% of Brazil's population is centered in its main urban cities. This influx of population from the rural to the urban areas has created severe demands on the cities' infrastructure, energy supply, and municipal services. With increased employment opportunities, an enhanced quality of life, and greater disposable income, the urban population in Brazil is showing characteristics typical of other major metropolitan areas in the world which include greater consumption of water and energy, enhanced use of transportation and communication facilities, and generation of municipal solid waste. In addition, the location of large industrial facilities in and around major cities is generating significant quantities of industrial wastes. Therefore, among many of its responsibilities, the Federal government, states, and municipalities are faced with a major challenge for the collection, recycling, and disposal of both municipal and industrial wastes.

Recycling experiments are being introduced in a number of cities. Also, many city governments are actively implementing sewage and wastewater treatment projects as well as sanitation and cleanup initiatives. Many urban homes have a waste collection service on an ongoing basis, and huge open-air landfills are still the final destination of most of the collected waste, including hazardous substances. Some of the cities are also experimenting with composting of municipal waste and incineration of hazardous, toxic, and medical waste.

Brazil has a total of 4,974 municipalities. Of these 3,611 or 72.6 percent of the municipalities have less than 20,000 inhabitants and have a total population of approximately 23 million. Twenty one of the largest municipalities, with population greater than 600,000 inhabitants, have a combined population of approximately 34 million. The average production of municipal solid waste in Brazil is approximately 0.5 kg per capita per day. In large cities such as São Paulo, however, the average municipal waste production per capita per day can be as high as 0.85 kg.

A considerable amount of the municipal solid waste generated by the 4,974 municipalities is dumped illegally into scattered and unauthorized dump sites or water streams. The Instituto Brasileiro de Geografia e Estatistica (IBGE) has estimated that approximately 76 percent of the total municipal waste generated in all of Brazil's municipalities is dumped in illegal dumping areas; 13 percent of the waste is delivered to controlled landfills; 10 percent is delivered to sanitary landfills; 0.9 percent is used for composting; and 0.1 percent is incinerated (primarily hospital waste).

The responsibility for the collection and disposal of all solid waste is at the municipality or city level. The municipalities are responsible for selecting landfill sites, arranging for the collection of all the waste (either themselves of through a private contractor), and disposal of the waste in

environmentally sound ways. Also, the municipalities must ensure that the landfill sites are designed and operated in full compliance with the federal and local environmental laws and regulations with respect to the collection, monitoring, and disposal of all waste including hazardous and toxic waste, sewerage, and industrial waste. Many of the smaller municipalities, however, are unable to address the environmental problems caused by the municipal waste. This lack of effective municipal solid waste management is due to a number of factors including (i) a lack of specific waste management policy at the local level, (ii) budgetary constraints faced by many small and medium-sized municipalities, many of which do not have any collection fees or other revenue streams to justify the cost of solid waste management, (iii) a lack of availability of skilled and trained environmental and sanitary engineers and technicians, especially within small municipalities, (iv) a lack of appropriate monitoring, control, and treatment technologies, and (vi) absence of any programs for control, enforcement, and penalties for illegal dumping. The chemical composition of the municipal waste in the 21 largest municipalities is very similar. The analysis of the waste collected in São Paulo, the largest city in Brazil, producing approximately 9,000 tons of municipal waste per day, shows that the waste is approximately 60 percent organic in content, starting in 1993.

Recently there has been a decline in the organic content and a steady increase in the paper, glass and metal content in the municipal waste in São Paulo. This is indicative of the change in the urban economies including the introduction of paper and plastic products, packaged foods, and the use of glass bottles and cans for beverages. The waste composition data for the City of São Paulo, are indicative of the waste composition in other major cities such as Rio, Belo Horizonte, Salvador, Curitiba, Porto Alegre, Florianópolis, Goiânia, etc.

In most of the major cities the process for the collection and management of the municipal solid waste is organized in one of the following ways: (i) the landfill is owned and operated by the municipality, (ii) the landfill is owned by the municipality but is operated by a private entity under contract with the municipality, or (iii) the landfill is owned and operated by the private sector. The most common pattern in Brazil appears to be the ownership of the landfill by the municipality and operation by a private contractor. There are only two landfill sites in Brazil that are wholly owned and operated by the private sector.

Recognizing (i) the urgent need for mitigating many of the environmental, health, and safety effects of LFG, (ii) the potential for the use of LFG as a marketable resource, producing revenues for the municipalities and states, (iii) the need for more skilled technicians, engineers, and managers to manage the landfill sites, and (iv) the availability of technology from the U.S. for the recovery and utilization of methane from LFG, the U.S. Agency for International Development (USAID) in Brasília requested assistance from the USAID-funded Energy Technology Innovation Project (ETIP) to assemble a team of experts to visit key landfill sites in Brazil, assess the site conditions and the potential for LFG recovery and utilization, and make specific technical and policy recommendations for the development of a comprehensive LFG program for Brazil.

In December 1996, ETIP organized a team of U.S. and Brazilian experts to select and visit key landfill sites throughout Brazil which offer the greatest promise for (i) accruing environmental health and safety benefits, and (ii) the commercial scale recovery and utilization of LFG. The team visited Brazil during the first two weeks of December and conducted site assessments at thirteen major landfill sites in Brazil. In addition, members of the team also visited several state, municipal, and Federal government officials and held discussions on policy, financial, and institutional issues linked to a more effective management of the country's landfill sites and the recovery and sale of LFG.

The study objectives were as follows:

1. Identify and characterize candidate landfill sites that are representative of major population centers and high secondary growth areas in Brazil.

2. Identify commercial potential, potential markets, and economic benefits of LFG recovery and utilization.

3. Develop options for private participation in this sector, thereby reducing the burden on the cities and municipalities, increasing efficiency, and generating employment.

4. Identify policy and institutional barriers and make recommendations for policy and institutional changes that will facilitate LFG recovery and commercial utilization.

Based on data on population, amount of waste generated and disposed at the landfill sites, and geographical considerations, ETIP selected the following 13 landfill sites in 12 of Brazil's major cities. They are listed here in alphabetic order.

- Bandeirantes Landfill, São Paulo, São Paulo
- Belo Horizonte Landfill, Belo Horizonte, Minas Gerais
- Biguacu Landfill, Florianópolis, Santa Catarina
- Caximba Landfill, Curitiba, Paraná
- Delta I Landfill, Campinas, São Paulo
- Goiânia Landfill, Goiânia, Goiás
- Gramacho Landfill, Duque de Caxias, Rio de Janeiro
- Joinville Landfill, Joinville, Santa Catarina
- Joquei Landfill, Brasília, Distrito Federal
- Lara Landfill, Mauá, São Paulo
- Santa Barbara Landfill, Campinas, São Paulo
- Sao Joao Landfill, São Paulo, São Paulo
- Zona Norte Landfill, Porto Alegre, Rio Grande do Sul

The total population of all the states visited by the team is approximately 92 million persons, or 58% of Brazil's population. The total population of cities where the selected sites were located is approximately 33.2 million persons. The total municipal solid waste produced in the country is estimated at 241,614 metric tons per day. The total municipal solid waste produced in the twelve cities covered by the thirteen selected sites is estimated at 142,697 metric tons per day which is approximately 59% of the total municipal waste in the country.

In addition to visiting the landfill sites the ETIP team also visited Brasília and held discussions with senior energy, environmental, and planning officials in the Federal government. These discussions included current and planned policies for municipal solid waste management, the institutional sector, and financing of solid waste management collection, treatment and disposal projects. During these discussions the team explored the potential for active participation by the private sector in both municipal solid waste management and the production and utilization of LFG as an energy resource, especially in view of the government's recently enacted Concession Law and the IPP regulations.

The following are the key issues common to all of the landfill sites visited by the teams and are representative of the waste management practices throughout Brazil:

1. Most of the legal landfill sites are managed by city/municipality officials. Generally, the collection and transportation of solid waste to the sites as well as all operations at the sites are managed by city employees. In the case of some of the larger waste management sites such as the Bandeirantes site in São Paulo and the Gramacho site in Rio de Janeiro, the collection and operation of the sites is carried out by private Brazilian contractors. The Lara Site in Mauá and the Biguacu Site in Florianpolis are wholly owned and operated by private Brazilian companies. However, these are sporadic and unusual cases.

2. While the topography of the sites varied considerably, the climatology was generally similar, with minor differences in temperatures, total rain falls, etc. The slopes of the various sites are consistent with those found in other countries, typically 2-3 horizontal and 1 vertical, and the use of compacted clay for final cover as well as liners is commonly practiced at most of the sites. Also, the medium sized landfills such as Lara and Sao Joao, were located in close proximity to heavily populated areas, posing health and safety risks to these populations.

3. All of the sites are actively engaged, to varying degrees, in site layering and remediation on a regular basis and most of them have top soil, dirt, and concrete available on the sites for intermediate and final covers.

4. All sites have generally poor systems for the collection and treatment of leachate. A considerable amount of leachate was found at virtually all the sites which poses significant hazards to on-site workers and neighboring populations. In some cases, such as the Bandeirantes site, leachate was collected in ponds, pumped into trucks, and transported to a leachate treatment facility. This operation is also in need of significant improvement.

5. Only one site, the Bandeirantes Landfill is engaged in composting of appreciable quantities of municipal solid waste. Currently it is composting 2,500 tons of waste per day, producing approximately 600 tons per day of raw compost for commercial applications. This site has an active plan under consideration to double its composting production within one year.

6. There was no evidence of any organized pre-sorting of waste (recyclable materials such as plastic, paper, glass, and metals) at any of the sites. However, there is considerable presorting activities similar to that found in many other countries. Preliminary estimates indicate that at some of the larger sites such Bandeirantes and Gramacho, that recyclable materials in value exceeding US $5,000 per day could be recovered through the development of an organized pre-sorting system.

7. There was a general absence of incineration of hospital wastes at most of the sites. Only one site visited had an on-site microwave incineration system treating approximately 8 tons of hospital waste per day. This system was being operated with U.S. technology by a private Brazilian contractor.

8. The system for the collection of LFG varied from site to site and was not sufficiently comprehensive. Flaring of LFG was common to all sites and there was virtually no organized collection and treatment of LFG for commercial uses. Also, none of the sites utilized the LFG for steam and/or power generation. Given the climate in Brazil and the presence of more than 60% organic waste at most of the sites, Brazilian landfill sites produce an abundant amount of LFG. Therefore, the recovery and utilization of LFG for commercial applications offers the cities and municipalities an attractive opportunity not only to reduce environmental, health, and safety risks of LFG, but also partially offset the operations cost of the landfills through the recovery of revenues from commercial sales of LFG and/or LFG based power.

In addition to the technical findings at the landfill sites, the teams also reviewed existing policy, legislative frameworks, and institutional practices pertaining to municipal solid waste management in the country and explored the potential for extensive private participation in this sector. The following are the teams' key findings:

1. There are a large number of Federal agencies, committees, semi-government institutes, state ministries, municipal agencies and departments, all of which are involved in one or more aspects of the overall municipal solid waste management in the country. Although as a matter of general policy, the responsibility for the management and collection of solid waste lies with the municipalities/cities, there is considerable overlap in policy formulation, regulations development, permitting and licensing processes, site inspections, and monitoring and enforcement among the various entities. In addition, there appears to be a lack of coordination among the various entities, especially in the area of policy formulation, standards development, and project planning.

2. In recent years, the Federal and state governments in Brazil have enacted legislation and published a large number of rules and regulations specific to the collection, transportation, treatment, monitoring, and disposal of municipal solid waste. Yet, a large portion of the country's municipal solid waste (close to 75%) continues to be dumped in illegal dump sites. Despite the various regulations and policies, the government faces the difficulty to control the illegal dumping as well as monitoring and enforcing legally allowed penalties.

3. Currently, the municipalities must bear the entire cost of waste collection, transportation, treatment, disposal, and site operations. The main source of revenue to the municipalities is the dumping fee which varies from US $8 per ton to US $20 per ton based on a variety of factors (waste content, truck size, repeat volume, etc.). Other potential sources of revenue such as income from the sale of recyclable materials, composting of organic waste, and recovery and utilization of LFG as an energy resource are largely untapped. At the same time, the states and the municipalities are faced with the requirements of expansion of existing landfills, development of new landfills, closure and reclamation of landfills at total capacity, and management of leachate and toxic and hazardous wastes by using environmental technologies in compliance with new stricter standards, all of which continue to add significant pressure to their already constrained budgets.

4. With the passage of the Concession Law and the potential for profits from the utilization of the waste and LFG for commercial products (compost, recyclables, and LFG) a number of private Brazilian firms are actively pursuing opportunities with the states and municipalities for turnkey landfill site management contracts. For example, SLU and ENTERPA, two of the existing contractors for the Sao Joao Landfill and the Joquei Landfill in Brasília respectively, are actively pursuing opportunities for new contracts with the municipalities. However, a number of regulatory and financial constraints continue to exist which need to be rationalized prior to these and other Brazilian firms taking an active interest in the waste management sector.

5. Except for the largest sites, there is a dearth of trained technicians, planners, and managers for waste management and landfill site operations in the country. Also, budgetary constraints have prevented the municipality/city from deploying new cost-effective technologies (incineration, source separation, anaerobic process for composting, etc.) for the treatment of waste, as well as leachate. In the case of many of the sites there was considerable evidence of LFG leakage and exposure to nearby populations creating health hazards. In order for Brazil to implement its environmental standards and ensure health and safety of its population, particularly those located in close proximity to the landfill sites, the government will need to utilize more advanced and cost effective technologies. Accordingly, there is a considerable need for the transfer of technology from the U.S. to Brazil in this sector.

6. The bold policy moves made by the Brazilian government, particularly the privatization policy, the Concession Law, the IPP regulations, the new environmental standards, and the country's historical commitment to the use of alternative, cleaner technologies, provide the framework for active private sector involvement and technology transfer to address the increasing problems of municipal solid waste management. While the government has articulated its policies in sufficient detail, considerable work is needed in streamlining the process for eligibility criteria, bidding and financing procedures, permitting and licensing, and contracting.

The Instituto Brasilerio de Geografia e Estatistica has estimated that a total of 241,614 tons of municipal solid waste is generated in Brazil every day in all of its 4,974 municipalities. Of this amount, approximately 76 percent or 183,627 tons of waste per day is dumped in illegal, unorganized dumps. Approximately 10 percent of the waste goes to sanitary landfills; 0.9 percent is used for composting; 0.1 percent is incinerated; and the remaining 13 percent or 31,409 tons per day is disposed in controlled landfills. The total waste transported and dumped at the 13 sites visited by the team is estimated at 28,425 tons per day. Of this amount, approximately 11 percent is used for composting, sanitary landfill, and incineration. The remaining 25,298 tons per day is covered at the 13 landfills and is attributable to the generation of LFG. Thus, the amount of waste directly attributable to the generation of LFG at the thirteen sites visited by the team is approximately 80.5 percent of the total waste collected and transported to legally controlled and operated landfill sites.

Furthermore, the composition of the waste is generally the same from site to site, especially the organic waste content which is estimated to be in the range of 50-90 percent, with the average being around 60 percent, high enough to generate significant amounts of LFG. The 12 cities where the 13 sites are located have a population of approximately 33 million. The total urban population of the 46 major cities/municipalities in Brazil with a population greater than 300,000 residents is estimated to be approximately 42 million.

Thus, the population of the sample cities selected for this study represents approximately 78.5 percent of the total urban population in the country which generates not only more per capita waste but also the majority of the waste in Brazil.

Accordingly, the 13 sample sites selected for the study are quite representative of the municipal waste management practice in Brazil. In addition, the sites are also representative of the waste management patterns in the country -- wholly owned and operated by the city/municipality; owned by the city and operated by a private contractor; and wholly owned and operated by the private sector. Furthermore, the selected sites are located in 8 of Brazil's 12 most populated states and are geographically reflective of the country's waste generation, collection, transportation, and disposal pattern.

Given the sample of the 13 sites selected for the study is representative of the country as a whole, it can be concluded that the opportunities for technical, policy, and institutional enhancements at these sites would also be applicable to other sites in the country. Specifically, the technologies for the recovery and separation of methane from LFG, leachate collection and treatment, composting, incineration, and LFG-based energy recovery applicable to the 13 sample sites can also be applied to other sites throughout the country. In terms of waste disposal practices, private sector participation, ownership/management patterns, concession and bidding procedures, financing approaches, and public-private partnership, any conclusions reached for these 13 sample sites may also be applicable to other sites in Brazil.

The U.S. Environmental Protection Agency (U.S. EPA) Landfill Air Emission Estimation Model (DOS Model, Version 2.0) was used to estimate landfill gas generation potential at each of the 13 Brazilian landfill facilities. Table 1 provides a summary of the estimated methane generation potential at each site. The Table presents the team's estimates for methane generation for the year 1996 and for the 20-year period from 1997 through 2016. Methane generation estimates are presented for two scenarios -- a low methane generation scenario and a high methane generation scenario.

The low-generation scenario estimates are based on a methane generation decay rate of 0.04 per year, which is typical for sites in the U.S. where the average rainfall exceeds 635 millimeters per year. The high methane generation scenario estimates are based on a methane generation decay rate of 0.1 per year. Because the sites report average annual precipitation rates that exceed 635 millimeters per year, the higher decay rate is used to estimate an upper-end methane generation potential. Site-specific methane generation decay rates, which can be measured in the field, are recommended for methane generation estimates at sites where landfill gas collection system development is under consideration. For the year 1996, the total methane generation potential for the low-generation scenario is estimated at 303.7 million cubic meters. The high generation scenario, potentially more applicable to the sites in Brazil due to the country's high average rainfalls, yields an estimate of potential methane generation at 578 million cubic meters per year.

TABLE 1
ESTIMATED METHANE GENERATION POTENTIAL

SITE	1996 METHANE GENERATION ESTIMATE (Million Cubic Meters/Yr)		POTENTIAL 1997 - 2016 METHANE RESERVES (Million Cubic Meters)		COMMENTS
	Low Generation (k=0.04/Yr)	High Generation (k=0.10/Yr)	Low Generation (k=0.04/Yr)	High Generation (k=0.10/Yr)	
Bandeirantes Landfill	67.7	131.7	2,009.3	3,000.8	High methane generation potential (1). Favorable M:A ratio (2).
Belo Horizonte Landfill	28.5	51.8	662.5	896.0	Medium methane generation potential.
Biguacu Landfill	1.4	3.4	110.2	196.9	Current low methane generation potential. Large disposal capacity. Waste receipts will increase. Favorable M:A ratio (2)
Caximba Landfill	10.8	23.5	345.0	532.2	Medium methane generation potential.
Delta I Landfill	5.0	11.3	98.2	141.9	Low methane generation potential.
Goiania Landfill	9.0	18.3	356.6	564.4	Medium methane generation potential.
Gramacho Landfill	102.7	176.6	3,099.6	4,477.9	High landfill gas generation potential. Favorable M:A ratio.
Joinville Landfill	3.5	6.2	65.9	82.4	Low methane generation potential. Site will close in 3 years.
Joquei Landfill	14.6	27.7	396.0	569.8	Medium methane generation potential. Unfavorable M:A ratio.
Lara Landfill	15.2	30.2	568.2	925.8	Medium methane generation potential.
Santa Barbara Landfill	4.4	7.0	59.1	57.2	Site is closed. Low methane generation potential.
Sao Joao Landfill	26.9	63.6	1,775.6	3,112.6	High methane generation potential. Favorable M:A ratio.
Zona Norte Landfill	13.9	26.9	195.4	233.3	Low methane generation potential. Unfavorable M:A ratio.
TOTALS	***303.7***	***578.1***	***9,741.5***	***14,791.3***	

NOTES:

1. Methane generation potential: low = less than 499 million cubic meters; medium = 500 to 1,499 million cubic meters; high = greater than 1,500 million cubic meters.
2. M:A = mass-to-area ratio. Represents the ratio of total landfill design capacity, in metric tons, to the landfill footprint area, in hectares. Generally, the higher the ratio, the more favorable the site for landfill gas system development.

During the 20 year period (1997-2016), the estimates for total methane generation potential in the low-generation and high-generation scenarios are 9.741 billion cubic meters and 14.791 billion cubic meters respectively which provide an average annual generation potential under the two scenarios as 487 million cubic meters and 739.5 million cubic meters respectively. This increase in the average annual generation of methane over the 1996 estimates is reflective of increasing quantities of municipal solid waste which will be disposed at these sites in the future.

Of the 13 sites selected for the study, the Gramacho Landfill site and the Bandeirantes Landfill site offer the greatest promise for landfill gas generation estimated at 102.7 million cubic meters and 67.7 million cubic meters respectively. Eight of the 13 sites have a low methane generation scenario estimate of 280.4 million cubic meters which is approximately 92.3 percent of the total 1996 methane generation potential. These percentages are similar during the next twenty year period. Bandeirantes, Belo Horizonte, Caximba, Gramacho, and Sao Joao Landfill sites offer the potential for appreciable quantities of methane generation both in 1996 and during the future twenty year period.

Estimates of electrical power generation potential for each site are summarized in Table 2 for a 20-year period at four milestones --1998, 2007, 2012, and 2017. The first milestone, the year 1998, represents the first year of operation of a landfill gas-to-electrical energy system, assuming that the construction of such a system would occur in 1997. The 10-year milestone (2007) represents the minimum return-on-investment period, typically required by the power industry, for a gas-to-electrical energy project. The 15-year and 20-year milestones in 2012 and 2017 complete the 20-year period for which the LFG availability and power generation estimates have been developed. The conversion factor for the conversion of heat energy to electrical energy is assumed to be 12,500 Btus per kilowatt-hour. This conversion factor is typically used by the industry for preliminary planning purposes and is equivalent to a 25 percent generation efficiency, which is conservative as typical generation efficiencies are in the range of 30-40 percent for traditional gas-fired power generation.

The cumulative power generating potential for the 13 sites for the low methane generation scenario ranges from a low of 60.6 MW in 1998 to a high of 91.8 MW in 2007. After the year 2007, the potential for power generation gradually declines to 70.5 MW in the year 2017 due to a reduction in the availability of methane resulting from the closure of some of the landfills visited. However, other landfill sites will come on line potentially providing additional LFG. Therefore the potential for power generation may maintain the level indicated or potentially increase beyong the present estimates. The cumulative potential for power generation in the high methane generation scenario for the 13 landfill sites ranges from a low estimate of 68.8 MW in the year 2017 to a high estimate of 144.2 MW in the year 2007. Once again, in high methane generation scenario as well, the potential for power starts at 113.3 MW in 1998, peaks at 144.2 in 2007, and declines to 68.8 in the year 2017 due to reduced methane availability resulting from landfill site closures.

TABLE 2
POTENTIAL ELECTRIC POWER GENERATION ESTIMATES

SITE	LOW METHANE GENERATION SCENARIO				HIGH METHANE GENERATION SCENARIO			
	MILESTONE	YEAR	CM/YR (1)	MW (2)	MILESTONE	YEAR	CM/YR (1)	MW (2)
Bandeirantes Landfill	Install System	1998	8.09E+07	13.2	Install System	1998	1.52E+08	24.9
	10-yr	2007	1.19E+08	19.5	10-yr	2007	1.85E+08	30.1
	15-yr	2012	9.77E+07	15.9	15-yr	2012	1.12E+08	18.3
	20-yr	2017	8.00E+07	13.0	20-yr	2017	6.79E+07	11.1
Belo Horizonte Landfill	Install System	1998	3.34E+07	5.4	Install System	1998	5.96E+07	9.7
	10-yr	2007	3.45E+07	5.6	10-yr	2007	4.33E+07	7.1
	15-yr	2012	2.82E+07	4.6	15-yr	2012	2.63E+07	4.3
	20-yr	2017	2.31E+07	3.8	20-yr	2017	1.59E+07	2.6
Biguacu Landfill	Install System	1998	2.40E+06	0.4	Install System	1998	5.35E+06	0.9
	10-yr	2007	5.89E+06	1.0	10-yr	2007	1.07E+07	1.7
	15-yr	2012	7.35E+06	1.2	15-yr	2012	1.21E+07	2.0
	20-yr	2017	8.55E+06	1.4	20-yr	2017	1.30E+07	2.1
Caximba Landfill	Install System	1998	1.44E+07	2.4	Install System	1998	3.00E+07	4.9
	10-yr	2007	1.90E+07	3.1	10-yr	2007	2.79E+07	4.6
	15-yr	2012	1.56E+07	2.5	15-yr	2012	1.69E+07	2.8
	20-yr	2017	1.27E+07	2.1	20-yr	2017	1.03E+07	1.7
Delta I Landfill	Install System	1998	6.80E+06	1.1	Install System	1998	1.44E+07	2.4
	10-yr	2007	4.74E+06	0.8	10-yr	2007	5.87E+06	1.0
	15-yr	2012	3.88E+06	0.6	15-yr	2012	3.56E+06	0.6
	20-yr	2017	3.18E+06	0.5	20-yr	2017	2.16E+06	0.4
Goiania Landfill	Install System	1998	1.20E+07	2.0	Install System	1998	2.39E+07	3.9
	10-yr	2007	2.28E+07	3.7	10-yr	2007	3.89E+07	6.3
	15-yr	2012	1.87E+07	3.0	15-yr	2012	2.36E+07	3.8
	20-yr	2017	1.53E+07	2.5	20-yr	2017	1.43E+07	2.3
Gramacho Landfill	Install System	1998	1.22E+08	19.8	Install System	1998	2.10E+08	34.2
	10-yr	2007	1.90E+08	31.0	10-yr	2007	2.98E+08	48.7
	15-yr	2012	1.56E+08	25.4	15-yr	2012	1.81E+08	29.5
	20-yr	2017	1.28E+08	20.8	20-yr	2017	1.10E+08	17.9
Joinville Landfill	Install System	1998	4.12E+06	0.7	Install System	1998	7.31E+06	1.2
	10-yr	2007	3.21E+06	0.5	10-yr	2007	3.50E+06	0.6
	15-yr	2012	2.63E+06	0.4	15-yr	2012	2.12E+06	0.3
	20-yr	2017	2.15E+06	0.4	20-yr	2017	1.29E+06	0.2
Joquei Landfill	Install System	1998	1.75E+07	2.8	Install System	1998	3.23E+07	5.3
	10-yr	2007	2.20E+07	3.6	10-yr	2007	3.10E+07	5.1
	15-yr	2012	1.80E+07	2.9	15-yr	2012	1.88E+07	3.1
	20-yr	2017	1.47E+07	2.4	20-yr	2017	1.14E+07	1.9
Lara Landfill	Install System	1998	1.83E+07	3.0	Install System	1998	3.52E+07	5.7
	10-yr	2007	2.97E+07	4.8	10-yr	2007	4.84E+07	7.9
	15-yr	2012	3.44E+07	5.6	15-yr	2012	5.20E+07	8.5
	20-yr	2017	3.61E+07	5.9	20-yr	2017	4.87E+07	7.9
Santa Barbara Landfill	Install System	1998	4.04E+06	0.7	Install System	1998	5.70E+06	0.9
	10-yr	2007	2.82E+06	0.5	10-yr	2007	2.32E+06	0.4
	15-yr	2012	2.31E+06	0.4	15-yr	2012	1.41E+06	0.2
	20-yr	2017	1.89E+06	0.3	20-yr	2017	8.53E+05	0.1
Sao Joao Landfill	Install System	1998	4.26E+07	6.9	Install System	1998	9.51E+07	15.5
	10-yr	2007	9.93E+07	16.2	10-yr	2007	1.79E+08	29.3
	15-yr	2012	1.23E+08	20.1	15-yr	2012	2.02E+08	33.0
	20-yr	2017	1.01E+08	16.4	20-yr	2017	1.23E+08	20.0
Zona Norte Landfill	Install System	1998	1.34E+07	2.2	Install System	1998	2.32E+07	3.8
	10-yr	2007	9.33E+06	1.5	10-yr	2007	9.45E+06	1.5
	15-yr	2012	7.64E+06	1.2	15-yr	2012	6.24E+06	1.0
	20-yr	2017	6.25E+06	1.0	20-yr	2017	3.47E+06	0.6
CUMULATIVE POWER GENERATION POTENTIAL			YEAR	MW (2)			YEAR	MW (2)
			1998	***60.6***			***1998***	***113.3***
			2007	***91.8***			***2007***	***144.2***
			2012	***84.1***			***2012***	***107.4***
			2017	***70.5***			***2017***	***68.8***

NOTES:
1. Cubic meters per year generated, as estimated using the U.S. EPA Landfill Air Emission Estimation model.
2. Megawatts, assuming 50% landfill gas collection efficiency, and a conversion factor of 12,500 BTUs per kilowatt-hour.

Thus, the overall potential for power generation for all 13 sites together ranges from a low value of 60.6 MW in 1998 to a high value of 144.2 MW in 2007. It must be noted, however, that some of the landfill sites are not good candidates for gas-to-energy development. Consequently, the likely cumulative potential for power generation at these sites will be less than that estimated in this report. Detailed site-specific assessments and technical and financial feasibility studies will be required prior to developing projects for potential financing.

Based on preliminary assessments of the 13 Brazilian landfill sites, five sites are ranked according to their potential as candidate sites for landfill gas collection system and LFG-power generation projects development as shown in Table 3. These sites offer the best prospects for further assessment as candidate projects. The selection and ranking of these sites are based on the following criteria:

1. the quantity of methane reserves, based on preliminary estimates, during the period from 1997 through 2016;

2. a representative sample of the institutional management of landfill sites in Brazil. Current management patterns at the 13 study sites include (i) wholly municipally-owned and operated, (ii) municipally-owned and privately-operated, and (iii) privately-owned and privately-operated;

3. the availability and accessibility to potential markets for methane gas, gas-based heat energy, and gas-based electric power in the vicinity of the landfill sites; and

4. the mass-to-area ratio of the landfill. Generally speaking, the greater this ratio, the more favorable the conditions are for landfill gas system development.

Based on these selection and ranking criteria, the following five landfill sites are considered to be the best prospect candidates for landfill gas and power generation development and are listed in descending order:

1. Gramacho Landfill, Rio de Janeiro, Rio de Janeiro
2. Bandeirantes Landfill, São Paulo, São Paulo
3. Lara Landfill, Mauá, São Paulo
4. Sao Joao Landfill, São Paulo, São Paulo
5. Belo Horizonte Landfill, Belo Horizonte, Minas Gerais

As mentioned earlier, the total municipal solid waste collected and disposed at these 13 landfill sites is approximately 80.5 percent of the total waste collected and disposed in country's controlled landfill sites. Assuming that the same ratios for organic content of the waste, methane recovery rate, and power generation rate were to prevail at the remaining controlled landfill sites, the total potential for on-site LFG-based power generation in the country will be in the range of 75.3 MW and 179.2 MW. At approximately an average installed cost of US

TABLE 3
SUMMARY OF SITE RANKINGS

SITE	ESTIMATED METHANE RESERVES (Million Cubic Meters) Low Generation	ESTIMATED METHANE RESERVES (Million Cubic Meters) High Generation	ESTIMATED DESIGN CAPACITY (Million Metric Tons)	ESTIMATED LANDFILL AREA (Hectares)	MASS-TO-AREA RATIO	POTENTIAL ENERGY END USERS
Gramacho Landfill	3,099.6	4,477.9	58.1	110	0.53	Commercial and residential developments west of site represent possible end users of methane gas and electricity. Potential on-site uses include electrical power generation and leachate evaporation. Electric power transmission lines located near site.
Bandeirantes Landfill	2,009.3	3,000.8	35.2	100	0.35	Large residential community and industrial lots near the site represent possible end users of methane gas and electricity. Electric power transmission lines located less than 1 km from site, and a gas transmission pipeline located 1 to 2 km from site.
Lara Landfill	568.2	925.8	12.4	52	0.24	Industrial lot development is occurring nearby the site, representing possible users of methane gas and electricity. There are electric power transmission lines near the site.
Sao Joao Landfill	1,775.6	3,112.6	34.5	87	0.40	Although no industrial developments exist near the site, residential developments surround the site, representing possible end users of methane gas and electricity. There are electric power transmission lines less than 1 km from the site.
Belo Horizonte Landfill	662.5	896.0	11.8	80	0.15	Although no industrial developments exist near the site, residential developments surround the site, representing possible users of methane and electricity.

$1,200 per kilowatt of installed capacity, the total maximum likely investment required for power generation facilities alone will range from US $90.4 to $215 million.

It must be noted that while this represents the maximum power generation and the likely investment requirements, many of the LFG-based power generation projects at individual landfill sites may not be economical for a variety of reasons including their small size, absence of a local dedicated market, errors in the estimation of long-term methane availability, etc. Although the ETIP team has been conservative in estimating the overall potential for LFG-based power generation, each individual project will need to be evaluated on its own merits through further technical and financial feasibility studies to arrive at a more realistic assessment of the power generation potential based on LFG recovery.

The five best prospect projects selected as part of this study represent an overall potential for LFG-based power generation in the range of 43-50 MW. These projects have the best potential for being realized. However, they also face the same policy, institutional, financial, and economic barriers as the rest of the landfill projects. The total potential investment required for these best prospect projects will range from US $51.6 million to US $60 million for the power generation facilities alone.

Effective management of the nation's municipal solid waste landfills offers Brazil significant opportunities for environmental, health, and economic benefits. Methane is 20-30 times more potent than CO_2 and thus has more adverse health effects. Furthermore, unrestrained flaring of LFG, as is prevalent in Brazil, increases the overall quantity of CO_2 in the atmosphere. Therefore, the extraction and utilization of methane from LFG will reduce the methane-related environmental effects as well as reduce the CO_2. In addition, the deployment of effective technologies and management procedures for waste disposal will result in a number of additional environmental and health benefits. These include a reduction in adverse health effects resulting from waste decomposition such as the emissions of harmful gases and the leakage of leachate into groundwater reservoirs. In addition, extraction and utilization of landfill gas will directly contribute to a reduction in CO_2 levels and thus a reduction in greenhouse gases. Hence, there is a net positive impact to Global Climate Change. It should be noted that the health benefits are especially significant to the large populations located in close proximity to many of the landfill sites in the country.

The integrated management of the landfill sites has the potential for resulting in both direct and indirect economic benefits to the Brazilian economy. The direct economic benefits include revenues from resource recovery and utilization. Specifically, the direct economic benefits include revenue generation from (i) sale of compost, (ii) use of on-site waste for incineration of hospital and other toxic waste (currently mostly contracted out), and (iii) utilization of landfill gas for generation of heat and/or electricity. All of these direct economic benefits will not only enhance the participation of the private sector but also reduce the fiscal burden on the state and municipal government which must otherwise bear all of the costs of landfill management under tight budgetary constraints.

The indirect economic benefits include the creation of private industry for composting, waste-to-energy production, recyclables separation, private concessions for the operation of the landfills, etc., all of which will create new employment in the private sector, greater economic activity in and around the landfill sites, and a more positive income distribution.

While a number of environmental and economic opportunities exist there are also a number of potential barriers to achieving the benefits represented by these opportunities. The primary barriers include (i) the existing institutional capacity, (ii) a lack of effective regulations, (iii) a lack of private sector participation, (iv) the perception of the private sector regarding risks associated with investments in waste management projects, and (v) the availability of attractive financing. The government's policies with respect to concessions and private ownership and operation of entities traditionally held under government control need to be well understood by the private sector. The process for enhancing the involvement of the private sector in the management of landfills needs to be rationalized and simplified. In addition, specifically designed fiscal and financial incentives may initially be needed for the private sector to participate in the management of municipal waste, an activity largely administered by the state and city governments.

Finally, the involvement by the private sector will increase the prospects for the utilization of new cleaner technologies for leachate treatment, resource recovery, composting, and waste-to-energy generation, all of which will not only result in environmental benefits but also in significant economic benefits for Brazil.

I. OVERVIEW OF THE BRAZILIAN ECONOMY

Brazil is the largest country in Latin America with its total territory encompassing 3.3 million square miles. The population of Brazil is 167 million inhabitants and is growing at an average annual rate of 1.93%. The country's Gross Domestic Product (GDP) per capita in 1996 was US $4,000 and the GDP growth rate in 1996 stood at 3 percent per year. The 1996 GDP of Brazil was approximately US $670 billion. The total Brazilian exports in 1996 were estimated at US $47.4 billion, whereas imports to the country stood at US $52 billion, creating an overall trade deficit of approximately US $5 billion. The total foreign debt of the country increased from US $157.4 billion in 1995 to US $160 billion in 1996.

At the sectoral level, the growth rates in 1995 included -- industry at 2%, agriculture at 4.9%, and services at 5.7%. New economic programs developed from 1990 onwards are re-directing the Brazilian economy toward macro-economic stabilization, privatization, deregulation and further liberalization of Brazil's foreign trade, with the aim of integrating Brazil into the growing world markets. Productivity, efficiency, technological innovation and higher quality of living standards are being stimulated under this new development model that fosters internal and external competition and encourages foreign investment into the country.

From the world's largest rain forest in the Amazon region to the State of São Paulo, which accounts for over 50% of Brazilian industrial output, to the significant mineral reserves, vast agribusiness complex, and the new high-tech industries, Brazil is well endowed with natural and human resources, has the most diversified industrial base among developing countries, and ranks as the tenth largest economy in the world. Over the last two decades, and especially since the mid 1980's, Federal, state, and local governments have been enacting laws and regulations and designing specific initiatives and programs to ensure that economic development remains compatible with the sustainability of the country's rich resource base, and with sound environmental quality. The regulatory reform process is continuously underway as Brazil is convinced that the key to its economic growth is through regulatory reform and increased private sector investment in those sectors and enterprises which have been traditionally owned and operated by the public sector.

In urban areas, 90 percent of the dwellings receive water and sewage service and have electrical power. However, in rural areas only 17 percent of the dwellings receive water and sewage service, and only approximately 55 percent have electrical power. There is approximately one installed telephone and one automobile for every ten Brazilians.

During the last half-century, the Brazilian population has aged. The fraction under 14 years of age has fallen from 43 percent to 34 percent, while the fraction over 60 years of age has risen from four percent to eight percent. Life expectancy at birth has increased from 46 years to 65 years. The literacy rate has increased from 50 percent to 77 percent. As more adults enter the work force, approximately 1,600,000 new jobs would have to be created each year to accommodate new, first-time job seekers. Accordingly, a cornerstone of the government's policies is to create new domestic jobs through private sector investments.

Brazil's exports represent 8.2 percent of its GDP of which industry accounts for about 37 percent, a pattern found in many developed countries. In 1994 the estimated labor force in Brazil was about 66 million people. Services account for approximately 59 percent of the work force, agriculture 13 percent, and industry 28 percent.

Brazil derives approximately 80 percent of its energy supply from renewable sources such as hydroelectricity and ethanol. It produces domestically about half of the oil it consumes. Brazil is one of the world's largest exporters of iron ore, and it is also a major exporter of steel. Other major raw materials produced in Brazil are petrochemicals, aluminum, non-ferrous metals, fertilizers, and cement. Major manufactured products include motor vehicles, aircraft, electrical and electronic appliances, textiles, garments, and footwear. The U.S., Germany, Switzerland, Japan, England, France, Argentina, Mexico, and Canada are Brazil's major trading partners.

A. COUNTRY ECONOMICS

Historically, Brazil was predominantly an agricultural based economy with timber, cane sugar, and other agricultural products industries being the main employers and contributors to the country's GDP. The industrialization of the Brazilian economy began in the 1940's, primarily after World War II. One of the earliest examples of assistance offered by the U.S. to Brazil was financing from the U.S. Export-Import Bank (Ex-IM Bank) for the construction of the country's first steel factory in Volta Redonda in the State of Rio de Janeiro. The industrialization process from the 1950's to the 1970's led to the expansion of important sectors of the economy such as the automobile industry, petrochemicals, and steel. The development of these sectors in the country led to the initiation of large infrastructure projects. During the decades of the 1950's, 1960's and 1970's, the Gross National Product (GNP) of the country continued to grow at an impressive rate. During the 1970's, Brazil received massive investments from the U.S., Japan and Western Europe, primarily for the development of large infrastructure projects. Also, a large number of state enterprises were created to manage the development of the Brazilian economy. This large influx of foreign capital was directly responsible for the growth of the Brazilian economy and the GDP growth rate of the country averaged at 8 percent per year between 1970 and 1980.

In the early 1980's, however, a sudden and substantial increase in interest rates in the world economy, coinciding with lower commodity prices, precipitated South America's debt crisis. Brazil was one of the hardest hit countries in South America and was forced to adhere to strict economic adjustment programs which resulted in a negative growth rate for the economy. At the same time, there was a sudden reduction in foreign investment in the country and the country's debt continued to increase. In 1987, for the first time, Brazil was unable to service its foreign debts and a number of large projects were suspended. Until the late 1980's, Brazil implemented restrictive economic policies aimed at import substitution as its principal strategy for economic growth. This policy restricted the import of manufactured products from abroad and protected its domestic industry from foreign competition.

In the early 1990's, in direct contrast to the protective policies of the 1980's, Brazil's economic development strategy included three main objectives: (i) economic stabilization; (ii) moving the country away from protectionism toward a more open, market-driven economy; and (iii) normalizing relations with the international financial community. With respect to the first objective, economic stabilization, the country has followed a strict fiscal discipline, adopted tax reforms and measures to enforce tax compliance, carried out programs of deregulation and privatization, reduced and eventually eliminated all price controls and established a true market-based economy.

With respect to the second and third objectives, the government has opened virtually all sectors of the economy to foreign participation and the emphasis continues to be on the development of a private sector led economy. In 1994, for the first time, Brazil adopted limits to the issuance of its currency and introduced the Real as its new currency linked to international currencies. With the introduction of an internationally tradeable currency, the country's annual inflation rate fell drastically and was brought under control in 1994. Simultaneously, Brazil introduced comprehensive trade reform policies, especially tariff reform, which reduced average tariffs on imported goods from 32 percent in 1990 to 14 percent in 1993. The maximum tariff of 105 percent, for example, was reduced to 35 percent. Moreover, all quantitative restrictions to trade were eliminated, making Brazil one of the very few countries in the world with no quantitative barriers to imports. For example, a government program that reserved the Brazilian market for Brazilian electronic and software products to only domestic participation was abolished.

These policies provided strong signals to the international markets of the country's commitment to implementing economic reform, trade liberalization, and private sector investment. Consequently, Brazil was able to renegotiate all of its debt service agreements with foreign creditors, and clear the way for new additional investments in all sectors of the economy. As a result of the government's new policies, the foreign portfolio investment has increased from US $760 million in 1991 to US $22.6 billion in 1995. During the same period, foreign direct investment increased from US $700 million to US $3.3 billion.

One of the main problems in Brazil continues to be the availability of an adequately trained workforce needed to implement economic growth. The vastness of the country further creates regional disparity with respect to the availability of skilled and semi-skilled workers. The unemployment rate in the country has been declining in recent years and in 1994, the unemployment rate stood at 6.15 percent in the manufacturing sector, 6.0 percent in the construction sector, and 3.84 percent in the services sector. However, the country continues to face sporadic labor strikes and wage and salary disputes, creating loss of worker productivity and corporate profits. Labor unions have been organized in most sectors of the economy and the government has created regulatory and judicial institutions for resolving labor related disputes. The Ministry of Labor is currently developing labor law reforms to facilitate direct labor-management negotiations and to deregulate and limit the labor courts rule-making authority.

B. TRADE AND EXPORTS

Brazil, being the largest economy in Latin America, offers significant export opportunities and is a major trading partner of the U.S. The Divisao de Informacao Comercial, Ministerio das Relacoes Exteriores, Brazil has estimated the overall trade in 1995, 1996, and 1997 as follows:

TRADE IN US $ Millions FOB
(valued at current prices)

	1995	1996 (Est.)	1997 (Est.)
Total Brazilian Exports	46,506	47,436	48,384
Total Brazilian Imports	49,663	52,062	54,665
Exports to U.S.	8,798	8,855	9,032
Imports from U.S.	11,873	12,466	12,839

Source: Divisao de Informacao Comercial, Ministerio das Relacoes Exteriores, Brazil

During 1995-1997, the U.S. share of Brazilian imports is in the range of 23-24 percent of total imports and the U.S. has an average trade surplus of approximately US $3.6 billion.

In 1995, the U.S. trade surplus with Brazil was approximately US $3.1 billion, which was approximately six times the trade surplus in 1994. Also, U.S. exports to Brazil in 1995 totaled US $12 billion, an increase of 55% from the level of exports in 1994. Brazil was the United State's fourteenth largest export market in 1995. In response to the continued trade deficit, in 1995, the government significantly increased import tariffs on a number of consumer goods. These measures are viewed to be temporary and are not indicative of any impending change in Brazil's otherwise liberal trade policy.

The principal growth sectors in the Brazilian economy are industry, agriculture, mining and minerals, transportation, telecommunications, and manufactured goods. The best prospects for U.S. exports and investments in the non-agricultural sector of the Brazilian economy in 1997 include the telecommunications sector, estimated to have a market size of approximately of US $8 billion; the computer hardware and products sector, estimated to have a total market size of US $5 billion; medical equipment and supplies, estimated to have a total market size of US $1 billion; electric power systems and equipment with an estimated market size of US $2.2 billion; petroleum machinery and equipment, with an estimated market size of US $4.4 billion; pollution control equipment, with an estimated total market size of US $400 million; processed food, with a total estimated market size of US $53.3 billion; transportation equipment, with a total estimated market size of US $1.5 billion; and mining industry equipment, estimated to have a total market size of US $3.2 billion. Other sectors which represent potential export opportunities include plastic machinery, agricultural equipment, food processing and packaging equipment, aircraft and parts, automotive parts and service equipment, and cosmetics and other consumer goods. In the agricultural sector, significant opportunities exist for U.S. exports of beer, pet food, and processed food.

The principal export products from Brazil, as estimated for 1997, include medical equipment and supplies (US $230 million), electric power systems (US $275 million), oil and gas machinery and equipment (US $120 million), pollution control equipment (US $42 million), computer software (US $60 million), processed foods (US $7.6 billion), machine tools (US $102 million), mining industry equipment (US $310 million), plastics production machinery (US $30 million), agricultural equipment (US $380 million), food processing equipment (US $69 million), aircraft and parts (US $387 million), cosmetics and toiletries (US $42 million), and apparel (US $550 million). Among these, the best Brazilian exports are in the agricultural equipment, food processing and packaging equipment, apparel sector and processed food sectors where Brazil continues to enjoy sizeable trade surpluses.

Although Brazil maintained strict barriers to U.S. exports and investment throughout the 1980's, beginning in 1990 it has demonstrated impressive progress in reducing trade barriers to permit the importation of U.S. products and services, as evidenced by the continued increase in U.S. exports to Brazil. Some of the measures implemented by the government include liberalization of tariffs, rationalization of the import licensing process, and a reduction of arbitrary quotas. Some barriers to U.S. agricultural products continue to exist mainly due to sanitary and phytosanitary concerns. As such, items such as meats treated with hormones, are currently not imported by Brazil.

On March 26, 1991, the Southern Common Market (MERCOSUL) was created when Brazil, Argentina, Paraguay, and Uruguay signed the Treaty of Asunción. The trade pact took effect as a customs union and partial free-trade zone on January, 1995. The aim of MERCOSUL is to allow for the free movement of capital, labor, and services among the four countries. Since 1991, trade among the MERCOSUL countries has more than doubled. Brazil's trade with the MERCOSUL countries reached US $10.6 billion in 1994, up from US $3.6 billion in 1990. As part of Brazil's MERCOSUL's implementation efforts, Brazilian phytosanitary regulations are currently being revised for several agricultural products.

Historically, Brazil has used tariffs as the primary method for regulating foreign imports. In 1994, the average tariff on imported products was 11.3%, significantly less than the 32% level in 1990. Although, in response to an import surge and continued trade deficit, the government significantly raised import tariffs on a number of consumer goods (reaching as high as 70% on some products), these tariffs are expected to be consistent with the MERCOSUL common external tariffs in the near future. It should be noted that the tariff increase by the government on consumer goods did not effect capital goods which constitute approximately 40 percent of U.S. exports to Brazil. The U.S. and Brazil continue to have bilateral negotiations subsequent to the 1991 trade and investment framework agreement between the two countries with the objective of tariff reductions on products which will benefit U.S. industries' export opportunities.

The government of Brazil, including the state and municipal governments, still continue to implement tight procurement policies with the focus on procuring goods and services from Brazilian sources. Although Brazil follows the international competitive bidding procedures (ICB) on all donor financed projects, many of the state enterprises routinely issue tenders open only to Brazilian firms. This restrictive policy offers a significant barrier to U.S. exports in key sectors such as telecommunications, computer equipment, and computer software. In 1995, under pressure from international donors, Brazil passed a law eliminating the distinction between foreign and national capital and opening the state telecommunications, petroleum, and natural gas distribution companies to private, including foreign, participation. While this law greatly helps foreign firms with a presence in Brazil which usually receive preferential treatment in government procurements, it does not help those U.S. firms desiring an entry into the Brazilian market. The U.S. government continues to pressure the Brazilian government for adoption of competitive procurement procedures and the elimination of any policies or procedures which favor domestic producers.

Although many of Brazil's statutes on intellectual property rights are consistent with western standards and Brazil is a member of all key international organizations protecting intellectual property rights, there continue to be many violations of intellectual property rights in the country. In response to the continued proliferation of these violations, the government passed a law to be implemented in May 1997 which is expected to protect patents, trademarks, and trade secrets, thereby enhancing the confidence of foreign industry in the Brazilian market.

Other potential barriers to trade and exports include market access barriers (e.g. the computer software market), service barriers (e.g. arbitrary procedures), and a number of investment barriers which continue to be present. Some of these investment barriers include the following:

1. Prohibition of foreign ownership of land in rural areas and areas adjacent to international borders;

2. Limited foreign equity participation and unusually high local content requirements;

3. Linking foreign equity participation to export performance requirements (e.g. computer and digital electronics sector, automotive sector);

4. Total restriction on foreign majority participation in mining and health care projects; and

5. Discriminatory procurement practices which favor Brazilian firms and foreign firms with facilities in Brazil over foreign firms.

Many of these restrictions are in the process of being eliminated through constitutional amendments which were passed in 1995 and are awaiting implementation.

C. INVESTMENT POLICIES

1. General Investment Climate

In 1995, the Brazilian congress approved constitutional amendments to eliminate the distinction between foreign and national capital. Most foreign investment in the country is governed by the Foreign Capital Law, passed in 1962, and several subsequent amendments. Since 1991, foreign nationals are permitted to invest in the Brazilian stock market as a result of which the foreign portfolio investment in Brazil increased from US $760 million in 1991 to US $22.6 billion in 1995. In 1995, the government passed several constitutional amendments which have opened traditionally closed sectors to foreign investment and partial ownerships. Some of the sectors where foreign investment is permitted include the petroleum, mining, power generation, telecommunications, and transportation sectors. In addition, the government has announced plans to open the health care and banking sectors for foreign participation as well. However, despite the government's policies, foreign investment in the major state-owned enterprises continues to be very political and many monopolies are opposed to such foreign investments. Despite the government's commitment to an open market policy, discriminatory local production and assembly requirements for government procurements continue to exist in the telecommunications, computers, and electronics industries. In addition, government regulations introduced in 1993 permit the state procurement agencies to implement non-price factors in tender evaluation. The government has set specific performance requirements to be used as the basis to evaluate offers for procurement of goods and services. These requirements include local employment generation, value added to the economy, local industry development, regional economic development, etc.

The government provides a number of investment incentives which are typically offered by the state and municipal governments and the federal government administers incentives for certain export production, investment in underdeveloped areas and export promotion zones. The incentives typically offered by the state and municipal governments include tax holidays, tax reduction for greenfield investments and expansions leading to local income generation and employment.

In the area of profit, royalties, and conversion and transfer of capital, there are few restrictions as per the government policies. However, the Central Bank of Brazil tightly controls all transactions in and out of the country and has broad administrative authority in regulating the transfer of funds and remittances. The current policies of the government permit foreign investors to convert Brazilian currency at commercial or at floating rates. All investments involving royalties, franchises and technology transfer must be registered with the National Institute of Industry Property (INPI) as well as with the Central Bank Foreign Capital Registration and Supervision Office (FIRCE). All foreign investors are permitted to repatriate dividends, capital, and royalties after all applicable Brazilian taxes have been paid.

Prior to 1991, the government, through the Central Bank, exercised severe controls on loan payments by private investors to foreign entities, remittance of royalties, repatriation of capital and dividends, etc. However, the government has relaxed many of the requirements and restrictions during the last five years which has boosted foreign investment in the country.

Other legal and regulatory requirements on all foreign investors such as taxes, expropriation and compensation, performance requirements, etc. are under review by the government with the objective of rationalizing them and simplifying procedural requirements to facilitate even greater foreign investment in the country.

2. Brazil's Privatization Program

One of the most significant actions taken by the government of Brazil during the last four years is the promulgation of a policy aimed at privatization of its state-owned enterprises. The current policies of the government permit private sector equity investments and capitalization of its major state enterprises. The most significant law passed by the government is the Concession Law (Law No. 9.074) under Article 84, Item IV of the Brazilian Constitution. The Concession Law, passed in July 1995, permits the private sector to invest in and operate state enterprises which were traditionally owned and operated by the Federal, state, and municipal governments. As a result of the passage of this law, a number of foreign and Brazilian investors have approached the government with specific proposals for concessions for water, sewerage, and industrial waste projects. This law also permits independent power producers (IPPs) to generate and sell electricity to the electric utilities. In 1996, the government published the regulations for IPPs which describe the various provisions of the Law and the regulatory procedures for private power generation.

The privatization program is an integral part of the reform of the Brazilian economy. Its principal objectives are to (i) achieve a lasting fiscal adjustment, (ii) reduce government debt, (iii) concentrate government activities on the social area, (iv) stimulate industry's modernization, and (iv) strengthen capital markets by broadening their popular base. The government has promoted the sale of state-owned enterprises in the industrial sector. The initial candidates slated for privatization are steel, petrochemical and fertilizer companies. The National Privatization Program (PND), as it is referred to within the Brazilian government, has so far resulted in generating US $ 8.2 billion from auctions and US $ 400 million from the sale of government minority corporate shares in state holdings. In addition, a number of private investors have collectively pledged to assume government loans in the amount of US $ 3.2 billion. The key benefits from the privatization program include the following: (i) increased investment for the modernization, rehabilitation, expansion, and operation of state-owned enterprises, thereby reducing the pressure on the already tight Federal and state budgets, (ii) increases in tax revenues collected by the government on new private sector investments, (iii) new employment opportunities in the private sector, and (iv) gains in efficiency and worker productivity in key sectors of the economy.

The government has created a cabinet level organization -- the National Council on Privatization (CND) -- reporting directly to the President, which has the responsibility to make all major decisions to implement the government's privatization program. This new entity expands the scope of the PND and streamlines the decision implementation process as the members of the Council will also be the officials responsible for the implementation process for the privatization of the state enterprises linked to their respective ministries. One of the earliest decisions taken by CND was to begin the privatization of the country's petrochemical sector. In addition, the CND has initiated specific projects for the privatization of the power sector, the national railroad and the banking sector.

Other key decisions taken by the CND include (i) the implementation of a full privatization of the petrochemical sector in 1995, including Copene and fourteen minority participations; (ii) privatization of Escelsa, the Espírito Santo electric distribution company; (iii) privatization of the power sector including the Rio de Janeiro electric distribution company; (iv) initiating the privatization of financial institutions with the Banco Meridional as the first candidate; (v) privatizing the cargo railway sector by permitting the Federal Railroad System (RFFSA) to grant concessions for private-sector operation; (vi) permitting foreign investors to participate in the privatization of the country's banks; and (vii) initiating the process to privatize Companhia Vale do Rio Doce.

The planned sale of the large electric distribution companies, LIGHT and ESCELSA, and of the concession of cargo transportation services, mark a new phase in the privatization program. This phase establishes the regulatory framework essential for the proper development of these activities. In ending its role as a producer, the government will not be neglecting its basic obligations, but rather will be focusing on its role as a regulator.

The CND is actively encouraging potential foreign and domestic investors to become partners with the government in making investments for the rehabilitation and modernization of existing state enterprises as well as the construction of new facilities wholly financed by the private sector. The key sectors which are open for private sector investments include the power sector (generation, transmission and distribution), the communications sector (local, long distance, and international calling), and the transportation sector (railroads, toll roads and expressways, bridges, etc.).

One of the success stories of the government's privatization program is the steel sector. During the last four decades, the Brazilian government invested over US $25 billion in its steel sector, with an estimated dividend payment of only US $600 million. During the last four years, the government privatized eight of its steel plants, all of which are now partially owned and operated by the private sector. This privatization not only resulted in private sector investments but also significantly improved plant efficiency, increased worker productivity, and generated US $150 million in dividends in 1993 alone. The government effectively generated a total of US $10.6 billion during this privatization process of which US $5.5 billion was raised from the sale of shares, US $2.6 billion of existing debt was assumed by the new owners, and new investments in the order of US $2.5 billion are planned by the private sector. Government estimates indicate that approximately 2,500 new jobs were created in the steel sector as a result of this privatization. The success of the privatization of the steel sector has demonstrated to both the government and the private sector the obvious benefits to the economy that can be harnessed through the privatization process. It has also demonstrated to the private sector the government's firm commitment to facilitate and protect private sector investments in the country.

During the first five years of the privatization program, initially begun in 1991, the government identified thirty four state owned companies and thirty two state held companies with a minority share by the state for its first stage privatization program. For example, the sale of Usiminas alone, in 1991, generated twice the revenues of all prior privatization initiatives. Many of these state holdings are undergoing rapid privatization through foreign equity investments and sales of shares by the government.

In order to accelerate the privatization program, the government has taken additional regulatory steps which permit the following:

(i) the wider use of Federal Treasury debts as privatization currency,

(ii) the sale of the State's minority company ownerships, and

(iii) 100% foreign equity investment and ownership of selected state enterprises.

As a result, in 1994, the privatization program generated receipts of US $2 billion, of which over 70% was in direct cash transfer to the government. This was used by the government to service some of its outstanding debts. The success of the government's privatization program is further demonstrated by the fact that approximately 90 percent of all the cash received by the government through the privatization of selected enterprises was generated in the year 1994 alone.

In 1995, the government initiated the privatization of ESCELSA, the electricity distribution company in the State of Espírito Santo. The government sold 50 percent of the company's shares which generated approximately US $390 million, two thirds of which were received by the government in cash payments. Currently, the government is initiating the privatization of LIGHT, another state owned power distribution company. Other entities slated for near term privatization include the various companies owned and operated by ELECTROBRAS such as FURNAS, CHEFS, ELETROSUL and ELETRONORTE.

A quick summary of the success of the government's privatization program is provided in Table I-1 below:

TABLE I-1: STATUS OF BRAZIL'S PRIVATIZATION PROGRAM

PERIOD	NUMBER OF COMPANIES PRIVATIZED	AMOUNT RECEIVED IN CASH (US$ MILLION)	TOTAL RECEIPTS (US$ MILLION)
1990-92	15	16	3,494
1992-94	18	1,581	5,113
1995-	2	284	642
TOTAL	**35**	**1,881**	**9,249**

Source: Superintendent of Privatization, BNDES

There are a number of other privatization projects that have taken place during part of 1995 and 1996 for which data are being currently compiled by the government. The government estimates that it will affect privatization in the range of approximately US $25-50 billion during the next four years.

The privatization of public financing institutions constitutes one of the program's new frontiers. It is slated to begin with the sale of the Meridional, a bank which operates principally in the south. Following the federal government's example, some states, such as Minas Gerais and Ceará, are working to privatize their financial sectors. Having successfully privatized the steel and fertilizer sectors, the CND is planning to complete the privatization of the petrochemical sector and the infrastructure sector, especially the transport and communications sectors.

Together with the privatization program, the Concessions Law will permit the private sector to offer public services on behalf of the State, using assets that will revert to the public sector. This law will benefit directly the power sector, transportation, highway construction, ports and airports, basic sanitation, and water supply.

II. OVERVIEW OF THE ENVIRONMENTAL SECTOR

A. SECTOR BACKGROUND AND KEY ISSUES

Brazil has a comprehensive legal, regulatory, and institutional framework for the protection of its considerable natural resources and for the management of its environment. The cornerstone of Brazil's environmental policy is detailed in the country's 1981 National Environment Policy Act (NEPA). The guiding principles that led to the enactment of the NEPA are as follows:

1. the protection of Brazil's environment for present and future generations is a common responsibility of the State and the community;

2. every citizen is entitled to a sound environment and to participate in the environmental management process;

3. property rights and economic activities must be consistent with, and not detrimental to, the protection of the environment;

4. the federal government shall (1) set standards for environmental quality, (2) issue rules regulating the granting of permits for activities that may pollute or harm the ecosystems where they are carried, and (3) define conservation strategies for the main Brazilian ecosystems (considered "national heritage" under the Constitution); it shall also plan, coordinate and monitor the implementation of the Brazilian Environmental Policy; and

5. state and local governments will have broad regulatory autonomy on matters related to environmental protection and environmental quality initiatives, within the limits set forth by the constitutional provisions and federal legislation in force; most environmental monitoring and licensing activities rest with state and local governments, except when otherwise provided for in the specific legislation.

1. Environmental Regulatory Framework

The regulatory framework for the protection of the environment is provided in article 225 of the Federal Constitution of 1988, which ensures that the development of Brazil is consistent with a healthy environment. The key federal legislation in the environmental sector is Law No. 6938, and its subsequent amendments -- Laws Nos. 7804, of 07.18.1989, and 8.028. Together, these laws govern the country's environmental policies. At the federal level, planning and coordination responsibilities for all environmental issues is under the jurisdiction of the Ministry of Environment and Amazon Affairs. The National Council for the Environment (CONAMA), a consultative body, acts as the executive agency for the implementation of the government's environmental policies. CONAMA includes representatives from the federal, state and local agencies, as well as from the private sector and non-governmental organizations (NGOs). CONAMA's key responsibility is to develop basic guidelines for environmental protection and regulations for the preparation of environmental impact assessments and reports. The Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) works closely with CONAMA in a number of areas, especially assessing the impact of national development strategies on the environment. IBAMA often makes specific recommendations to CONAMA for the promulgation of new environmental policies and standards.

In addition, there are other laws which regulate activities which may adversely affect the country's environment. These include (i) Law No. 6803 which regulates the industrial zoning in critically polluted areas, and (ii) Law No. 7347 which establishes the judicial procedure necessary to assess the liability for environmental damages.

At the state level, for example in the State of São Paulo which is the most industrially developed state in the country, environmental protection is regulated by articles 191 to 216 of the State Constitution and, in general, by State Law No. 997 and its amendment, Law No. 1874. The State Council for the Environment (COEMA) is the key body responsible for the implementation of state environmental policies and programs. The State Secretariat for the Environment (SMA) acts as the executing agency for many of the environmental programs in the State. The procedure for the implementation of projects in São Paulo includes the publishing of the project objectives in the State Official Gazette. All project sponsors are required to apply and obtain a number of permits before commencing the project, including a license for the project which is issued by the Basic Sanitation Technology and Water Pollution Control (CETESB), a state regulatory agency. All projects requiring new construction or expansion of an existing facility are required to obtain a permit from the State of São Paulo on the basis of an Environmental Impact Assessment (EIA), which is required for all projects.

The existing environmental policies within the state government permit state agencies to levy penalties in cases of environmental violations. Also, the State may use its authority to shut down or interrupt the operation of facilities which are in violation of applicable environmental laws and regulations. The State has also used the denial of fiscal and financial incentives as a tool to ensure compliance of environmental standards. The judicial process for resolving disputes, enforcing fines and sanctions, and affecting compliance is in place. Similar environmental policies and programs exist in other states in the country to varying degrees.

The government of Brazil is committed to the protection of its natural resources and the management of its land, water, and air. A number of Federal laws and decrees have been promulgated by the government for regulating forestry activities, protection of flora and fauna, promotion of fisheries, and controlled use of fertilizers, pesticides and chemicals to minimize their impact upon the environment. There are federal standards for water quality, water management, air quality, emissions from automotive vehicles and pollution of the marine environment.

With respect to the conversation and the sustainable use of its resources, Brazil has developed a comprehensive resource conservation policy which includes (i) maintenance of essential ecological processes and living systems, (ii) protection of the genetic diversity of Brazilian ecosystems, and (iii) sustainable use of species within a given ecosystem. In order to ensure the conservation of resources and the protection of species, Brazil has recently completed the first phase of the ecological zoning of the Amazon, which is being expanded to the state level.

Given the rapid industrial development in the country during the last three decades which utilized energy intensive technologies and inexpensive natural resources and labor, the government is faced with shifting to newer cleaner technologies in order to protect the environment. The Ministry of Environment has developed a national environmental protection plan and in conjunction with the Ministry of Science and Technology, is actively pursuing the desirability of "green farming" and environmentally sound agricultural practices. Also, given the considerable growth in the mining sector in the country, the government is actively considering revising its environmental pollution standards to ensure that the industrial, agricultural, and mining activities proceed in a balanced manner while protecting the environment.

In the agricultural sector, which continues to grow rapidly, the country has faced severe problems such as soil degradation, water pollution, and pesticide imbalances. Accordingly, the government is developing new standards as well as the introduction of biocides, new generation agrotoxins, and environmentally sound irrigation techniques. In the industrial sector, the chemicals, petrochemicals, steel, pulp and paper, and utility industries, are some of the largest polluters of the environment. At the same time, their growth is essential to the economic development of the country as they contribute significantly to the nation's GDP and are major employers in the economy. Although environmentally sound technologies are available for potential applications in all these sectors, the development of these industries in the past has largely been with little or no regard to the environment. However, the current legal requirements, as well as the government's ability to enforce environmental standards, have been given considerable impetus to the utilization of environmentally sound technologies.

The backbone of Brazil's rapid industrial development has been the abundant availability of relatively inexpensive renewable energy. Close to 80% of Brazil's total energy comes from renewable sources, mainly, hydroelectric dams and bagasse based power generation and ethanol production. IBAMA has introduced a comprehensive permitting process as a way to ensure that the development of any new energy generation facility utilizes environmentally clean technologies and complies with all applicable environmental regulations.

2. International Cooperation on Global Climate Change (GCC)

Brazil is a party to various international legal agreements adopted in recent years to protect the global environment: the Basel Convention on Transboundary Movements of Hazardous Wastes, the Montreal Protocol on the Protection of the Ozone Layer, the Biodiversity and the Climate Change Conventions. Accordingly, it complies with specific provisions of each agreement such as inventories of greenhouse gas emissions, or of CFC production and consumption, etc.

Being the first signatory of the United Nation's Framework Convention on Climate Change at the June 1992 United Nations Conference on Environment and Development (known as the Rio "Earth Summit"), Brazil has maintained a commitment to address climate change issues in the years that have followed. Brazil has attended and actively participated in the Conferences of Parties on climate change which were brought about as a result of the Rio Summit and the Climate Change Convention following the the Summit. The Convention was ratified by the Brazilian Congress in February 1994 and was enacted in May of the same year.

As a signatory of the Convention, Brazil committed itself to produce and periodically update a "National Communication" which is an inventory of emissions by sources and removals by "sinks" (repositories) of all greenhouse gases (GHGs) not controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol requires an inventory of chloroflourocarbon emissions by source. Brazil's Communication consists of two main chapters. The first is a comprehensive inventory of emissions in the energy, industry, forestry and land use, agriculture and livestock, and waste treatment sectors, and the second is a description of those actions being taken by Brazil to implement the Convention. The Convention is being implemented through the guidance of the Brazilian Ministry of Science and Technology and in coordination with more than 60 institutions in both the public and private sectors. These include the United Nations Development Program (UNDP), the Global Environment Facility (GEF), and the United States' Country Studies Program through the United States' Initiative for Climate Change. The numerous establishments within Brazil that are involved in environmental activities include such diverse organizations as the Brazilian National Institute for Space Research (INPE), the Brazilian Power Sector Holding Company (ELECTROBRAS), the Brazilian Oil and Natural Gas Company (PETROBRAS), the Cooperative of Sugar Cane, Sugar and Alcohol Producers (COPERSUCAR), the Brazilian Foundation for Sustainable Development (FBDS), and the National Institute for Energy Efficiency (INEE).

Brazil has furthermore established within its National Institute for Space Research a Center for Weather Prediction and Climate Research with the ability to do climate modeling to better understand the complexities of GHG effects. Brazil is the host of the Inter-American Center for Global Change Research in San Jose dos Campos.

Brazil and the United States are also part of a Common Agenda for the Environment which is intended as a framework for policy discussions and cooperation between the two countries. The objectives of the Common Agenda include: (i) exchanging ideas and information on such issues as Global Climate Change, desertification and depletion of the ozone layer, etc., (ii) cooperation on strategies for conservation and sustainable development of resources, (iii) cooperation on environmentally sound technologies and practices and their applications in the energy sector, and (iv) the exchange of science and technology to address common environmental problems.

3. Greehouse Gases and Global Climate Change

Global Warming or Global Climate Change (GCC) is a problem of particular concern to Brazil because of both domestic and international concerns that deforestation in its Amazon region might lead to GCC. Many of these concerns were discussed in the Rio Earth Summit by numerous international bodies. The Earth's atmosphere is primarily made up of nitrogen (78.1%) and oxygen (21%) but it is the lessor remaining one percent of the atmosphere which is of concern. It is these lessor components of the earth's atmosphere that are commonly referred to as greenhouse gases (GHGs) due to their tendencies to trap heat. The GHGs include, but are not limited to, carbon dioxide (CO2), water vapor, methane (CH4), chloroflourocarbons (CFCs) and ozone, which are directly responsible for GCC.

The GHGs allow short-wave solar energy to radiate to the Earth's surface where it is converted into heat energy which heats the Earth's surface. The Earth's heated surface then becomes a radiator of long-wave or infrared heat energy which is radiated back towards space. Most of this long-wave heat energy is absorbed however by the GHGs within the atmosphere thus adding the heat to the atmospheric system. The warm GHGs then re-radiate the trapped heat back towards the ground which further heats the Earth's surface. The heated surface of the Earth radiates the long-wave heat once again into to the atmosphere. The cycle is repeated until no more infrared heat energy is available for absorption by the Earth's surface. The action of the GHGs is similar to the action of greenhouse glass when it traps radiant heat energy within a greenhouse. Thus, the greenhouse effect results in the retention of heat energy by the atmosphere and the surface of the Earth.

The fear for GCC is that increases of the GHGs in the atmosphere will lead to a gradual warming of the earth causing severe environmental repercussions such as a long-term melting of the ice caps leading to higher sea levels and flooding of coastal lowlands.

The most common GHG is water vapor which on average constitutes 0-4% of the atmosphere. Fortunately, levels of water vapor in the lower atmosphere are not directly determined by human activity. They are instead determined by the natural cycle of evaporation and rainfall, so the addition of water vapor to the lower atmosphere is not much cause for alarm. On the other hand, Carbon Dioxide (CO2) -- the "natural" level of which averages about 0.3% of the atmosphere -- is affected by human activity. The Brazilian deforestation of the Amazon, a natural sink of CO2, has become a cause of concern both to the Brazilian government and the international community. The effects of deforestation on the atmospheric quantities of CO2 are hard to quantify, but "extra," above normal levels of CO2 have been measured in the atmosphere, equaling roughly 49% of the "extra" greenhouse gases.

Another concern for GCC is the amount of time the GHGs remain in the atmosphere or the "life-cycle" of the gases. This is important because it determines how much extra heat these gases will trap before they are removed from the atmosphere. For naturally occurring gases such as CH4 and CO2 the process of removal from the heat cycle is usually through reuse by another biological process. Therefore, these GHGs have relatively short estimated life-cycles of roughly ten years each. CFCs, alternatively, are man-made molecules with no natural biological processes to break them down. Thus, the life-cycles for CFCs tend be of longer duration averaging roughly 60-100 years in the atmosphere.

The effects of GHGs on GCC are further complicated by the way in which these gases interact with each other. CFCs destroy another GHG, ozone, in the upper atmosphere which to some extent mitigates the effect of CFCs on GCC. The process which destroys methane, on the other hand, also produces water vapor. Thus, though methane is no longer in the atmosphere retaining heat, it is replaced by another GHG. And, though water vapor may not be too large of a concern in the lower atmosphere, when these actions occur in the upper atmosphere the results are less certain. It may well be the case that methane's affect as a GHG could be 5-40% greater than presently supposed. Therefore, there continues to be a strong focus on addressing environmental issues in Brazil.

4. Environmental Market and Financing

The international financial community is closely working with the Brazilian government in identifying and financing key environmental projects to ensure that the country's industrial development is consistent with sound environmental practices. The government has received numerous technical assistance grants from bilateral assistance agencies and a number of loans, totaling US $5 billion, for the implementation of key environmental projects. In addition, the Brazilian National Development Bank (BNDES) has invested more than US $1 billion on environmentally friendly projects sponsored by the private sector. The U.S. Export-Import Bank guarantees both working capital loans for U.S. exporters and the repayment of loans by foreign purchasers of U.S. goods and services. The EX-IM Bank also provides credit insurance that protects U.S. exporters against the risks of non-payment by foreign buyers for political or commercial reasons and is open in Brazil for financing of environmentally friendly projects.

Given the country's rapid industrialization, its vast resources, and the expansion and diversification of its energy sector, Brazil offers an enormous market for U.S. environmental technologies, goods, and services. The U.S. Department of Commerce has estimated a market for environmental technologies and services in Brazil in the range of approximately US $1 billion per year. In addition, conservative estimates indicate that the total environmental market in Brazil could be as high as US $20 billion, a little over 5% of the country's GDP, in the near term.

Some of the best prospects for U.S. firms in the Brazilian market include wastewater treatment technologies and equipment, centrifuges, conveyors, dryers, filters, shredders, separators, incinerators, heavy metal treatment technologies, air pollution control and monitoring equipment, landfill gas recovery technologies, and soil remediation technologies.

B. URBAN ENVIRONMENT

The rapid industrialization of Brazil has resulted in an alarming increase in the urban population of the country. Large cities such as São Paulo, have a daytime population which is as much as 25 percent greater than the fixed population of the city, predominantly due to daily migrant workers to take advantage of enhanced employment opportunities in the city. There has been a steady migration of workers from the rural areas to the major cities over the last three decades. Currently, over 75% of Brazil's population resides in its main urban cities. This influx of population from the rural to the urban areas has created severe demands on the cities' infrastructure, energy supply, and municipal services. With increased employment opportunities, an enhanced quality of life, and greater disposable income, the urban population in Brazil is showing characteristics typical of other major metropolitan areas in the world which include greater consumption of water and energy, enhanced use of transportation and communication facilities, and enhanced generation of municipal solid waste. In addition, the location of large industrial facilities in and around major cities is generating ever increasing quantities of industrial wastes. Therefore, among many of its responsibilities, the Federal government, states, and municipalities are faced with a major challenge for the collection, recycling, and disposal of both municipal and industrial wastes.

Recycling experiments are being introduced in a number of cities. Also, many city governments are actively implementing sewage and wastewater treatment projects as well as sanitation and cleanup initiatives. Many urban homes have a waste collection service on an ongoing basis, and huge open-air landfills are still the final destination of most of the collected waste, including hazardous substances. Some of the cities are also experimenting with composting of municipal waste and incineration of hazardous, toxic, and medical wastes.

The U.S. Department of Commerce has estimated that the Brazilian market for sewage and wastewater sanitation was US $130 million in 1992, and currently the market may be as high as US $400 million. Several Brazilian states are now launching major sanitation and clean-up initiatives, most of which will eventually be partially financed by multilateral financial institutions -- the World Bank and Inter-American Development Bank (IDB). The States of São Paulo and Rio de Janeiro are already in the contracting phase of the multi-year Tietê River and Guanabara Bay clean-up projects, which will involve the purchase and installation of wastewater and sewage treatment systems for the two largest urban and industrial areas in Brazil. The total investment required for these projects is estimated at US $2.6 billion and US $800 million, respectively. The Tietê-Paraná waterway project, running through the most important grain-producing region and the largest industrial development area in Brazil, has an environmental component of US $200 million and an energy generation component, focusing on "alternative" sources, estimated at US $4.2 billion. The states of Rio Grande do Sul, Bahia, Pernambuco, Paraná and Santa Catarina are also building sewage cleaning plants and installing or expanding sewage collection networks, with a total estimated investment of US $700 million, financed primarily by the IDB. The States of Ceará, Pará and Amazonas have proposed several sanitation projects with an estimated investment requirement of US $300 million for consideration by the IDB.

In addition to the projects sponsored by the public sector, the Concession Law has cleared the way for private sector environmental projects which will also require massive private sector investment. Private companies in Brazil are increasing investments in pre-treatment processes and waste management systems at their own initiative to comply with new environmental requirements. In addition, smaller towns, unable to finance the considerable investment required to install water and sewage treatment systems and municipal waste management technologies, are looking to signing contracts with private companies for the development and/or provision of these services under the Concession Law.

C. MUNICIPAL SOLID WASTE MANAGEMENT

Approximately 75% of Brazil's population lives in the country's major cities. The country has a total of 4,974 municipalities. The number of municipalities having less than 20,000 inhabitants is 3,611 or 72.6 percent and have a total population of approximately 23 million. Twenty one of the largest municipalities, with population greater than 600,000 inhabitants, have a combined population of approximately 34 million. The Table II-1 below shows the distribution of the municipalities by population:

TABLE II-1: DISTRIBUTION OF MUNICIPALITIES IN BRAZIL BY POPULATION

POPULATION	NUMBER OF MUNICIPALITIES	PERCENT OF TOTAL
Less than 20,000	3,611	72.6
20,000-50,000	903	18.2
50,000-100,000	280	5.6
100,000-300,000	134	2.7
300,000-600,000	25	0.5
Greater than 600,000	21	0.4

Source: Anuario Estatistico do Brasil - 1992
Instituto Brasileiro de Geografia e Estatistica (IBGE)

The average production of municipal solid waste in Brazil is approximately 0.5 kg per capita per day. In large cities such as São Paulo, however, the average municipal waste production per capita per day can be as high as 0.85 kg.

A considerable amount of the municipal solid waste generated by the 4,974 municipalities is dumped illegally into the scattered and unauthorized dump sites or water streams. The IBGE has estimated that approximately 76 percent of the total municipal waste generated in all of

Brazil's municipalities is dumped into illegal dumping areas; 13 percent of the waste is delivered to controlled landfills; 10 percent is delivered in sanitary landfills; 0.9 percent is used for composting; and 0.1 percent is incinerated (primarily hospital waste).

The responsibility for the collection and disposal of all solid waste is at the municipality or city level. The municipalities are responsible for selecting landfill sites, arranging for the collection of all the waste (either themselves of through a private contractor), and for the disposal of the waste in environmentally sound ways. Also, the municipalities must ensure that the landfill sites are designed and operated in full compliance with the federal and local environmental laws and regulations with respect to the collection, monitoring, and disposal of all waste including hazardous and toxic waste, sewerage, and industrial waste. However, as mentioned earlier, more than 75 percent of the waste generated in the country is dumped or discarded illegally. Many of the smaller municipalities are simply not paying any attention to the environmental problems caused by the generation of municipal waste. This lack of effective municipal solid waste management is due to a number of factors including (i) a lack of specific waste management policy at the local level, (ii) budgetary constraints faced by many small and medium-sized municipalities, many of which do not have any collection fees or other revenue streams to justify the cost of solid waste management, (iii) a lack of availability of skilled and trained environmental and sanitary engineers and technicians, especially within small municipalities, (iv) a lack of appropriate monitoring, control, and treatment technologies, and (v) absence of any programs for control, enforcement, and penalties for illegal dumping.

The chemical composition of the municipal waste in the 21 largest municipalities is very similar. An analysis of the waste collected in São Paulo, the largest city in Brazil which also produces approximately 9,000 tons of municipal waste per day, shows that the waste is approximately 60 percent organic in content, as estimated in 1993. A breakdown of the materials content of the waste is shown in Table II-2 at intervals during the years 1927 through 1993.

Recently there has been a decline in the organic content and a steady increase in the paper, glass and metal content in the municipal waste in São Paulo. This is indicative of the change in the urban economies including the introduction of paper and plastic products, packaged foods, and the use of glass bottles and cans for beverages. While these data provided are for the City of São Paulo, they are indicative of the waste composition in other major cities such as Rio, Belo Horizonte, Salvador, Curitiba, Porto Alegre, Florianópolis, Goiânia, etc.

In most of the major cities, the process for the collection and management of the municipal solid waste is organized in one of the following ways: (i) the landfill is owned and operated by the municipality, (ii) the landfill is owned by the municipality but is operated by a private entity under contract with the municipality, or (iii) the landfill is owned and operated by the private sector. The most common pattern in Brazil appears to be the ownership of the landfill by the municipality and operation by a private contractor. There are only two landfill sites in Brazil that are wholly owned and operated by the private sector.

TABLE II-2: COMPOSITION OF MUNICIPAL SOLID WASTE IN SÃO PAULO, BRAZIL (Percent)

MATERIAL	1927	1947	1965	1969	1972	1989	1990	1993
Paper and Cardboard	13.4	16.7	16.8	29.2	25.9	17.0	29.6	14.4
Leather/Rag	1.5	2.7	3.1	3.8	4.3	-	3.0	4.5
Plastics	-	-	-	1.9	4.3	7.5	9.0	12.0
Glass	0.9	1.4	1.5	2.6	2.1	1.5	4.2	1.1
Metals	1.7	2.2	2.2	7.8	4.2	3.3	5.3	3.2
Organic	82.5	76.0	76.0	52.2	47.6	55.0	47.4	64.2
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: City of São Paulo - Secretaria de Serviços e Obras

D. INSTITUTIONAL ISSUES

There are a large number of Federal, state and municipal agencies and institutes that are involved in the management of the country's municipal solid waste. At the Federal level, the Sistema Nacional de Meio Ambiente - SISNAMA, created by Law No. 6938/81, is the highest national body responsibile for all environmental issues in the country. Its primary responsibility is to promote the environmental quality in the country and to guide the policies and programs of all environmental entities. Article 23, parts III, IV, VI, and VII of the Federal Constitution provides the municipalities with the responsibility to implement environmental policies and programs developed at the Federal level. Cities and municipalities do not develop policies and regulations but rather act as executing agencies and are responsible for implementing municipal solid waste collection and disposal programs. Their responsibilities focus on providing the needed services and include the complete organization of waste management.

The basic organization of the SISNAMA includes the following departments, agencies, and functions:

1. Conselho do Governo (Superior Department - Federal): This organization has the basic responsibility to advise the president of the country on the formulation of the national environmental policy.

2. Conselho Nacional do Meio Ambiente - CONAMA - (Consultative Department - Federal): This body has the primary responsibility to study and analyze all proposed policies, rules, regulations, standards, and control and monitoring programs and advise the government in the development of environmental legislation.

3. Ministerio do Meio Ambiente dos Recursos Hidricos e da Amazonia Legal - (Federal Ministry): The Ministry's responsibilities include the planning, coordination, and supervision of all environmental policy and program development. The Ministry also works with the private sector, international agencies, international financial institutions, and other ministries in the country to ensure that sound environmental policies and programs are developed, financed, and implemented and to ensure that the national environmental policy is implemented effectively throughout the country.

4. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renovaveis - IBAMA - (Federal Institute): IBAMA is an independent institute and is authorized to act as the executing agency for the implementation of the national environmental policy.

5. State Level Departments of Environment: Each state has a cabinet level department in charge of all environmental programs including the management of solid waste. These department are responsible for enforcing all Federal and state environmental policies, standards, regulations, permitting requirements, etc. Examples of state level departments include - Secretarias Es Taduais do Meio Ambiente and agencies such as CETESB in the State of São Paulo, FATMA in the State of Santa Catarina, FEEMA in the Sate of Rio de Janeiro, etc.

6. Local Government Entities: Most of the municipalities have a department of environmental affairs which also develops local environmental standards, permitting requirements, and regulations. In addition, they are responsible for implementing all Federal and state policies and regulations.

Typical of most countries at similar stages of economic development (e.g., Thailand, Malaysia, Indonesia, etc.), there appear to be too many Federal, state and municipal level government entities that are involved in developing environmental policies and programs and at the same time have the responsibility for the implementation of these policies and standards. There is obvious overlap and duplication of roles and responsibilities among these various entities. Also, although not the objective of this study, there appears to be a need for more effective coordination among the various agencies to ensure that the environmental management in Brazil is carried out effectively and efficiently.

III. OVERVIEW OF THE POWER SECTOR

A. SECTOR BACKGROUND AND KEY ISSUES

The Ministry of Mines and Energy, created in 1960, is the highest level Federal agency in Brazil in charge of the country's energy program. The Department of Water Resources and Energy (DNAEE) within the Ministry, is the regulatory body with the responsibility for developing energy policy, planning the utilization of energy resources (hydroelectric power and thermal power and the water resources in the country, setting the tariffs, developing power sector investment plans, proposing and developing all energy regulations, implementing the provisions of the 1995 Concessions Law, and implementing the newly passed IPP Law. In December 1996, the Brazilian Senate unanimously approved the creation of a new agency -- The National Agency of Electric Energy (ANEEL) with the responsibility to oversee energy supply and prices in the country. ANEEL will absorb most of the energy related functions of DNAEE and operate independently of the Ministry of Mines and Energy in a manner similar to public utility commissions in the U.S. As an independent regulatory body, ANEEL will also be responsible for reviewing proposals for power projects, granting concessions and permits, negotiating power and water tariffs, and implementing all regulations. It will also have jurisdiction over the review and approval of IPPs. ANEEL's other responsibilities will include (i) working closely with the states and assisting the states in the implementation of the energy regulations and policies as well as policies related to the use of water for hydroelectric power generation, (ii) developing and implementing programs for efficient utilization of energy resources, (iii) developing and implementing energy regulatory measures to ensure the interests of energy consumers and investors, and (iv) assisting the Ministry of Mines and Energy in the development of national energy policies. The government currently is in the process of developing a detailed management structure, organization, and mission and function for the newly created ANEEL.

ELECTROBRAS has the primary responsibility for implementing Brazil's power sector development program, including sector policy development, project financing, and supervising the construction, operation, and expansion of power generation, transmission and distribution systems. ELECTROBRAS was established in 1962 under Brazilian Law No. 3.890-A, promulgated in April 1961. It was structured as a public sector corporate entity with its share being traded on the São Paulo and Rio de Janeiro stock exchanges. Initially, ELECTROBRAS had two principal subsidiaries -- Companhia Hidro Elétrica do Sao Francisco (CHESF), and Centrais Elétricas S.A. (FURNAS). Subsequently, ELECTROBRAS created two other regional companies -- Centrais Elétricas do Sul do Brazil S.A. (ELECTROSUL) in the southern part of Brazil and Centrais Electricas do Norte do Brazil S.A. (ELECTRONORTE). In 1991, ITAIPU was created as a binational company under Electrobras as a result of a treaty between Paraguay and Brazil.

ELECTROBRAS is responsible for the production of approximately 60% of the total electric energy produced in Brazil (including 50% of the gross generation of ITAIPU). This electricity is sold to the various electric utilities throughout Brazil for ultimate distribution to the end use consumers. ELECTROBRAS also owns approximately 80% of Brazil's transmission network system (120,000 km).

ELECTROBRAS and all of its subsidiaries are included in the privatization program being implemented by Brazil. Accordingly, for the first time, ELECTROBRAS will be competing with the private sector for the construction and operation of new hydroelectric and thermal power projects. A number of institutional issues, most importantly the relationship between ELECTROBRAS and the newly created ANEEL are being studied by the government. ELECTROBRAS also has a number of key committees which are responsible for various functions such as environmental planning, power sector expansion planning, human resources planning, power generation quality, and labor safety and health issues. As the institutional structure of ANEEL is developed, some of these functions may need review and reassignment.

There are two large interconnected electrical energy systems in the country. The first system includes generation and distribution in the South, Southeast, and Central West regions of the country, and the second system connects the North and Northeast power generation systems. The predominant form of electrical energy in both systems is hydroelectric power and several times during each year, one system or the other has, temporarily, excess electrical energy. Thus the two interconnected systems are able to sell excess surplus power to each other on a temporary basis in order to maintain the supply of electricity throughout the country. The excess power within these two systems is sold on a commercial basis through three different types of contractual arrangements -- (i) Temporary Substitute Energy (ETST), (ii) Temporary Surplus Energy (EST), and (iii) Energy With Special Tariffs - Decree No. 1063/93. As of December 1995, there were a total of 296 ETST contracts between the concessionaires and consumers approved by DNAEE. In addition, DNAEE approved 31 EST contracts and 30 contracts under the special tariff Decree No. 1063/93. In 1997, DNAEE plans to revise its procedure for the commercialization of surplus electric energy. The new procedure will define specific rules that will provide greater access to the consumer for any surplus electricity in the Brazilian power system while providing the concessionaires adequate revenues in order to ensure that the commercialization program proceeds efficiently.

The current power generation system in the country has an installed capacity of 55,512 MW. There are a total of 64 companies which are responsible for power generation and distribution throughout the country, as shown in TABLE III-1.

Of the 55,512 MW installed capacity in the country, over 90% is generated through hydroelectric schemes. There are a total of 4,700 water collection stations strategically distributed in 8 great river basins in the country -- The Amazon - Basin 1; The Araguaia/Tocantins - Basin 2; The South Atlantic-Northern part - Basin 3; Sao Francisco - Basin 4; The South Atlantic-Eastern part - Basin 5; Paraná/Paraguay - Basin 6; Uruguay - Basin 7; and South Atlantic-Southern part - Basin 8.

TABLE III-1: INSTALLED CAPACITY OF THE BRAZILIAN POWER SYSTEM

TYPE OF COMPANY	NUMBER OF COMPANIES	INSTALLED CAPACITY (MW)	PERCENT
PRIVATE COMPANIES			
Generators/Distributors	21	249	0.4
Federal Distributors	7	0	0.0
FEDERAL COMPANIES			
Generators	2	11,345	20.4
Generators/Distributors	2	14,702	26.5
Distributor	1	776	1.4
STATE COMPANIES			
Generators/Distributors	21	22,128	39.9
Distributors	6	0	0.0
MUNICIPAL COMPANIES	3	12	0.1
BINATIONAL ITAIPU	1	6,300	11.3
TOTAL	**64**	**55,512**	**100**

Source: SIESE/ELECTROBRAS/DNAEE (1995)

The Brazilian government's strategy for meeting the future demand for electricity in the country will continue to include a large percentage of hydroelectric power schemes. However, there is a specific plan and commitment to diversify the country's generation mix by including a larger percentage of thermal power plants over the next several years.

The continuous industrialization of Brazil and the improvement in the disposable income and general quality of life of its citizens have resulted in a significant increase in the demand for power in the country. Recent estimates indicate that over the next fifteen years, the demand for electric power in Brazil is expected to grow at a rate higher than the GDP growth rate. A bulk of the public sector power plants in Brazil have been financed through multilateral financing sources, primarily the Inter-American Development Bank and the World Bank. Both of these lenders require setting of electricity tariffs based on the long run marginal cost pricing (LRMC) methodology. DNAEE has developed a financial and economic model which explicitly incorporates all investment costs, power systems losses, and power thefts to develop tariffs for electricity generated by the Federal companies, state owned companies and municipalities. In general, Brazil has adopted the life line approach to the first 100 kW of power and a building block approach for consumers based on demand and actual use of electric power. The tariffs developed and implemented by Brazil are generally lower than those warranted by the lenders and required by the investors. As a result, in 1996, DNAEE has developed a new comprehensive methodology for the adjustment of its tariffs, especially in view of the potential for private investors to become involved in power generation in the country.

In the Brazilian power system with a total installed capacity of over 55,000 MW, 216 generating plants have an installed capacity of greater than 10 MW. The vastness of the country, the necessity to provide electricity to remote rural areas, and the locations of river systems throughout the country necessitate the development of strategically located power generating stations sited in proximity to demand and often at long distances from one another. The Law of Concessions promulgated in 1995 has provided the generating companies and the government a tool to commission a number of power generating schemes throughout the country. DNAEE has the responsibility to implement the provisions of the Concession Law and is currently engaged in developing detailed regulations and procedures which will streamline the concession process. Specifically, DNAEE will soon publish detailed procedures for the following:

1. Detailed description of the bidding prospectus on concessions for the generation, transmission, and distribution of electricity;

2. Description of regulations for independent power production;

3. Bidding procedures for granting concessions to IPPs;

4. Bidding procedures for granting concessions for private power generation for self use;

5. Detailed procedures for granting extensions of existing concessions or regrouping of concessions for power distribution systems;

6. Rules and procedures for connection to existing grids;

7. Rules and procedures for regulating all cogeneration systems; and

8. Detailed procedures for all documents and studies required by DNAEE from concessionaires as part of the concession awards process.

Prior to the passage of the concession law, DNAEE had received 33 specific concession requests for hydroelectric projects covering a total 19,570 MW of new capacity. The construction of all of these power schemes was required to begin prior to February 1995 when the Law No. 8.987 was published. Since none of the projects began construction prior to this date, the government canceled all concessions. However, 24 of these projects were included for a new round of bidding after the passage of the law. Another 22 concession projects, that had begun construction prior to the passage of the law, were behind schedule or were stopped for a variety of reasons. These plants, together, will provide a total of 10,132 MW of new installed capacity at an investment in the order of US $11 billion. These projects are also included in the new round of bidding and are slated for completion. The schedule for the commissioning of these 22 concessions is provided in Table III-2.

TABLE III-2: INSTALLED AND AVAILABLE CAPACITY SCHEDULE OF 22 CONCESSIONS

YEAR	INSTALLED CAPACITY	AVAILABLE CAPACITY
1996	350	315
1997	580	287
1998	2,460	1,393
1999	2,947	1,473
2000	1,565	776
2001	402	216
2002	529	407
2003	697	360
2004	600	307
TOTAL	**10,131**	**5,537**

Source: DNAEE, Brasília, Brazil

The government has also developed a policy to actively encourage cogeneration of power and steam particularly in response to the sizeable potential for cogeneration in the country's sugar industry. DNAEE has published incentives to encourage cogeneration jointly with the secretariat of energy of São Paulo. As a result of the government's policy to encourage cogeneration, the government reviewed and approved permits for the generation of excess electricity at six alcohol plants in São Paulo with a potential for a total installed capacity of 75.9 MW. It is anticipated that the government will continue to encourage cogeneration and the total cogeneration of electricity in the sugar sector may exceed over 300 MW in the next five years.

In response to the continued demand for new capacity, and the lack of availability of government funds, DNAEE, in consultation with the Ministry of Mines and Energy, has developed a hydroelectric and thermal power concessions program for the period 1995-2004. The government will offer a total of 71 new concessions for hydroelectric power (61) and thermal power schemes (10) with a total potential installed capacity of 32,921 MW. Forty one of these schemes will be commissioned during the period 1995-1999 and the remaining 30 schemes are slated to be on line during the period 2000-2004. Given the fast demand for power, the proposed schemes need to be developed at an accelerated pace. As per DNAEE's current plans, 23,705 MW of new capacity will be commissioned during the first five years of the ten-year bidding program.

Together these 71 schemes will require an investment of the order of US $30 billion, virtually all of it to be financed by the private sector. The Brazilian government has expressed a need to bring the international financial community representatives to Brazil to publicize the enormous investment opportunity the country's power sector represents to the international community. Also, DNAEE is preparing the description of its Concession Law and IPP program including the detailed procedures. The newly created IPP law for the first time permits private power generation and sale to utilities. It will permit the commissioning and financing of power schemes completely by the private sector and will create the legal, regulatory and financial climate needed for the proposed commissioning schedule which is ambitious given the experience of IPP development in other countries.

Table III-3 shows the bidding and commissioning schedule for the proposed 71 power concessions.

B. PRIVATE POWER GENERATION

The regulations for independent power producers were published in late 1996 on the basis of the powers granted to the President of Brazil under Article 84, Item IV of the Constitution, and as provided in Law 9.074 of July 7th 1995. The general provisions of the regulations, as described in Article 1 of the Decree issued by the President, address the generation of electricity for self consumption and/or by independent power producers for sale to utilities. The published rules in the Decree mostly define the terms "self generation" and "IPP", set rules, guidelines, and restrictions, and provides the general requirements for the granting of a concession or license. The Decree does not describe the procedure for applying for the licenses and concessions nor does it describe the procedure for the negotiation of power purchase agreements with the concerned utility before an IPP scheme can be commissioned.

TABLE III-3: SCHEDULE FOR THE COMMISSIONING OF NEW HYDROELECTRIC AND THERMAL POWER PLANTS IN BRAZIL

YEAR	NO. OF BIDS	NO. OF PLANTS	INSTALLED CAPACITY (MW)
1995	4	4 (HYDRO)	249
1996	9	7 (HYDRO) 2 (THERMAL)	2,503
1997	8	4 (HYDRO) 4 (THERMAL)	4,567
1998	13	12 (HYDRO) 1 (THERMAL)	1,584
1999	7	5 (HYDRO) 2 (THERMAL)	1,481
1995-99	**41**	**32 (HYDRO) 9 (THERMAL)**	**23,705**
2000-04	30	29 (HYDRO) 1 (THERMAL)	9,218
1995-2004	**71**	**61 (HYDRO) 10 (THERMAL)**	**32,921**

Source: DNAEE, Brasília, Brazil

The following are the specific provisions/definitions/requirements as stated in the presidential Decree:

1. An independent power producer (IPP) is defined as a legal investor entity or consortium of several legal business entities which is granted a concession or license to produce electricity at their own risk and financing for sale to the public grid. Generation for self consumption, however, is limited to generation of sufficient electricity for on-sight consumption and not sale to the local utility.

2. Public tenders will be required for all IPP hydropower projects greater than 1 MW capacity and all self generation hydropower projects greater than 10 MW in capacity.

3. A license is required for all IPP or self generation thermal power projects greater than 5 MW in capacity and for all self generation hydropower projects with a minimum capacity of 1 MW and a maximum capacity of 10 MW.

4. For hydroelectric power plants of up to 1 MW and for thermal power plants for up to 5 MW, the regulations do not require either a concession or a license. However, a registration with the government or the appropriate utility is required.

5. All public tenders for concessions for IPP or self generation projects must comply with the requirements of the general law on public bidding -- Law No. 8.987, promulgated in February 1995.

6. The qualifications requirements for the bidders include technical expertise and financial capabilities as well as satisfactory financial and legal record.

7. Most concessions and licenses will be enforced for 35 and 30 years respectively from the date of signing of the licensing agreement and may be extended by mutual agreement between the regulating body and the bidder.

8. Concessions for hydroelectric power projects will be required to conform with the provisions of the Concession Agreement for the Utilization of Public Property. This agreement includes (i) rights and responsibilities of IPPs or self consumption producers for hydroelectric power, (ii) general conditions for operating power plants and selling electricity, (iii) financial charges levied on the production of electricity as per government regulations, (iv) penalties in the event of the forfeiture of concessions, and (v) conditions for transferring the concessions.

9. In order to guarantee the sale and utilization of electricity, IPPs and self consumption producers are assured free access to the transmission and distribution systems of concessionaires of public utilities, with appropriate fees for the transmission of electricity.

10. The law permits the IPPs and self consumption producers to operate their plants in an integrated or non-integrated mode. An integrated option is one in which the operation maximizes benefits from existing and future electric power resources. A non-integrated mode would permit an IPP or self producing generator to produce electricity independent of the local utility system's transmission and distribution network.

11. The IPP law provides for the collection of specific charges from the IPPs and self consuming producers. These include (i) financial compensation to the states, Federal district, and municipalities as well as appropriate federal agencies for the utilization of hydroelectric resources for the purposes of generating electricity, (ii) fees for the supervision of electricity services, to be collected in accordance with

the schedule and amounts published in the tender document and agreed to in the final contracts, and (iii) monthly quotas of Conta de Consumo de Combustiveis - CCC, sub account Sul/Sudoeste/Centro-Oeste, or sub-account Norte/Nordeste.

12. Specific provisions with respect to supervision and sanctions, equipment inspections, and other applicable Federal and state laws are briefly described in the IPP law and will be published in detail for each specific tender.

13. The law also describes the actions to be taken in the case of non-performance by the IPPs and self consuming producers. These include transferring of concession agreements or licenses and revoking the license consistent with the legal procedures.

14. The IPPs may sell electricity to concessionaires or licensees of public utilities, consumers of electricity, groups of consumers of electricity, and local distributors. Such sale of electricity will be governed by the prices subject to general rules as fixed by the concession granting authority.

15. The self consuming producers are required to demonstrate to the regulatory authorities that the electricity produced will be for self consumption only. The law permits transfer and exchange of electricity among groups of self consuming producers also for self consumption.

16. The law also permits the purchase of excess electricity produced by concessionaires and licensees of distribution companies, including economic exchange of equivalent amounts of electricity.

The Public Law No. 9.074 of July 1995 includes further details than those summarized above. It should be noted that while this law clears the way for IPP and self use generation of electricity, and provides general guidelines, it does not provide detailed procedures required by all potential bidders for private power generation. The Department for the Coordination of Concessions within DNAEE is responsible for developing detailed procedures to assist potential bidders for a host of thermal and hydropower projects on an IPP basis. DNAEE is currently working on developing these procedures and has recognized that as these functions are transferred to the newly created ANEEL, detailed procedures will need to be published in order to ensure significant participation by the private sector in Brazil's power sector development program.

IV. STUDY BACKGROUND AND OBJECTIVES

A. BACKGROUND

The rapid industrialization and population growth in Brazil during the last three decades has resulted in a significant urbanization of its key cities including São Paulo, Rio de Janeiro, Belo Horizonte, Porto Alegre, and Curitiba. In addition, medium size cities such as Campinas, Goiânia, Florianópolis, Joinville, Recife, Natal, and Fortaleza, have also grown in population due to the location of industry and the resultant employment opportunities. Due to regularly few employment opportunities in the adjoining rural areas around these cities, a significant workforce influx occurs daily. The "migrating" workers add considerably to the demand for basic resources and services provided by the cities.

One of the main environmental problems faced by Brazil's major and medium size cities is the sizeable amount of municipal solid waste generated on a daily basis. The state governments and municipalities (cities) have the primary responsibility for the collection, transportation, and disposal of all the municipal waste generated within their jurisdictions.

Approximately 75% of Brazil's population lives in the country's major cities. The country has a total of 4,974 municipalities. Of these 3,611, or 72.6, percent of the municipalities, have less than 20,000 inhabitants and have a total population of approximately 23 million. Twenty one of the largest municipalities, with population greater than 600,000 inhabitants, have a combined population of approximately 34 million.

The average production of municipal solid waste in Brazil is approximately 0.5 kg per inhabitant per day. In large cities such as São Paulo, however, the average municipal waste production per inhabitant per day can be as high as 0.85 kg. A considerable amount of the municipal solid waste generated by the 4,974 municipalities is not collected and is dumped illegally into scattered and unauthorized dump sites or water streams. The IBGE has estimated that approximately 76 percent of the total municipal waste generated in all of Brazil's municipalities is dumped in illegal dumping areas; 13 percent of the waste is delivered to controlled landfills; 10 percent is delivered in sanitary landfills; 0.9 percent is used for composting; and 0.1 percent is incinerated (primarily hospital waste).

Many of the smaller municipalities are simply not paying any attention to the environmental problems caused by the generation of municipal waste. This lack of effective municipal solid waste management is due to a number of factors including (i) a lack of specific waste management policy at the local level, (ii) budgetary constraints faced by many small and medium-sized municipalities, many of which do not have any collection fees or other revenue streams to justify the cost of solid waste management, (iii) a lack of availability of skilled and trained environmental and sanitary engineers and technicians, especially within small municipalities, (iv) a lack of appropriate monitoring, control, and treatment technologies, and (v) an absence of any programs for control, enforcement, and penalties for illegal dumping. The chemical composition of the municipal waste in the 21 largest municipalities is very similar. An analysis of the waste collected in São Paulo, the largest city in Brazil which produces approximately 9,000 tons of municipal waste per day, shows that the waste is approximately 60 percent organic in content. While the above data are for the City of São Paulo, they are indicative of the waste composition in other major cities.

In most of the major cities the process for the collection and management of the municipal solid waste is organized in one of the following ways: (i) the landfill is owned and operated by the municipality, (ii) the landfill is owned by the municipality but is operated by a private entity under contract with the municipality, or (iii) the landfill is owned and operated by the private sector. The most common pattern in Brazil appears to be the ownership of the landfill by the municipality and operation by a private contractor. There are only two landfill sites in Brazil that are wholly owned and operated by the private sector.

Many of the landfill sites in and around the large and medium sized cities (the largest producers of municipal solid waste) are facing capacity problems due to the lack of the availability of land. Also, virtually all of the landfill sites are releasing landfill gas (LFG), a normal byproduct of biological anaerobic decomposition of organic materials in the landfills. The decomposition process is carried out by anaerobic microorganisms and results in the formation of a gas that is approximately 55% methane and 45% carbon dioxide by volume. A portion of the gas at the Brazilian landfills visited is currently being flared. Not only does the release of this gas pose significant environmental, health, and safety problems for the surrounding neighborhoods and has national environmental implications, it is also a valuable resource which is currently being wasted. The LFG can be a great asset because of its energy content and the potential for use as a fuel. The component of the LFG which offers the greatest energy resource is its methane content. Pure methane has a heating value of approximately 1,000 Btus per standard cubic foot (Scf). In the United States, there are over 100 currently operating landfill gas-to-energy systems which represent a major use of LFG.

The primary markets for landfill gas in Brazil could include the following:

1. Medium Btu (approximately 500 Btu per scf) fuel gas can be used for direct sale to industrial gas consumers without the requirement of any processing such as dehydration.

2. The gas can be used for on-site power generation in either an internal combustion engine, gas turbine, or steam turbine generator. However, this will require some processing and cleanup of the LFG.

3. High Btu (1,000 Btu per scf) pipeline quality gas can be sold directly to utility companies. This process, however, will require extensive processing and removal of virtually all constituents from the LFG except methane.

In addition, LFG, after initial processing, may be compressed to produce Compressed Natural Gas (CNG) for use as a transport fuel. Other uses of LFG may also include use as chemical feed stocks, carbon dioxide recovery, etc.

The Government of Brazil has had an active policy for the development of alternative energy sources (e.g., the country's well known alcohol fuels program, successful track record in the hydropower program). Also, Brazil has been a major proponent of cleaner environment including global warming issues and the deployment of cleaner technologies throughout its economy. The country's commitment to environmental issues was well demonstrated by its sponsorship of the Rio Summit. Therefore, the concern expressed by senior government officials regarding the country's solid waste management problem is consistent with its commitment to implementing effective technologies and policies to not only manage the solid waste effectively with due regard to environmental health effects, but also to look for commercial opportunities to deploy LFG as an alternate energy resource.

Recognizing (i) the urgent need for mitigating many of the environmental, health, and safety effects of LFG, (ii) the potential for the use of LFG as a marketable resource, producing revenues for the municipalities and states, (iii) the need for more skilled technicians, engineers, and managers to manage the landfill sites, and (iv) the availability of technology from the U.S. for the recovery and utilization of methane from LFG, led the U.S. Agency for International Development (USAID) to assess the overall potential of landfill gas recovery and utilization in Brazilian cities. The USAID Mission in Brasília requested the USAID-funded Energy Technology Innovation Project (ETIP) to assemble a team of experts to visit key landfill sites in Brazil, assess the site conditions and the potential for LFG recovery and utilization, and make specific technical and policy recommendations for the development of a comprehensive LFG program for Brazil.

In December 1996, ETIP organized a team of U.S. and Brazilian experts to select and visit key landfill sites throughout Brazil which offer the greatest promise for (i) accruing environmental health and safety benefits, and (ii) developing the commercial scale recovery and utilization of LFG. The team visited Brazil during the first two weeks of December and conducted site assessments at thirteen major landfill sites in Brazil. In addition, members of the team also visited several state, municipal, and Federal government officials and held discussions on policy, financial, and institutional issues linked to a more effective management of the country's landfill sites and the recovery and sale of LFG. Annex I provides a list of all public and private sector officials with whom the various members of the team held discussions during the field mission. The annex also includes key contacts in the U.S. government in Washington, São Paulo, and Brasília who generously offered their time, guidance, and support to the team in carrying out its assignment.

B. OBJECTIVES OF THE PROPOSED STUDY

Methane gas emissions from waste landfills are a significant contributor to global climate change. The control of these greenhouse gas emissions through LFG recovery and utilization presents a viable opportunity for mitigating adverse environmental impacts while providing potential economic benefits through the commercial application of the recovered methane. Accordingly, the primary objective of the proposed LFG assessment in Brazil was to gather and present site specific information for Brazil's key landfill sites that will encourage the utilization of LFG in the country. Specifically, the study objectives were as follows:

1. Identify and characterize candidate landfill sites that are representative of major population centers and high secondary growth areas in Brazil.

2. Identify commercial potential, potential markets, and economic benefits of LFG recovery and utilization.

3. Develop options for private participation in this sector, thereby reducing the burden on the cities and municipalities, increasing efficiency, and generating employment.

4. Identify policy and institutional barriers and make recommendations for policy and institutional changes that will facilitate LFG recovery and commercial utilization.

The specific activities included (i) pre-mission planning -- including the selection of the team members; selection of landfill sites based on data on population, waste generation, and other factors; development of three teams for concurrent site visits; and the logistics arrangements, (ii) training of the teams in data collection and site interviews and site visits to candidate landfill sites and Brasília for discussions with key government officials, and (iii) post-mission activities -- including the preparation of a final report. The type of information collected by the teams visiting various sites included the following:

1. General Information

Population, site management and contacts, total amount of waste collected daily and any seasonal variations, waste collection history, waste composition, site area, topography, site climatology, elevation, site design and expansion plans, potential for expansion, LFG recovery and utilization (if applicable), leachate collection and treatment, permits, availability of back-fill soil, and end-use plans for the site.

2. **LFG Market Information**

Potential markets for landfill gas such as nearby gas pipelines, power utilities, industrial facilities, etc.

3. **Institutional and Policy Information**

Site operation and management practice, coordination with local authorities, permitting process, site inspections and record keeping, waste management policy, policy regarding illegal dumping, etc.

4. **Financial Information**

Operations cost, costs due to labor problems or strikes, revenues recovered from legally employed truck drivers, leachate collection and treatment costs, composting costs and revenues (if applicable), etc.

The teams utilized a detailed data collection form at each site. Annex III includes copies the forms for 13 sites visited by three teams.

C. METHODOLOGY FOR REPRESENTATIVE LANDFILL SITE SELECTION

The key objective of the selection of the sites was to ensure that (i) each candidate site was representative of other neighboring sites in selected cities, (ii) collectively all the sites were representative of the country as a whole, (iii) the total amount of daily waste at the selected sites was a sizeable portion of the total amount of legally collected waste in the country, and (iv) the operations and management of the waste collection and disposal at these sites included sites wholly owned and operated by the public sector, sites owned by the public sector and operated by a private contractor, and sites wholly owned and operated by the private sector.

Based on data on population, amount of waste generated and disposed at the landfill sites, and geographical considerations, ETIP selected a total of 13 sites in 12 of Brazil's major cities. The total population of all the states visited by the team is approximately 92 million persons, or 58% of Brazil's population. The total population of cities where the selected sites were located is approximately 33.2 million persons. The total municipal solid waste produced in the country is estimated at 241,614 metric tons per day. The total municipal solid waste produced in the twelve cities covered by the thirteen selected sites is estimated at 142,697 metric tons per day which is approximately 59% of the total municipal waste in the country.

Based on the criteria discussed here, the following landfill sites were selected for site visits and evaluation and are listed in alphabatic order:

- Bandeirantes Landfill, São Paulo, São Paulo
- Belo Horizonte Landfill, Belo Horizonte, Minas Gerais
- Biguacu Landfill, Florianópolis, Santa Catarina
- Caximba Landfill, Curitiba, Paraná
- Delta I Landfill, Campinas, São Paulo
- Goiânia Landfill, Goiânia, Goiás
- Gramacho Landfill, Duque de Caxias, Rio de Janeiro
- Joinville Landfill, Joinville, Santa Catarina
- Joquei Landfill, Brasília, Distrito Federal
- Lara Landfill, Mauá, São Paulo
- Santa Barbara Landfill, Campinas, São Paulo
- Sao Joao Landfill, São Paulo, São Paulo
- Zona Norte Landfill, Porto Alegre, Rio Grande do Sul

D. METHODOLOGY FOR ESTIMATING LANDFILL GAS CONTENT

The U.S. Environmental Protection Agency (EPA) Landfill Air Emission Estimation Model (DOS Model, Version 2.0) was used to estimate landfill gas generation potential at each of the 13 Brazilian landfill facilities. The Model estimates emission rates of methane, carbon dioxide, non-methane organic compounds (NMOCs), and toxic air pollutants expected to be emitted from landfill. The emission estimates are based on the landfill gas generation rate, generation potential of the refuse mass, and the amount of refuse in place.

The Model is based on a first-order decomposition model, which estimates landfill gas generation rates using two parameters:

- L_0 — *Potential methane generation capacity* of the refuse, in cubic meters per metric ton (m^3/Mg). The potential methane generation capacity depends on the amount of decomposable organic matter in the refuse.

- k — *Methane generation decay rate*, which accounts for how quickly the methane generation rate decreases once it reaches its peak rate ($year^{-1}$). The methane generation decay rate is a function of moisture content in the landfill refuse, availability of nutrients for methanogens, pH, temperature, and other factors.

The Model allows the user to enter site-specific L_0 and k values obtained from actual field testing. Field testing was not performed as a part of this preliminary study, but is recommended for sites proceeding to subsequent phases of landfill gas collection system development.

The Model's default potential methane generation capacity, L_0, of 124.9 (m^3/Mg) was used in all of the landfill gas generation estimates. This value is considered a reasonable average for sites in the U.S. based on a typical refuse organic content of 50 percent. However, this default value may be considered conservative for landfills in Brazil based on reported organic contents of landfilled wastes ranging from 50 to 70 percent.

The methane generation decay rate, k, is primarily affected by the moisture within the waste that is available to the methane-producing microorganisms. Generally speaking, the higher the moisture content of the waste, the higher the generation rate. A higher generation rate results in a higher estimated peak flow of landfill gas, as well as a shorter generation period.

A generation rate of 0.04 per year typically is used in the U.S. where rainfall exceeds 635 millimeters per year or more. The 0.04 per year landfill gas generation rate was used for the "low-generation" estimates at the Brazilian sites. The Brazilian sites reported average annual precipitation rates that greatly exceed 635 millimeters per year. Based on a relatively high annual precipitation rate, a high-end generation rate of 0.1 per year was utilized for the "high-generation" estimates.

It is strongly recommended that site-specific generation rates be measured by field testing for those landfills that prove to be strong candidates for landfill gas collection system development. Site-specific generation rates can then be used to more-accurately estimate landfill gas generation, and subsequent design of the landfill gas collection system.

Waste receipt data for the Brazilian sites generally was not available to the project researchers. Many facilities simply had not maintained records of waste receipts, or had only recently begun the practice of keeping such records. As such, much of the waste receipt input data for the Model was estimated, and should be considered preliminary at this time. Sites that prove to be good candidates for further consideration should be reviewed with respect to the waste receipt estimates, and refined if possible. The team augmented available waste data during meetings with site managers and operators as well as through observations during site visits.

V. FIELD MISSION TO LANDFILL SITES AND MEETINGS

A. DESCRIPTION OF MEETINGS AND COMMON KEY ISSUES

The field mission was carried out during the first two weeks of December 1996. The entire project team consisting of three U.S. experts and three counterpart Brazilian experts assembled in Rio de Janeiro. The first activity was to review pre-prepared site data collection forms and discuss the approach for meetings and discussions at the different landfill sites. As part of this activity, a training program was conducted for the entire team to ensure consistency in the collection of data during the actual site visits. Also, the entire project team visited the Gramacho Landfill in Duque de Caxias, Rio de Janeiro to collectively conduct the meetings and complete the site data collection form.

Given the project schedule, three separate teams, each consisting of one U.S. expert and one Brazilian expert were formed and the specific site assignments were made. Table V-1 shows the assignments of the 13 sites among the three teams.

TABLE V-1: TEAM ASSIGNMENTS FOR LANDFILL SITE VISITS IN BRAZIL

NO	TEAM	LANDFILL SITES VISITED
1.	TEAMS I, II, III	Gramacho Landfill in Duque de Caxias, Rio de Janeiro
2.	TEAM I	Caximba Landfill, Curitiba, Paraná; Joinville Landfill, Joinville, Santa Catarina; Biguacu Landfill, Florianópolis, Santa Catarina; Zona Norte Landfill, Porto Alegre, Rio Grande do Sul
3.	TEAM II	Bandeirantes Landfill, São Paulo, São Paulo; Delta I Landfill, Campinas, São Paulo; Santa Barbara Landfill, Campinas, São Paulo; Lara Landfill, Mauá, São Paulo; Sao Joao Landfill, São Paulo, São Paulo
4.	TEAM III	Belo Horizonte Landfill, Belo Horizonte, Minas Gerais; Goiânia Landfill, Goiânia, Goiás; Joquei Landfill, Brasília, Distrito Federal
	TOTAL SITES	13 landfill sites

Team I visited the Caximba Landfill, Curitiba, Paraná; the Joinville Landfill, Joinville, Santa Catarina; the Biguacu Landfill, Florianópolis, Santa Catarina; and the Zona Norte Landfill, Porto Alegre, Rio Grande do Sul. Team II visited the Bandeirantes Landfill, São Paulo, São Paulo; the Delta I Landfill, Campinas, São Paulo; the Santa Barbara Landfill, Campinas, São Paulo; the Lara Landfill, Mauá, São Paulo; and the Sao Joao Landfill, São Paulo, São Paulo.

Team III visited the Belo Horizonte Landfill, Belo Horizonte, Minas Gerais; the Goiânia Landfill, Goiânia, Goiás; and the Joquei Landfill, Brasília, Distrito Federal. Team III could not visit the landfill site in Salvador as was scheduled due to a last minute workers strike on the site. However, the team members were able to hold discussions with city and municipal officials in Salvador regarding the city's waste management practices and solid waste management problems. Exhibit V-1 shows the map of Brazil with the location of key sites visited by the three teams.

None of the team members was able to visit sites in the northern Brazilian cities of Recife, Natal, and Fortaleza. Senior municipal officials in these cities were contacted, however due to elections and worker related problems, no actual site visits could be conducted. All three cities are similar to other urban cities visited by the team in terms of waste per capita, industry structure, and waste generation, collection, and disposal practices. The team was able to confirm through conversations with site officials, as well as discussions during meetings with environmental officials in Brasília, that the conclusions reached by the team regarding the thirteen sites actually visited can also be considered representative of the waste management practices in these cities as well.

No landfill sites were visited in the interior part of Brazil for a variety of reasons including: (i) scattered locations of towns and cities with long distances among them, (ii) the virtual absence of organized waste collection and disposal by the municipalities, (iii) the abundance of illegal dumping activity, (iv) relatively low populations, (v) mostly rural character cities thereby generating less waste per capita than in the targeted urban areas, (vi) the lack of potential for any appreciable recovery of LFG, and (vii) the lack of an industrial and end-user market for LFG in the vicinity of the towns and cities.

In addition to visiting the landfill sites, the ETIP team also visited Brasília and held discussions with senior energy, environmental, and planning officials in the Federal government. These discussions included the government's and municipalities' current and planned policies for municipal solid waste management, the institutional sector, and financing of solid waste management collection, treatment and disposal projects. During these discussions the team explored the potential for active participation by the private sector in both municipal solid waste management and the production and utilization of LFG as an energy resource, especially in view of the government's recently enacted Concession Law and the IPP regulations.

At the end of all site visits, key members of the three teams held a meeting in São Paulo and compiled all the data and information collected during the visits to facilitate the preparation of the report. During this meeting the team members also discussed the similarities and differences in the waste collection and management practices at the various sites, the potential for LFG recovery and utilization, and the need for policy and institutional reforms for accelerating the participation of the private sector in Brazil's solid waste management and LFG recovery and potential energy production for commercial use.

EXHIBIT V-1: LOCATIONS OF LANDFILL SITES VISITED

1 - Bandeirantes Landfill, Sao Paulo
2 - Belo Horizonte Landfill, Belo Horizonte
3 - Biguacu Landfill, Florianopolis
4 - Caximba Landill, Curitiba
5 - Delta I Landfill, Campinas
6 - Goiania Landfill, Goiania
7 - Gramacho Landfill, Duque de Caxias
8 - Joinville Landfill, Joinville
9 - Joquei Lanfill, Brasilia
10 - Lara Landfill, Maua
11 - Santa Barbara Landfill, Campinas
12 - Sao Joao Landfill, Sao Paulo
13 - Zona Norte Landill, Porto Alegre

The following are the key issues common to all of the landfill sites visited by the teams and are representative of the waste management practices throughout Brazil:

1. Most of the legal landfill sites are managed by city/municipality officials. Generally, the collection and transportation of solid waste to the sites, as well as all operations at the sites, are managed by city employees. In the case of some of the larger waste management sites such as the Bandeirantes site in São Paulo and the Gramacho site in Rio de Janeiro, the collection and operation of the sites is carried out by private Brazilian contractors. The Lara Site in Mauá and the Biguacu Site are wholly owned and operated by private Brazilian companyies. However, these are sporadic and unusual cases.

2. While the topography of the sites varied considerably, the climatology was generally similar, with minor differences in temperatures, total rain falls, etc. The slopes of the various sites are consistent with those found in other countries, typically 2-3 horizontal and 1 vertical, and the use of compacted clay for final cover as well as liners is commonly practiced at all the sites. Also, the medium sized landfills such as Lara and Sao Joao, were located in close proximity to heavily populated areas, posing health and safety risks to these populations.

3. All of the sites are actively engaged, to varying degrees, in site layering and remediation on a regular basis and most of them have top soil, dirt, and concrete available on the sites for intermediate and final covers.

4. All sites have generally poor systems for the collection and treatment of leachate. A considerable amount of leachate was found at virtually all the sites which poses significant hazards to on-site workers and neighboring populations. In some cases, such as the Bandeirantes site, leachate was collected in ponds, pumped into trucks, and transported to a leachate treatment facility. This operation is also in need of significant improvement and was not consistent with safe environmental practices.

5. Only at one site, the Bandeirantes Landfill is engaged in composting of appreciable quantities of municipal solid waste. Currently it is composting 2,500 tons of waste per day, producing approximately 600 tons per day of raw compost for commercial applications. This site has an active plan under consideration to double its composting production within one year.

6. There was no evidence of any organized pre-sorting of waste (recyclables such as plastic, paper, glass, and metals) at any of the sites. However, considerable illegal presorting activity similar to that found in many other countries existed. Preliminary estimates indicate that at the larger sites, such Bandeirantes and Gramacho, that recyclables in value exceeding US $5,000 per day could be recovered through the development of an organized pre-sorting system.

7. There was a general absence of incineration of hospital wastes at most of the sites. Only one site visited had an on-site microwave incineration system treating approximately 8 tons of hospital waste per day. This system was being operated with U.S. technology by a private Brazilian contractor.

8. The system for the collection of LFG varied from site to site and was not sufficiently comprehensive. Flaring of LFG was common to all sites and there was virtually no organized collection and treatment of LFG for commercial uses. Also, none of the sites utilized the LFG for steam and/or power generation. Given the climate in Brazil and the presence of more than 60% organic waste at most of the sites, Brazilian landfill sites produce an abundant amount of LFG. Therefore, the recovery and utilization of LFG for commercial applications offers the cities and municipalities an attractive opportunity not only to reduce environmental, health, and safety risks of LFG, but also partially offset the operations cost of the landfills through the recovery of revenues from commercial sales of LFG and/or LFG-based power.

In addition to the technical findings at the landfill sites, the teams also reviewed existing policy, legislative frameworks, and institutional practices pertaining to municipal solid waste management in the country and explored the potential for extensive private participation in this sector. The following are the teams' key findings:

1. There are a large number of Federal agencies, committees, semi-government institutes, state ministries, municipal agencies and departments, all of which are involved in one or more aspects of the overall municipal solid waste management in the country. Although as a matter of general policy, the responsibility for the management and collection of solid waste lies with the municipalities/cities, there is considerable overlap in policy formulation, regulations development, permitting and licensing processes, site inspections, and monitoring and enforcement among the various entities.

   In addition, there appears to be a lack of coordination among the various entities, especially in the area of policy formulation, standards development, and project planning.

2. In recent years, the Federal and state governments in Brazil have enacted legislation and published a large number of rules and regulations specific to the collection, transportation, treatment, monitoring, and disposal of municipal solid waste. Yet, a large portion of the country's municipal solid waste (close to 75%) continues to be dumped in illegal dump sites. Despite the various regulations and policies, the government faces the difficulty to control the illegal dumping as well as monitoring and enforcing legally allowed penalties.

3. Currently, the municipalities must bear the entire cost of waste collection, transportation, treatment, disposal, and site operations. The main source of revenue to the municipalities is the dumping fee which varies from US $8 per ton to US $20 per ton based on a variety of factors (waste content, truck size, repeat volume, etc.). Other potential sources of revenue such as income from the sale of recyclable materials, composting of organic waste, and recovery and utilization of LFG as an energy resource are largely untapped. At the same time, the states and the municipalities are faced with the requirements of expansion of existing landfills, development of new landfills, closure and reclamation of landfills at total capacity, and management of leachate and toxic and hazardous wastes by using environmental technologies in compliance with new stricter standards, all of which continue to add significant pressure to their already constrained budgets.

4. With the passage of the Concession Law and the potential for profits from the utilization of the waste and LFG for commercial products (compost, recyclables, and LFG) a number of private Brazilian firms are actively pursuing opportunities with the states and municipalities for turnkey landfill site management contracts. For example, SLU and ENTERPA, two of the existing contractors for the Sao Joao Landfill and the Joquei Landfill in Brasília, respectively, and are actively pursuing opportunities for new contracts with the municipalities. However, a number of regulatory and financial constraints continue to exist which need to be rationalized prior to these and other Brazilian firms taking an active interest in the waste management sector.

5. Except for the largest sites, there is a dearth of trained technicians, planners, and managers for waste management and landfill site operations in the country. Also, budgetary constraints have prevented the municipality/city from deploying new cost-effective technologies (incineration, source separation, anaerobic process for composting, etc.) for the treatment of waste, as well as leachate. In the case of many of the sites visited, there was considerable evidence of LFG migration and exposure to nearby populations creating health hazards. In order for Brazil to implement its environmental standards and ensure health and safety of its population, particularly those located in close proximity to the landfill sites, the government will need to utilize more advanced and cost effective technologies. Accordingly, there is a considerable need for the transfer of technology from the U.S. to Brazil in this sector.

6. The bold policy moves made by the Brazilian government, particularly the privatization policy, the Concession Law, the IPP regulations, the new environmental standards, and the country's historical commitment to the use of alternative, cleaner technologies, provide the framework for active private sector involvement and technology transfer to address the increasing problems of municipal solid waste management.

While the government has articulated its policies in sufficient detail, considerable work is needed in streamlining the process for eligibility criteria, bidding and financing procedures, permitting and licensing, and contracting.

The Ministries of Science and Technology, Mines and Energy, and Environment, Water Resources, and Amazon Affairs, have expressed their commitment to working with the state governments and municipalities to address the issue of streamlining the process and creating a better framework for private sector financing and operations of municipal solid waste management projects and landfill sites.

B. CHARACTERIZATION OF SITES VISITED

This section presents a summary evaluation of the basic site characteristics and the utilization of landfill gas for purposes of power generation at 13 landfill facilities in Brazil. Table V-1 provides a summary of the landfill characterization of the 13 sites in terms of site location, site management, currently permitted design capacity, current average daily waste receipt, waste composition, and the estimated organic content of the waste for each of the landfill sites. The discussion includes basic site information, waste characterization and landfilling practices, and landfill gas generation estimates for each of the following sites visited by the team:

- Bandeirantes Landfill, São Paulo, São Paulo
- Belo Horizonte Landfill, Belo Horizonte, Minas Gerais
- Biguacu Landfill, Florianópolis, Santa Catarina
- Caximba Landfill, Curitiba, Paraná
- Delta I Landfill, Campinas, São Paulo
- Goiânia Landfill, Goiânia, Goiás
- Gramacho Landfill, Duque de Caxias, Rio de Janeiro
- Joinville Landfill, Joinville, Santa Catarina
- Joquei Landfill, Brasília, Distrito Federal
- Lara Landfill, Mauá, São Paulo
- Santa Barbara Landfill, Campinas, São Paulo
- Sao Joao Landfill, São Paulo, São Paulo
- Zona Norte Landfill, Porto Alegre, Rio Grande do Sul

Following data collection, the team developed estimates for the total amount of energy that could be generated at each of the sites. These estimates are based on a collection efficiency of 50% and a power generation conversion of 1 kilowatt hour (kwh) equivalent to 12,500 Btus in accordance with typical industry specifications. Furthermore, the estimates presented in this report represent total energy production values. Values of actual amounts of energy collected are expected to be 50 to 70 percent of the total energy produced due to production and conversion losses.

TABLE V-2
LANDFILL CHARACTERIZATION SUMMARY

SITE	LOCATION	INSTITUTIONAL MANAGE-MENT (1)	CURRENTLY PERMITTED DESIGN CAPACITY (Million Mg) (2)	CURRENT AVERAGE DAILY WASTE RECEIPTS (Mg/Day)	WASTE COMPOSITION (3)	ESTIMATED ORGANIC CONTENT (%)
Bandeirantes Landfill	Sao Paulo, Sao Paulo	COW, POP	20	6,000	75% R/C, 10% CD, 7% YLC, 8% O	55
Belo Horizonte Landfill	Belo Horizonte, Minas Gerais	COW, COP	11.8	2,100	R/C, CD, YLC, O	65 - 70
Biguacu Landfill	Florianopolis, Santa Catarina	POW, POP	6,500 Mg/Month	275	95% R/C, 5% YLC	60
Caximba Landfill	Curitiba, Parana	COW, POP	33,000 Mg/Month	1,450	80% R/C, 20% CD, YLC	65
Delta I Landfill	Campinas, Sao Paulo	COW, COP	Not Available	700	R/C, YLC	65
Goiania Landfill	Goiania, Goia	COW, POP	Not Available	1,200	90% R/C, 10% YLC, S, O	High
Gramacho Landfill	Duque de Caxias, Rio de Janeiro	COW, POP	Not Available	7,500	R/C, I, CD, YLC, L, O	Not Available
Joinville Landfill	Joinville, Santa Catarina	COW, POP	8,000 Mg/Month	300	70% R/C, 20% I (inert), 6% YLC, 4% O	50 - 60
Joquei Landfill	Brasilia, Distrito Federal	COW, COP	Not Available	1,300	All Wastes Accepted	Not Available
Lara Landfill	Maua, Sao Paulo	POW, POP	Not Available	1,200	72% R/C, 5% CD, 8% YLC, 15% O	65
Santa Barbara Landfill	Campinas, Sao Paulo	COW, COP	Not Available	Closed	R/C, I (Type II & III), YLC	60
Sao Joao Landfill	Sao Paulo, Sao Paulo	COW, POP	8 (Phase I)	5,100	R/C	60
Zona Norte Landfill	Porto Alegre, Rio Grande Do Sul	POW, COP	Not Available	1,300	66% R/C, 1.5% I, 1.5% CD, 26% YLC, 5% O	60
TOTALS				***28,425***		

1. Institutional Management: COW = City-Owned; POW = Privately-Owned; COP = City-Operated; POP = Privately-Operated
2. 1 Mg (Megagram) = 1 Metric Ton = 1.1023 Imperial Tons
3. Waste Composition: R/C = Residential and Commercial; I = Industrial; CD = Construction & Demolition Debris; S = Sludges; YLC = Yard & Land Clearing Wastes; L = Liquids; O = Other Waste

1. BANDEIRANTES LANDFILL

a. Basic Site Information

The Bandeirantes Landfill site is located in the City of São Paulo in the São Paulo State. The site is owned by the City, and operated by Logos Engenharia, a private company contracted by the city. The site's currently-permitted disposal capacity is 20 million metric tons. An expansion beyond the current landfill footprint is planned in the near future to include an additional 47 hectares. This expansion will provide an additional 15 million metric tons of waste disposal capacity. Future landfilling will occur both horizontally within the expansion area and vertically within the currently-defined footprint.

The Bandeirantes Landfill site reportedly started operation and began accepting waste in 1980, and is operated as a canyon/quarry-type landfill. It is estimated that there is currently 16.5 million metric tons of waste in place. The current average daily waste disposal rate is 6,000 metric tons, which occurs 24 hours per day, 7 days per week. Plans are underway for the development of the closure activities scheduled for the year 2016. However, historical and projected waste receipt information indicates that site disposal capacity will be exhausted in the year 2006 based on a currently-planned 35 million metric ton disposal capacity. Although future expansions beyond the 35 million metric ton capacity may occur, and there is potential for some expansion of the site, the data reported here are for the existing site capacity only.

The Bandeirantes site has a base lining system consisting of clayey and sandy soils. The leachate collection system consists of two lined leachate holding ponds. The impounded leachate is transported daily to a nearby wastewater treatment plant for disposal. The reported groundwater elevation is 30 meters, which is approximately 10 meters above the elevation of the base lining system. Thus, it is possible that a portion of the waste may be too close to the groundwater.

b. Waste Characterization and Landfilling Practices

Materials accepted for disposal consist of 55 percent residential, 20 percent commercial, 10 percent construction and demolition debris, 7 percent yard and land clearing wastes, and 8 percent other wastes. The site does not accept industrial waste, sludge, and liquid wastes. The estimated organic content of the waste is 55 percent. The current average waste depth is 18 meters, with a current maximum waste depth of 27 meters. The planned final maximum waste depth is 37 meters. The waste deposited at the site is compacted utilizing landfill compactors. Approximately 50 percent of the site is under final cover, with the remaining portion under intermediate and daily cover. Soils used for cover purposes are available at the site and consist of a range of soil types. Clayey soils are used for the intermediate and final cover systems.

c. Landfill Gas Generation Estimates

Estimates of landfill gas generation were accomplished using the U.S. Environmental Protection Agency's (EPA) Landfills Air Emissions Estimation Model (version 2.0 Model). No waste receipt data was available at the site. However, a previous U.S. EPA-funded study involving landfill gas generation estimates ("Feasibility Assessment for Gas-to-Energy at Selected landfills in São Paulo, Brazil - Public Review Draft," EPA 68-W6-0004, September, 1996) provided waste receipt data for the years 1980 through 1995. This data was used to develop and confirm estimates in this report. Actual waste receipt data from 1995 were used for the period from 1996 through 2006.

Based on the 20 million metric ton disposal capacity that is currently permitted) and a near-term planned expansion which will provide an additional 15 million metric tons of waste disposal capacity, a total disposal capacity of 35 million metric tons was estimated. Based on the 1995 waste receipts and the future trends for the daily waste collection, the 35 million metric tons disposal capacity of the site is expected to reach its final capacity by the year 2006.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 185,000 and 370,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are approximately 2,551,707,000 million joules or 2,419,000 million Btus per year and 4,964,619,000 million joules or 4,706,000 million Btus per year for the low and high methane generation estimates, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 2,009,332,000 to 3,000,844,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 75,751,544,000 million joules or 71,802,000 million Btus and 113,131,389,000 million joules or 107,234,000 million Btus.

2. BELO HORIZONTE LANDFILL

a. Basic Site Information

The Belo Horizonte Landfill site is in the City of Belo Horizonte in the Minas Gerais State. The site is owned and operated by the City of Belo Horizonte. The site property encompasses approximately 150 hectares, of which 80 hectares is occupied by the landfill itself and the remaining 70 hectares may be available for potential expansion. However, expansion beyond the current landfill footprint is not planned. Approximately 90 percent of the permitted landfill area is currently occupied by disposed wastes. Future landfilling will occur both horizontally and vertically within the currently-defined permitted area.

The site began accepting waste in 1973 and is operated as a canyon-fill landfill. Disposal activities were largely uncontrolled during the first 10 years of operation, but the site has since been operated in a controlled and planned manner. It is estimated that 7 million metric tons of waste is currently in place at the site. The current daily waste disposal rate is 2,100 metric tons, which occurs 24 hours per day, 6 days per week. The site is scheduled to be closed in the year 2004. However, waste receipt projections indicate exhaustion of the site's disposal capacity in the year 2002.

The site has a base lining system consisting of clay soils with permeabilities on the order of 10^{-7} centimeters per second. A leachate collection system collects and transmits leachate to two holding tanks. The City is considering leachate recirculation into the waste mass as a future leachate disposal option. The groundwater elevations range from 2 to 45 meters below the ground surface within the site.

A landfill gas collection system was installed at the site in 1989, but has since been abandoned. The system consisted of 12 to 18 vertical and horizontal wells connected to header piping and two blowers. The design flow capacity of the system is reported as 330 cubic meters per hour. The collected methane gas was used as fuel for cars by CEMIG, a local power utility.

b. Waste Characterization and Landfilling Practices

According to information obtained during the site visit, the material landfilled consists of residential, commercial, construction and demolition debris, and yard and land clearing wastes. Approximately 25 metric tons per day of hospital wastes are also accepted for disposal at the site. Industrial, sludge, and liquid wastes are not accepted. The estimated organic content of the waste ranges from 65 to 70 percent.

The current average waste depth at the site 25 meters, with a current maximum waste depth of 45 meters. The planned final maximum waste depth is 50 meters. Current and final sideslope ratios are 3:1 (horizontal:vertical). Wastes are compacted utilizing bulldozers but no landfill compactor machinery is utilized. The site operator reports that a compaction density of 700 kilograms per cubic meter is achieved. Approximately 80 percent of the site is under intermediate cover and no portion of the site has received final cover. Clay soils are used for cover purposes are available at the site.

c. Landfill Gas Generation Estimates

Waste receipts for the years 1973 and 1974 were estimated as 100,000 metric tons each year. Based on the permitted disposal capacity of 11,856,000 metric tons, projected waste receipts for the years 1996 through 2002 were straight-line averaged.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 78,000 and 142,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are approximately 1,072,998,000 million joules or 1,017,000 million Btus per year and 1,951,682,000 million joules or 1,850,000 million Btus per year for the low and high methane generation estimates, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 662,493,000 to 896,002,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 24,975,877,000 million joules or 23,674,000 million Btus and 33,779,161,000 million joules or 32,018,000 million Btus.

3. BIGUACU LANDFILL

a. Basic Site Information

The Biguacu Landfill site is near the City of Florianópolis in the State of Santa Catarina. The site is owned and operated by Formacco Construcao e Comercio Ltda., a privately held construction company. The site property encompasses approximately 190 hectares, of which 60 hectares is currently permitted to receive wastes. The landfill currently occupies approximately 70 percent of the permitted area. Expansion beyond the current landfill footprint is planned, and is expected to occur in two phases. The total planned expansion area is 120 hectares, resulting in a total final permitted disposal area of 180 hectares.

The site began accepting waste in 1993, and is operated as a canyon-fill landfill. It is estimated that 300,000 metric tons of waste is currently in place at the site. Wastes from five nearby communities are accepted for disposal at the site. It is anticipated that 10 additional communities may also be using this site for waste disposal within the next 2 to 3 years. The current daily waste disposal rate at the site is between 250 and 300 metric tons per day during the winter, and between 500 and 600 metric tons per day in the summer. Future landfilling within the permitted disposal area will occur both horizontally and vertically. Landfilling activities occur 7 days per week. No site closure schedule was reported as future expansions offer substantial additional disposal capacity.

The site has a base lining system consisting of clay soils with permeabilities ranging from 10^{-7} to 10^{-12} centimeters per second. A leachate collection system collects and transmits leachate to four leachate lagoons (one anaerobic, two facultative, and one maturation-facultative). The site owner/operator intends to dispose of the collected leachate by recirculation into the waste mass. The groundwater elevations range from 2 to 3 meters above sea level within the site.

b. Waste Characterization and Landfilling Practices

Approximately 90 to 95 percent of the waste disposed at the site is residential and commercial and the remaining 5 to 10 percent consists of yard and land clearing wastes. A small percentage of hospital wastes is also accepted for disposal at the site. Industrial, construction and demolition debris, sludge, and liquid wastes are not accepted. The estimated organic content of the waste is 60 percent. The current average waste depth is 10 meters, with a current maximum waste depth of 15 meters. The planned final maximum waste depth is 63 meters. Current and final sideslope ratios are 3:1 (horizontal:vertical). Waste is compacted utilizing bulldozers.

Most of the site is under intermediate cover. As vertical filling operations are continuing, no portion of the site has received final cover. Clay soils used for daily and intermediate cover purposes are available on the site and from a borrow area located approximately 700 meters from the site.

c. Landfill Gas Generation Estimates

The waste receipt data was not provided for the site, and was thus estimated for the years 1993 through 2022 based on reported in-place waste tonnage and current average daily waste receipts. The daily disposal rate, once additional communities are serviced by the site, are not available. Therefore waste receipt estimates are considered conservative as they do not include these additional communities.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 4,000 and 9,000 cubic meters per day of methane was generated in the year 1996. The energy values associated with the 1996 estimates are 54,088,000 million joules or 51,000 million Btus per year and 126,411,000 million joules or 120,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 110,155,000 to 196,864,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 4,152,824,000 million joules or 3,936,000 million Btus and 7,421,732,000 million joules or 7,035,000 million Btus.

4. CAXIMBA LANDFILL

a. Basic Site Information

The Caximba Landfill site is located near the City of Curitiba in the State of Paraná. The site is owned by the City of Curitiba and operated by Cavo - Cia Auxiliar de Viacao e Obras, a private company that also collects refuse for the City. The site property encompasses approximately 41 hectares, of which 27 hectares currently is permitted to receive wastes. The landfill currently occupies approximately 70 percent of the permitted area. Expansion beyond the current landfill footprint is not planned. However, the City intends to develop another landfill site in the near future. One possible location for the new landfill site is on adjacent property. The new landfill likely will be designed with a 25-year capacity.

The site began accepting waste in 1990 and is operated as a valley-fill landfill. It is estimated that 2.4 million metric tons of waste is currently in place at the site. The current average daily waste disposal rate is 1,450 metric tons. Future landfilling within the permitted disposal area will occur both horizontally and vertically. Landfilling activities occur on a 24 hours per day, 7 days per week basis. The site is scheduled to be closed in 2003.

The site has a recompacted, in-situ base lining system consisting of clayey sand soils with permeabilities averaging 10^{-5} centimeters per second. A leachate collection system collects and transmits leachate to two leachate lagoons where the leachate is left to evaporate.

b. Waste Characterization and Landfilling Practices

According to the City, 80 percent of the waste disposed at the site is residential and commercial and the remaining 20 percent consists of construction and demolition debris and yard and land clearing wastes. Industrial, sludge, and liquid wastes are not accepted. The estimated organic content of the waste is 65 percent. The reported current average waste depth is 20 meters, with a current maximum waste depth of 24 meters. The planned final maximum waste depth is 44 meters. Current and final sideslope ratios are 2:1 (horizontal:vertical). Wastes are compacted utilizing bulldozers. Although a compactor was present at the site, it was not being utilized.

Approximately 45 percent of the site is under intermediate cover, and 35 percent is under final cover. A large percentage (i.e., 20 percent) of the site is uncovered. Clay soils used for cover purposes are obtained both on-site and from a City-owned borrow area near the site.

c. Landfill Gas Generation Estimates

The waste receipt data was provided for the period from 1990 through 1995. Waste receipts for the period from 1996 to closure were estimated based on the current average disposal rate and an anticipated site closure date in the year 2003.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 30,000 and 64,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 408,060,000 million joules or 387,000 million Btus per year and 884,983,000 million joules or 839,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 345,037,000 to 532,158,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 13,007,836,000 million joules or 12,330,000 million Btus and 20,062,292,000 million joules or 19,016,000 million Btus.

5. DELTA I LANDFILL

a. Basic Site Information

The Delta I Landfill site is in the City of Campinas in the State of São Paulo. The site is owned and operated by the City. The permitted disposal area encompasses approximately 60 hectares, of which 30 percent has received wastes. A 60-hectare expansion beyond the current landfill footprint is planned.

The site began accepting waste in 1992 and is operated as a valley-fill landfill. It is estimated that 1 million metric tons of waste is currently in place at the site. The current average daily waste disposal rate is 700 metric tons per day. Future landfilling within the permitted disposal area will occur both horizontally and vertically until site closure which is scheduled for 1998. Landfilling activities occur on a 22 hours per day, 6 days per week basis.

The site has a recompacted, in-situ base lining system consisting of silty soil. A leachate collection system collects and transmits leachate to anaerobic storage tanks and the site operator used trucks to transport leachate to a nearby treatment facility.

b. Waste Characterization and Landfilling Practices

Types of wastes accepted for disposal at the site include residential, commercial, and yard and land clearing wastes. Industrial, construction and demolition debris, sludge, and liquid wastes are not accepted at the site. The estimated organic content of the waste is 65 percent.

The reported current average waste depth is 30 meters. Current and final sideslope ratios are 3:1 (horizontal:vertical). Wastes are compacted utilizing several bulldozers available on the site. Approximately 50 percent of the site is under intermediate cover, with 45 percent under final cover. Clay soils used for cover purposes are available on the site.

c. Landfill Gas Generation Estimates

The waste receipt data was not available, and therefore the existing in-place waste was estimated based on current average daily waste receipts. Based on the current average disposal rate, and an anticipated closure date in the year 1998, a total capacity of 1.5 million metric tons is estimated for the current phase of operation of the site. No information was provided regarding the planned expansion area disposal capacity and is therefore not included in the landfill gas generation estimate.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 14,000 and 31,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 190,150,000 million joules or 180,000 million Btus per year and 425,249,000 million joules or 403,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 98,219,000 to 141,913,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 3,702,858,000 million joules or 3,510,000 million Btus and 5,350,087,000 million joules or 5,071,000 million Btus.

6. GOIANIA LANDFILL

a. Basic Site Information

The Goiânia Landfill site is in the City of Goiânia in the State of Goiás. The site is owned by the City and operated by Enterpa Engenharia Ltda., a private company contracted by the City. The total site area encompasses 50 hectares, of which 25 hectares is the permitted fill area. Future landfilling will occur both vertically and horizontally within the current permitted landfill footprint.

The site reportedly began accepting waste in 1976 and the site is operated as a mound-type landfill. No data is available regarding the total site capacity or waste receipts for the years 1976 through 1989. Waste receipt data for the period from 1990 through 1996 were provided be the site operator. The current daily waste disposal rate is 1,200 metric tons, which occurs on a 24 hours per day, 6 days per week basis.

The site has a base lining system, consisting of a low-permeability clay liner with a leachate collection system. The leachate collection system collects and transmits leachate to three lagoons (one anaerobic lagoon and two sedimentation basins). The impounded leachate is currently evaporated, but recirculation of the leachate into the waste mass is under consideration as a potential leachate disposal option. The reported groundwater elevation within the site area ranges from 8 to 14 meters below the ground surface.

b. Waste Characterization and Landfilling Practices

Materials accepted for disposal consist of 90 percent residential and commercial wastes. The remaining 10 percent is comprised of yard and land clearing wastes and sludges. Industrial, construction and demolition debris, and liquid wastes are not accepted at the site. The organic content of the waste appears to be too high, despite the fact that 90 percent of the total waste is residential and commercial waste.

The reported current average waste depth is 12 meters, with a current maximum waste depth of 15 meters. The planned final maximum waste depth is 40 meters. Wastes are compacted utilizing bulldozers. No portion of the site has received final cover. Clay soils used for cover purposes are available on the site.

c. Landfill Gas Generation Estimates

Recorded waste receipt data for the years 1990 through 1996 was used to estimate overall waste availability for future years. Waste receipt input data for the period from 1976 through 1989 were estimated based on an assumed annual increase in waste receipts of 20 percent, reflective of the considerable population migration and increased commercial activity in the area. Total disposal capacity was estimated based on the reported average maximum landfill height of 40 meters, and an assumed in-place waste density of 700 kilograms per cubic meter. Finally, based on the reported average daily waste acceptance rate of 1,200 metric tons, the site is expected to reach its final disposal capacity in the year 2007.

Based on preliminary estimates of waste receipts, a total disposal capacity of 6.3 million metric tons of disposal capacity was estimated. Based on these waste estimates, the total methane generated was estimated to be 25,000 and 50,800 cubic meters per day in 1996. The energy values associated with the 1996 estimates for the methane are 341,331,000 million joules or 324,000 million Btus per year and 690,242,000 million joules or 654,000 million Btus per year for the low and the high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 356,642,000 to 564,420,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 13,445,363,000 million joules or 12,744,000 million Btus and 21,278,570,000 million joules or 20,169,000 million Btus.

7. GRAMACHO LANDFILL

a. Basic Site Information

The Gramacho Landfill site is located in Duque de Caxias in the State of Rio de Janeiro. The site is owned by the City of Rio de Janeiro and operated by Queiroz Galvao, a private company contracted by the City. The site property encompasses approximately 140 hectares, of which 110 hectares is occupied by the landfill. Expansion beyond the current landfill footprint is not planned and future landfilling will occur vertically within the currently-defined footprint.

Communities currently being served by the site include Duque de Caxias, Petropolis, Nilopolis, Sao Joao Demeriti, and Rio de Janeiro. Approximately 80 percent of the waste landfilled at the site originates in the City of Rio de Janeiro, with the remaining 20 percent originating in the other communities.

The site began accepting waste in 1978 and it is operated as a mound-type landfill. It is estimated that 28 million metric tons of waste is currently in place at the site and that approximately 2 million metric tons of waste per year has been landfilled since 1990. The current daily waste disposal rate is 7,500 metric tons, which occurs on a 24 hours per day, 7 days per week basis. The site is expected to close to receipt of wastes in the year 2006 or 2007.

Landfilled wastes were placed directly on the ground surface, which consists of bay soils of high clay content. No leachate collection system or base lining system was installed prior to landfilling on the existing ground surface. Reported in-situ permeability of the bay soils is on the order of 10^{-8} cm/sec. The site operator's estimates indicate that the bay soils have settled as much as 6 meters and that an average settlement of 20 centimeters will result for every 1 meter of deposited waste. Because groundwater is essentially at the ground surface at the site, it is assumed that a portion of the waste is in the groundwater.

Although no leachate collection system was installed, plans are underway to construct a dolomite-filled trench along the landfill perimeter beginning in 1997. A horizontal leachate collection pipe will be installed in the trench to allow for leachate withdrawal. It is estimated that as much as 1,000 cubic meters per day of leachate will be collected. A perimeter barrier trench which extends approximately 1 meter below groundwater is near completion. This barrier trench is anticipated to significantly decrease the amount of groundwater flow into the waste mass.

The disposal of leachate is expected to be accomplished on site through recirculation into the waste mass as nearby wastewater treatment plants will not accept leachate from the site. The collected leachate may require treatment depending on the measured biological oxygen demand. Should treatment be required prior to on-site disposal, the site operator plans to purchase and utilize an on-site treatment system. The site planners have conducted a preliminary assessment for the potential of using collected landfill gas to evaporate leachate and this option is under active consideration.

b. Waste Characterization and Landfilling Practices

According to data compiled for the years 1993 through 1995 by the City, the material landfilled at the site consists of residential, commercial, industrial, construction and demolition debris, and yard and land clearing wastes. The site also accepts small quantities of industrial liquid wastes (200 Mg per day) and medical wastes (50 Mg per day). The site operator reports that the acceptance of liquid wastes at the site will cease in the future.

The current average waste depth at the site is 17 meters, with a current maximum waste depth of 21 meters and the planned final maximum waste depth is 45 meters. Of the 110 hectare landfilled area, the landfill "deck" will comprise approximately 100,000 square meters, or 10 percent of the total area. The remaining 90 percent of the landfilled area will be sloped at 10:1 (horizontal:vertical). Wastes are compacted utilizing bulldozers. Scavenging activities are allowed and are performed by nearby residents. Observed scavenged wastes include primarily paper, plastics, glass and metals.

Approximately 50 percent of the site, primarily the interior portion of the landfill area, is under intermediate cover and the remaining portions of the site have little or no cover. These uncovered areas are medium to heavily vegetated and encompass the outer portions of the landfill. No portion of the site is under final cover. Soils used for cover purposes are obtained off-site within a 10 kilometer radius as on-site soils are unavailable.

c. Landfill Gas Generation Estimates

The actual waste receipt for the years 1993-1995 and estimates of waste receipt for the year 1996 were provided by the site operator. Based on an estimated 28,000,000 metric tons of in-place waste, and waste receipt data for the years 1993 through 1996, waste receipts for the years 1978 through 1992 were estimated using an average linear growth rate. Finally, based on an anticipated waste stream of 7,500 metric tons per day, and the planned closure of the site in the year 2007, waste receipt data for the years 1997 through 2007 were estimated.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 281,000 and 484,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 3,870,267,000 million joules or 3,668,500 million Btus per year and 6,657,928,000 million joules or 6,311,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 3,099,652,000 to 4,477,930,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 116,856,454,000 million joules or 110,764,000 million Btus and 168,817,332,000 million joules or 160,017,000 million Btus.

8. JOINVILLE LANDFILL

a. Basic Site Information

The Joinville Landfill site is in the City of Joinville in the State of Santa Catarina. The site is owned by the City and operated by Engepasa - Engenharia do Pavimento S.A., a private company contracted by the City. The site property encompasses approximately 168 hectares, of which 56 hectares is occupied by the landfill itself. The permitted disposal area is planned to be expanded by 16 hectares in early 1997 which will only provide three years additional life for the site. Landfilling in the current disposal area will occur vertically until the expansion area is permitted to receive wastes.

The site began accepting waste in 1980 and is operated as a mound-type landfill. It is estimated that 900,000 metric tons of waste is currently in place. The site is expected to close in 1999. The current daily waste disposal rate is 300 metric tons which occurs on a 24 hours per day, 6 days per week basis.

The site has a base lining system consisting of sandy clay soils. A leachate collection system collects and transmits leachate to three lagoons (one anaerobic and two facultative) where disposal occurs via evaporation. The site operator is considering the installation of a more advanced treatment system which may include physical/chemical and/or physical/biological leachate treatment technologies.

b. Waste Characterization and Landfilling Practices

The current waste at the site consists of 70 percent residential and commercial, 20 percent industrial (Type I-inert), 6 percent yard and land clearing wastes, and 4 percent medical wastes. Construction and demolition debris, sludge, and liquid wastes are not accepted at the site. The estimated organic content of the waste ranges from 50 to 60 percent.

The current maximum waste depth is 21 meters, with a planned final maximum waste depth of 27 meters. Current sideslope ratios are 3:1 (horizontal:vertical), with a 2.5:1 planned final sideslope ratio. Sideslopes comprise approximately 36 percent of the total disposal area. Wastes are compacted utilizing bulldozers.

Most of the existing disposal area is under final cover. The site operator maintains a small working face at the site. Clay soils used for cover purposes are available at the site and additional clay is obtained from an off-site source located 500 meters from the site.

c. Landfill Gas Generation Estimates

The waste receipt data was available only for the period from 1993 through 1995. Thus, much of the annual waste receipts were estimated for modeling purposes. Based on the limited waste receipt data and reported current in-place waste of 900,000 metric tons, estimates for annual receipts were made for the period from 1980 through 1992. Waste receipt projections for the period from 1997 through 1999 were based on the reported daily disposal rate of 300 metric tons per day.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 9,500 and 17,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 130,788,000 million joules or 124,000 million Btus per year and 234,138,000 million joules or 222,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 65,871,000 to 82,395,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 2,483,324,000 million joules or 2,354,000 million Btus and 3,106,271,000 million joules or 2,944,000 million Btus.

9. JOQUEI LANDFILL

a. Basic Site Information

The Joquei Landfill site is located in the City of Brasília in Distrito Federal. The site is owned by the Governo do Distrito Federal and operated by Servico de Limpeza Urbana. The disposal area encompasses an area of approximately 162 hectares. Landfilling has occurred over most of this area to date, and the waste is estimated to be 3 meters thick.

The site began accepting waste in 1979 and is operated as a mound-type landfill. No information regarding the mass of in-place waste was available. The current daily waste disposal rate is 1,300 metric tons, which occurs on a 24 hours per day, 6 days per week basis. The site is expected to close in 2004.

The site does not have a base lining or a leachate collection system. Wastes are disposed on the existing ground surface. Leachate flows freely onto the ground surface and presumably into groundwater located 2 to 3 meters below the ground surface.

b. Waste Characterization and Landfilling Practices

Materials landfilled at the site consist of residential, commercial, industrial, construction and demolition debris, sludges, yard and land clearing wastes, liquids, and other wastes, including medical wastes. No data was available regarding the percentage of the waste types disposed at the site. The reported current average waste depth is 3 meters. No data was available regarding planned final grades for the site and no portion of the site is under cover.

c. Landfill Gas Generation Estimates

The waste receipt data was not available, and thus was estimated based on reported current average waste thickness, disposal area, and assumed density of waste. Based on these assumptions, it is estimated that 3.6 million metric tons of waste is currently in place at the site.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 40,000 and 76,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 550,913,000 million joules or 522,000 million Btus per year and 1,044,599,000 million joules or 990,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 396,052,000 to 569,810,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 14,931,118,000 million joules or 14,153,000 million Btus and 21,481,746,000 million joules or 20,362,000 million Btus.

10. LARA LANDFILL

a. Basic Site Information

The Lara Landfill site is located in Mauá in the State of São Paulo. The site is owned and operated by Lara Comercial & Prestacao de Serviços, Ltda. The site property encompasses approximately 45 hectares, of which 12 hectares is the permitted disposal area. Landfilling in the disposal area will continue to occur both horizontally and vertically. Communities served by the Site include Diadema, Ribefirao Pires, Mauá, Sao Bernardo do Campo, and Sao Caetano do Sul.

The site began accepting waste in 1987 and is operated as a quarry-fill landfill. It is estimated that 3.6 million metric tons of waste is currently in place. The current average daily waste disposal rate is 1,200 metric tons, which occurs on a 24 hours per day, 7 days per week basis. The site is expected to reach capacity and close in 2016.

The site has a base lining system consisting of sandy clay soils. A leachate collection system collects and transmits leachate to an aeration lagoon.

b. Waste Characterization and Landfilling Practices

Materials landfilled at the Lara site consist of residential, commercial, construction and demolition debris, and yard and land clearing wastes. Industrial, sludge, and liquid wastes are not accepted at the site. The estimated organic content of the waste is 65 percent and the current average waste depth is 35 meters. Wastes are compacted utilizing bulldozers and no landfill compactor machinery is available at the site.

Approximately 45 percent of the site is under intermediate cover, with 30 percent under final cover. Clay soils used for cover purposes are available on the site.

c. Landfill Gas Generation Estimates

Waste receipt data was not available for the site, thus waste receipts for the period from 1987 through 1996 were projected linearly using the in-place waste mass of 3.6 million metric tons as a base. Waste receipts for the period from 1997 through 2016 were straight-line averaged based on a daily disposal rate of 1,200 metric tons.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 42,000 and 83,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 572,780,000 million joules or 543,000 million Btus per year and 1,140,261,000 million joules or 1,081,000 million Btus per year the low and high methane generation estimates, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 568,190,000 to 925,752,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 21,420,676,000 million joules or 20,304,000 million Btus and 34,900,738,000 million joules or 33,081,000 million Btus.

11. SANTA BARBARA LANDFILL

a. Basic Site Information

The Santa Barbara Landfill site is a closed landfill located in the City of Campinas in the State of São Paulo. The site is owned and operated by the City. The permitted fill area encompasses approximately 35 hectares. The site began accepting waste in 1984 and was operated as a mound-type landfill. The site was closed in 1992, as no expansion land was available in the vicinity of the site. It is estimated that 1.2 million metric tons of waste is currently in place at the site.

The site has a base lining system consisting of silty clay soils overlaid by a polyethylene membrane liner and leachate collection system. The leachate collection system collects and transmits leachate to a lagoon where it undergoes physical/chemical treatment.

The City intends to utilize a portion of the site for recreational purposes, with some restrictions. A landfill gas collection and control system is in place and is currently operating. The system has 20 extraction wells spaced at approximately 50 meter intervals. The wells are interconnected via header piping which leads to a small candle flare where the landfill gas is burned. The system was installed in 1990.

b. Waste Characterization and Landfilling Practices

Materials landfilled at the site consisted of residential, commercial, industrial, and yard and land clearing wastes. Construction and demolition debris, sludge, and liquid wastes were not accepted at the site. The estimated organic content of the waste averages 60 percent. The reported average waste depth is 30 meters, with a maximum waste depth of 40 meters. Sideslope ratios are 3:1 (horizontal:vertical). The entire disposal area is under final cover.

c. Landfill Gas Generation Estimates

The waste receipt data was not available, and thus was estimated for modeling purposes. Based on the reported in-place waste mass of 1.2 million metric tons, waste receipts were straight-lined for the period 1984 through 1992.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 12,000 and 19,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 165,060,000 million joules or 156,000 million Btus per year and 262,431,000 million joules or 249,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 59,061,000 to 57,240,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 2,226,594,000 million joules or 2,111,000 million Btus and 2,157,933,000 million joules or 2,045,000 million Btus.

12. SAO JOAO LANDFILL

a. Basic Site Information

The Sao Joao Landfill site is located in the metropolitan area of the City of São Paulo in the State of São Paulo. The site is owned by the City and operated by Enterpa, a private company contracted by the City. The currently-permitted disposal area encompasses 33 hectares. Two planned expansions are expected to add 54 hectares to the total permitted disposal area. Landfilling in the current disposal area will occur vertically until the expansion areas are permitted to receive wastes.

The site began accepting waste in 1992 and is operated as a canyon-fill landfill. It is estimated that 5.6 million metric tons of waste is currently in place at the site. The current average daily disposal rate is 5,100 metric tons, which occurs on a 24 hours per day, 7 days per week basis. The current site is expected to close in 2000. The 54 hectare expansion planned for the site will be accomplished in two phases and will add an additional 10 years to the life of the site based on anticipated waste receipt rates. The site has a base lining system consisting of sandy clay soils. A leachate collection system collects and transmits leachate to lined lagoons for storage. The stored leachate is then transported via trucks to a nearby wastewater treatment plant for disposal. Approximately 1,000 cubic meters per day of leachate is transported to the wastewater treatment plant for disposal.

b. Waste Characterization and Landfilling Practices

Material landfilled consists solely of residential and commercial wastes. Other waste types are not accepted at the site. The estimated organic content of the waste is 60 percent. The current average waste depth is 11 meters, with a current maximum waste depth of 15 meters. The planned final maximum waste depth is 18 meters. Current and planned sideslope ratios are 2:1 (horizontal:vertical). Wastes are compacted utilizing landfill compactors located on the site. Approximately 50 percent of the site is under intermediate cover. The site's final cover system comprises 45 percent of the current disposal area. Clay soils used for cover purposes are available on the site.

c. Landfill Gas Generation Estimates

A previous EPA study involving landfill gas generation estimates ("Feasibility Assessment for Gas-to-Energy at Selected Landfills in São Paulo, Brazil - Public Review Draft," EPA 68-W6-0004, September, 1996) provided waste receipt input data for the years 1994 through 2012. This data was used for projecting the availability of methane.

Based on a low and a high methane generation scenario, preliminary estimates indicate that between 74,000 and 174,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 1,014,918,000 million joules or 962,000 million Btus per year and 2,395,829,000 million joules or 2,271,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 1,775,551,000 to 3,112,623,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 66,938,011,000 million joules or 63,448,000 million Btus and 117,345,443,000 million joules or 111,228,000 million Btus.

13. ZONA NORTE LANDFILL

a. Basic Site Information

The Zona Norte Landfill site is located in the City of Porto Alegre in the State of Rio Grande do Sul. The site is owned and operated by the City. The site property encompasses 50 hectares, of which 40 hectares is the permitted disposal area. Landfilling in the current disposal area will occur vertically until site closure which is planned for March 1997. No expansion of the site is planned due to limited land availability.

The site began accepting waste in 1983 and was legally permitted in 1989. The site is operated as a mound-type landfill and is comprised of 5 separate mounds. It is estimated that 3.4 million metric tons of waste is currently in place at the site. The current average daily disposal rate is 1,300 metric tons per day which occurs on a 24 hours per day, 6 days per week. The site has a base lining system consisting of clay soils. A leachate collection system collects and transmits leachate to sumps where it is recirculated into the waste mass.

b. Waste Characterization and Landfilling Practices

Materials landfilled at the site consist of 66 percent residential and commercial, 1.5 percent industrial, 1.5 percent construction and demolition debris, and 31 percent yard and land clearing wastes. Sludge and liquid wastes are not accepted at the site. The estimated organic content of the waste is 60 percent.

The current average waste depth is 3 meters, with a current maximum waste depth of 10 meters. The planned final maximum waste depth is 15 meters. Current and planned sideslope ratios are 3:1 (horizontal:vertical). Wastes are compacted utilizing bulldozers located on the site.

Most of the site is under final cover, with approximately 10 percent of the site under daily and intermediate cover. Clay soils used for cover purposes are available on the site.

c. Landfill Gas Generation Estimates

The waste receipt data for the period from 1992 through 1995 was provided for the site. Estimates of waste receipts for years prior to 1992 were made based on estimates of in-place waste and the limited waste receipt data available at the site.

Based on a low and a high methane generation scenarios, preliminary estimates indicate that between 38,000 and 74,000 cubic meters per day of methane was generated in 1996. The energy values associated with the 1996 estimates are 525,075,000 million joules or 498,000 million Btus per year and 1,014,704,000 million joules or 962,000 million Btus per year for the low and high methane generation scenarios, respectively.

Total methane generation estimates over the next 20 years, from 1997 through 2016, range from 195,391,000 to 233,334,000 cubic meters for the low and high methane generation scenarios, respectively. Energy values associated with these cumulative methane generation estimates range from 7,366,213,000 million joules or 6,982,000 million Btus and 8,796,664,000 million joules or 8,338,000 million Btus.

C. NATIONAL IMPLICATIONS BASED ON THE SELECTED SITES

The Instituto Brasilerio de Geografia e Estatistica has estimated that a total of 241,614 tons of municipal solid waste is generated in Brazil every day in all of its 4,974 municipalities. Of this amount, approximately 76 percent, or 183,627 tons of waste per day, is dumped in illegal, unorganized dumps. Approximately 10 percent of the waste goes to sanitary landfills; 0.9 percent is used for composting; 0.1 percent is incinerated; and the remaining 13 percent or 31,409 tons per day is disposed in controlled landfills. The total waste transported and dumped at the 13 sites visited by the team is estimated at 28,425 tons per day. Of this amount, approximately 11 percent is used for composting, sanitary landfill, and incineration. The remaining 25,298 tons per day is covered at the 13 landfills and is attributable to the generation of LFG. Thus, the amount of waste directly attributable to the generation of LFG at the thirteen sites visited by the team is approximately 80.5 percent of the total waste collected and transported to legally controlled and operated landfill sites.

Furthermore, the composition of the waste is generally the same from site to site, especially the organic waste content which is estimated to be exceeding 50 percent in most of the country's landfill sites. The 12 cities where the 13 sites are located have a population of approximately 33 million. The total urban population of the 46 major cities/municipalities in Brazil with population greater than 300,000 residents is estimated to be approximately 42 million. Thus, the population of the sample cities selected for this study represents approximately 78.5 percent of the total urban population in the country which generates not only more per capita but also the majority of the waste in Brazil.

Accordingly, the 13 sample sites selected for the study are quite representative of the municipal waste management practice in Brazil. In addition, the sites are also representative of the waste management patterns in the country -- wholly owned and operated by the city/municipality; owned by the city and operated by a private contractor; and wholly owned and operated by the private sector. Furthermore, the selected sites are located in 8 of Brazil's 12 most populated states and are geographically reflective of the country's waste generation, collection, transportation, and disposal patterns.

Given that the sample of the 13 sites selected for the study is representative of the country as a whole, it can be concluded that the opportunities for technical, policy, and institutional enhancements at these sites would also be applicable to other sites in the country. Specifically, the technologies for the recovery and separation of methane from LFG, leachate collection and treatment, composting, incineration, and LFG-based energy recovery applicable to the 13 sample sites can also be applied to other sites throughout the country. In terms of waste disposal practices, private sector participation, ownership/management patterns, concession and bidding procedures, financing approaches, and public-private partnership, any conclusions reached for these 13 sample sites may also be applicable to other sites in Brazil.

VI. NATIONAL LANDFILL GAS MARKET POTENTIAL

A. OVERALL POTENTIAL FOR LANDFILL GAS AVAILABILITY

The team utilized the U.S. Environmental Protection Agency (EPA) *Landfill Air Emission Estimation* model (DOS Model, Version 2.0) to develop estimates for landfill gas generation potential at each of the 13 landfill sites in the country. Table VI-1 provides a summary of the estimated methane generation potential at each site. The Table presents the team's estimates for methane generation for the year 1996 and for the 20-year period from 1997 through 2016. Methane generation estimates are presented for two scenarios -- a low methane generation scenario and a high methane generation scenario.

The low-generation scenario estimates are based on a methane generation decay rate of 0.04 per year, which is typical for sites in the U.S. where the average rainfall exceeds 635 millimeters per year. The high methane generation scenario estimates are based on a methane generation decay rate of 0.1 per year. Because the sites report average annual precipitation rates that greatly exceed 635 millimeters per year, the higher decay rate is used to estimate an upper-end methane generation potential. Site-specific methane generation decay rates, which can be measured in the field, are recommended for methane generation estimates at sites where landfill gas collection system development is under consideration.

For the year 1996, the total methane generation potential for the low-generation scenario is estimated at 303.7 million cubic meters. The high generation scenario, potentially more applicable to the sites in Brazil due to the country's high average rainfalls, yields an estimate of potential methane generation at 578 million cubic meters per year.

During the 20 year period (1997-2016), the estimates for total methane generation potential in the low-generation and high-generation scenarios are 9.741 billion cubic meters and 14.791 billion cubic meters respectively which provide an average annual generation potential under the two scenarios of 487 million cubic meters and 739.5 million cubic meters, respectively. This increase in the average annual generation of methane over the 1996 estimates is reflective of the increasing quantities of municipal solid waste which will be disposed of at these sites in the future.

Of the 13 sites selected for the study, the Gramacho Landfill site and the Bandeirantes Landfill site offer the greatest promise for landfill gas generation estimated at 102.7 cubic meters and 67.7 cubic meters respectively. Eight of the 13 sites have a low methane generation scenario estimate of 280.4 cubic meters which is approximately 92.3 percent of the total 1996 methane generation potential. These percentages are similar during the next twenty year period. Bandeirantes, Belo Horizonte, Caximba, Gramacho, and Sao Joao Landfill sites offer the best potential for appreciable quantities of methane generation both in 1996 and during the future twenty year period.

TABLE VI-1
ESTIMATED METHANE GENERATION POTENTIAL

SITE	1996 METHANE GENERATION ESTIMATE (Million Cubic Meters/Yr)		POTENTIAL 1997 - 2016 METHANE RESERVES (Million Cubic Meters)		COMMENTS
	Low Generation (k=0.04/Yr)	High Generation (k=0.10/Yr)	Low Generation (k=0.04/Yr)	High Generation (k=0.10/Yr)	
Bandeirantes Landfill	67.7	131.7	2,009.3	3,000.8	High methane generation potential (1). Favorable M:A ratio (2).
Belo Horizonte Landfill	28.5	51.8	662.5	896.0	Medium methane generation potential.
Biguacu Landfill	1.4	3.4	110.2	196.9	Current low methane generation potential. Large disposal capacity. Waste receipts will increase. Favorable M:A ratio (2)
Caximba Landfill	10.8	23.5	345.0	532.2	Medium methane generation potential.
Delta I Landfill	5.0	11.3	98.2	141.9	Low methane generation potential.
Goiania Landfill	9.0	18.3	356.6	564.4	Medium methane generation potential.
Gramacho Landfill	102.7	176.6	3,099.6	4,477.9	High landfill gas generation potential. Favorable M:A ratio.
Joinville Landfill	3.5	6.2	65.9	82.4	Low methane generation potential. Site will close in 3 years.
Joquei Landfill	14.6	27.7	396.0	569.8	Medium methane generation potential. Unfavorable M:A ratio.
Lara Landfill	15.2	30.2	568.2	925.8	Medium methane generation potential.
Santa Barbara Landfill	4.4	7.0	59.1	57.2	Site is closed. Low methane generation potential.
Sao Joao Landfill	26.9	63.6	1,775.6	3,112.6	High methane generation potential. Favorable M:A ratio.
Zona Norte Landfill	13.9	26.9	195.4	233.3	Low methane generation potential. Unfavorable M:A ratio.
TOTALS	*303.7*	*578.1*	*9,741.5*	*14,791.3*	

NOTES:

1. Methane generation potential: low = less than 499 million cubic meters; medium = 500 to 1,499 million cubic meters; high = greater than 1,500 million cubic meters.
2. M:A = mass-to-area ratio. Represents the ratio of total landfill design capacity, in metric tons, to the landfill footprint area, in hectares. Generally, the higher the ratio, the more favorable the site for landfill gas system development.

The mass to area ratio of landfill sites is typically used in the waste management industry as an indicator of the potential for the development of a landfill gas collection system. Generally, the higher the ratio, the more favorable is a site with respect to the development of landfill gas collection systems. Most of the 13 sites have a favorable mass to area ratio (M:A). The Zona Norte landfill and the Joquei Landfills have an unfavorable mass to area ratio and do not appear to be attractive candidates for the development of landfill gas collection systems. These two sites also do not offer a sizeable potential for the recovery of methane (less than 15 million cubic meters per year).

The Biguacu Landfill, the Delta Landfill, the Goiânia Landfill, the Joinville Landfill, and the Santa Barbara Landfill currently (1996) have a limited potential for methane generation (less than 5 million cubic meters per year in the low methane generation scenario). However, of these five sites, all except the Santa Barbara Landfill, do offer a more sizeable potential for methane generation over the next 20 years because of the potential for site expansion and the sizeable increase in the amount of daily waste receipt anticipated due to high economic growth and population increase, both within their own, and within the neighboring municipalities which may use the site. The Santa Barbara site, however, will soon be closed and will not receiving any municipal waste after a few years. Therefore, in the long run, this site's methane generation potential shows a decline.

B. POTENTIAL MARKETS FOR LANDFILL GAS UTILIZATION

In many countries where the recovery of methane from LFG is prevalent, the uses/markets for the recovered methane include both on-site utilization for the purposes of municipal waste treatment as well as off-site uses in the form of either gas or heat/power. Specifically, the following markets for the recovered methane could prove to be promising for Brazilian landfill sites:

1. On-site Uses For the Treatment of Municipal Waste

A portion of the methane generated at the site could be used for (i) the treatment of leachate, (ii) incineration of medical wastes, and (iii) incineration of waste for the purposes of volume reduction in sites with limited expansion capacity. Any of these uses of the recovered methane will (i) result in environmental benefits associated with the proper treatment of wastes, (ii) permit the use of waste as a valuable resource which is currently largely untapped, and (iii) will reduce or eliminate the need for cost associated with off-site treatment of medical wastes and leachate thus offsetting the costs of operation of the landfill sites.

2. Off-site Uses As an Energy Source

The recovered methane could be processed as pipeline quality gas and sold to PETROBRAS. This option, however, will be economical only if a particular landfill site is located in close proximity to a pipeline and if the price of this methane will be less than the marginal cost of producing a unit of gas in the PETROBRAS system.

Provided that sufficient quantities of methane availability at a particular landfill site can be assured over a 15 to 20 year time frame, the site has the option to generate both thermal and electrical energy in a cogeneration mode and sell low temperature steam and electricity to nearby end users. Typically, such an option could be economical provided the generation costs are comparable to those utilizing other energy resources and a dedicated market will be available in the vicinity of the site. In the case of some of the sites, a large number of residents are located near the site and existing industry or new industrial facilities are moving closer to the site. Conceivably, these residents and the industrial facilities could serve as the market for both steam and electricity generated at the site.

The site also has the option to generate electricity for transfer to the local utility on a transfer price basis through a power purchase agreement. Both this option, and the cogeneration option discussed earlier, are permitted since the passage of the Concession Law and the development of the IPP regulations in the country.

In the case of some of the landfill sites, the project team observed large populations of low income housing units. Many of these residents do not have electric power available to them and could therefore potentially serve as a market for the methane based power generated at the landfill site. Alternatively, the methane at the site could be pressurized and bottled in cylinders for sale to these residents for purposes of cooking, hot water, etc. Considering that many of these residents are in the lower income group, the price of methane will be the main determinant as to the viability of this end user as a market. However, this option is not likely to be cost effective as it would require the recovery of pure methane from LFG.

C. POTENTIAL FOR LANDFILL GAS BASED POWER GENERATION

Methane is a source of energy that can be utilized in a number of different ways, including the generation of electricity where the heat energy associated with the methane is converted to electrical energy using electrical generators. Estimates of electrical power generation potential for each site are summarized in Table VI-2. Power generation estimates, in megawatts (MWs), are provided in Table VI-2 for a 20-year period at four milestones --1998, 2007, 2012, and 2017.

The first milestone, the year 1998, represents the first year of operation of a landfill gas-to-electrical energy system, assuming that the construction of such a system would occur in 1997. The 10-year milestone (2007) represents the minimum return-on-investment period, typically required by the power industry, for a gas-to-electrical energy project. The 15-year and 20-year milestones in 2012 and 2017 complete the 20-year period for which the LFG availability and power generation estimates have been developed.

TABLE VI-2
POTENTIAL ELECTRIC POWER GENERATION ESTIMATES

SITE	LOW METHANE GENERATION SCENARIO				HIGH METHANE GENERATION SCENARIO			
	MILESTONE	YEAR	CM/YR (1)	MW (2)	MILESTONE	YEAR	CM/YR (1)	MW (2)
Bandeirantes Landfill	Install System	1998	8.09E+07	13.2	Install System	1998	1.52E+08	24.9
	10-yr	2007	1.19E+08	19.5	10-yr	2007	1.85E+08	30.1
	15-yr	2012	9.77E+07	15.9	15-yr	2012	1.12E+08	18.3
	20-yr	2017	8.00E+07	13.0	20-yr	2017	6.79E+07	11.1
Belo Horizonte Landfill	Install System	1998	3.34E+07	5.4	Install System	1998	5.96E+07	9.7
	10-yr	2007	3.45E+07	5.6	10-yr	2007	4.33E+07	7.1
	15-yr	2012	2.82E+07	4.6	15-yr	2012	2.63E+07	4.3
	20-yr	2017	2.31E+07	3.8	20-yr	2017	1.59E+07	2.6
Biguacu Landfill	Install System	1998	2.40E+06	0.4	Install System	1998	5.35E+06	0.9
	10-yr	2007	5.89E+06	1.0	10-yr	2007	1.07E+07	1.7
	15-yr	2012	7.35E+06	1.2	15-yr	2012	1.21E+07	2.0
	20-yr	2017	8.55E+06	1.4	20-yr	2017	1.30E+07	2.1
Caximba Landfill	Install System	1998	1.44E+07	2.4	Install System	1998	3.00E+07	4.9
	10-yr	2007	1.90E+07	3.1	10-yr	2007	2.79E+07	4.6
	15-yr	2012	1.56E+07	2.5	15-yr	2012	1.69E+07	2.8
	20-yr	2017	1.27E+07	2.1	20-yr	2017	1.03E+07	1.7
Delta I Landfill	Install System	1998	6.80E+06	1.1	Install System	1998	1.44E+07	2.4
	10-yr	2007	4.74E+06	0.8	10-yr	2007	5.87E+06	1.0
	15-yr	2012	3.88E+06	0.6	15-yr	2012	3.56E+06	0.6
	20-yr	2017	3.18E+06	0.5	20-yr	2017	2.16E+06	0.4
Goiania Landfill	Install System	1998	1.20E+07	2.0	Install System	1998	2.39E+07	3.9
	10-yr	2007	2.28E+07	3.7	10-yr	2007	3.89E+07	6.3
	15-yr	2012	1.87E+07	3.0	15-yr	2012	2.36E+07	3.8
	20-yr	2017	1.53E+07	2.5	20-yr	2017	1.43E+07	2.3
Gramacho Landfill	Install System	1998	1.22E+08	19.8	Install System	1998	2.10E+08	34.2
	10-yr	2007	1.90E+08	31.0	10-yr	2007	2.98E+08	48.7
	15-yr	2012	1.56E+08	25.4	15-yr	2012	1.81E+08	29.5
	20-yr	2017	1.28E+08	20.8	20-yr	2017	1.10E+08	17.9
Joinville Landfill	Install System	1998	4.12E+06	0.7	Install System	1998	7.31E+06	1.2
	10-yr	2007	3.21E+06	0.5	10-yr	2007	3.50E+06	0.6
	15-yr	2012	2.63E+06	0.4	15-yr	2012	2.12E+06	0.3
	20-yr	2017	2.15E+06	0.4	20-yr	2017	1.29E+06	0.2
Joquei Landfill	Install System	1998	1.75E+07	2.8	Install System	1998	3.23E+07	5.3
	10-yr	2007	2.20E+07	3.6	10-yr	2007	3.10E+07	5.1
	15-yr	2012	1.80E+07	2.9	15-yr	2012	1.88E+07	3.1
	20-yr	2017	1.47E+07	2.4	20-yr	2017	1.14E+07	1.9
Lara Landfill	Install System	1998	1.83E+07	3.0	Install System	1998	3.52E+07	5.7
	10-yr	2007	2.97E+07	4.8	10-yr	2007	4.84E+07	7.9
	15-yr	2012	3.44E+07	5.6	15-yr	2012	5.20E+07	8.5
	20-yr	2017	3.61E+07	5.9	20-yr	2017	4.87E+07	7.9
Santa Barbara Landfill	Install System	1998	4.04E+06	0.7	Install System	1998	5.70E+06	0.9
	10-yr	2007	2.82E+06	0.5	10-yr	2007	2.32E+06	0.4
	15-yr	2012	2.31E+06	0.4	15-yr	2012	1.41E+06	0.2
	20-yr	2017	1.89E+06	0.3	20-yr	2017	8.53E+05	0.1
Sao Joao Landfill	Install System	1998	4.26E+07	6.9	Install System	1998	9.51E+07	15.5
	10-yr	2007	9.93E+07	16.2	10-yr	2007	1.79E+08	29.3
	15-yr	2012	1.23E+08	20.1	15-yr	2012	2.02E+08	33.0
	20-yr	2017	1.01E+08	16.4	20-yr	2017	1.23E+08	20.0
Zona Norte Landfill	Install System	1998	1.34E+07	2.2	Install System	1998	2.32E+07	3.8
	10-yr	2007	9.33E+06	1.5	10-yr	2007	9.45E+06	1.5
	15-yr	2012	7.64E+06	1.2	15-yr	2012	6.24E+06	1.0
	20-yr	2017	6.25E+06	1.0	20-yr	2017	3.47E+06	0.6

CUMULATIVE POWER GENERATION POTENTIAL	YEAR	MW (2)		YEAR	MW (2)
	1998	***60.6***		***1998***	***113.3***
	2007	***91.8***		***2007***	***144.2***
	2012	***84.1***		***2012***	***107.4***
	2017	***70.5***		***2017***	***68.8***

NOTES:
1. Cubic meters per year generated, as estimated using the U.S. EPA Landfill Air Emission Estimation model.
2. Megawatts, assuming 50% landfill gas collection efficiency, and a conversion factor of 12,500 BTUs per kilowatt-hour.

The methodology used for developing the conversions of available methane at each landfill site (in cubic meters per year) to electrical power (in megawatts) is as follows:

- The EPA Landfill Air Emission Estimation Model (DOS Model, Version 2.0), utilized for estimating the quantity of methane available at each landfill site, assumes that the landfill gas is comprised of 50 percent methane, and the methane recovery estimates are based on this assumption. This assumption is an industry standard for preliminary studies such as the present study.

- Once landfill methane generation estimates are calculated, a landfill gas collection system efficiency is assumed. Typical collection efficiencies range from 50 to 70 percent. For purposes of this study, a collection efficiency of 50 percent is used. Thus, it is assumed that 50 percent of the methane that is generated in the landfill is finally collected for the purposes of energy conversion.

- Once the methane is collected, an industry-standard average heat value of 1,012 Btus per standard cubic foot of methane is applied to calculate the heat value of the collected methane at each landfill site.

- The conversion factor for the conversion of heat energy to electrical energy is assumed to be 12,500 Btus per kilowatt-hour. This conversion factor is typically used by the industry for preliminary planning purposes and is equivalent to a 25 percent generation efficiency, which is conservative as typical generation efficiencies are in the range of 30-40 percent for traditional gas-fired power generation.

Based on these assumptions, Table VI-2 provides electrical power generation potential estimates for the first year of operation of a gas-to-energy system, and at subsequent 10-year, 15-year and 20-year increments from the time of installation of the system. The cumulative power generating potential for the 13 sites for the low methane generation scenario ranges from a low of 60.6 MW in 1998 to a high of 91.8 MW in 2007. After the year 2007, the potential for power generation gradually declines to 70.5 MW in the year 2017 due to a reduction in the availability of methane resulting from landfill site closures. The cumulative potential for power generation in the high methane generation scenario for the 13 landfill sites ranges from a low estimate of 68.8 MW in the year 2017 to a high estimate of 144.2 MW in the year 2007. Once again, in the high methane generation scenario as well, the potential for power starts at 113.3 MW in 1998, peaks at 144.2 in 2007, and declines to 68.8 in the year 2017 due to reduced methane availability resulting from the potential closure of some of the sites visited.

Thus, the overall potential for power generation for all 13 sites together ranges from a low value of 60.6 MW in 1998 to a high value of 144.2 MW in 2007. It must be noted, however, that some of the landfill sites are not good candidates for gas-to-energy development. Consequently, the likely cumulative potential for power generation at these sites will be less than that estimated in this report.

Detailed site-specific assessments and technical and financial feasibility studies will be required prior to developing projects for potential financing. The following example for the Bandeirantes Landfill site illustrates the process utilized for developing power generation estimates for the 13 landfill sites presented in Table VI-2.

The estimated electrical power generation potential at the Bandeirantes Landfill for the year 1998, assuming the system is operational on January 1, 1998, is 13.2 MW under the low methane generation scenario. Therefore, it can be assumed that, based on the estimated generation and collection of methane from the Bandeirantes Landfill, the site can support a 13 MW electrical power generating station in 1998. A review of the subsequent milestone years -- 2007, 2012, and 2017 -- indicates that, based the projected amounts of methane availability, a 13 MW facility can be supported during the entire 20-year period. The electrical power generation potential estimates also indicate that site is capable of supporting a 19.5 MW electrical power generating station in the year 2007. Thus, additional power generating capacity can be added to the existing 13 MW facility to accommodate the additional generation potential in 2007.

Using the high methane generation scenario for the Bandeirantes Landfill as an example, the estimates indicate that at a minimum a 11 MW generating facility can be accommodated during the 20-year period. Additional power-producing capacity can be added up front, as estimates indicate that 24.9, 30.1, and 18.3 MWs can be produced in the years 2007, 2012, and 2017, respectively.

Therefore, the preliminary assessment conducted as part of this study indicates that a 10 MW LFG-power generation facility can potentially be supported at the Bandeirantes Landfill site for a 20-year period which is typically required by IPPs for private sector investment. It would, therefore, appear that a LFG-power generation project at the Bandeirantes Landfill site could be a promising candidate for further assessment and potential private sector participation.

D. BEST PROSPECTS FOR ENERGY RECOVERY FROM LFG

Based on preliminary assessments of the 13 Brazilian landfill sites, five sites are ranked according to their potential as candidate sites for landfill gas collection system and LFG-power generation projects development. These sites offer the best prospects for further assessment as candidate projects. The selection and ranking of these sites is developed based on the following criteria:

1. the quantity of methane reserves, based on preliminary estimates, during the period from 1997 through 2016;

2. the institutional management of the sites. Current management patterns at the 13 study sites include (i) wholly municipally-owned and operated, (ii) municipally-owned and privately-operated, and (iii) privately-owned and privately-operated;

3. the availability and accessibility to potential markets for methane gas, gas-based heat energy, and gas-based electric power in the vicinity of the landfill sites; and

4. the mass-to-area ratio of the landfill. Generally speaking, the greater this ratio, the more favorable the conditions are for landfill gas system development.

Based on these selection and ranking criteria, the following five landfill sites are considered to be the best prospect candidates for landfill gas and power generation development and are listed in descending order:

1. Gramacho Landfill, Rio de Janeiro, Rio de Janeiro

2. Bandeirantes Landfill, São Paulo, São Paulo

3. Lara Landfill, Mauá, São Paulo

4. Sao Joao Landfill, São Paulo, São Paulo

5. Belo Horizonte Landfill, Belo Horizonte, Minas Gerais

A brief discussion of the rationale for the selection of these five sites as well the potential offered by the sites for power generation, follows. Table VI-3 presents a summary of the ranking of the five best prospect landfill sites.

1. Gramacho Landfill Site

Preliminary methane gas reserve estimates for the Gramacho Landfill indicate that the total potential for methane generation ranges from 3.1-4.5 billion cubic meters during the period 1997-2016, as presented in Table VI-3. With an estimated 28 million metric tons of waste in place, and projected waste receipts of 7,500 metric tons per day, 365 days per year, as much as 30 million metric tons of additional waste will be disposed of in the Gramacho Landfill over the next 11 years. Based on this preliminary waste receipt data, the total capacity of the site is estimated to be 58 million metric tons. This amount of waste will be able to provide sufficient quantities of methane to sustain a 15-20 MW methane-based power generation facility over the next 20 years.

In addition, a number of other characteristics that make the Gramacho Landfill a good candidate for further assessment include the following:

1. The landfill has a favorable mass-to-area ratio, estimated as 0.53 Mg per hectare, which also exceeds that of the other four sites.

TABLE VI-3
SUMMARY OF SITE RANKINGS

SITE	ESTIMATED METHANE RESERVES (Million Cubic Meters)		ESTIMATED DESIGN CAPACITY (Million Metric Tons)	ESTIMATED LANDFILL AREA (Hectares)	MASS-TO-AREA RATIO	POTENTIAL ENERGY END USERS
	Low Generation	High Generation				
Gramacho Landfill	3,099.6	4,477.9	58.1	110	0.53	Commercial and residential developments west of site represent possible end users of methane gas and electricity. Potential on-site uses include electrical power generation and leachate evaporation. Electric power transmission lines located near site.
Bandeirantes Landfill	2,009.3	3,000.8	35.2	100	0.35	Large residential community and industrial lots near the site represent possible end users of methane gas and electricity. Electric power transmission lines located less than 1 km from site, and a gas transmission pipeline located 1 to 2 km from site.
Lara Landfill	568.2	925.8	12.4	52	0.24	Industrial lot development is occurring nearby the site, representing possible users of methane gas and electricity. There are electric power transmission lines near the site.
Sao Joao Landfill	1,775.6	3,112.6	34.5	87	0.40	Although no industrial developments exist near the site, residential developments surround the site, representing possible end users of methane gas and electricity. There are electric power transmission lines less than 1 km from the site.
Belo Horizonte Landfill	662.5	896.0	11.8	80	0.15	Although no industrial developments exist near the site, residential developments surround the site, representing possible users of methane and electricity.

2. The landfill site operator is actively considering possible uses of methane from landfill gas, including electrical power generation. The site operator is considering the treatment and disposal of leachate. One potential option under consideration is the use of methane for on-site evaporation of leachate.

3. The methane-based electrical power generating potential at the site ranges from 18 MW to 49 MW based on preliminary low and high methane generation scenarios.

4. The site operator has planned for a good final cover system although it does not include the use of geosynthetic material (i.e., polyethylene derivatives).

5. The planned sideslope which will cover 90 percent of the total landfilled area will be 10 horizontal to 1 vertical, thus reducing concerns of air intrusion through the sideslope.

One possible barrier to the full development of a landfill gas extraction system at the Gramacho Landfill site may be the high leachate levels reported at the landfill. However, the site operator has developed an approach to lower leachate levels in the landfill, which should be implemented during 1997.

2. Bandeirantes Landfill Site

Preliminary methane gas reserve estimates for the Bandeirantes Landfill site are in the range of 2-3 billion cubic meters of methane during the period from 1997 through 2016. With an estimated 16 million metric tons of waste in place, and projected waste receipts ranging from 5,000 to 7,000 metric tons per day, 365 days per year, a minimum of 19 million metric tons of additional waste will be disposed of in the Bandeirantes Landfill over the next 10 years. Based on this preliminary waste receipt data, the total capacity of the site is estimated to be 35 million metric tons, which is more than sufficient to sustain a 10 MW methane-based power generation facility over the next 20 years.

Other factors making the Bandeirantes Landfill site a good candidate for further consideration include the following:

1. The Bandeirantes Landfill site also has a favorable mass-to-area ratio, estimated as 0.35 which is somewhat less than that for the Sao Joao and Gramacho Landfill sites. However, its power generation potential is much greater than that for the Sao Joao Landfill site and comparable to that for the Gramacho Landfill site.

2. There are over 10,000 reported residents and an industrial estate is being developed within 1 kilometer of the site, which offers a potentially dedicated market for methane-based heat and power.

3. The electrical power generating capacity for the site ranges from 11 MW to 30 MW making it a fairly attractive candidate for a commercial size power generation facility.

3. Lara Landfill Site

Preliminary methane gas reserve estimates for the Lara Landfill site indicate that between 568 and 925 million cubic meters of methane could be potentially recovered during the period 1997-2016. With an estimated 3.6 million metric tons of waste in place, and projected waste receipts estimated at 1,200 metric tons per day, 365 days per year, a minimum of 8.8 million metric tons of additional waste will be disposed of in the Lara Landfill over the next 20 years. Based on this preliminary waste receipt data, the total capacity of the site is estimated at 12.4 million metric tons which is capable of sustaining an approximately 5 MW power generation facility.

Although the Lara Landfill ranks fifth in terms of estimated methane reserves, it offers an attractive option as a case study as it is one of two sites which is wholly owned and operated by a private company. It is well managed and is running profitably. Thus, this site can be used as an example to encourage other private investors to participate in the country's municipal solid waste management program. Privatization of the landfill sites is a priority of the Federal, state, and city governments and therefore the support of a potential methane-to-power generation project at this site will be consistent with the government policy.

A summary of the key characteristics of the Lara Landfill site which make it an attractive candidate for further consideration is as follows:

1. The site is located adjacent to a densely populated section of Mauá. In addition, because of Mauá's location close to São Paulo, one of the most densely populated cities in the country, many manufacturing companies are either relocating existing facilities or establishing new plants away from São Paulo. Mauá offers an attractive alternative as the price of land in São Paulo continues to rise. Currently a sizeable industrial estate is being developed very near the landfill site. This offers a potentially dedicated market for methane-based power cogeneration facility.

2. The methane-based electrical power generating potential at the site is estimated to range from 3 MW to 8 MW during the next 20 years.

3. The site is well operated, is profitable and the owner/operator has expressed a strong interest in developing new projects at the site.

4. Sao Joao Landfill Site

Preliminary methane gas reserve estimates for the Sao Joao Landfill site indicate that between 1,700 and 3,100 million cubic meters of methane could be generated during the period 1997-2016. With an estimated 5.6 million metric tons of waste already in place, and projected waste receipts of 5,100 metric tons per day, 365 days per year, a minimum of 29 million metric tons of additional waste will be disposed of in the Sao Joao Landfill over the next 16 years. Based on this preliminary waste receipt data, the total capacity of the site is estimated at 34.5 million metric tons. The methane availability from the site is expected to be sufficient to sustain an approximately 10 MW methane-based power generation facility.

Other factors making the Sao Joao Landfill a good candidate for further consideration include the following:

1. The site has a favorable mass-to-area ratio, estimated as 0.40.

2. There are residential developments surrounding the site, representing possible end users for electricity and/or methane gas.

3. The electrical power generating potential at the site ranges from 7 MW to 33 MW based on preliminary low and high methane generation scenarios.

5. Belo Horizonte Landfill Site

Preliminary methane gas reserve estimates for the Belo Horizonte Landfill site indicate that between 660 and 890 million cubic meters of methane could be generated during the period 1997-2016. With an estimated 7.5 million metric tons of waste already in place, and projected waste receipts of 2,100 metric tons per day, 312 days per year, a minimum of 4.3 million metric tons of additional waste will be disposed of in the Belo Horizonte Landfill site over the next 7 years. Based on this preliminary waste receipt data, the total capacity of the site is estimated to be 11.8 million metric tons, which is sufficient to sustain a 3-5 MW methane-based power generation facility.

Other factors which make the Belo Horizonte Landfill site potentially a good candidate for further consideration include the following:

1. There are residential developments surrounding the site, representing possible end users for electricity and/or methane gas.

2. The electrical power generating capacity ranges from 3 MW to 10 MW, based on preliminary low and high methane generation scenarios.

3. The site is well managed and offers the potential for rapid privatization.

It must be noted that some of the remaining eight landfill sites also offer the opportunity for the development of landfill gas collection systems. For example, the Biguacu Landfill site in Florianópolis, SC, appears to be a good future candidate for the development of a landfill gas collection system and a power generation facility based on its potential disposal capacity and geometric configuration. The preliminary methane reserves estimates for the Biguacu Landfill are currently low, ranging from 110 to 197 million cubic meters, not considered sufficient to sustain a power generation facility at this time. However, the owner/operator of the site has indicated that the daily municipal waste receipts are expected to increase significantly due to the planned utilization of this site for the disposal of municipal waste from several nearby cities and towns. These potential waste receipts were not included in the preliminary estimates of methane generation developed for this site.

While these five best prospect landfill sites offer the promise for methane recovery and possible power generation based on the initial review, their full potential needs to be assessed in greater detail through individual site assessments and technical and financial feasibility studies.

E. INVESTMENT INCENTIVES, POLICY REFORM, AND INSTITUTIONAL REQUIREMENTS

The ETIP teams' initial assessment indicates that technically there is potential for (i) more effective management of the municipal solid waste collection, transportation and disposal, (ii) enhancing environmental, health, and safety benefits in the country, (iii) recovery of methane from the landfill gas, (iv) the utilization of LFG-based methane as an energy source, and (v) significant privatization of the waste management activities through leasing and operations contracts, permitting of private ownership, financing, and operation of landfill sites, and generation of revenues from composting, resource recovery, and energy production. However, the realization of this potential requires a commitment at the Federal, state, and municipal levels to develop and implement well designed policies and programs aimed at fostering accelerated participation by the private sector.

The passage of the Concession Law and the regulations permitting independent power generation for sale to utility as well as self use, are much needed steps taken by the government of Brazil. These initiatives create the financial and economic climate without which private participation in traditionally public sector controlled activities will not be possible. Additional steps, however, need to be taken to encourage the private sector to take advantage of these new regulations. The privatization program designed by the government of Brazil will undoubtedly lead to greater sector efficiency, more private sector employment, and a positive income distribution. The privatization of some of the environmental functions of the government will not only add to the overall environmental quality in the country but also create a commercial climate providing the same benefits.

The management of municipal solid waste has traditionally been viewed as a public sector responsibility financed through the tax base in most countries. Many of the inherent commercial advantages in the collection and disposal of solid waste have not been demonstrated sufficiently for the private sector to take an active interest. Several countries during the last decade have initiated and implemented programs which have yielded impressive results and created a private sector based ownership and operation of municipal solid waste management. For example, during the last 15 years, South Korea and Taiwan have successfully privatized a significant portion of their municipal solid waste management functions including the development of composting plants, incineration projects, and in some cases, waste-to-energy generation projects. Indonesia, Thailand, and Malaysia are actively engaged in creating an economic environment to foster private sector ownership and operation of many of the functions traditionally undertaken by cities and municipalities such as wastewater and sewerage treatment, drinking water supply, solid waste management, etc.

While the Brazilian private sector is aware of the opportunities presented by the country's Concession Law and privatization policies, considerable impediments still exist for the private sector to take an active role due to a variety of reasons. For example, in many cases the impediment is simply due to the perceived risks for undertaking projects such as municipal solid waste management, as there is little prior experience demonstrating the success of such projects. Secondly, there is a lack of understanding of the procedure and process required for the private sector to plan and bid for projects which have been traditionally in the public domain. In this regard, the government needs to provide detailed procedures and conduct an outreach program, including possible demonstrations of such projects, to induce the private sector to take an aggressive role in the management of municipal solid waste projects.

The existence of regulations is necessary to create the climate needed for fostering private sector development. At the same time however, cumbersome and costly procedures can act as significant barriers to private sector involvement. Therefore, the government needs to simplify the procedures for permitting, licensing, bidding, financing, etc., all of which are viewed by the private sector as factors which add significantly to the project development costs. For example, a "one-stop" permitting and licensing process will considerably reduce the burden on the private sector investors and facilitate new investments more rapidly. Currently, a number of Federal, state, and municipal bodies in Brazil exercise regulatory control over municipal solid waste management and the procedure for obtaining permits and licenses is lengthy and time consuming.

The success of the transferring of traditional public sector functions to the private sector has often required fiscal and financial incentives, albeit for a limited period of time, as an initial step to motivate the private industry and reduce some of the perceived risks of such projects. Many countries, particularly Korea and Taiwan, have created "promoted projects" schemes and made such projects eligible for certain financial and fiscal incentives. Some of these incentives have included tax breaks, low cost loans, subsidies such as feasibility study grants, training grants, etc., exemption from customs duties on imported equipment, government sponsored demonstration projects through public-private cost sharing, outreach programs to advertise successful projects and private sponsors of such projects, etc.

The successful creation of a private sector led municipal solid waste management program, including the generation of revenues through waste products such as compost, recyclable materials, energy, etc., in Brazil will undoubtedly require a similar role by the Federal, state, and municipal governments in the country. The government has a legitimate role in demonstrating the commercial success of such ventures and the private sector needs such demonstrations before private investment in this sector can be realized.

Another opportunity for the government to accelerate private sector participation in solid waste management is to act as a catalyst for the provision of training to technicians, engineers, and managers in modern methods for the operation of landfill sites and the management of solid waste disposal. There is a need for a government sponsored training program which will be received favorably by the private sector and act as an added incentive for private participation in this sector.

The primary responsibility for developing and implementing programs for the management of municipal solid waste rests with the cities and municipalities. There is little participation from the private sector other than sporadic landfill sites where the transportation and disposal of waste is contracted out to a private operator. In order to accelerate private sector participation as desired by the government, there is a need for the government to implement an outreach program and seek greater participation by the private sector in the regulatory process itself. The well developed private sector in Brazil, compared with other countries at similar stages of development, has a considerable experience which could benefit the government's planning process and assist in reaching its objective of rapid privatization.

As mentioned earlier, a considerable amount (close to 75 percent) of the country's municipal waste is dumped illegally in uncontrolled sites. Also, there is a sizeable unauthorized pre-sorting activity prevalent at virtually all of the controlled landfill sites. The recyclable materials offer a considerable market and are clearly supporting localized economic pockets in the vicinity of the landfill sites. Based on the experience of other countries, it is difficult for any government to enforce penalties and fines to curb such activities. Furthermore, there is a considerable variation in the dumping fees charged at the various sites. Finally, there is a virtual absence of an organized waste collection fee from residential and many commercial waste generators. Generally, in most developing and newly industrialized countries, the resident population assumes that the collection of the waste is the state's responsibility and is accustomed to receiving this service at no fee. Therefore, a sudden introduction of a collection fee system in Brazil's large and medium cities may not be feasible in the near term. However, it would be advisable to gradually create a climate whereby major residential and commercial waste generators are required to pay some collection fees. This is necessary because the commercial viability of municipal solid waste management projects requires as many sources of revenues as possible to off-set the overall project capital and on-site operation costs.

F. INVESTMENT REQUIREMENTS AND POTENTIAL FINANCING OPTIONS

1. Potential Investment Opportunities and Requirements

The overall potential for power generation for all 13 sites together ranges from a low value of 60.6 MW in 1998 to a high value of 144.2 MW in 2007. It must be noted, however, that some of the landfill sites are not good candidates for gas-to-energy development. As mentioned earlier, the total municipal solid waste collected and disposed at these 13 landfill sites is approximately 80.5 percent of the total waste collected and disposed in country's controlled landfill sites. Assuming that the same ratios for organic content of the waste, methane recovery rate, and power generation rate were to prevail at the remaining controlled landfill sites, the total potential for on-site LFG-based power generation in the country will be in the range of 75.3 MW and 179.2 MW. At approximately an average installed cost of US $1,200 per megawatt of capacity, the total maximum likely investment required for power generation facilities alone will range from US $90.4 to $215 million.

It must be noted that while this represents the maximum power generation and the likely investment requirements, many of the LFG-based power generation projects at individual landfill sites may not be economical for a variety of reasons including their small size, absence of a local dedicated market, errors in the estimation of long-term methane availability, etc. Although the ETIP team has been conservative in estimating the overall potential for LFG-based power generation, each individual project will need to be evaluated on its own merits through further technical and financial feasibility studies to arrive at a more realistic assessment of the power generation potential based on LFG recovery.

The five best prospect projects selected as part of this study represent an overall potential for LFG-based power generation in the range of 43-50 MW. These projects have the best potential for being realized. However, they also face the same policy, institutional, financial, and economic barriers as the rest of the landfill projects. The total potential investment required for these best prospect projects will range from US $51.6 million to US $60 million for the power generation facilities alone.

In addition to the investments required for power generation facilities at the landfill sites, additional investments will be needed for a variety of municipal waste management activities such as leachate treatment, incineration of medical waste, resource recovery, composting, etc. For instance, the U.S. Department of Commerce has estimated that investments for recovering recyclable materials alone at the country's landfill sites could exceed US $25 million. In the area of recycling, a number of international firms in joint-venture with Brazilian firms are active in the Brazilian market. These include Dresser Industria e Comercio Ltda. (a Brazilian subsidiary of Dresser Industries), Semco Recursos Ambientais Ltda. (joint venture between Semco and Brazilian Ral), Asea Brown Bovery, Seimens do Brasil, Sulzer do Brasil, etc. Additional investments will be required for waste residue incineration. A number of U.S. and foreign firms are actively pursuing opportunities in the incineration sector. These include Elanco (subsidiary of the U.S based Eli Lilly & Co.), Hoechst, Bayer Ciba-Geigy, and Rhodia.

2. Potential Financing Options

Given the current economic climate in Brazil and the government's focus on enhanced private sector participation, it is anticipated that any major power generation projects at the landfill sites will very likely be required to generate private sector financing. At the same time, however, private capital flow to these projects will be limited at best due to a number of uncertainties surrounding such projects. In the absence of a well demonstrated experience, the newness of the Concession Law and IPP regulations in the country, the uncertainties regarding the roles of existing government entities and newly created governmental bodies such as ANEEL, and a lack of special fiscal and financial incentives, the ETIP team believes that the government will need to play a bridging role to start a few initial projects before the private sector will show an aggressive participation in this sector.

Therefore, the first few projects will need significant support from the public sector. The financing options available to the government for public sector sponsored projects include grants and credits from bilateral and multilateral institutions. Bilaterally, USAID and two primary arms of ODA, Japan (Japan International Cooperation Agency -- JICA and Overseas Economic Cooperation Fund -- OECF) are quite active in Brazil in a number of sectors including the environmental sector. Japan's foreign aid program, administered through JICA and OECF, has a number of untied aid packages which offer U.S. suppliers a unique opportunity to participate in the waste management projects in Brazil. In addition, both the World Bank and the Inter-American Development Bank are active in financing environmental projects.

In addition, two key Brazilian agencies, BNDES and FNIEP, are available for long-term project financing. The U.S. Export-Import Bank guarantees both working capital loans for U.S. exporters and the repayment of loans by foreign purchasers of U.S. goods and services. EX-IM Bank also provides credit insurance to protect U.S. exporters against risks of non-payment by foreign buyers for political or commercial reasons. In addition, the Overseas Private Investment Corporation finances U.S. overseas business investments on a case by case basis.

Finally, a large number of commercial banks and investment banks worldwide are available to make investments in various sectors of the Brazil economy. However, the investment patterns are guarded due to Brazil's considerable foreign debt, the government's inability to guarantee commercial loans, unfavorable interest rates, and the uncertainties surrounding the Brazilian policies for foreign investment. In addition, municipal solid waste management projects will undoubtedly take a second seat to those projects which have a well demonstrated track record in the Brazilian economy. Therefore, it is unlikely that sizeable investments will be forthcoming for LFG-based power generation from the private sector alone and some form of public-private partnership will be initially required before these projects can be financed wholly in the private sector.

G. ENVIRONMENTAL AND ECONOMIC OPPORTUNITIES AND POTENTIAL BARRIERS

Effective management of the nation's municipal solid waste landfills offers Brazil significant opportunities for environmental, health, and economic benefits. Methane is 20-30 times more potent than CO_2 and thus has more adverse health effects. Furthermore, unrestrained flaring of LFG, as is prevalent in Brazil, increases the overall quantity of CO_2 in the atmosphere. Therefore, the extraction and utilization of methane from LFG will reduce the methane-related environmental effects as well as reduce the CO_2. Furthermore, the deployment of effective technologies and management procedures for waste disposal will result in a number of additional environmental and health benefits. These include a reduction in adverse health effects resulting from waste decomposition such as the emissions of harmful gases and the leakage of leachate into groundwater reservoirs. In addition, extraction and utilization of landfill gas will directly contribute to a reduction in CO_2 levels and thus a reduction in greenhouse gases. Hence, there is a net positive impact to Global Climate Change. It should be noted that the health benefits are especially significant to the large populations located in close proximity to many of the landfill sites in the country.

The integrated management of the landfill sites has the potential for resulting in both direct and indirect economic benefits to the Brazilian economy. The direct economic benefits include revenues from resource recovery and utilization. Specifically, the direct economic benefits include revenue generation from (i) sale of compost, (ii) use of on-site waste for incineration of hospital and other toxic waste (currently mostly contracted out), and (iii) utilization of landfill gas for generation of heat and/or electricity. All of these direct economic benefits will not only enhance the participation of the private sector but also reduce the fiscal burden on the state and municipal government which must otherwise bear all of the costs of landfill management under tight budgetary constraints.

The indirect economic benefits include the creation of private industry for composting, waste-to-energy production, recyclables separation, private concessions for the operation of the landfills, etc., all of which will create new employment in the private sector, greater economic activity in and around the landfill sites, and a more positive income distribution.

While a number of environmental and economic opportunities exist there are also a number of potential barriers to achieving the benefits represented by these opportunities. The primary barriers include (i) the existing institutional capacity, (ii) a lack of effective regulations, (iii) a lack of private sector participation, (iv) the perception of the private sector regarding risks associated with investments in waste management projects, and (v) the availability of attractive financing. The government's policies with respect to concessions and private ownership and operation of entities traditionally held under government control need to be well understood by the private sector. The process for enhancing the involvement of the private sector in the management of landfills needs to be rationalized and simplified. In addition, specifically designed fiscal and financial incentives may initially be needed for the private sector to participate in the management of municipal waste, an activity largely administered by the state and city governments.

Finally, the involvement by the private sector will increase the prospects for the utilization of new cleaner technologies for leachate treatment, resource recovery, composting, and waste-to-energy generation, all of which will not only result in environmental benefits but also in significant economic benefits for Brazil.

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(NOTE: The team was not able to visit this site due to a last minute worker strike but was able to have a meeting with Mr. Azevedo.)

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